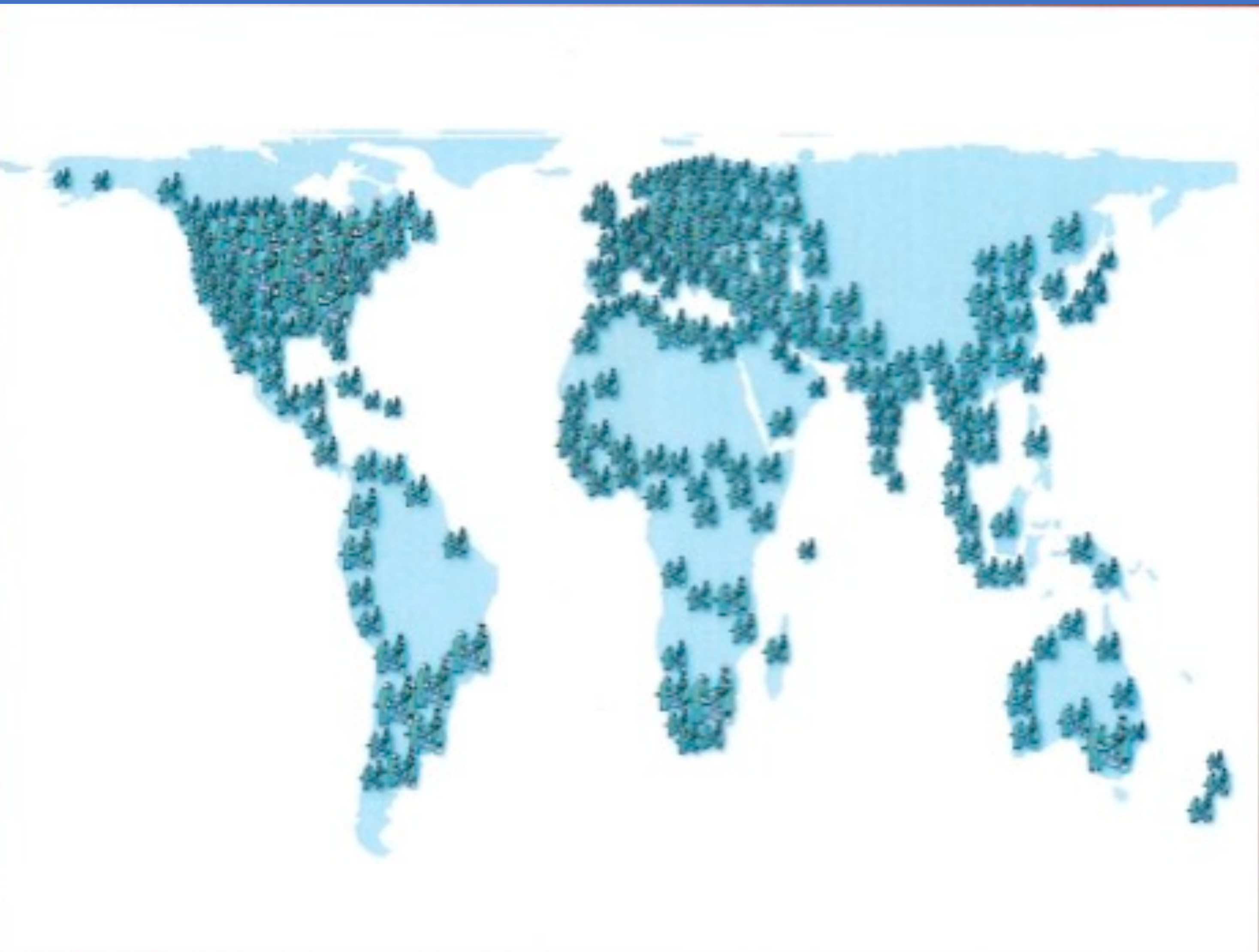
Primary Surgery

[Volume Two: Trauma]

2nd edition

Chief Editor: Michael Cotton



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GLOBAL HELP

Primary Surgery
Volume Two: Trauma (Second edition)

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Foreword

When Michael Cotton invited me to write the Foreword to this second and significantly changed edition of *Primary Surgery*, I was delighted, and I have three reasons.

First, I greatly respected Michael's work as a front line surgeon and a most dedicated teacher of surgery during his many years in Bulawayo, Zimbabwe. I was often asked by colleagues in training where they should go to learn operative surgery in Africa; Michael was always the one who came to mind first, because I knew that he would take the trouble to teach sound, careful and relevant surgery. I knew also that his colleagues would be working with a man of resolute integrity. This book is the expression of all his work as a surgeon at the front line; it was a further delight when I found that he had recruited Olive Kobusingye to be his assistant editor. I have been with Olive on take-in evening ward rounds at Mulago Hospital. Kampala; I witnessed team work, clear thinking and the practice of excellent clinical surgery. Thus this book has editors who have been proved as teachers and surgeons.

My second reason for delight is that the book will be a real help to those who have to practise surgery at the front line. For too long such colleagues, whether surgical clinical officers or medical officers, have not had a book which was written for them, to enable them to treat rural patients, the injured and those who are unable to meet the costs of travel to, and accommodation at, a regional or national teaching hospital. I believe that if the book's sound common sense and clear practice are followed, the victims of injury will be treated early and acute emergencies will be dealt with before they progress and complications develop. Patients will thus be able to get back to work and families will not suffer socially and economically.

Finally, I am certain that, where good life-saving and worker-restoring surgery is done, people who may have been afraid to bring their family member to hospital will lose that fear. Good surgery will be a great advocate and foundation for the public health of a community, now assured that disease and injury which previously could not be treated is not only treated but treated successfully. Surgery will no longer be forgotten by the administrators and those who are responsible for providing a nation's health service; it will take its rightful place in health care. This book, properly used, will help to accomplish this and will be blessed by many whose surgical needs have been met by the skills which it has helped to develop. I wish it well as I confidently expect its readers to enjoy successful and fulfilling primary surgical practice.

Eldryd Parry, OBE, Visiting Professor & Honorary Fellow,
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DEDICATION

This book is dedicated to the world's poor, so that when they need surgical help, they may get it, and it may be done well.

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Contents

Albrecht Dürer (1471-1528) made a famous woodcut of Cain slaying Abel (Genesis 4.8), which depicts man's innate violence, the cause of much trauma described in this volume. It is likely, had Abel survived, he might have needed control of arterial bleeding, wound toilet, care of an open head wound, and treatment of a skull fracture.

40 Trauma

40.1 Neglected injury: a marker of one of the greatest inequities of our time

"Of all the forms of inequality, injustice in health is the most shocking and the most inhuman because it often results in physical death", said Martin Luther King at the second convention of the Medical Committee for Human Rights, over 50 years ago.

BACKGROUND

Injury represents one of the largest contributors to the Global Burden of Disease, with mortality and morbidity figures surpassing HIV, TB, and malaria combined.

A disease of modern times, it is now the leading cause of death of men and women under the age of 45yrs, and is responsible for the loss of more productive years of life than heart disease and cancer combined. The magnitude and extent of the problem is well-documented, as are massive disparities in incidence, prevalence, and case fatality rates regardless of injury type, pattern, systemic occasion, geographic locale, or socioeconomic strata.

In 2000, approximately 5 million people died of injuries. More than a decade later, that figure has remained at 4.8 million people, while almost a billion sustained an injury that warranted some type of healthcare. Children bear the brunt of injuries with almost one million dying every year.

Road traffic crashes in 2018 constituted the second highest cause of death in adolescents, killing 115,186 individuals. More than 90% of these deaths are found in low- or medium income countries. Indeed, if you live in such a country, your chances of surviving an injury are far less than those living in a high-income nation, and the risk of your dying from trauma is much greater than from any disease.

Road crash mortality rates are more than twice as high in Africa and Southeast Asia compared with high-income countries, and sometimes ten times as high (when related to vehicle numbers). Simply put, injury as a disease does respect national boundaries!

GLOBAL ROAD CRASH MORTALITY

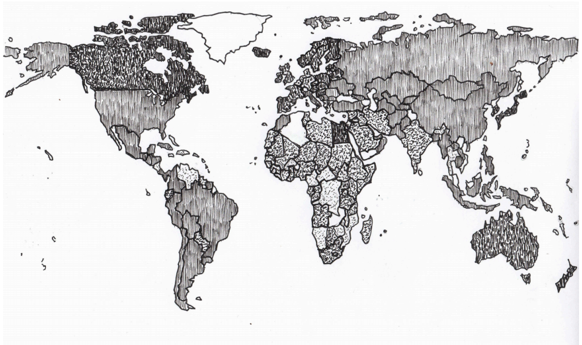


Fig. 40-1 DISTRIBUTION OF GLOBAL ROAD CRASH MORTALITY RATES. The lighter the shade, the more likely you are to die. The 2019 figures show the Dominican Republic to be the most dangerous per 10^5 of population according to the *WHO Road safety estimated death rate*. *https://gamapserver.who.int/gho/interactive_charts/road_safety/road_traffic_deaths2/atlas.html*

Children suffering from burns of >40% total body surface area have a 100% mortality in Subsaharan Africa compared with 7.7% in the USA.

Effective management strategies in most high-income countries have drastically reduced trauma deaths. Mitigation, therefore, is amenable to public health strategies.

The World Health Organization has recognized this epidemic and classifies injuries as both intentional and unintentional.

Unintentional injuries include road traffic crashes, drowning, poisoning, burns, and falls while intentional injuries result from wars and civil conflict, suicide, child abuse and neglect, and crime and violence.

In almost every category listed, >80% deaths are found in LMICs.

National action plans to prevent violence and injury were recommended after the release of the WHO world report on violence and health. The Decade of Action for Road Safety (2011-2020) was launched at the United Nations General Assembly in 2010 with a goal to decrease by 50% injury mortality rates from road traffic crashes.

In a follow-up report in 2015 on the global status of road safety, the number of road traffic deaths had plateaued to 1¼ million every year.

A ROAD DISASTER WAITING TO HAPPEN

Fig. 40-2 THE POTENTIAL FOR INJURY IS HUGE!

While there is progress towards improving road safety legislation (*e.g.* laws on seat-belts, drunk driving, motorcycle helmet or child restraints), the report showed that the rate of change is too slow.

Although injury prevention measures have shown success in decreasing the case fatality rates from injuries, the last 20yrs have shown that no system will prevent all injuries.

Indeed, for every trauma death, there are 20-50 more non-fatal occurrences that result in profound disability and loss of economic viability.

The deaths, therefore, are only a fraction of the problem. We need to address the massive number of neglected trauma patients that number some 100 million globally.

Trauma care, which encompasses all aspects of the care of the injured and includes prehospital care, initial resuscitation and definitive treatment at the hospital, and rehabilitation, is a global obligation.

Strong evidence suggests that good organization of trauma care reduces mortality by c.15% and any form of pre-hospital care system, especially in rural areas, reduces mortality in LMICs by c.25%.

Instituting a trauma hospital in a rural area has been found to be very cost-effective compared, for example, with seatbelt law enforcement.

This book seeks to show how to improve trauma care locally, and hopefully also regionally. Obviously if you can influence your medical directors and ministries so much the better!

Starting quality improvement programmes and strengthening of emergency and essential surgical care at first referral facilities closest to the community will have an enormous impact.

This chapter therefore outlines and discusses critical skills you will need to be able to handle any case that comes your way.

The 15 surgical conditions, accepted by the Amsterdam Declaration as an ‘essential surgery list’ that all district hospitals should be able to deal with, include a majority which deal with injury or its complications.

(1) Reduction of fractures & dislocations
(2) Splinting & external fixation of fractures
(3) Thoracostomy
(4) Craniotomy
(5) Tracheostomy & Cricoidotomy
(6) Exploratory laparotomy
(7) Debridement of wounds
(8) Skin grafting

These must serve as the basis for the creation of training tools for the provision of emergency and essential surgical care.

40.2 Wound assessment

The skin is the largest organ in the human body. As a physical barrier, it prevents infection, helps regulate body temperature, and protects underlying delicate structures. Along with subcutaneous fat and fascia, the skin is a resistant, but *soft*, tissue.

Any breach of the skin allows entry of microbes and can damage underlying structures. A major wound of the skin, such as a large burn, also puts into question the regulation of body temperature (50.7).

You must do everything possible to prevent infection and diagnose the severity of a wound. This may well mean wound toilet and debridement (46.2).

Assess the general seriousness of trauma to the whole body, by using the *physiological* parameters of the C-ABCDE algorithm (41.1).

Assess the wound, by looking at the *anatomical* parameters of the extent of tissue injury and the anatomic site:
(a) How large is the soft tissue wound?
(b) What are the underlying structures: organ, artery, bone, nerve, or tendon?
(c) What is the mechanism of injury?

Tissue damage after a stab wound is not the same as a bullet or after a crush injury or a fall from a motorbike.

(a) Big wounds and small ones

In general, the larger the wound the more contaminated it is and the easier for bacteria to enter. Dead and devitalised tissue is an excellent culture medium for bacteria. In a small wound, the body's natural defence mechanisms (macrophages, white blood cells, antibodies etc.) can usually overcome the bacteria present. In a large wound, the amount of tissue damage and bacterial colonisation can easily overcome these mechanisms and, therefore, the importance of wound debridement. There is also a greater chance of injury to deeper structures.

Even small wounds can be dangerous: *a small puncture wound can overlie an important structure*. A deep puncture wound may be anaerobic in its depths, creating the best atmosphere for *Clostridia tetani* or other bacteria*. Make sure your patient is vaccinated against tetanus.*

(b) Wound examination

When examining a wound, make a mental picture in your mind:
(1) How big is it?
(2) How dirty is it?
(3) How deep is it?
(4) Is there obvious bleeding, torn fascia or muscle, exposed bone?

Think of photographing the wound for reference later. *Beware, though, in war zones, you may be thought a spy if you take pictures!*

Then think of the anatomic site of the wound. Wounds of the head and neck, thorax or abdomen take priority for treatment because of the vital organs they contain.

But *don't forget the soft tissue wound* after you have completed a laparotomy, placed a chest tube or explored a nasty head or neck wound.

For wounds of the limbs, which make up the great majority of trauma, think of the anatomy of the arterial supply, the innervation, and the functions determined by the bones and tendons. Each of these structures has its own diagnostic tests.

(1) **For arteries**: note the six Ps: pain, paraesthesia, pallor, paralysis, poikilothermia, distal pulse weak or absent (49.2)
(2) **For nerves**: check for sensation and motor power in the distal limb (48.1)

N.B. Arteries and nerves tend to be bunched together in bundles. Injury to one is often accompanied by injury to the other.
(3) **For tendons**: test specific movements at different joints depend on intact tendons (48.4).
(4) **For bones**: close observation will show any deformity of the limb and gentle palpation will tell you if the bone is fractured. A radiograph or ultrasound will confirm the type and extent of fracture.
(5) **For missile wounds**, place a radio-opaque object (needle or coin) at the entry and any exit wound.

When it comes to bullet or shrapnel wounds, *don't speculate!* You are not a forensic specialist! Describe the wound that you see, and note the weapon used, how distant was the victim. Know your limits!

40.3 Preventing trauma

Trauma - the tearing apart, burning, crushing, maiming, lacerating, or irradiating of the human frame is potentially one of the most preventable of mankind´s afflictions.
Injuries are the results of accidents or of violence: personal, animal, communal, political or international. Violence may also be institutional and deliberate, including torture (40.11).

Whilst psychological trauma may be very long-lasting (40.5), here we consider physical hurt.
Since most injuries can be avoided, it is important that injury prevention programmes are set up. If they already exist, they may need to be properly enforced on a country or local basis.

Almost all injuries could be prevented, so the *absolute importance of prevention*, applies to all injuries described. Common prudence would prevent most injuries!

Causes of injuries can be classified into different groups:
(1) war or political instability (40.9)
(2) natural catastrophe (40.8),
(3) exposure to fire & live electric cables,
(4) poor technical standards,
(5) poor governmental & institutional regulations,
(6) poor enforcement of such regulations,
(7) poor awareness or educational attainment,
(8) personal conflict,
(9) self-harm
(10) sports/games
(11) proximity to wild animals (46.10)
(12) untreated pathology.

So, by reducing occurrence of such factors you would automatically reduce the burden of injuries.
Except in situations of strife, road crashes are the major cause of death & disability in low & middle-income countries, accounting for more mortality & morbidity than important infectious disease combined!

Statistics of road crashes are really horrendous. WHO figures make very sad reading. There is a hundred-fold difference in consequences of road crash for victims in low & middle-income compared to rich countries. The reasons are not usually because the vehicles are newer or better maintained in the latter, but that road safety rules are not followed.

Prevention measures against road crashes are extremely urgent, as this is an epidemic worse than AIDS, Ebola or COVID!

Among other things, this means:
(1) The wearing of seat belts for all car drivers & passengers and helmets for all two-wheeler drivers & their passengers.
(2) The absolute rule that nobody should ever drive after having taken any alcohol or sedative drugs whatsoever, not even a single drink.
(3) The prohibition of driving whilst manipulating something else at the same time: this should include mobile phones, cigarettes, & food and even the putting on of gloves!
(4) Improvement of road traffic management (speed restrictions, *i.e.* humps, traffic lights, etc.) and rigid enforcement of safety regulations:
(a) driving licenses obtainable without bribery and after proper educational courses,
(b) vehicle proficiency testing certificates obtained after proper testing,
(c) separation of motorized traffic from pedestrians.
(d) restrictions on moped passengers.
(e) automatic controls at road/rail crossings.
(f) the carriage & use of functioning lights on all vehicles including bicycles after dusk.
(5) Reduction of huge overcrowding of private transport in cities.
(6) Avoiding traveling at night if at all possible.

DON'T DRINK & DRIVE

ROAD SIGN WARNING OF ALCOHOL

Fig.40-3 ROAD SIGN warning against drinking alcohol & driving.

THE DANGER OF TEXTING & DRIVING

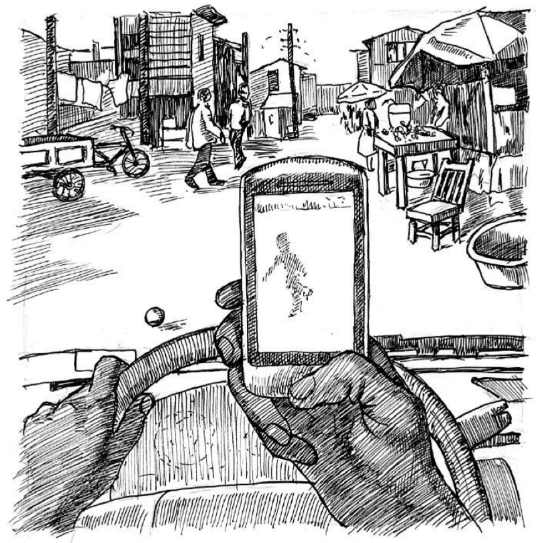


Fig.40-4 DANGERS OF USING A PHONE & DRIVING. Not only may the phone distract the driver, it may completely block out the view of a child crossing the road! Using a mobile phone increases the risk of collision 4-fold hands-free sets being not much safer)

Penalties *must be enforced* for non-compliance

N.B. Road blocks checking on vehicles on highways are probably less effective than spot checks within towns & cities!

The risk of early death from road crash is far greater than from exotic tropical illness! Therefore these precautions apply to all of us.

Accidents with industrial or agricultural machines are often gravely mutilating. Proper precautions by the owners and enforcement of proper government regulations would prevent many injuries.

This applies both to machines, the temperature or environs of work area, as well as work in hazardous places. Workers who might fall great heights if they slip must be securely attached to safety harnesses. Helmets are needed where falling masonry or objects can be expected. Proper cleaning & washing areas are also very necessary, and minimal exposure to toxic substances.

If the same hazard causes the same injury in a succession of patients, always ask how it happened. *Do your best to see that the danger is removed*.

Safety at work needs to be managed. It doesn't just happen! This entails: Inspection, Monitoring & Audit.

BARBECUE PLACES FOR COOKING

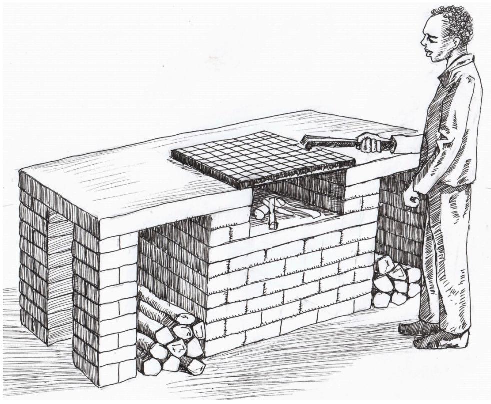


Fig. 40-5 BARBECUE PLACE. The cooking is done at arm level, *not on the floor.* The fire & pots are protected,

Inflammable and explosive substances must be stored in secure places; this includes gas cylinders for sale in shops.

Educational limitations make certain people more vulnerable: this should be accounted for. However, the disabled are often discriminated against in this respect, as are epileptics.

Children are especially liable to injury, principally on roads, but also at home from burns, especially from open fires. Protective measures include building cooking places at waist, rather than floor, level (40-2).

N.B. A wet floor, loose floor rugs & clutter increase the risk of injury at home, as does poor lighting.

Supervision of babies & toddlers is mandatory.

In many mega-cities, but also in rural areas, social disintegration is causing increasing violence. The causes may be lack of access to potable water, arable land, educational opportunities, or simple overcrowding.

The situation in the shanty towns of many megacities is frankly appalling, though high rise buildings also pose their own challenges.

Many of the resultant injuries are due to fists, teeth, bottles, knives, sticks, and bullets, and many are inflicted under the influence of alcohol, or other drugs. Violence during robbery and rape (57.4) are also factors.

Even in more affluent societies, the poor are more vulnerable than the rich. In the USA, blacks have a 5% higher chance of being murdered, and their mortality from road crashes is 17 times as high as for white children, and twice as high from other injuries. Obviously the causes are multi-factorial, but this goes to show that poor backgrounds result in more frequent and more serious injury

A serious global epidemic is also the easy availability of guns in many places. The result is that in certain civilian situations, casualties resemble war victims entirely.

The control of hand weapons is an immediate concern for everyone who takes prevention seriously.

Keeping a register of injuries is a very useful tool, for any workplace, but also hospitals.

40.4 Psychological care in trauma

(a) In general

You might think that mental health & surgery are opposite sides of the health spectrum. However, especially in a crisis setting, psychosocial support is crucial to a holistic response. This is even more important in multiple trauma and war situations.

In the latter, there is usually an exodus of qualified personnel, exacerbating an already low number of experienced staff. As the general infrastructure of a war zone deteriorates, every aspect of health care, including logistics, becomes more complex, more time-consuming and frustrating. A decrease in resilience, and exposure to gross trauma, often overstretches the functioning of the existing work force and makes everyone more psychologically vulnerable.

Furthermore, the extent of trauma individually and corporately far exceeds average peacetime experience. Demands for supplies (*e.g.* for blood, prostheses, surgical space etc.) may quickly outstrip supply.
Also, demands for social and psychological support, frequently way beyond everyone's usual experience, often falls on health staff where no such social infrastructure exists, or where it is itself no longer functional.

(b) In the immediate situation

In the early hours after a serious trauma event, both health care staff and victims are in a state of chaos, confusion and exhibit general loss of control.
In this phase, it is crucial to provide, as much as possible, a sense of safety and control. *Regular and clear communication are crucial, both amongst staff and with patients.*

This includes creating a satisfactory safe working zone, explaining the next steps, obtaining opinions from involved persons, and explaining decisions. These may need to be repeated several times. *Don't give the impression you are too rushed, or you are losing control. Don't get angry! Remember that psychological, emotional & social wellbeing of patients and staff may be their greatest acute need. Don't trivialize injuries.*

MARIA WENT MISSING: CAN YOU ANSWER TRUTHFULLY:
"We don't know, Madam, but we have told the police and given them her name and a description of her. We have also given them our mobile number, so they can call us as soon as they have any information"

Make sure you have in place:
(1) An immediate response.
(2) Contact & dialogue with the wounded.
(3) Relay of relevant Information.
(4) Monitoring of patients one-to-one
(5) A safe secure environment.
(6) A sense of order & calm.
(7) Organized use of non-medical personnel.
(8) A social/psychological support team.
(9) Liaison with the public.
(10) Refreshments.

Early supportive intervention is the most effective way to prevent post-traumatic stress. Be attentive to the needs of the patients and allow them to express their emotions.

Whilst most will show an acute stress reaction, with an adrenaline rush and hypervigilance, others may become mute & withdrawn.

Handling agitated relatives, who may contribute significantly to the general chaos around a mass casualty event, may significantly reduce the burden on health staff and contribute to better care.

(c) Patients

Don't forget that you must deliver a holistic approach to trauma care. Simply fixing a fracture without considering a patient's psychological, emotional & social wellbeing ignores what may be the greatest need.

It is important to communicate with patients, care givers & relatives, and so identify and detect early signs & symptoms of psychological distress.
Give guidance according to culturally acceptable practice, and offer help. The more you do this, the more your nursing staff will follow suit.

PSYCHOLOGICAL RESPONSE TO TRAUMA

Fig.40-6 PSYCHOLOGICAL RESPONSE TO TRAUMA may be profound but hidden.

You should highlight that it is completely normal that adverse events cause mood changes; the more serious the event the greater the effect on mood. Thus a serious mood change does not imply a patient is mentally sick. Furthermore, confrontation with death of others will produce profound emotional and social reactions. *These are normal reactions to an abnormal situation.*

Sleeping and eating may be affected; some 30% of victims experience nightmares and flashbacks, which usually last <2-3 days.

The initial reaction is intense, but is usually short-lived if normal function is resumed quickly.

If there is a life-changing event, understanding needs to grow to accept losses and changes. This is especially so after trauma, and particularly if body parts or image are lost.
Try to accompany victims in accepting and integrating their loss, developing strategies to return to independence or help train support if that too is lost.

Psychological trauma implies a crucial experience of loss of control, and it is very important to lead the victim to take back control as soon as possible.

This is time-consuming, so you should delegate this task to others, who have an interest and expertise in this kind of work. You need to show them how to recognize exacerbations or relapse of pre-existing mental illness.

INFORMATION GIVES A SENSE OF CONTROL

Fundamental elements of counselling are:
(1) listening attentively,
(2) addressing pre-occupations,
(3) encouraging coping mechanisms,
(4) explaining emotional reactions to loss,
(5) helping adjustment.
Ask open questions & be friendly. Use a private room for this if possible, and ensure it is a safe place.

Careful explanations of treatment options are mandatory. *Don't make false promises!* Be patient & positive, and ready to repeat details, and show empathy. *Don't be judgmental, and avoid "what if" conversations.* Link up a victim with a support group, if possible.

If victims are agitated, violent or very passive, get help, *don't leave them alone,* speak calmly & gently, reason with them and attempt to negotiate. *Don't argue or contradict, & avoid sudden or threatening movements*. Reassure & re-orientate them (if necessary), explaining the next steps, giving choices.

Protect a patient from harming himself or others. You may, rarely (with the help of others), need to apply restraint. Document the reason for this. You may need large doses of haloperidol (37.2).

Monitor the patient when you use sedation.
Get the psychological support team to be involved in treatment planning, join in medical rounds & report back. Get them to develop peer support groups, and develop group consultations and online chat groups.

Make sure pain relief is adequate. Phenothiazines usefully boost pain relief therapy (37.2)

THE EARLIER THE ANALGESIA, THE BETTER THE OUTCOME!

COMBINATION THERAPY IS MORE EFFECTIVE THAN MONOTHERAPY!

MIDDLE & LONG TERM EFFECTS
This is outside the scope of this book, but you will need an integrated holistic approach, which includes: rehabilitation, occupation therapy, psychotherapy, and more. Do not rely on medications alone: all these have their advantages and limits.

N.B. Remember post-traumatic stress disorder: it is real!

(d) Yourself

Dealing with the pain of others day in & day out will also stress you!
This is also termed vicarious trauma, compassion fatigue or secondary traumatization.
It actually happens because you care, and in a sense you take on the suffering of the victim.

PROTECTING YOURSELF
Recognize the signs in yourself:
(1) Extreme fatigue,
(2) Having no time or energy for yourself,
(3) Neglecting to eat, drink, sleep or wash,
(4) Becoming irritable,
(5) Disconnecting from loved ones,
(6) Withdrawing socially,
(7) Getting into conflict with colleagues,
(8) Becoming cynical, sarcastic, or depressed,
(9) Having nightmares, or poor sleep,
(10) Becoming oversensitive.
N.B. Beware of developing alcohol or drug dependency!

PREVENTION
(1) Physically:
Eat healthily & regularly; take exercises; get enough sleep; play sport; do things you enjoy.
(2) Psychologically:
Take time for self-reflection; write a journal; read books (unrelated to work); discuss your feelings with others (preferably not colleagues); be open with others. *Don't deny your own frailty!*
(3) Emotionally:
Keep enjoyable company; stay in touch with your loved ones; *don't bottle feelings up!*
(4) Professionally:

Take a break, especially during the week; discuss with your colleagues; iron out disagreements & conflicts; share your successes. Reassess your priorities. Realign your own expectations.

(e) Your staff

You may see the signs listed above for one or more members of staff. Note also:
(1) Inability to co-operate with others,
(2) Loss of respect for others & victims,
(3) Diminished capability at work,
(4) Impaired ego (heightened or suppressed),
(5) Being excessively demanding,
(6) Dissociation & depersonalization,
(7) A tendency to generalize,
(8) Exacerbations of pre-existing ailments,
(9) Changes in self-view, spirituality, world view,
(10) Behavioural change.

Allow your staff the same self-care, and make sure you examine the demands made on your staff. Workshops are very helpful: act out role-plays, have case discussions, use questionnaires, get feedback, do regular debriefings, arrange for on-site teaching, and look out for resources outside your hospital environment. Finally, set up peer review & mentoring systems.

(f) Your organization

Look at how your hospital functions overall; reflect about what you can do as manager or team leader. Consider, for example, what you can do to improve pain management in your trauma unit.

To evaluate results, look at changes in 4 different areas:
(1) Physical improvements
(2) Efficiency
(3) Emotional change in patients & staff
(4) Behavioural changes

40.5 At the scene of the injury

A severe accident kills some patients instantly. Other patients die shortly afterwards from causes that could be prevented, if they had been properly treated immediately after the accident. First aid involves those measures that preserve life, preventing unnecessary death, further injury, and disability *before the patient ever reaches hospital*.

You, the surgeon sitting in your hospital wants to receive an injured patient in the best condition possible. This helps in getting the best outcome possible for the greatest number of patients. It decreases the workload on the hospital in general and the nursing staff in particular. It allows for the most efficient use of often scarce resources.

A good ambulance or pre-hospital emergency service help in many ways:
(1) Access to medical care for those who otherwise would not get to a hospital,
(2) Early evacuation of the severely injured,
(3) Emergency medical care before arriving at a hospital,
(4) Triage of multiple patients in the field so that the most severely injured arrive at the hospital first,
(5) Care of many minor injuries so that hospitals are not overburdened with them,
(6) All of the above in case of a major disaster or armed conflict.

For an ambulance service to function efficiently there are a number of requirements that you must meet: organisation, training of personnel, equipment, supplies, communications, financing, public support. An ambulance is not just a “taxi” for sick and wounded people.

In many countries, prehospital services are woefully inadequate, even non-existent. Indeed, many, if not most, injured people often reach hospital by private means. The first people to help are usually the public passing by; if the average knowledge of first aid in the community is high, this would be of great benefit. In some countries, the National Red Cross or Red Crescent Society has an ambulance service & first aid volunteers, and they have trained the police, taxi and lorry drivers in basic first aid.

In other countries, there are private ambulance services. In some, there is nothing and the sick and wounded depend entirely on private means of transport to get to a hospital. You should encourage all training programmes in community-based first aid.

If your hospital has an ambulance, try to send a nurse or medical assistant with the ambulance to an accident. You will probably be unable to keep one on permanent standby, so put your most aware and interested driver in charge of the ambulance and teach him the basics of first aid. Interest him by letting him see how you care for injured patients in the emergency department and the theatre.

N.B. An ambulance is not a taxi service!

AT THE SCENE OF A SERIOUS CRASH

Fig.40-7 THE FIRST RESPONDER AT THE SCENE. The immediate need is to maintain safety of survivors, and tend to the most seriously injured.

AT THE SCENE OF AN ACCIDENT
The basic rules of First Aid are basic common sense.
The site of an accident, especially a road traffic crash, is a 'danger' zone; vehicles are still travelling on the road. *Security comes first!* Warn other traffic by displaying a red triangle, or hazard warning lights, or other lights, or by any other means.

EXTRACTING A VEHICLE CRASH VICTIM

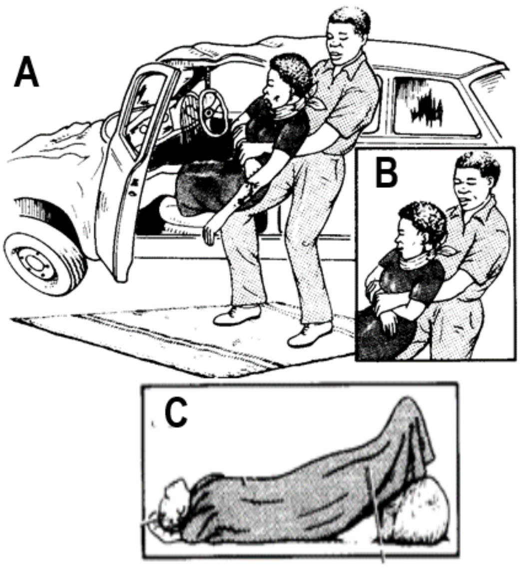


Fig. 40-8 EXTRACTING A VICTIM. A, lift the victim onto your thighs, kneel, and then slide her onto a blanket or a stretcher. If her arm is injured, let it hang free. B, if both arms are normal, lock your arms under both of hers. When a shocked patient is waiting for transport, lie her as in C, horizontal, the legs raised, and the head tilted backwards. Wrap her up for warmth, but *don't overheat her. N.B. These passers-by probably had no headboard to slide behind her and steady the cervical spine, nor experience how to use such.* *Adapted from Hanns Pacy, Road Accidents: Medical Rescuer. Med J Austral 1967; 1(16):806-810 with kind permission.*

Get everyone to extinguish lighted cigarettes or other fire hazards and ask drivers to switch off their engines.

Get uninjured people out of vehicles and into a safe place; only then go to the casualties.

PREVENT FURTHER INJURY: REMOVE CASULALTIES FROM DANGER!

Seek help from passers-by if necessary and try to ensure the cooperation of the patient.

MULTIPLE CASUALTIES
Often, there are several injured persons after a single accident, *e.g.* from an overturned bus or lorry carrying passengers. Again, securing the scene and seeking help are the basis of the management of the scene.
A triage of the victims is then necessary (40.8), putting them in categories of priority for care, and then priority for evacuation, which are not the same thing.

EXTRACTING A TRAPPED VICTIM

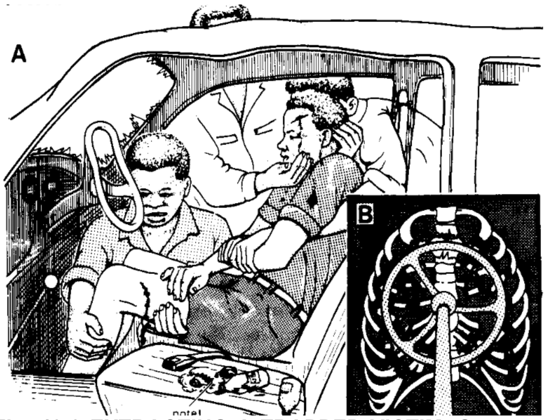


Fig. 40-9 EXTRACTING A TRAPPED VICTIM. One man uses the grip shown (40-6), another stabilizes the victim's neck and keeps the airway clear, while a third eases the legs out. B, shows what the steering wheel has done to the chest. *N.B. This is the typical result of a head-on collision where the driver has no seat-belt, and there is no air bag!* *Adapted from Hanns Pacy, Road Accidents: Medical Rescuer. Med J Austral 1967; 1(16):806-810 with kind permission.*

PREVENT WORSENING THE INJURY: SHELTER THE CASUALTIES!

First, if there are more than just a few, call out: "everyone who can walk, stand up and come over here", under a tree for example. These patients will usually have relatively minor injuries. Examine first those patients who cannot move; they are more likely to be seriously injured.

CATEGORY I (CODE RED)
Victims with life-threatening injuries who require immediate measures: *e.g.*
(1) catastrophic external haemorrhage;
(2) airway or breathing problems;
(3) coma, apart from the moribund.

CATEGORY II (CODE YELLOW)
Victims who require transfer to hospital, but their condition is not so serious that they cannot wait, *e.g.* (1) fractures & soft tissue wounds.

CATEGORY III (CODE GREEN)
Victims who only need basic first aid measures that you can provide on the spot. If there are too many, transfer them last to hospital for ambulatory care.

CATEGORY IV (CODE BLACK OR WHITE)
Victims who are dying, or already dead. Separate these & evacuate them last of all.

The priority for treatment is not the same as priority for transfer to the hospital. Evacuation of patients depends on the particular situation to hand. Are you in a city, only minutes from the hospital? Are you in a rural area hours or days away? What is the state of the roads and traffic? Are the roads passable? These factors, and others, all affect the *time* to reach the hospital. *Distance to a hospital is not measured in distance but time!*

(a) Minimum first aid
Here are some of the things to teach your ambulance driver and rescue personnel.

Apart from security measures, the driver & nurse (or extra personnel) should know how to examine a casualty for immediate life-threatening conditions according to C-ABCDE (41.1). Once these are under control, protect casualties from the elements (sun, rain, wind etc.) and put them in the most comfortable position and get others to provide psychological support.

Then, proceed with stabilization measures and check the casualty's condition and effectiveness of the measures taken, before evacuation to the hospital, if admission is necessary. Often, it is not, and first aid measures are sufficient.

The first responder should ideally be able to:
(1) Stop massive external bleeding by packing a wound and applying a pressure bandage, or a proper tourniquet (if available: see below).
(2) Clear the airway by holding the jaw forward (42-2) and removing blood, vomit, and foreign bodies from the mouth.
(3) Insert an oropharyngeal airway (42-4).
(4) Use nasal or oropharyngeal suction.
(5) Place the patient in the recovery position (42-1) *for transport to hospital. Not doing this is a common critical mistake.*
(6) Lift and carry a victim appropriately, particularly if a spinal injury is suspected (54-5).
(7) Fit a temporary cervical collar if necessary.
(8) Close an open chest wound.
(9) Ventilate with an Ambu-bag & intubate, as well as give external cardiac massage and mouth-to-mouth ventilation.
(10) Control other bleeding by raising a wounded limb, and applying local pressure.
(11) Stabilise any fractures.
(12) Wash any open wounds or burns.
(13) Keep the casualty warm.
(14) Start an intravenous infusion.

The most common cause of preventable death is continuing peripheral haemorrhage, hence the "C" in C-ABCDE.
N.B. This is more often the case at the site of an accident than in the hospital emergency room.

There is no use in evacuating a massively bleeding casualty first if he dies en route. Give priority to those patients who have serious injuries but also have a good probability of survival (40.8).

CAUTION!
(1) Transporting an unconscious accident victim on the back without proper attention to the airway is a major cause of unnecessary death.
(2) *The use of a tourniquet, especially an improvised one* (44.2) *is likely to do more harm than good*. The proper application of a tourniquet requires training, knowing when it is really necessary, and how to monitor it. *Use only a special manufactured tourniquet* (44-7). To improvise an efficient tourniquet requires more knowledge than the average first aider, or even doctor, has.

Intervening after a serious accident can be psychologically difficult for someone untrained. *Don't forget to debrief those involved after every incident.* It is the best way to improve skills, help them to recuperate and relax, and go out again to the scene of another accident.

(b) First aid for suspected fractures

(1) Spine
Move the victim en bloc (54-4) preferably on a board, a door, or strapped to a plank.
Don't try to remove a helmet!
(2) Pelvis
Tie 3 triangular bandages firmly round the pelvis, put pads between the legs and tie them together.
(3) Arm
Put the arm in a sling and bandage it firmly to the body, or tie the arm to a splint which reaches the axilla.
(4) Thigh
Put the leg in a well-padded Thomas splint. *Take especial care to pad the neck of the fibula to prevent paralysis of the common peroneal nerve.* If you can, use a few plaster bandages.
(5) Lower leg
Tie a Thomas splint, or if unavailable, pad a piece of wood or bamboo, or even a palm branch, to the injured leg, and bandage this to the uninjured one.

(c) Minimum requirements for an ambulance

THE AMBULANCE BOX
The contents of this will depend on the training, competency and experience of the user. It should include, as much of the following as possible:

Torch, with spare batteries and spare bulb
Searchlight connectable to the vehicle battery
Permanent marker pens (different colours)
Writing pens & pencils
Notepads & triage cards
Non-sterile disposable & sterile gloves
Soap and hand towels
Rubbish bags
Face mask or shield
Antiseptic solution
Bandages
Elastic gauze
Triangular bandages
Sterile gauze compresses
Cotton wool pack
Adhesive bandage (wound plaster)
Aluminized dressing for burns 35x45 cm (2)
Oral rehydration salts
Drinking water flasks
Rescue sheet 210x160 cm
Sharp & blunt scissors (small & large)
Dressing scissors
Toothed & non-toothed forceps, 9.5 cm
Self-inflating (AMBU) bag (1)
Face masks and oral airways (different sizes)

40.6 Disaster management & hospital triage

SITUATIONS CREATING MASS CASUALTIES
In a normal day in your hospital, you face every single patient one by one. You take a history, examine the patient, ask for radiographs or laboratory tests.

You do everything possible within the limits of your hospital to diagnose and treat your single patient for every single patient.

One day, there is a major accident: a bus or lorry, carrying many passengers, turns over and a large number of patients arrive at the hospital more or less at the same time. You call in staff off duty, you work through the night, you prioritize the patients for emergency care, for operation, and for semi-urgent management.

You manage in the end to treat all the patients. Although you have performed triage of a major incident involving multiple casualties, you have still managed to do everything for everyone.

Then, one day, there is an earthquake, or an epidemic, an isolated terrorist bomb blast, a stampede or fighting breaks out between a rebel group and the government. All of a sudden, a very large number of injured or sick patients arrive at your hospital. Calling in off duty personnel and working without a break are not enough: there are just too many patients. Now, you must practice triage of mass casualties. *You can no longer compensate by mobilising extra resources and personnel. You can no longer do everything for everyone. You need to change your way of thinking, the organisation of your hospital, and how you practice medicine.*

DISASTER SITUATION

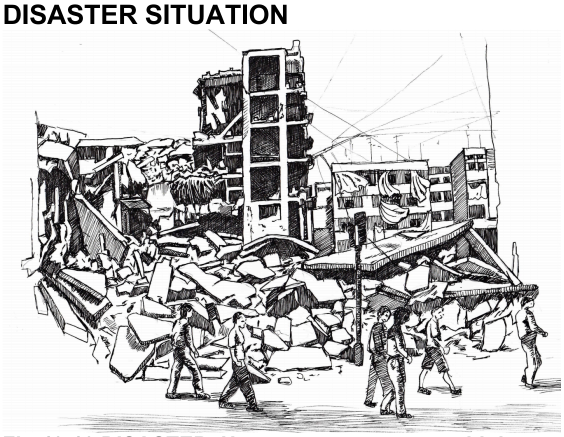


Fig.40-10 DISASTER. Here you can expect multiple casualties, serious or superficial, arriving either in a rush or sequentially.

WHEN TO PERFORM TRIAGE OF PATIENTS

This defines priorities of treatment among many patients with differing severity of injury. You must now try to do the best possible for the greatest number. *You can no longer do everything for everyone.* This 'best for most' policy can create ethical dilemmas.

It is not easy to change your way of thinking and how you face your patients. But if you want to help the greatest number, according to the capacity of your hospital, then *you must be prepared to make this change*.

Having to decide out of many patients whom to admit and whom not is no easy task.

Imagine your everyday out-patient department, with tens or even hundreds of patients waiting to be examined. Some will be quiet, in pain; others will be busy talking to their neighbours, children will be running about, or crying, and everybody will be accompanied by family members or friends. There is a considerable amount of noise.

Now, multiply that number by 5 or 10. Many victims will be severely injured and bleeding; everybody will be afraid. Many patients will be very lucid with a relatively minor injury, such as a closed fracture of the forearm, which will give them great pain. They will see blood around them and be very afraid. Some will become hysterical, shouting that they are "dying" and try to bring attention to themselves.

The noise may be unbearable. *The severely injured patient, of course, lies still, and does not make noise!*

Organising the management of such a crowd of injured patients, some severely hurt, others not so much, and yet others with relatively minor injuries is a challenge in the best of circumstances. *You need a plan to face this challenge*. Such a disaster preparedness plan must be made during a time of quiet and requires a re-organisation of the ordinary running of the hospital, training of the personnel, and simulation exercises.

To organise a good response to a mass casualty event, you must realise that there are no hard rules. There are guidelines and a logic that you must understand, and which you can then apply to many different situations. If you understand this logic, then you will be able to reorganise the functioning of your hospital and medical team to meet new challenges.

CREATING A DISASTER PLAN.

Keep it simple; there will already be enough confusion with the arrival of a very large number of patients. Everybody in the hospital, not just the clinical staff, but paramedical, administrative, cleaning, maintenance, kitchen and laundry staff must understand what they are supposed to do, and how it differs from their everyday workload.

The hospital disaster plan may be part of a regional or national disaster plan. It should describe who declares the emergency and what routine procedures should cease. The plan should stay as close as possible to the normal routines of the hospital.

Too many changes only create more confusion in what is already a chaotic situation. Obviously, such a plan involves the entire staff and must be prepared beforehand. This does not require money or special technology, only time, effort and commitment.

ONE-OFF INCIDENT OR ARMED CONFLICT

A natural disaster, a major accident or an isolated terrorist bomb attack is usually a one-off event. All the victims suffer injury at one point in time. You will have to organise the hospital facilities and personnel to meet the extra need.

The mobilisation of resources is called the *surge capacity*. This is different from hospital to hospital and from community to community depending on the means and resources available.

Some extra help might arrive from other hospitals in other areas of the country or, in a major incident, from abroad: foreign medical teams.

Armed conflict is different. The wounded arrive today, and tomorrow, and the day after, until the end of the fighting. This might be weeks, months or even years. Surge capacity is of little use if you have to face a large number of wounded every day. You have to re-think the organisation of the hospital and change the personnel roster to meet a continual need. Even if everyone in the hospital can work through 24h to treat the patients after a one-off event, this is not now possible for a longer time if you have large numbers of new patients, day in and day out. The hospital has to find a new work rhythm. The basic principles of triage apply in both situations, but you must understand the differences as well.

THE CRITICAL BALANCING ACT
Every hospital is different: infrastructure, number of beds, number and experience of the personnel. Therefore, the capacity of each hospital is different. How many patients does it take to overwhelm your hospital? This will not necessarily be the same for your colleague's hospital in the next district. Again, you must understand the logic of triage, and adapt according to your circumstances.

What are the needs? And what are the resources and personnel available? This is the balancing act you must manage and not only will it change from hospital to hospital, but even in your hospital from day to day.

NEEDS
Estimate the number of patients and their pathology. Are there many patients with penetrating trauma, or burns?
The first requires a great deal of surgery; the second a great deal of resuscitation and nursing care.

RESOURCES FOR TRAUMA SURGERY
(1) Personnel: surgeons, anaesthetists, theatre nursing staff, sterilisation staff
(2) Operating tables
(3) Equipment: instrument boxes of different types
(4) Number of hospital beds
(5) Staffing of post-operative beds

Not only does the number of new patients change every day during a war – some days there is heavy fighting, other days not so much – but the situation in the hospital can also change dramatically.
Imagine in your hospital you have two general surgeons. One day, one of them falls sick with an attack of malaria. Now, you only have one surgeon.
This will affect how you triage the patients, who will have priority for operative treatment.

WHERE TRIAGE OCCURS
Under the best circumstances, triage of priority patients begins at the point of wounding. It continues through first aid and evacuation, all the way to the hospital. It occurs at reception at the hospital and then continues during the victim's admission.

An examination of the patient and putting that patient in a triage category is like taking a photograph of the patient: it is the patient's condition at that point in time and space.

But the patient is actually like a moving picture, getting better or worse over time from wounding to final treatment. You must always keep in mind that, whatever triage decision you make, you might have to change it as the patient's condition changes.

In many countries, prehospital care is woefully inadequate and little in the way of first aid or ambulance evacuation is available.

Triage, in these cases, only occurs on arrival at the hospital. The longer the evacuation time and the more difficult the transport, the greater the number of severely injured patient who will die before reaching the hospital. Short evacuation times, as occurs when a disaster strikes or fighting takes place in a city, make for the more seriously injured arriving alive at the hospital.

THINK 'SALT':
SORT, **A**SSESS, **L**IFE SAVE & **T**REAT
(OR **T**RANSPORT)

TRIAGE CATEGORIES
Many triage systems exist. Keep yours simple and make sure that all members of the hospital team understand it. One system, based on physiological and anatomic parameters, and used by many organisations is this (40.7):

Category I: Severely wounded requiring resuscitation and immediate surgery.
(Usually designated the 'red' category.)

These victims have life-threatening injuries, but have a good chance of recovery if treated in time. Remember ABC (41.1)
Some examples are:
(1) Maxillo-facial trauma or burns to the face and neck requiring a tracheostomy;
(2) Tension pneumothorax;
(3) Internal haemorrhage, wounds to major peripheral arteries;
(4) Head injury with deteriorating GCS & lateralizing signs (coning);
(5) Asphyxiation & crush injuries;
N.B. Usually, this group accounts for 5-10% of the wounded after a major event.

Category II: Seriously wounded requiring surgery, but who can wait.
(Usually designated the 'yellow' category.)

This is a relatively large cohort, c. between 25-30% of victims. Serious wounds, not immediately threatening the life of the patient include:

(1) Abdominal injury without signs and symptoms of haemorrhage, most probably injury to hollow organs only;
(2) Head injury with GCS≥8 with intact airway
(3) Most compound fractures and major soft tissue injuries.
Admit these patients, make sure someone is responsible that they receive analgesia, antibiotics and IV fluids, and undergo any necessary investigations.

Category III: Superficially wounded, ambulatory management is sufficient.
(Usually called the 'green' category.)

This is a very large group, up to 50-60%. These patients do not need admission and you can arrange for them to go to an out-patient spot, for cleaning & dressing of wounds, or for immobilisation of closed fractures.

Category IV: Supportive.
(The 'black' or 'white' category.)

These patients have wounds that are so severe that survival is unlikely even in peacetime circumstances, or whose survival would mean excessive disability, or whose treatment is impossible or just too onerous on scarce resources.
They include:
(1) Head injury with GCS <8;
(2) Quadriplegia;
(3) Burns covering >40% body surface area;
(4) Exsanguinating haemorrhage when no blood is available for transfusion.

You do not 'neglect' these patients, but allocate someone to be with & comfort them in a quiet and isolated corner, to die in dignity, receiving palliative care.

N.B. Once you have dealt with all the Category I wounded, you may attempt to salvage these patients if they are still alive, depending on facilities available.

N.B. These categories are not rigid: victims can improve or worsen while awaiting treatment. *So, their categorization may change!* A continual reappraisal, and re-triage, is necessary.

For example, a victim with a severe maxillo-facial wound (Category I) gets an immediate tracheostomy. Then the debridement and repair, which may take several hours, can wait: (Category II).

Category III patients are numerous and have relatively superficial trauma, which are painful; they are lucid and frightened (they have just survived an earthquake or bombardment), and often become hysterical and create problems of crown control in the hospital. You must be prepared to deal with them, and their relatives!
Try to separate Category III patients from I & II.

Rarely, a Category III patient may deteriorate; make sure your staff for these patients keep an eye open for this eventuality, and re-categorize them accordingly!

There is an 'unofficial' Category V patient of utmost urgency: a young combatant, often under the influence of alcohol and other drugs, puts a rifle into your ribs and commands you to take care of his buddy first. Most often, the comrade is shouting in pain and fear and has a relatively minor wound. It is wise to take care of this fellow first and let the pair leave the hospital as soon as possible!

TWO-STEP PROCESS OF TRIAGE
The first hospital triage decision is a two-step process: sift and sort. Both involve prioritization.

'Sift' is putting victims in one of the major categories.
'Sort' determines what you need to do first.
Your clinical judgement is important: how serious is this injury? What are the chances of survival?

Make an initial examination taking only 15-30secs. Look at, talk to, listen to the patient, and perform a whole-body palpation.

You can easily see and hear most life-threatening injuries: airway compromise and possible suffocation; dyspnoea and laboured breathing; the mental status of the exsanguinating patient.

Check if the patient responds to your questions: the airway is free, and he is lucid.
Check the rate and character of the pulse:

Palpable radial pulse = BP > 90mmHg,
Palpable femoral pulse = BP >70-80mmHg,
Palpable carotid pulse = BP >60mmHg.

So, by looking, listening, & palpating, you can arrive at a physiological diagnosis of injury severity: the basis of the ABC system.

Now, palpate the whole body of the patient: from head to toe, back, front and sides. You may not see a small fragment or bullet wound, but you will feel the hole and see the blood on your gloved finger.

You must therefore be especially careful of any body part that has normal hair: head, axilla, and pubis. You will be able to feel a penetrating wound by palpation of the head, but also a depressed fracture or boggy haematoma overlying a fracture.

Press the rib cage and quickly palpate the abdomen: are there any fractured ribs or guarding of the abdomen?
Palpate the arms and legs and press the pelvis together: any fractures should be obvious.

This '10-finger whole-body scan' allows you to form a pretty accurate anatomic diagnosis.

You can now classify the victim to one of the main categories. It is important to separate the two extremes of injury: the superficially wounded (Category III) and the probably lethal (Category IV).
These victims should not interfere with the treatment of the seriously injured. Concentrate on Categories I and II. This classification does not depend on the number of victims, but only on the specific condition of the specific patient.

N.B. The clinical triage officer should not treat any patients while performing triage; he must only examine and categorise, accompanied by an assistant who takes notes on each patient, or better fills in a card hanging on the victim.

The 3 exceptions are:
(1) the comatose patient
(2) the compromised airway
(3) catastrophic peripheral haemorrhage

Put the victim in the lateral position to prevent aspiration in case of vomiting, clear the airway, or apply a tourniquet. This is best done by an assistant if available.

The first triage decision does not depend on any laboratory work or imaging by radiography or ultrasound, even less by CT-scan if available. *It is a purely clinical decision.*

In the 2nd phase ('sort'), determine which victims have priority for treatment. You may have 10 Category I patients requiring immediate surgery, but only 2 operating teams. You must decide which 2 of the 10 go to theatre first, and then decide on the next, and the next…

Base these decisions on the severity of the wounds and the expectation of good results in the least amount of operating time.
While patients are waiting to go to theatre, you may be able to perform more detailed examinations and get paraclinical investigations done, unless you have another wave of victims to deal with.

TRIAGE TEAMS AND PERSONNEL
You will need a disaster plan before the disaster arrives on your doorstep! Although things never go entirely according to plan, having a structure helps enormously.

Make bright coloured posters or laminated display cards highlighting:
(1) Basic triage (C-ABC)
(2) Who is supposed to do what
(3) How hospital areas are to be utilized in an emergency situation
(4) An evacuation plan.

N.B. Everyone must wear a large label saying what their role is, *e.g.* REGISTRATION, SURGEON, TRIAGE OFFICER etc. so that is clear what everyone does.
Several meetings of the hospital staff are necessary to organise this hospital disaster plan and to allocate specific responsibilities.
Everyone in the hospital needs to know the plan and what is expected of them and how their work may differ from their everyday work.

TRIAGE TEAM LEADER
This is the chief coordinator who announces the initiation and end of the disaster plan. It is usually the hospital director. The leader must have an overall view of what is happening in the hospital, including changing needs for personnel, supplies and equipment.

Communication with the outside world: prehospital services, police, public authorities, journalists all come under the leader's general coordination.

Of course, assistants should be designated to deal with different aspects and report back to the team leader.

CLINICAL TRIAGE OFFICER
This is the person charged with performing the first admission triage. Whether this a senior surgeon, anaesthetist or nurse is not as important as their clinical experience and the respect and trust the staff have in this person.

When a community is hit by a disaster or armed conflict, there can easily be relatives and friends of the staff who are among the victims. If you have to decide on priority for treatment purely on a medical basis, this can lead to very difficult decisions and ethical dilemmas. The respect and trust of the hospital staff in the triage officer are essential. There is no time for arguments or discussion!

HEAD NURSE or MATRON
This is the chief organiser, responsible for the nursing and paramedical personnel and, together with the hospital administrator, for the non-medical support staff: kitchen, laundry, stretcher-bearers, cleaners etc.

RESUSCITATION TEAM
These are personnel allocated to Category I patients to prepare them for theatre. Ideally, each doctor and nurse should have a defined A&E bed and should not move from it.

N.B. Allow the patients to be brought to you. *If everyone in emergency reception rushes to the first patient admitted, chaos ensues.*

The 2nd victim arrives, and then the 3rd, and by the time the last victim comes in, nobody knows who is responsible for whom.
Your underlying motto remains: **Survival – Function – Cosmesis** in that order!

Specific staff should be responsible for putting up IV fluids while taking blood for grouping and cross-matching, tetanus prophylaxis, antibiotics, analgesics, dressing wounds and immobilising fractures, and any necessary bladder catheterisation. If staff numbers allow, keep one 'nurse' to stay with the one patient.

Someone must be designated to perform the 'sort' triage, *i.e.* who goes to theatre first. This may be the same clinical triage officer or someone else, depending on the number and experience of the personnel in any specific hospital.

FOLLOW-UP TEAMS
For the other Categories of patients, specific doctors and nurses need to be designated to do complete clinical examinations, order any investigations necessary, and begin treatment.
Admitted Category II patients will need a second phase 'sort' triage to prioritize who gets surgery first.

Most of these patients will have large soft tissue injuries and fractures: an orthopaedic surgeon is usually best placed to perform this 2nd triage.

N.B. A short procedure may take precedence over a large debridement because of time factors!

For Category III patients, nurses in charge will need to make certain that none of these victims actually have a more serious injury requiring admission. As soon as possible, they should be discharged home with reassurance and a follow-up plan.

N.B. Records (on a card) of such patients treated are important in order for relatives later to be informed and for any follow-up.

Put Category IV victims in a quiet and preferably secluded corner and make sure a nurse gives compassionate palliative care.

ADMINISTRATIVE TEAM
The admission of any patient requires paperwork: registration, a patient file; collecting and safeguarding valuables, money and identity papers (in a small plastic bag) and soiled clothing (in a large plastic bag); contacting and informing the family and organising patient visits when appropriate; and making necessary information available to the public authorities.

In the confusion of a mass casualty extent, this can be very difficult, especially the control and informing of families and friends. Administrative staff should have a *simple* system in place to do all their usual work under unusual conditions.

N.B. Some administrative personnel may well be assigned to serve as stretcher-bearers or some other function according to the needs of the specific hospital.

SECURITY TEAM
Security officers should be under the direct orders of the triage team leader. A mass or multiple casualty incident always involves a mass invasion of the hospital by friends, relatives, curious onlookers, police, & journalists. Crowd control is a major issue, especially during combat when many of the 'visitors' are armed.

N.B. Put in place a system for keeping weapons out of the hospital and this may require assistance from the local police or even the military.
During armed conflict a specific culture develops and, little by little, people begin to understand the rules.

THE TEAM
We describe the functions of the different team members in an ideal situation. Which person fulfils which function, or more than one function, depends on the personnel roster of the hospital.

All too often, the hospital director is the sole surgeon. Who is the triage team leader, coordinator or clinical triage officer in such a situation? Each hospital must make all these preparations for the distribution of responsibilities according to your specific situation, *best in advance!*

The surgeon or anaesthetist cannot insist on being the triage officer, and then goes off to the theatre. When more patients arrive, who should then perform triage? This must be planned beforehand and be part of the disaster plan.

Mass casualty situations are always stressful and tiring for the hospital staff. Rest and relief are essential to keep up with the increased workload. Adapt work rosters accordingly. No one should try to be a 'hero', and work till they drop! *An overworked doctor or nurse falling asleep on their feet is no longer efficient and becomes a danger to the patients.*

RE-ORGANIZATION OF HOSPITAL SPACE
It is impossible to perform triage of mass or multiple casualties properly within the normal functional organization of your hospital.

Your Admissions & Emergency Reception area will not be big enough, there will be many superficially injured patients shouting for help, and there is general confusion and chaos.

Your hospital team will have to study the outlay of the hospital. Maybe the best place for the 1st triage will be the car park, the A&E reserved for Category I victims, and the out-patient department for Category III patients.

Category II patients, waiting for surgery, could be admitted to the wards while waiting. Each hospital is different, and you will have to find the best arrangement given the organisation and space available in your hospital. You may well need to discharge those patients already in the hospital early.

N.B. Each Category of patients will need their own specific area.

EQUIPMENT AND SUPPLIES
Think of everything needed during ordinary work, and multiply: extra stretchers and trolleys; beds, blankets, and sheets.
Make up specific 'triage boxes' containing essential supplies to cover dressings, IV fluids, catheters, tubes, PoP, splints, gloves etc.

Whether extra supplies of medications are held in the hospital pharmacy or elsewhere will depend on the organisation and infrastructure of each hospital.

N.B. Beware with many 'visitors' to the hospital, that equipment does not 'disappear'!

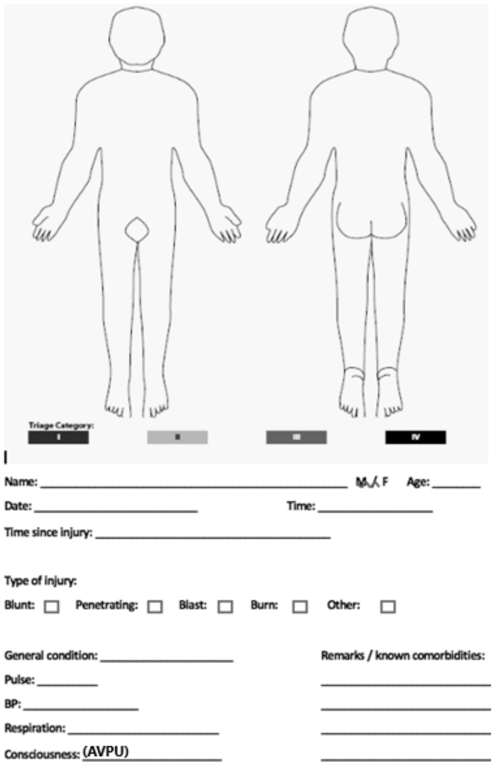
DOCUMENTATION
This must be simple & standard; a supply of specially numbered triage cards prepared beforehand is ideal (40-9). Put the triage card in a plastic sleeve: *in the ensuing chaos, blood, urine and vomit will quickly render any paper unreadable.*

Use an annotation; ICRC recognizes these:

O	wound
#	fracture
→	haemorrhage
Z	burn
——	amputation site

Be prepared to improvise! For example, instead of using IV. stands, string a rope across the room from which to hang fluids or bags.

TRIAGE CARD



Triage Category: I II III IV

Name: ____ M / F Age: ____
Date: ____ Time: ____
Time since injury: ____

Type of injury:
Blunt: ☐ Penetrating: ☐ Blast: ☐ Burn: ☐ Other: ☐

General condition: ____ Remarks / known comorbidities:
Pulse: ____
BP: ____
Respiration: ____
Consciousness: (AVPU) ____

Fig. 40-11 TRIAGE CARD.

INFRASTRUCTURE
Your disaster plan should include extra stocks of spare parts, fuel, water, sanitation equipment and electric power, especially if you depend on generators.

N.B. Maintenance and repair workers need a special work roster as well as the medical staff.

HOSPITAL SERVICES
The kitchen, laundry and cleaning service will carry an extra burden as well: there are greater numbers of patients and staff to feed and clean for. Families of patients, and those seeking shelter in the hospital, can be mobilised to help preparing food, cleaning, and washing the hospital linen; even, after a proper training, as stretcher bearers.

COMMUNICATIONS
As part of the disaster plan, there should be a system to contact off-duty personnel. Communications need to be established with any prehospital services, the police, fire department and any other relevant authorities.

N.B. Many telephone or electronic networks quickly become overloaded! You may need special privileged lines! Mobile telephone networks often do not work after a major natural disaster or during armed conflict. A communication system based on VHF radio is usually better.

You need to make place for the mass media; a designated spokesperson for the hospital, giving out only specific information, should be the *only* person to speak to journalists.
Remember medical confidentiality!

Especially in a warzone, information can be considered a weapon and some information should not be given out. Individual hospital staff should avoid making any ‘statements’.

Communication with other hospitals or the ministry of health, either to transfer patients or to request extra personnel, also needs to be established, if possible.

You and your team should be prepared to act quickly, have your priorities of patient care in order and have a pre-organized plan to deal with multiple trauma. You must be flexible as well; *no event is the same* and you must be able to adapt.

Telephone & computer systems may well fail: use simple methods for recording (boards & pens).

Get team members to wear a label describing their function.

TRAINING
Hold simulation exercises on a regular basis to make certain that everyone knows what they are supposed to do and how their work may change from their everyday tasks. These exercises also help to establish standardised protocols for patient triage and management.

N.B. Many treat these exercises as a joke, but they will be very thankful in the actual event that they are carried out.

After a triage exercise, or especially after an actual event, hold a general debriefing of the entire hospital staff. Discussions of what went wrong or right, in a peaceful atmosphere away from any tensions, will help to refine the disaster plan. No plan is perfect and all require improvement based on experience. Such a time can enormously help staff ‘bonding’.

SECURITY
As well as victims, the patients previously in the hospital, friends, relatives, the curious, those seeking a safe place, all arrive at the hospital in a short time. This is particularly the case if prehospital triage is limited or non-existent.

Crowd control is essential for doctors and nurses to be able to work properly in the midst of an excited and shouting crowd. You must have some system of keeping people out of the hospital in general, and the triage area in particular, organized beforehand. This might involve security officers or the police.

A special organisation of the entrance may help in crowd control. Some hospitals have tried a preliminary triage tent staffed by first aiders, prior to actual hospital triage, or using a container ‘tunnel’ with holes cut in the ends wide enough only for a stretcher to pass. This creates an obligatory passage easily controlled by a security officer: only the stretcher and the stretcher bearers can pass.

To control family and friends, a system of information and control of patient visits is important. People appreciate the extra effort made to provide information about their loved ones and well-regulated visits when patient circumstances permit.

SUMMARY
Remember the ‘best for most’ is rational policy, because usually, ‘everything for everyone’, is not possible.

41 The severely injured patient

41.1 Approach to trauma care

There is only one thing more troubling than a badly injured patient presenting unannounced at your hospital: a truck full of several badly injured people unannounced! (40.8).

PREPARATION
You will inevitably not get much warning of a seriously injured victim. So, it is very important to have a prepared plan. Hardly any patients are likely to have received effective pre-hospital care at the trauma site.

AN ACCIDENT RECEPTION AREA

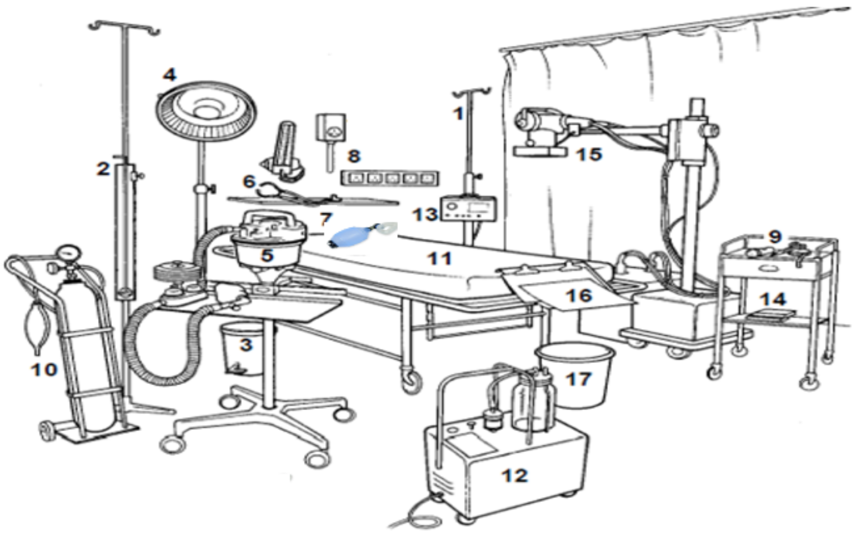


Fig. 41-1 AN ACCIDENT RECEPTION AREA. You may not be able to provide all these things, but try to provide most of them. The best place to take severely injured patient may be your intensive care unit or the operating room itself.
(1) Drip–stand, (2) central venous pressure set, (3) sluice bin, (4) mobile lamp, (5) a completely equipped anaesthetic machine (and a ventilator if you have one), (6) stethoscope & BP machine, (7) Ambu-bag, (8) large plug for portable X-ray machine & several power points, (9) tape measure, torch, and scissors, (10) oxygen cylinder and flow meter with rebreathing bag, (11) special bed or tipping trolley, (12) sucker, (13) blood warming bath, (14) admission books, (15) portable X–ray machine, (16) charts, (17) bin for clothes. You will also need an ophthalmoscope and an auroscope (otoscope), a labelling pen, urine test strips, drip sets, intravenous fluids and cannulae of multiple sizes, and a chest drain set.
N.B. 'Ambu' stands for 'artificial mechanical breathing unit' (not ambulance) and refers to a bag valve mask.

Designate a resuscitation area in your emergency room; otherwise use the operating theatre or the intensive care station. Get tilting resuscitation trolleys, which have a radio-translucent surface, a device to hold X-ray cassettes underneath, holders for an oxygen cylinder and a wire basket for patients' clothes.

Prioritize your tasks roughly this order:
(1) Prepare your team and environment to receive the patient.
(2) Allocate staff.
(3) Perform primary surveys (ABCDE): the goal is to identify life-threatening injuries and intervene appropriately.
(4) Resuscitate and monitor the patient.
(5) Decide whether damage control is needed.
(6) Perform secondary surveys (head-to-toe evaluations and patient history).
(7) Obtain radiographs, ultrasound, laboratory tests.
(8) Re-evaluate the patient & the overall situation.
(9) Provide stabilizing or definitive care.
(10) Prepare for the arrival of another seriously injured patient, or more!

The resuscitation area should contain:
(1) Oxygen, masks, and Guedel airways. You should be able to intubate patients, and so have laryngoscopes and tubes in various sizes (for children and adults) and the necessary drugs available.
N.B. Make sure you designate two persons to be responsible for checking all the instrument batteries routinely.
(2) Warmed intravenous crystalloid solutions at 37-40°C. (A box, or old refrigerator, warmed by multiple lightbulbs is one low-cost option).
N.B. Be sure to have a thermometer to check the temperature within the box. A big enough box can store blankets as well.
A microwave oven is helpful to warm more fluid rapidly or to exceed 40°C in cases of severe hypothermia. *Don't microwave sugar-containing solutions.*
(3) Intravenous giving sets and large-bore intravenous cannulae.
(4) Monitoring devices are very useful (for pulse and oxygen saturation), manual blood pressure cuffs or mechanical devices *must be in good working order*!
You should be ready to attach monitoring leads as soon as the patient arrives, and place an IV line (or two), drawing blood at the same time for necessary laboratory examinations and cross-matching.
(5) Gloves, face mask, eye protection and water proof gowns of various sizes.
(6) Naso-gastric tubes, urinary catheters, chest tubes of various sizes, as well as, tracheostomy or cricothyrotomy equipment.
(7) A portable ultrasound machine.
(8) A dedicated medical waste bin.

Identify a team leader to supervise care. This is vitally important as otherwise no-one knows what to do when, or everyone does everything at once! Choose the most experienced person (who may be yourself) to do the triage, and to supervise the resuscitation. If you have enough staff, this is best to choose 2 different people for these roles. You will need the help of an experienced nurse to supply what you need, especially one who knows where everything is kept, and what is needed when. *So, it's best to create such a team in advance!*

N.B. Remember: the resuscitation situation is fluid and may change at any time: it is vitally important that your team can accept that things are not going right if all is not well, and knows how to change direction, and accepts the decision to backtrack or do something different.

The key is that everyone knows who is doing what, and what they are supposed to do, and the leader communicates instructions, findings, and plans in a loud clear calm voice. Key aptitudes are: Calmness, Communication, Control & Confidence. *Don't panic!* You need to think logically what to do next: go back to first principles if you are stuck, and start again with ABCD.

When things don't go well, have a debriefing and discuss what could have been done better. *Learn from your failings, and do not see them as failures!*

IDENTIFY HIGH-RISK PATIENTS even before you know the extent of their injury. These are:

(a) Babies:

Babies, especially pre-term babies, have incomplete mechanisms for respiratory drive, haemostasis, warming and cooling. Therefore, they are very vulnerable.

Normal vital values are not as in adults:

Age (yrs)	Heart rate	Respiratory rate	Systolic BP
<1	110-160	30-40	70-90
1-2	100-150	25-35	80-95
2-5	95-140	20-25	80-100
5-12	80-120	15-20	100-120

(b) Children:

Remember these are not little adults: children have different kinds of injuries, react differently physiologically, and have different long-term results. They may not be aware of the danger of certain substances & situations.

Injury is by far the most common medical problem which children face, now more commonly than any disease. It is also the greatest cause of death.

Children have small blood volumes! They mask signs of hypovolaemia, even with severe volume depletion. A systolic BP of <(70 + 2 x yrs of age) mmHg is critical. Then, when this reserve is exhausted, deterioration is sudden and disastrous. *Bradycardia is the serious danger sign*.

PHYSIOLOGICAL CHILD NOMOGRAM

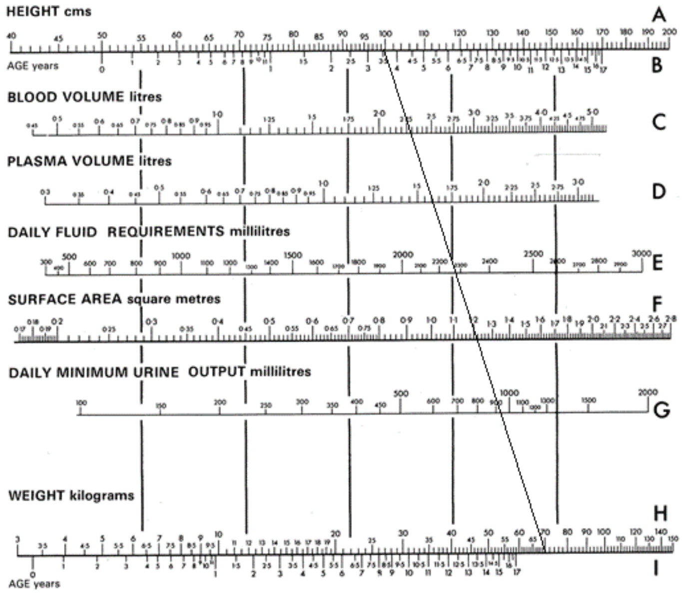


Fig. 41-2 Rule a line connecting your values of height & weight; this is drawn for someone 100cm tall weighing 70kg: where this line crosses C-G, read off the value.

Use a bolus of 20ml/kg IV crystalloids in hypovolaemia, or 10-15ml/kg blood in haemorrhage.
Poor children are often malnourished and anaemic, so replace fluid more slowly and transfuse blood earlier in these.

Children have a larger surface area to volume ratio than adults and so lose heat rapidly; *always keep this in mind*. Keep them warm, protect them from draughts and use warm IV fluids. A burn to a child's head carries much more surface area (50-2) than an adult.

There are specific patterns of injury in children & multiple injuries are common. Any impact has a greater chance of damage in a child: there may be extensive soft tissue injury without external signs.
For example, because of incomplete calcification of bones, rib fractures are uncommon and pulmonary contusion more frequent. The mobile mediastinum makes a pneumothorax more liable to cause mediastinal shift. Place a chest tube in the 2nd intercostal space *not the 5th* in a child, because the diaphragm is higher.

The head in a child is bigger compared to the rest of the body, and so is more likely to suffer trauma. Moreover, *cerebral injury in children presents with hypoventilation and apnoea* rather than tachypnoea. *Don't use rigid cervical collars in children!*

In a young child, the trachea is only 5–7cm long and the cricoid the narrowest point of the airway. *Don't do a cricothyroidotomy in a child <12yrs,* but a tracheostomy. *Always pass a nasogastric tube* to avoid injury to the oesophagus.

Don't ignore psychological stress in children: many may believe trauma is their fault even when it is not! Calm children's fears and be generous with the use of local anaesthetic creams, and ketamine in smaller appropriate doses.

Examine a child in the close company of a parent, if possible, to avoid psychological "withdrawal" when suffering pain or stress. *Don't restrain a struggling child*, but put him in the arms of a parent. *Don't discuss medical procedures in front of a small child*.

There are tragic situations where an injured child is a new orphan or combat involving civilian populations touches an entire family. Psychosocial and rehabilitation problems are great. *Don't forget the important social and economic role played by children in many traditional societies in low-income countries*.

The sight of injured children can also exact an emotional price and psychological burden on members of your team.

Make sure you have equipment of appropriate size! The intra-osseous route is very suitable; tranexamic acid is very good to arrest bleeding.

Median sternotomy and clamshell thoracic incisions are preferred since a left anterolateral approach does not give adequate access. Likewise, a transverse laparotomy incision is best in children.

The liver and spleen are relatively large in children and thus more susceptible to projectile and blast trauma. Avoid splenectomy if possible, owing to the problem of overwhelming post-splenectomy infection, and loss of immunological protection.

Fractures of long bones with growth plates can result in divergence of limb length and require corrective shoes afterwards. Contractures of joints are an immediate problem and can delay or prevent the fitting and use of protheses in amputees.

The collateral circulation is less developed in children with the consequent risk of distal ischaemia. The small size of vessels makes repair more of a surgical challenge. Autologous grafts grow with the child but late aneurysm formation is a possibility to keep in mind.

(c) Pregnant women:

Remember to check for pregnancy in any woman <45yrs: examine early for a gravid uterus and use pregnancy testing early.

Remember you are caring for 2 patients, but the mother takes priority, as she functions as the transport for the foetus, and her health is critical to the foetus.

Because of an increased blood volume in pregnancy, a woman may lose >2L before signs of hypovolaemia become evident.

If the mother suffers hypovolaemic shock, the chances are the foetus will die. A loss of 1L may be unnoticed and will give rise to foetal distress. Therefore, *assess the foetal heart rate early.*

In late pregnancy, the foetus presses on the IVC, and so in the supine position a pregnant woman may become hypotensive; *put a pillow under the right hip.*

Women in later stages of pregnancy have a physiologic anaemia but an expanded blood volume; they are also normally tachycardic and may lose 1.5L of blood without dropping their BP. They are also hypocapnic owing to hyperventilation, and so p_{CO2} at 35-40mm Hg may be a sign of respiratory failure. Also, gastric emptying is prolonged, *so insert a nasogastric tube early.*

A dilated pyelocalyceal system seen on US, glucose in the urine, a widened *symphysis pubis* (up to 8mm), are normal in pregnancy.
Proteinuria is not: beware that eclampsia may look like a head injury!

(d) The elderly:

With age, there is less physiological reserve, greater fragility, slower healing, intolerance of heat & cold, malnutrition or obesity, and diminished immunity.

Cardiac insufficiency is frequent; so administer IV fluids in smaller amounts more frequently, and watch for symptoms & signs of circulatory overload. Elderly patients are less able to compensate for blood loss.

Those taking ß-blockers and those with a pacemaker will not show an expected tachycardia with fluid or blood loss. In an 80-year old, the maximal tachycardia is c. 140/min. A hypertensive patient may be profoundly shocked with a systolic BP of 120mm Hg. Fluid overload is also a big risk in anaemia & chronic renal insufficiency, but poorly functioning kidneys do not tolerate hypovolaemia at all well.

Elderly patients tolerate chest injury badly, especially if there is underlying chronic obstructive airways disease or asthma.

Neurological deficits accumulate with age, and so neurological assessment after injury may be difficult or impossible. You may confuse the effects of hypoxia with simple confusion.

If there is liver disease, watch out for repeated episodes of hypoglycaemia.

Many elderly patients are taking a mixture of medication, not always regularly or logically. Their blood clotting may well be abnormal.

Fractures are common, and particularly of osteoporotic bones, which heal poorly. Old people do not manage bed rest well, and if you keep them in bed for >1 month, *they may never recover!*

Some elderly folk are abused by carers or even their family: *don't miss evidence of neglect or abuse.* Some elderly have previously expressed the wish not to be resuscitated (especially if they have a malignancy); *don't override such a decision if you think it justified.* Consider the possibility of suicide.

(e) The obese (BMI >30):

Apart from difficulties with venous access and diagnosis, cardiopulmonary reserve in the obese is reduced, so administer IV fluids more slowly.

(f) Athletes:

Although, it may seem odd to worry about the most fit of your patients, but they will have a physiologic response more like children and so you may not see the expected early signs of shock. *A pulse of 60/min may actually be a significant tachycardia.*

N.B. Note that if a person survives a severe injury, he develops a huge demand catabolism and loses up to 20g nitrogen/day in the urine.
This equates to 125g protein lost or 625g muscle mass every day! Therefore these patients *must* get a high protein diet to recover! *If they lose 40% of their body protein, they may not survive.*

41.2 Primary trauma care

PRIMARY SURVEY
The principle of a Primary Survey of a trauma patient is to detect (and treat) any life-threatening injuries before they kill him. *You must do this in a logical order.* Thus the most important element, the Airway, comes first, as, obviously, nobody can survive if oxygen is not getting to the lungs. The order follows the letters ABCDE, so is easy to memorize:

<u>A</u>irway (with control of the cervical spine (42.1-4),
<u>B</u>reathing and ventilation (43.1-7),
<u>C</u>irculation with haemorrhage control (44.1-8),
<u>D</u>isability (neurologic status) (45.1-2) &
<u>E</u>xposure/environment/extremities.

Start with a **10sec evaluation** as you introduce yourself and begin your evaluation. Ask the patient his name and what happened. An appropriate response suggests that the airway is intact (speech is clear), the breathing is satisfactory (there is enough air movement to speak), the circulation and neurologic status are probably also satisfactory (the perfusion of the brain is good enough to function).

If you can palpate a peripheral pulse, this gives a rough estimate of systolic blood pressure (radial >90, femoral >80, carotid >60mmHg). Check a good capillary return (<2sec) in the skin.

If this is not the case, deal with problems of **<u>A</u>** before you move on to **<u>B</u>**, and **<u>B</u>** before **<u>C</u>** & so on.
N.B. If at any time, the patient deteriorates during the resuscitation, you should return to the beginning of the ABCD and start again.

The idea is to assess a patient's injuries and resuscitate at the same time. Obviously, this may conflict with making a complete examination or doing various diagnostic tests. *You must strive to keep the patient alive!* This may well mean going to theatre to stop bleeding or to evacuate a haematoma pressing on the brain. *You should try to do this within 15mins, or at least in 30mins.*

In the primary survey, *don't try to calculate the Glasgow Coma Score*; '**AVPU**' (**<u>A</u>**lert, **<u>V</u>**erbal response, **<u>P</u>**ain response, **<u>U</u>**nresponsive) is more relevant. The patient may need mannitol to reduce cerebral oedema (45.1).
Always remember to stabilize the cervical spine (41.3) *until spinal injury has been ruled out!*

SECONDARY SURVEY
Once you have stabilized the patient, proceed with a complete history and physical examination.

N.B. If at any point, the patient deteriorates, return to the Primary Survey!
Look for other injuries, especially of the limbs, and back: log-roll the patient, keeping the neck stabilized.
N.B. Deal with back wounds before anterior chest or abdominal wounds, as turning a patient prone post-laparotomy may result in haemodynamic shock.

Deal with hypothermia by maintaining a warm environment, using warmed IV fluids, and keeping the patient covered with warm blankets (except when you are examining him).

Where haemostasis is not secure or not definitive, control fluid volumes to maintain a systolic BP at 80-90 mm Hg.

If your patient has a BP of 120/70 and good oxygen saturation, but 1h before had lost 4l of blood, he is hardly in a stable condition! He needs very close monitoring, probably more blood transfusion and maybe cardiac inotropic support. *He is not fit for definitive surgical repair,* and you need to think 'damage control' (41.4)

41.3 Cervical spine protection

The neck is easily injured, especially when the head is. A serious neck injury may be catastrophic resulting in tetraplegia, with or without respiratory paralysis, especially while extricating a victim from a vehicle or building.

You must assign someone to hold a trauma victim's head in line with his body till you are sure there is no danger to the cervical spine.

In the history, assure yourself there is:
(1) no dangerous mechanism of trauma,
(2) no numbness or tingling in the arms or hands,
(3) full capability to walk, or no neck tenderness on midline cervical palpation, or pain present before at the site of injury,
(4) voluntary ability to rotate the neck 45º to left or right.

A conscious patient who fulfils these criteria *does not need a rigid neck collar.* Put an unconscious patient in a modified lateral recovery position with neutral neck alignment.

Obtain AP & lateral radiographs which *must* show all 7 cervical vertebrae: for this you may need an assistant to pull on the arms to hold the shoulders down.

Don't apply a neck collar routinely because:
(1) you cannot assess neck vein filling (& the collar may increase intracranial pressure by venous congestion),
(2) you cannot examine the alignment of the trachea,
(3) mouth opening may be difficult, and so airway management impossible in case of vomiting,
(4) you cannot test for meningeal irritation,
(5) respiration may be restricted, especially in a penetrating wound of the neck,
(6) long wearing of the collar may cause pressure ulcers.

For example, a patient with a heart stab wound is hardly likely to need a cervical collar!

However, remember that *minor movements of an unstable cervical spine injury may result in damage to the spinal cord!* Even if a patient has survived a bumpy road journey unscathed, *do not assume his neck must be intact* as a result! So, protect the neck on a spine board from sudden movements with soft pillows and head straps.

41.4 Monitoring

You have now done all you can for an injured patient for the moment, but there may be more to do at any time, so make a thorough assessment thoroughly at definite intervals to observe any changes in his condition, because changes will then be more obvious. Repeat this survey more frequently if the condition deteriorates or there was previously severe hypotension, acidosis, hypothermia or coagulopathy.

Change is gradual, and you are more likely to observe it if you retain a mental picture at one moment and then return 15-30mins later. The change may be subtle: you may observe a change of 10 points in the pulse, increasing pallor, or the onset of sweating. These last cannot easily be measured and charted, yet they often precede a catastrophic fall in blood pressure. If you have even a simple intensive care unit, this is the place for a patient who is seriously ill, before and after surgery.

Record the following:
(1) pulse
(2) oxygen saturation
(3) acidosis
(4) blood pressure
(5) central venous pressure (CVP)
(6) conscious level (GCS)
(7) fluid input & output
(8) temperature: (you may need a special low temperature thermometer)

A quick summary of each patient should include:
(1) Age
(2) Time of injury
(3) Mechanism of injury
(4) Nature of injuries
(5) Signs
(6) Treatment

Nurses who diligently chart these observations are the patient's life-line.

N.B. Check the lungs twice daily at least: this way you will not miss a haemothorax or accumulation of pleural fluid.

It is really worth investing in a bedside monitor for this purpose.

41.5 Critical Care

Every hospital admits critically ill patients, whatever the pathology: medical, obstetric, or surgical, trauma or non-trauma.

In a hospital with limited resources in a low-income country, an intensive care unit (ICU), or intensive surgical care unit, usually with a nurse to patient ratio of 1:1, mechanical ventilation, sophisticated monitoring and therapeutic technology, all supported by sophisticated laboratory facilities, are not available.

Yet, that does not mean that you cannot, or do not, care for critically ill patients every day, the best you can, with the means available.

You therefore should concentrate equipment and staff in a designated critical care unit (CCU). The fundamental elements that are necessary are: a specialised area within the hospital, trained personnel, a higher nurse-to-patient ratio than in a general ward, 24h monitoring, and a steady supply of oxygen.

The care of the critically ill follows the same logic as the triage of mass casualties (40.8): it is always a balance between needs and the resources available.

The setting up of a CCU requires re-organisation of personnel and facilities so that it is possible to segregate, monitor and give the best care possible under the conditions pertaining, to the most seriously ill patients, without too much disruption to the rest of the hospital caring for the less severely ill.

Don't ask if critical care is appropriate; ask rather how it is possible. A lack of resources is not an excuse for not providing the most appropriate treatment available.

ALL HOSPITALS HAVE CRITICALLY ILL PATIENTS

ORGANISATION OF A CRITICAL CARE WARD

(a) Infrastructure
Depending on the infrastructure of your hospital, the ICU should be a room apart, best situated close to the emergency reception, theatres, and X-ray departments.

A post-operative recovery room could function as a high-dependency unit (HDU) and be placed between the theatres and the CCU. This arrangement allows for the same nursing personnel to staff both HDU & CCU and be in close liaison with anaesthetists and surgeons.

Depending on the total number of beds in the hospital and the workload, you should aim for at least 6 – 8 CCU beds. If the hospital infrastructure does not allow for this, then designate part of a large general ward with a localised higher nurse-to-patient ratio as an "acute" bed area.

You may need to make special arrangements for patients requiring isolation or for those with tetanus, who need a quiet and dark room: a small room will suffice.

(b) Arranging the space
Place the nursing station centrally, so that direct visualisation of all patients is possible. Place the beds in an 'L' or 'U' shape. You can separate the beds by a moveable curtain for patient privacy, if required. *Allow enough space around each bed for equipment and clinical manoeuvres.*

An easily accessible area for storing equipment, supplies and medicines, clean linen should be available, as well as for the removal of waste. A sink with running water, soap dispenser, and hand towels are essential. Alcohol-based hand gels are also useful.

(c) Equipment and supplies
Concentrate essential monitoring and therapeutic equipment in the CCU: pulse oximeter, suction, oxygen (either a cylinder or an oxygen concentrator), humidifier system, stethoscope and sphygmomanometer, laryngoscope and self-inflating Ambu-bag, simple ECG and defibrillator.

Organise a separate emergency life-support trolley, to include an Ambu-bag, equipment for intubation, ECG and defibrillator, and emergency medications.

If you have more sophisticated equipment available, and the staff is used to using them, so much the better: *viz.* mechanical ventilation, cardiac monitor, central venous lines.

N.B. Don't forget that the more sophisticated the technology, the greater the need for specialised personnel for maintenance and repair.

Oxygen supply by means of compressed cylinders has many logistical difficulties. Get an oxygen concentrator that can run off the mains current and, if electricity shortages are frequent but short-lived, an uninterruptible power supply (UPS). Battery backup power systems are now available, as well as solar power delivery. Cylinders can always be used as a backup source. Get what best serves your hospital.

(d) Laboratory support

At a minimum, in addition to blood grouping, screening and cross-matching, your laboratory should be able to perform basic blood analysis, biochemistry and serology. Serum electrolytes are good to have, if possible. Arterial blood gases are usually beyond the scope of a district hospital.

(e) Personnel

First and foremost, *increase the nurse-to-patient ratio*. If you have 1 nurse to 10-20 patients in the general ward, try to achieve 1 nurse to 3-4 in the CCU, over the full 24h period.

Optimally, a full-time physician, or at least one who can offer 75% responsibility to the CCU, should be available; a full-time matron is essential.

All too often, the level of training of nursing personnel is far lower than that of doctors. This means that fully trained surgeons, anaesthetists, and other specialist doctors must help in training staff in frequent monitoring of patients and in the early diagnosis of a clinical problem. Many countries, however, have non-physician clinicians who, with proper training and supervision, are highly reliable and efficient.

Families are often involved in patient feeding and care. You should probably restrict this in the CCU, but the particular circumstances of your hospital will decide the best measures to adopt. If family members are present, teach them hand hygiene and other essential procedures, including when & how they can feed their relatives!

(f) Internal CCU functioning

The most important factors are organizational. *A proper functioning CCU doesn't depend on equipment*; rather how you do things:

(1) good nurse–patient ratio;
(2) regular ward rounds;
(3) frequent evaluation and documentation of patients;
(4) structured handover between shifts;
(5) adherence to agreed protocols;
(6) admission and discharge policies.

Close co-operation among all staff involved is essential: you must ensure a daily multi-disciplinary ward round to monitor patients' progress and establish an integrated plan for care. Insist on systematic recording of patient observations and interventions.

A well-structured observation chart, adapted to the context, is extremely helpful. This allows for the establishment of an "early warning system".

Make regular observations of:
(1) airway sounds;
(2) respiratory rate;
(3) pulse and blood pressure;
(4) temperature;
(5) conscious level (AVPU system);
(6) oxygen saturation (by oximeter);
(7) urine output.

Then categorize these observations as normal (green), abnormal (yellow), and critical (red). Such documentation greatly facilitates both training and handover between nursing shifts.

Create clinical protocols and checklists suitable for your context to allow for safe and uniform practice. They also facilitate early recognition of any deterioration in a patient's condition and ensure prompt and appropriate management.

Documentation, protocols and checklists permit the early diagnosis of a problem. Deterioration of a patient's condition is usually preceded by a derangement of physiological signs and symptoms and the efficiency of critical care depends on continuous monitoring, timely recognition of patient deterioration, and prompt intervention.

There is little use in a nurse faithfully and carefully recording a rising pulse and decreasing blood pressure unless it is recognized & reacted upon! *A patient's condition rarely deteriorates suddenly; it is staff who should react suddenly!*

Use protocols to instruct nursing staff what response to make to acute conditions and which resuscitative measures to undertake until medical assistance arrives.

Good hygiene practice, in particular hand hygiene, is essential: simple hand washing *between* patient contact is essential. There are WHO guidelines on hand hygiene and recommendations for sustainable local preparation of hand rub formulations. You can print, laminate and display these prominently for ready reference.
Remember that excessive stress on staff will contribute to rushed care and increase in nosocomial infection

(g) Admission and discharge criteria

The success of a CCU depends mainly on the type of patients admitted. Consultation amongst staff is important to avoid any unnecessary tension and friction within the hospital team.

Again, the logic of triage is a help: *avoid fruitless efforts and recognise probable survivors*. The CCU is neither a casualty department, nor a terminal care unit. The patient who will most benefit will be an otherwise relatively healthy person suffering from an acute condition, so often the case after trauma.

An acute exacerbation of a chronic condition, or several chronic conditions, is a much more difficult clinical problem, with less chance of a positive outcome, especially when working with limited resources.

Examples of conditions that would benefit from admission include patients with:
(1) tracheostomy or chest drainage;
(2) tetanus,
(3) eclampsia,
(4) venomous snake or scorpion bite,
(5) coma & head injury,
(6) post laparotomy or Caesarean section,
(7) need of frequent monitoring, IV fluids, *e.g.* polytrauma cases

Just as criteria for admission need to be decided upon by the team, so likewise the criteria for discharge to the general ward. *Scarce resources and overworked personnel do not make a good mix.*

(h) Assisted ventilation

A condition requiring assisted ventilation is often given as criterion for admission to an intensive care unit in a high-income country.

In the absence of mechanical ventilation, this would appear to be a non-starter! However, relatively few patients actually need assisted ventilation.

If you do have the possibility to acquire a mechanical ventilator, find one with appropriate technology such as a ventilator that runs off an oxygen concentrator, rather than pressurised cylinders. This still requires a constant electricity supply and maintenance staff.

You can always 'bag' an intubated patient with an Ambu-bag. Mobilize volunteers from amongst family and friends and train them to squeeze the bag in synchrony with their own breathing. How long such improvisation can, or should, continue will depend on your circumstances.
However, your discharge criteria must define this situation very carefully.

Assisted ventilation, of whatever type, creates stress in the rest of the hospital. When to take a patient off ventilation (either because it is no longer needed, or no longer useful), can easily disturb the functioning of the other wards because of its consequences. Consider the repercussions on relations with the family. This is especially the case if the possibilities for assisted ventilation are limited and another critically ill patient requiring ventilation presents.

41.6 Damage control

DAMAGE CONTROL RESUSCITATION
The concept originated in the US Navy, referring to the ability of a ship to absorb damage and maintain mission integrity:

DAMAGE CONTROL

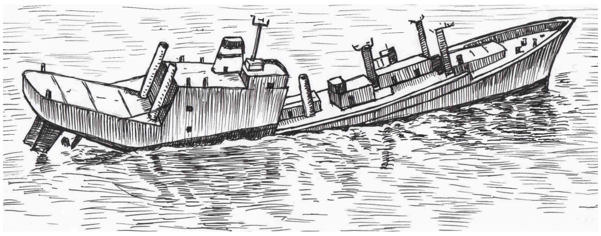


Fig. 41-3 DAMAGE CONTROL. The idea is to fix just as much as you need to get 'home' where you can make the proper repairs.

The idea behind 'damage control' is to try to limit the serious effects of injury, and not to add to them by unnecessary or futile procedures. Damage control resuscitation focuses on correcting initial hypotension by the early use of blood, and keeping the patient warm.

The combination of coagulopathy, hypothermia, & acidosis, which occurs in severe trauma, often results in death. Left untreated, the result is a vicious cycle in which each one of these increase the severity of other and the patient enters a downward spiral.

(a) Coagulopathy
Bleeding uses up clotting factors in the blood to try to stop the bleeding naturally. The more the blood loss, the greater the loss of clotting factors.
In pre-existing liver & renal failure, there are usually clotting disorders already present.

Transfusing fresh whole blood is much better at correcting coagulation than re-combining blood derivatives such as red cell concentrates, plasma, and platelets.

Fortunately, the procedures and availability of relatives and friends in low resource environments are often much simpler than in more sophisticated centres.

N.B. Use fresh frozen plasma (FFP), in other cases of coagulopathy. *Beware if your testing of HIV and other transmissible diseases is poor, the risk of using FFP is much higher than blood*, because it is pooled from several donors.
N.B. Clotting becomes worse with hypothermia & acidosis.

(b) Hypothermia (45.2)
Patients can become cold in any place, at any time of year and at any altitude. Patients may become cold in temperatures you might consider warm.
Always assume your patient's temperature is dropping right before your eyes, because it is, and much faster than you would expect (2ºC/h). Keep the examination room warm and minimize drafts.

Uncover the patient completely for examination, but cover up again as soon as you can. Remove all wet clothing and replace these with dry, warm blankets. Help the patient avoid shivering.

Administer only warmed fluids (37-40ºC): room-temperature (15-25ºC) fluid and chilled blood products given in any amount will exacerbate hypothermia.

Clotting is dependent on the temperature and pH. Also, hypothermia leads to impaired tissue oxygen delivery and so to decreased cardiac output, myocardial ischaemia, decreased cardiovascular response to catecholamines (adrenaline), and dysrhythmias such as atrial and ventricular fibrillation.
Hypothermia also impairs the function of white blood cells and leads to increased sepsis.

(c) Acidosis
Poor perfusion of the tissues, anaemia from acute blood loss, peripheral vasoconstriction in response to hypothermia and blood loss, and overall decreased cardiac output all severely impair oxygen delivery to the tissues.
Anaerobic metabolism results and the serum lactate level rises. *This may occur in the presence of normal or slightly abnormal vital signs.*

Moreover, normal (physiological, 0.9%) saline, which has a pH c. 5.5, far more acidic than the desired normal blood pH. So, in large volumes this produces a hyperchloraemic acidosis which compounds any existing lactic acidosis.

The high chloride levels increase systemic tissue inflammation and contribute to the coagulopathy. Ringer's lactate (Hartmann's) solution has a pH of 6.5, *but does not increase lactic acidosis* because its lactate is metabolized faster than it is infused.

Furthermore, breathing difficulties, whether central or local may also produce a respiratory acidosis owing to the accumulation of CO_2 levels, especially if there is pre-existing chronic obstructive pulmonary disease.
When the pH reaches <7.2, coagulation and oxygen delivery are both impaired and muscles, including respiratory muscles, become fatigued. Also, the mental state deteriorates, up to and including coma.

ABCDE
Clear the airway as a first priority: if you don't succeed, move rapidly to cricoidotomy or tracheostomy (42.3).

Establish good ventilation: this may mean a needle thoracostomy (43.1), chest drain (43.2), or endotracheal intubation (42.2). Administer oxygen.
Replace fluid loss: make sure you have large-bore IV access, and preferably a second IV cannula in place (in case the first falls out, blocks, or you need to pour in large volumes of blood). Start blood transfusion as quickly as possible if there is >2l blood loss in an adult (less in children and much less in babies).

Keep the patient warm: use warm blankets, warmed IV fluids (37-40°C), and warmed blood.

Stop the bleeding!! This may mean applying a tourniquet, quickly suturing a scalp wound (44.2), inserting a balloon tamponade, splinting broken bones, performing a laparotomy or (less commonly) a thoracotomy. *Don't delay!* Administer tranexamic acid.

Preserve brain function. The most frequent cause of brain damage is hypoxia, so make sure the airway & ventilation, and circulation are satisfactory first. If the signs suggest you need to perform a craniotomy, *don't delay!*

SURGICAL INTERVENTION

It's all a question of time.

TIME IS BRAIN; TIME IS LIFE

Get the patient to theatre without delay! Don't compromise on safety for the neck: keep it immobilized.

You don't need radiographs in the extreme situation. Unless you have an X-ray facility in the resuscitation bay, don't bother with radiographs even in acute cases. Use your clinical examination, and if possible, ultrasound (FAST, 43.2, 44.3).

N.B. A chest radiograph will often miss a significant haemothorax.

N.B. A cervical spine radiograph often misses some vertebrae, or is very difficult to interpret. A pelvic radiograph doesn't show if a fracture is bleeding.

Make sure the theatre is prepared for any time of day or night. If you have to call in staff, do so early on! Make sure you have packs, and blood available, and auto-transfusion equipment (5.3).

If your intervention will take >90mins, it will probably result in serious complications. So, if you are not experienced, or if you are naturally a slow surgeon, *don't perform complicated procedures!* The risk is the patient will die on the table or shortly afterwards.

Remember that the place to correct the stress of injury is not the theatre where there is more stress from surgical intervention!

Monitoring where you are every 10mins is an important way of keeping track of progress: use 'STACK':
(1) Systolic blood pressure
(2) Temperature
(3) Acidosis
(4) Coagulation diathesis
(5) Kit (make sure enough equipment is available)

In unsophisticated centres, it is best to do what is simple, quick and easy to perform. These will give the best results. *Don't try to fix everything the first time round!* Come back after the patient has had a respite, when the condition has improved, and there is more reserve to withstand more stress.

THE 4 PARTS TO DAMAGE CONTROL:
(1) DC0 is Disaster Control Resuscitation: the emphasis here is rapid assessment & initial treatment in your resuscitation room.
(2) DC1 is rapid control of bleeding and contamination, packing, and temporary wound closure in the operating theatre.
(3) DC2 is continuing intensive resuscitation to correct physiological & biochemical disorder and checking for other less important injuries.
(4) DC3 is definitive repair; this may require several separate visits to theatre if there are multiple injuries or problems.
Details of each of these stages are described in the following chapters, but these are important comments regarding each step:

(a) *Optimize cardiac output.*
If you can, insert a CVP catheter and measure pressures. with a manometer to guide fluid administration and normalize the hemodynamic status.
Try to check serum lactate levels, as this will give you an excellent guide whether your patient is improving; a return to normal levels by 24h are a good indication of recovery.

(b) *Optimize oxygen-carrying capacity.*
Correct underlying anaemia (use a Hb of 100g/L as your goal; remember that levels above this do not improve a patient's oxygenation).

(c) *Recognize need for re-operation in 24-36h.*
These causes will probably need an early or unplanned return to theatre:
(1) Failure to make regular progress towards normal Hb, lactic acid, pH, temperature, clotting times and oxygen saturation.
(2) Ongoing bleeding despite normalized clotting and core temperature.
(3) Visceral injury that you missed before.
(4) Development of abdominal compartment syndrome.
(5) Limb compartment syndrome.
(6) Sepsis: *the earliest symptom of this is loss of appetite & unexplained fall in urine output.*
(7) A smelly or obviously septic or contaminated wound.

Before you reach DC3, ask yourself if the patient is ready. If you ask another, more experienced, surgeon to do the second-look operation, you must discuss the case thoroughly and make a detailed hand-over.

42 Airway priority

42.1 Causes of airway obstruction

For any trauma patient, *you must always rapidly identify if there is an airway problem* because hypoxia can quickly be lethal, or cause irreparable brain damage.

Practice techniques on simulators, mannequins, & watching videos, and then on stable patients in the controlled setting of an operating theatre. Once you are familiar with the equipment and techniques, you will find managing the airway in trauma patients much easier and less stressful.

ABCDE:
AIRWAY, BREATHING, CIRCULATION, DISABILITY, EXPOSURE

PRIMARY SURVEY
If a patient survives the initial injuries & does not have catastrophic external haemorrhage, *the next immediate risk is obstruction of the airway.*

Ensure he can breathe: this must be your 1st priority.

Look for:
(1) coma or decreased conscious level (GCS <8),
N.B. This depresses protective airway reflexes, *so incurring risk of broncho-aspiration,* and causes relaxation of the tongue (which then falls backwards) and jaw musculature, *risking upper airway obstruction.*
(2) oro- or maxillo-facial injury,
(3) respiratory or facial burn,
(4) penetrating neck injury (especially with an expanding haematoma)
(5) anything that occludes the airway, such as broken or false teeth, laryngo-tracheal injury, or laryngospasm.
(6) aspirating vomit, or oils rubbed on the face (47.4).
(7) apnoea or hypoxia from any cause.

A patient who can speak clearly has an open airway.

Signs of upper airway obstruction are:
(1) Lack of air movement or any sound of breathing associated with forceful movements of the chest wall and abdomen,
N.B. This indicates complete airway obstruction and is an absolute emergency.
(2) Inward movements of the chest wall or epigastrium, & use of accessory muscles,
(3) General signs of hypoxia (initial tachycardia, later bradycardia)
(4) Restlessness, agitation or confusion,
(5) Cyanosis (often a difficult sign to detect),
(6) Sweating
Never sedate such a patient!
Monitoring will show a low O_2 saturation (<90%).
Hoarse voice, noisy breathing *(stridor)****, or sounds of snoring, indicate partial airway obstruction.***

N.B. Wet, bubbling sounds may indicate blood, secretions or vomitus in the upper airway or tracheo-bronchial tree.

Sometimes the airway is clear, but delayed obstruction is likely. So you should prepare for this. Suspect this in:
(1) Respiratory & facial burns,
(2) Neck injury,
(3) Subcutaneous emphysema in the neck,

N.B. If you wait, and do nothing, the obstruction usually gets worse!

Feel for:
Tracheal deviation,
Fractured ribs,
Subcutaneous emphysema,
& Listen for:
Decreased & abnormal breath sounds (as well as stridor).

AIRWAY MANAGEMENT
This is usually divided into basic (42.3) and advanced (42.4).
Always administer oxygen, if available, during airway manipulation.

If the patient has impaired cognitive function (GCS≤8), and there are no airway tools available, *make sure he is transported in the recovery position* (42-1).

IF IN DOUBT ABOUT THE AIRWAY, PERFORM A TRACHEOSTOMY. *DON'T DELAY!*

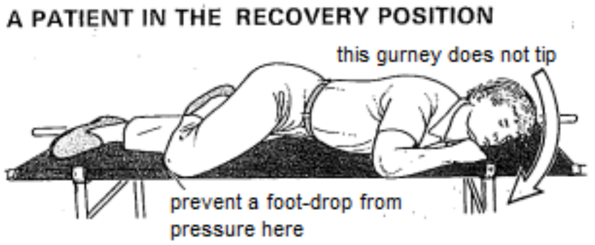


Fig. 42-1 THE ¾ PRONE POSITION. This is the 'recovery' position: on the side with the thorax at 45° to the horizontal. Support the chest with a pillow, but *don't let it interfere with breathing*. Flex the uppermost arm in front of the trunk with the hand under the jaw to give additional support. Keep the lower arm behind the back. Prevent rolling over by flexing the upper leg, while the other remains extended, but *don't let the knee press against the common peroneal nerve for a prolonged period,* as this can result in foot drop. *Always lay a pregnant woman on her left side!*
N.B. If a patient rolls over to the fully prone position, especially if obese, proper breathing may not be possible! So, return to the semi-prone position immediately!

HEAD TILT & JAW THRUST MANOEUVRES

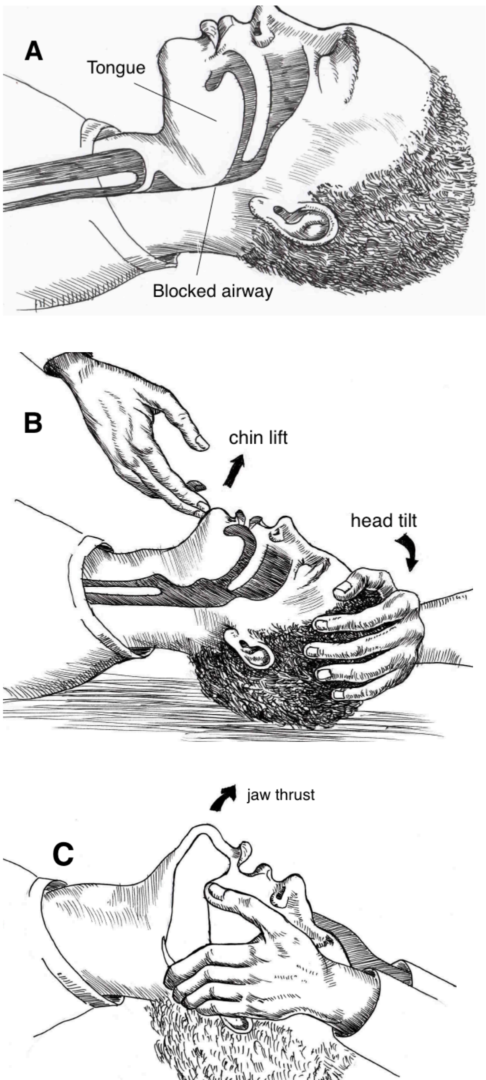


Fig. 42-2 CLEARING THE AIRWAY. A, the tongue from falling back & occluding the airway. B, the chin lift & head tilt or C, the jaw thrust freeing the airway.

If there is vomitus or blood in the oropharynx (and the patient is unconscious), clear the oropharynx with strong suction while the patient is in the lateral position.

N.B. Don't use your fingers, unless a bite block is in place.

The patient's tongue falling back is the most frequent cause of partial or complete airway obstruction in poorly responsive trauma patients. Perform the head-tilt/chin-lift or jaw-thrust manoeuvre (41-2) to improve airway patency.

THE CHILD IN THE SUPINE POSITION

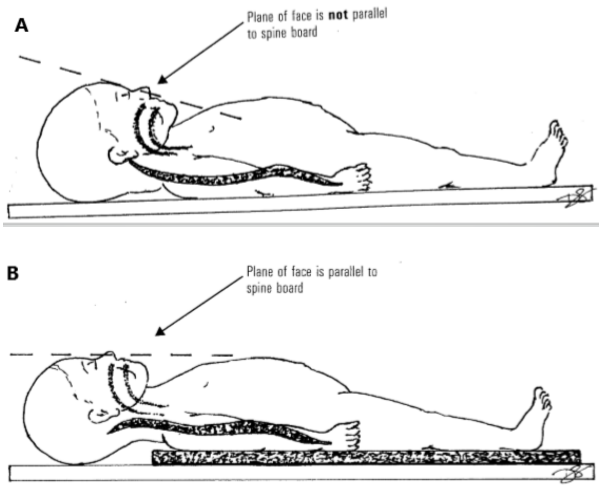


Fig. 42-3 LYING A CHILD SUPINE. A, the relative size of the head means that neck is flexed. B, when you put padding under the body, the face becomes parallel to the stretcher board.

In a child lying supine, the size of the head causes passive flexion of the neck. This threatens the airway, so place a layer of padding under the child's body (42-3).

N.B. If there is a chance of cervical spine injury, pull the tongue forward with a swab, forceps or suture, or use an oral (Guedel) airway (42-3).

THE ORAL (GUEDEL) AIRWAY

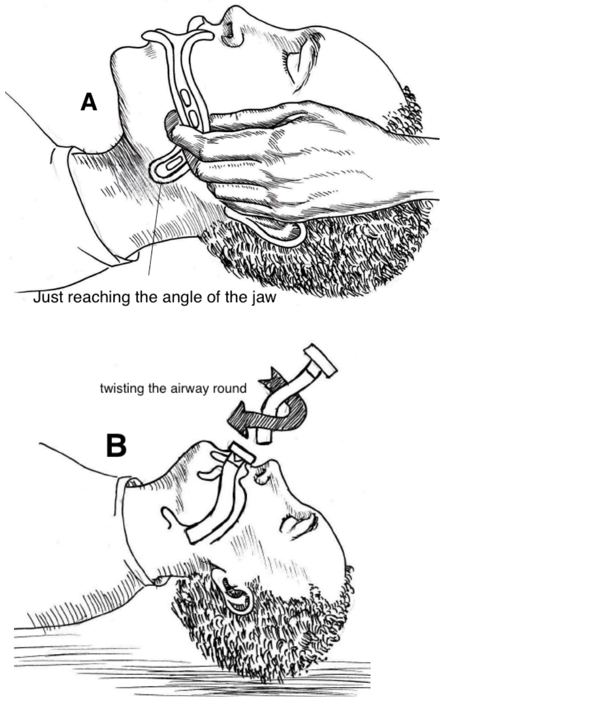


Fig. 42-4 INSERTING A GUEDEL AIRWAY. A, measure the correct size to use *(should reach the angle of the jaw)*. B, insert the airway upside down into the mouth, and then turn it round so it glides over the tongue. *N.B. Sanitize metal (non-disposable) airways thoroughly after use.*

N.B. If such an oral airway is well-tolerated, there is significant depression of the protective airway reflexes, which may mean you should intubate the patient, provided you have the necessary skills and equipment. The Guedel airway is often very useful in alcohol intoxication, in which case, however, you may not necessarily have to resort to tracheal intubation.

A naso-pharyngeal airway will also relieve airway obstruction by lifting the soft palate and tongue (42-5). These airways are better tolerated than oral ones. They are especially valuable in cases of trismus. Use ephedrine (or xylometazoline) vasoconstrictive nasal spray, LA and lubricant jelly before passing the airway through a nostril; this helps prevent nose-bleeding and eases its passage.

You can use the jaw thrust and chin lift, to restore airway patency quickly (42-2), but this needs manpower to maintain. So, to free you for other tasks, insert an airway if the conscious level does not improve substantially quickly.

N.B. A patient may need both an oral airway and a nasal trumpet (airway) to relieve obstruction.

Note if breathing responds to your initial management. If not, move rapidly to other options.

INSERTING A NASOPHARYNGEAL AIRWAY

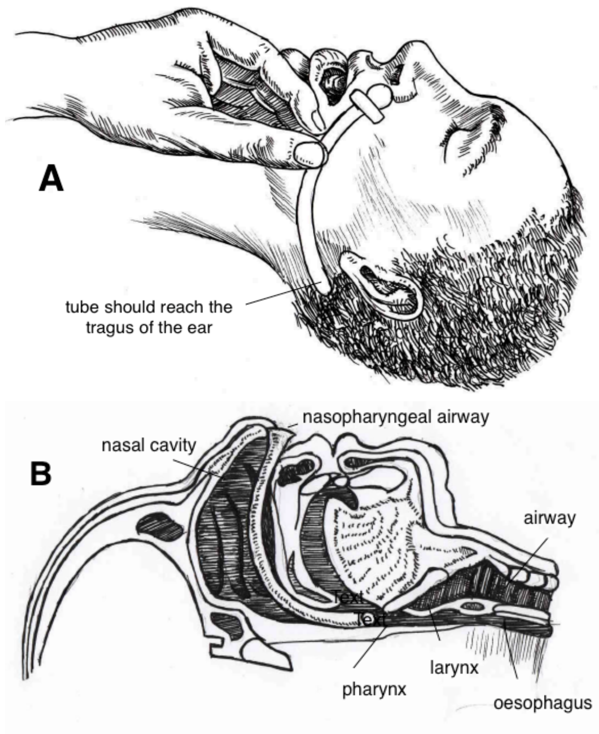


Fig. 42-5 INSERTING A NASOPHARYNGEAL AIRWAY. Choose the nostril which is least deviated. A, measure the correct size (to reach the tragus of the ear). B, pass it into the nasopharynx.

The Laryngeal Mask Airway (LMA, 42-6) is a very useful device in difficult situations. Its purpose is that the mask sits in the hypopharynx covering the glottic opening and providing an airway. The cuff forms a low-pressure seal around this opening.

LARYNGEAL MASK

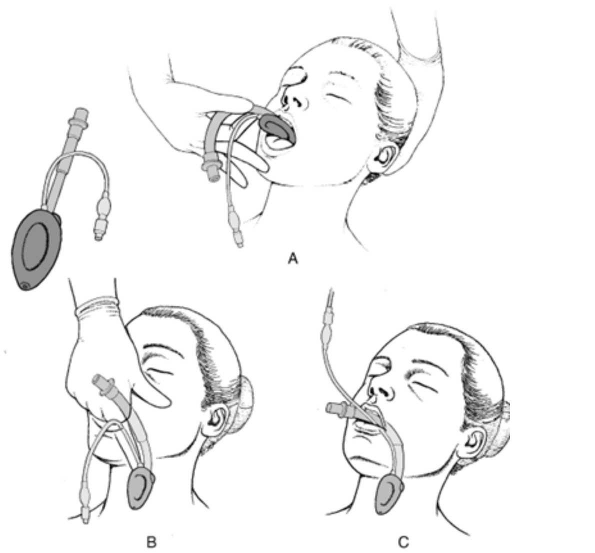


Fig. 42-6 INSERTING A LARYNGEAL MASK. A, press the LMA against the hard palate and slide it into the mouth. B, use your middle finger to push the jaw downward. C, advance the LMA till it sits in the oropharynx.

It is not a secure airway, because broncho-aspiration is still a risk, but it is an excellent rescue device if you cannot aerate a patient with a bag-mask nor intubate the trachea. After you have inserted an LMA, the patient may breathe spontaneously or need manual ventilation.

N.B. Like the Guedel airway, you can only use this device in poorly responsive, comatose or anaesthetized patients.
CAUTION! If residual reflexes are present, placement this tube may promote vomiting and subsequent broncho-aspiration.

To place an LMA, first prepare the device by deflating the cuff and lubricating the posterior surface. Open the patient's mouth and, under direct vision, press the tip of the LMA against the hard palate and slide it into the mouth (42-6A).You may use your middle finger to push the jaw downward (42-6B); this also ensures the tongue is not trapped within the LMA opening and dragged deeper into the oral cavity.
Advance the LMA until it resists additional forward motion (42-6C). Inflate the cuff and attempt ventilation. If there is a leak you can reposition the LMA or try using one size larger, or smaller:

Mask size	Weight (kg)	Patient	Cuff volume
1	<6.5	infant	2-3
2	6.5-20	small child	5-10
2.5	20-30	large child	5-15
43	>30	small adult	5-20
4	<70	adult	15-30
5	>70	large adult	20-30

Once you have performed the necessary manoeuvres to maintain an open airway, assess whether the patient needs ventilatory support.

Look for these signs:
(1) Bradypnoea,
(2) Gasping,
(3) Rapid shallow ventilation,
(4) Respiratory fatigue,
(5) Refractory hypoxia
(6) Apnoea.

These suggest a '**Breathing**' problem needing immediate attention (41.1, 43.1,2).

You can assist a patient's breathing or breathe for him with AMBU bag ventilation. This is a skill, and it takes time to acquire the necessary expertise to ventilate difficult patients effectively. When you hold the mask, it is important that the tip of your fingers grasp the bony contour of the mandible, not the soft tissues of the floor of the mouth, which would aggravate any obstruction (42-7).

Even in experienced hands, a two-hand/two-person technique may sometimes be more effective, with one person holding the mask with both hands and another squeezing the bag.
It is important to observe the patient's chest movements while performing BVM ventilation to ensure that you are actually ventilating the patient.

HOLDING A FACE MASK

Fig. 42-7 HOLDING A FACE MASK PROPERLY. This is a skill you must learn. Although the 'C-E' grip is recommended, you can't really properly hold on the mask with one hand.

If the patient is breathing spontaneously, but requires ventilatory assistance, squeeze the bag as the chest is rising and release the bag during exhalation.
N.B. If you are not in synchrony with the patient's efforts, you might even worsen the ventilation and oxygenation!

If you feel or hear an air leak around the mask, change your hand position to obtain a better seal.

If the patient is not breathing spontaneously (and you are assisting him), *make sure there is symmetrical chest movement with each administered tidal volume*. Get someone to check the patient's breath sounds with a stethoscope. If you have a pulse oximeter, you should maintain saturation >90%.

If you are having trouble ventilating the chest, consider another option to improve airflow (e.g. laryngeal mask or intubation).

If ventilation is not adequate, the patient is unlikely to survive. the only chance is intubation or one of the adjuncts (42.3) or a surgical airway.

42.2 Endotracheal intubation: indications, dangers & methods

Indications for endotracheal intubation include:
(1) Relief of airway obstruction,
(2) Airway protection in an unconscious patient,
(3) Airway support where the airway may be compromised later,
(4) Ventilatory support,
(5) Access for bronchoscopy,
(6) General anaesthesia.

N.B. A severely injured, poorly responsive or unconscious patient may not require anaesthetic drugs for intubation, but *remember the adverse effects of possible straining, gagging, and coughing*.

In preparation, work through as much of this checklist as is feasible in your specific situation:
(1) Rapidly assess the airway.
(2) Monitoring: (oximeter, blood pressure, ECG).
(3) Ensure the oxygen flowing (and pre-oxygenate, if there is time).
(4) Ensure adequate IV access.
(5) Ensure all equipment is present and ***working***!
(6) Ambu-bag with high flow oxygen.
(7) Masks of all sizes.
(8) Functioning laryngoscope with blades of different sizes.

(9) Endotracheal tubes
(7-8 for adult males; 6.5-7.5 for adult females).
N.B. The formulae (4 + ¼ x age of child) = uncuffed child tube size, & (3 + ¼ x age of child) = cuffed child tube size.
Use an uncuffed size 3 for infants >3.5kg and <1 year old.
(10) Smaller sized endotracheal tubes (unopened).
(11) Get a bougie or stylet ready.
(12) Ensure suction is available and ***working***!
(13) Draw up the necessary drugs into syringes, *and label them.*
(14) Position the patient.
(15) Have a LMA on the back table.
(16) Have a cricoidotomy or tracheostomy set available

INTUBATING USING DIRECT LARYNGOSCOPY

Positioning the patient is key to successful endotracheal intubation using direct laryngoscopy. The goal is to align the patient's head and neck in such a way as to allow direct visualization of the vocal cords (42-8). Use the 'sniffing position' (flexion of the lower cervical spine on the thoracic spine, and extension of the head on the upper cervical spine).

POSITION FOR ENDOTRACHEAL INTUBATION

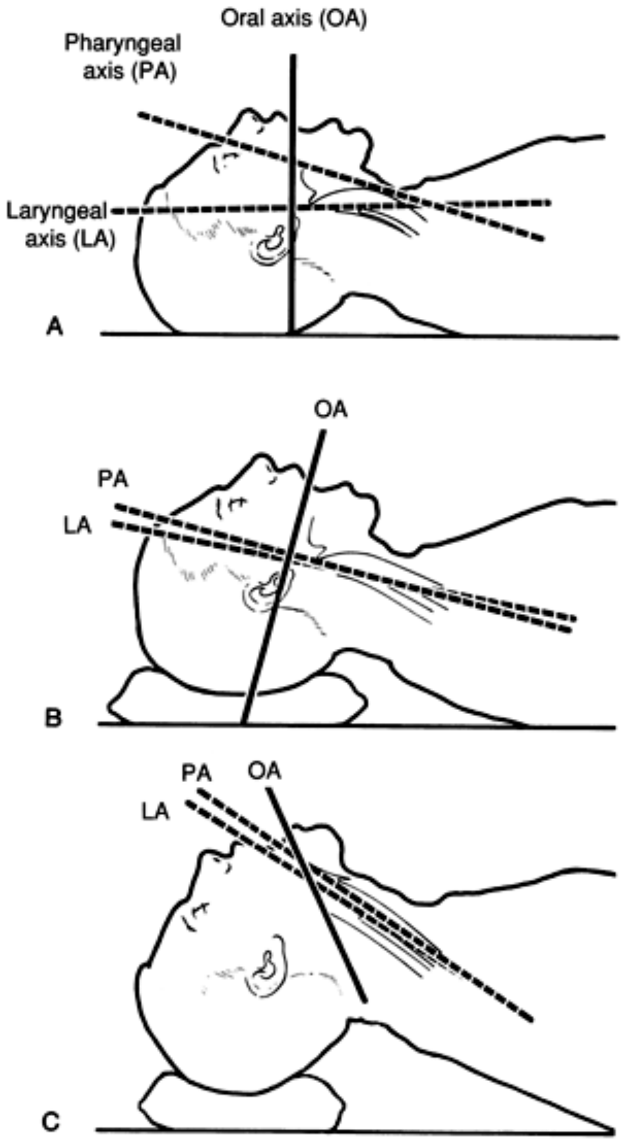


Fig. 42-8 POSITION FOR ENDOTRACHEAL INTUBATION. Use the 'sniffing position' Note how the laryngeal axis changes with position

In obese patients, ramp up the patient (42-8) by placing folded blankets under the thoracic spine, and then place him in a sniffing position. In the ideal ramped-up position, the tragus of the ear is at the same level as the sternal notch when you view the patient from the side.

Hold the laryngoscope in your left hand. Open the patient's mouth with your right hand, and introduce the laryngoscope into the right side of the mouth. Sweep the tongue to the left and hold it in that position with the flange of the laryngoscope blade (42-10).

Remove ill-fitting dentures, but keep well-fitting dentures in place.

POSITION FOR INTUBATION IN OBESE PATIENTS

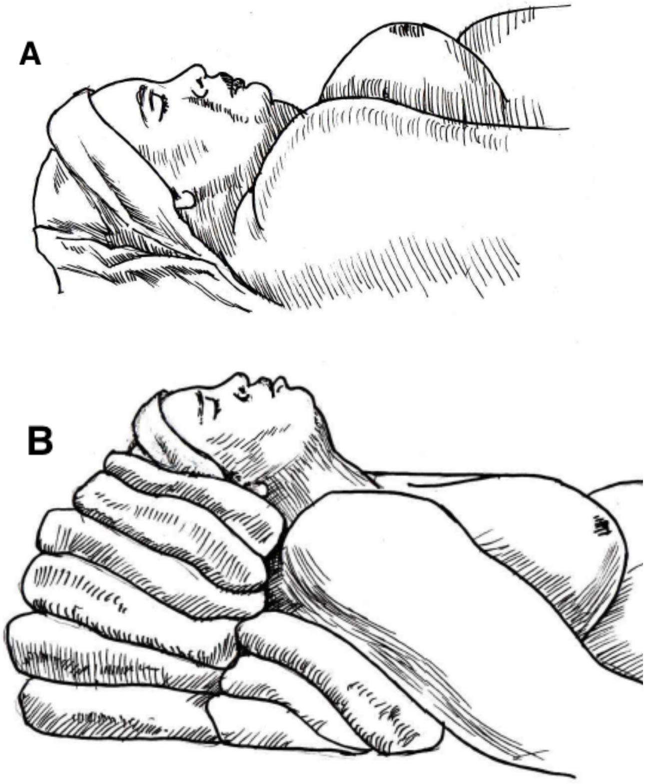


Fig. 42-9 A, the supine position *(endotracheal intubation impossible)*. B, the 'sniffing' position, maintained by a careful assembly of cushions.

INDUCTION AGENTS & PARALYTICS
Unless the patient is already unconscious, administer induction agents *before* paralyzing agents. Their duration of action is short (<3mins). For continued anaesthesia, replace them with longer acting sedatives, an inhalational agent, or a continuous infusion immediately following intubation. Ketamine is the best choice when expertise is limited. Neuromuscular blocking agents make intubation significantly easier, but are not always necessary, and carry serious additional risks.

Sweeping the tongue to the left gives a clearer view of the glottis and allows you to advance the endotracheal tube without the tube itself obstructing your view. Insert the tip of the curved blade into the vallecula, although you can also use it to lift the epiglottis. (A straight blade typically is better for this).

Don't tilt the handle back onto the upper teeth! Move it forward or upward, sometimes with considerable effort, in a curve aligning it with the handle of the laryngoscope. This lifts the mandible and soft tissue and exposes the vocal cords without damaging the teeth (42-11).

VIEW OF DIRECT LARYNGOSCOPY

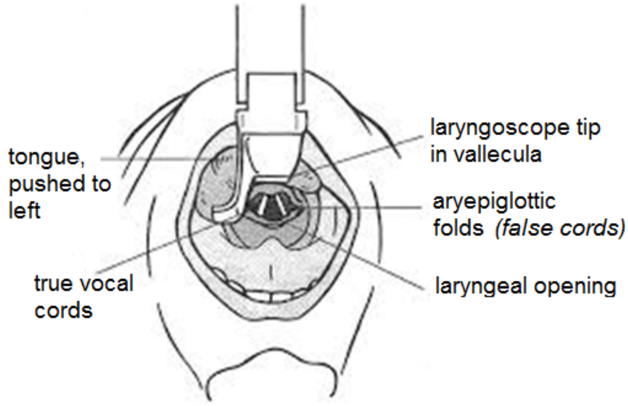


Fig. 42-10 DIRECT LARYNGOSCOPY VIEW.

VIEW OF THE VOCAL CORDS & TRACHEA

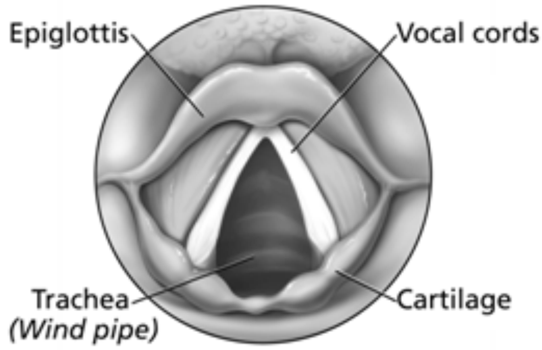


Fig. 42-11 VIEW OF THE TRACHEA

If you are worried about a cervical spine injury, keep the head and the neck in a neutral position and get an assistant to apply in-line-traction, either from the front (42-11) or from behind.

IN-LINE NECK STABILIZATION

Fig. 42-12 HOLDING THE NECK RIGID WHILST INTUBATING.

Holding the neck rigid may make it more difficult for you to visualize the entire glottic opening. Try using the bougie in this situation.

If you can visualize any portion of the epiglottis, advance the bougie directly under it. One end of the bougie has a flexed end to make this easier, and you can mould the bougie into a useful C-shape. When you enter the trachea, you will feel the bougie bump along the superior portion of the tracheal rings as you advance it. Hold the end of the bougie and avoid tearing the endotracheal tube cuff on the teeth as you advance it over the bougie into the mouth and into the trachea.

N.B. It is easier to succeed in placing the endotracheal tube, if you get an assistant either to hold the laryngoscope in position, or to advance the tube.

It is not uncommon for the inferior portion of the tube opening to snag against the arytenoids. This will stop you advancing it into the trachea, but you can easily overcome this problem by rotating the tube 360° and slide it into the trachea.

If you do not have a boogie, a metal stylet inside the tube will make it handier to shape as desired (*e.g.* U-shape, hockey stick, etc.). In this case, the tip of the stylet must never protrude beyond the tip of the tube where it risks lacerating the trachea or larynx.

During direct laryngoscopy, as soon as the tube tip approaches the cords, get an assistant to withdraw the stylet, and advance the tube (*without the stylet inside!)* into the trachea.

N.B. You can easily create your own stylet by using wire of the appropriate diameter.

FIBRE-OPTIC INTUBATION

If you have a video-laryngoscope or a fibre-optic laryngoscope, position the patient supine (*no need for a sniffing position,* and so it is very useful in neck injuries) and advance the laryngoscope down the middle of the tongue.

For a nasal fibre-optic intubation, prepare both nostrils with vasoconstrictive drops and spray both with LA. Introduce a nasal airway coated with lubricant jelly (the size of the endotracheal tube you intend to use) into each nostril and decide which side is easier. (Patients may themselves be able to report which is the better side.)

Administer 10mg ketamine IV and repeat this dose as necessary if the patient is uncooperative. Blow oxygen through the suction port of the fibre-optic scope (this will also blow secretions away from the tip).

Thread the endotracheal tube over the fiberoptic scope and secure it as close to the eyepiece as possible with a piece of tape. It will be threaded off the fiberoptic scope, through the nostril and into the trachea after the trachea has been entered and the carina visualized.

Advance the laryngoscope and when you visualize the glottis, spray the vocal cords and the upper trachea with 5-10ml LA through the injection port, while temporarily stopping the suction. This will make the patient cough at first, but he will subsequently be more comfortable.

Once inside the trachea, and visualizing the carina, get an assistant to hold the fibre-optic scope straight, and slide the endotracheal tube off the scope through the nostril and into the trachea.

If there is resistance to the endotracheal tube advancing (this may occur at the level of the choana or the arytenoids) rotate the tube slightly and push it further. When you are satisfied, withdraw the fibre-optic scope, *taking care not to dislodge the endotracheal tube*.

N.B. In rare instances, you can try a nasal intubation blind, *i.e.* without use of the fibre-optic scope, provided you have some experience, and understanding that the success rate is inevitably limited.

Changes in airflow from the outer opening of the tube, depending on the position of the tube and neck will help you guide the tube through the cords.

CAUTION! Don't do this if there might be a neck injury!

INTUBATION WITHOUT SEDATION

In an unconscious patient, sedation is not necessary. But this technique may still be stressful for the patient if he is poorly responsive (particularly as a result of excess alcohol) and carries an increased risk of regurgitation.

Prepare 10ml 2% LA; spray 4-5ml onto and over the back of the patient's tongue. Introduce a well-lubricated laryngoscope over the tongue until you see the tip of the epiglottis. Then spray a further 1-1.5ml onto it. When you see the vocal cords, spray a further 2–3 ml into the upper larynx and between the vocal cords.

Alternatively, puncture the cricothyroid membrane with a 21G needle attached to a 3ml syringe containing 2% LA. When you aspirate air, inject the LA. This will cause the patient to cough and will anaesthetize the inferior surface of the vocal cords and the trachea.

When the cords are widely abducted during inspiration, pass the endotracheal tube into the trachea and inflate the cuff. The patient may cough a little, but will tolerate the tube.

RAPID SEQUENCE INDUCTION & INTUBATION
Use this if you are confident in intubation, and have everything well prepared.
Position the patient 10-15º head-up (reverse Trendelenburg) if possible. This will help to prevent passive regurgitation during induction of anaesthesia. Pre-oxygenate with 100% oxygen for 3mins.

Get an assistant to administer ketamine IV 1-2mg/kg followed immediately by succinylcholine 1.5mg/kg as paralyzing (neuromuscular block) agent.

N.B. Cricoid pressure (the Sellick manoeuvre) used to be advocated to prevent regurgitation during intubation. However this manoeuvre may make intubation difficult and there is no guarantee that you will occlude the oesophagus this way. In fact it probably causes it simply to deviatethe airway laterally, though this may help the anaesthetist.

Once fasciculation starts, introduce the laryngoscope into the patient's mouth and intubate him as described above.

CONFIRMING CORRECT TUBE PLACEMENT
Once the endotracheal tube is in the trachea, inflate the cuff and ventilate the patient; watch and listen to the right chest, left chest and epigastrium.

If you hear breath sounds over the stomach but not on the chest (which is neither rising and falling as expected), the tube is in the oesophagus. Stop the ventilation (*overdistension and even gastric rupture may occur, especially in children*), remove the tube, re-ventilate by face mask, and reposition the patient before you try a second attempt at intubation.

If you hear breath sounds on the right, but not on the left, you probably have introduced the tube into the right main bronchus. Withdraw the tube slowly while checking breath sounds.
N.B. The correct position of the tube in most adult women is at 21cm from the teeth; and in most adult men at 23cm.

After intubation and appropriate positioning of the tube, inflate the cuff with the least amount of air needed to create a seal during ventilation. Withdraw air until there is an air leak during inspiration, and then inject an additional 1-2ml of air into the cuff.
N.B. Most endotracheal tubes today have high-volume, low-pressure cuffs that will not injure the mucosa. *Nonetheless, chronic use & high inflation pressures may cause a tracheal stenosis!*

TRANSPORT
A patient who has been intubated must have the tube fixed carefully in place by a figure-of-8 sticky plaster (or strap around the neck), and be accompanied by skilled personnel and equipment that will allow for mask ventilation, or re-intubation in case of accidental extubation.
If that is not available, tracheostomy is safer.

INABILITY TO INTUBATE
Limit the duration of your attempts at intubation! Hold your own breath when you start an intubation, and stop when you have to breathe again!
At all costs, *avoid hypoxia* to the patient (which is what you are trying to prevent). Ventilate by mask or let the patient breathe oxygen between attempts. Check the oximeter to guide you when to stop, if you have one. *Don't make >3 attempts!*
N.B. Excessive manipulation of the airway may lead to oedema, bleeding and its complete loss!

LOSS OF AN AIRWAY IS CRITICAL!!

Let the most experienced person take charge, and call for help. Cricoid puncture is the easiest quick solution.

If intubation is not possible, because of abnormal anatomy, lack of equipment, or lack of personnel with the needed skills, rely on *mask ventilation using a LMA, or perform an emergency cricoidotomy* (42.3) *(or tracheostomy in children), which can be life-saving*.

Put in place clear and agreed protocols for the difficult airway, tailored to what is locally available.

N.B. An emergency tracheostomy is difficult: cricoidotomy is preferable in the first instance in emergencies!

42.3 Cricoidotomy & tracheostomy

CRICOIDOTOMY (GRADE 2.2)
Place the patient supine with the neck extended (unless this compromises the cervical spine). Place your non-dominant thumb & index finger on either side of where you are to make a hole.

You may not have time for LA or even sterilization!
In a dire emergency, push in a 14G cannula to create an air entry. You will feel a "pop" as the needle enters the airway. Direct it 45º caudally. Attach a saline-filled syringe to these to check for bubbles appearing. If there are none or just blood, you have placed the needles too laterally: try again *in the midline!*

Secure the cannula with sutures and connect it an oxygen source (if possible).
Then proceed to cricoidotomy or tracheostomy.

Although a cricoidotomy can only take 30secs, infiltrating some LA may well help to keep a restless patient calm!

When you are ready, keep the skin tight. *Don't let go with the hand stabilizing the cricoid!* Then make a 2cm vertical incision through the skin (42-13C) and then a small horizontal incision through the cricothyroid membrane (42-13D), *taking care not to stab the posterior tracheal wall, or push the blade upwards!* As soon as you are in the airway, there will be coughing, spluttering of frothy bloody saliva.

Widen the incision with artery forceps (or by twisting the scalpel handle in the airway wound), both horizontally & vertically.

Introduce an endo-tracheal tube (size 6 for an adult) or tracheostomy tube and check it is in the airway. Inflate the cuff. Auscultate the chest to make sure there is good air entry on ventilation.
Fix the tube in place.

CRICOIDOTOMY

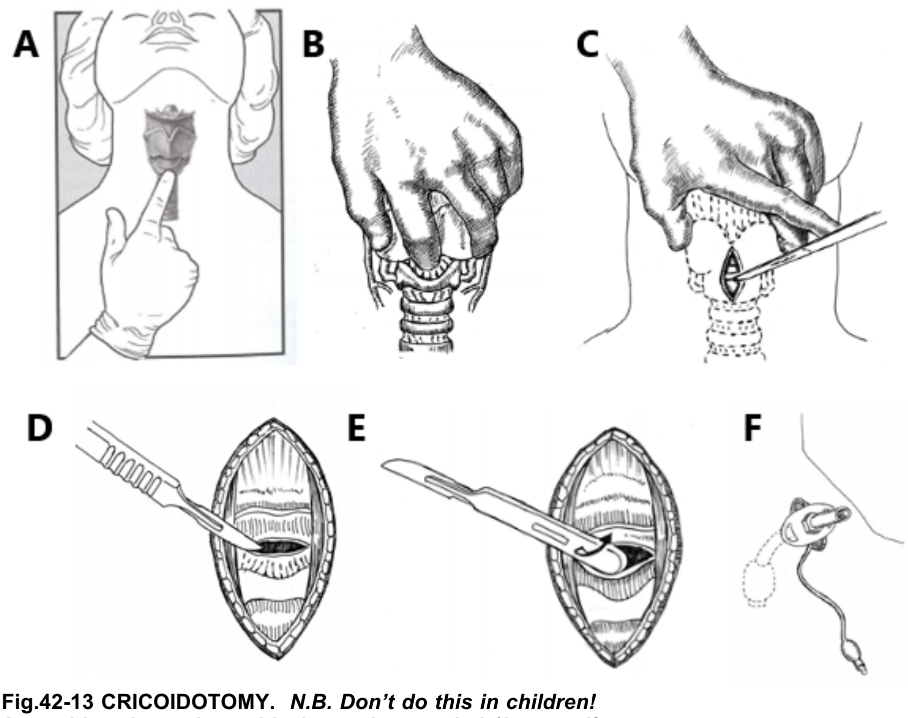


Fig.42-13 CRICOIDOTOMY. ***N.B. Don't do this in children!*** **A, position the patient with the neck extended (*beware if there is a neck injury*). Identify the space for insertion of an airway. B, Verify the position of the cricoid & hold the laryngeal cartilage steady with your non-dominant hand. C, make a vertical incision in the midline, *not* letting go of the cartilage. D, make a horizontal incision deep enough to enter the airway. E, widen the opening using the back end of the Bistouri. F, insert a cuffed tracheostomy tube (or if not available, an ET tube)** *After Eichelberger MR in Rob & Smith's Trauma Surgery Part 1, Butterworths, 4th ed 1983.*

Tracheostomy (29.17) is rarely needed in the emergency situation except in children. Then you can insert a Ch14 cannula at 45^0 to the vertical into the trachea and attach this to a 7.5 ET tube. Alternatively, if possible, introduce a longer tube with a guidewire.

However, you should always convert a cricoidotomy to a tracheostomy if it is needed for the longer term.

If the neck is fat & you cannot feel the cricoid cartilage, make a 6cm vertical skin incision *in the midline of the neck*. Spread the fat laterally with your fingers & insert a self-retaining retractor (or get an assistant to retract the tissues) and palpate the cricoid & trachea. When you have found your bearings, proceed as above.

If there is much bleeding (which is unusual), it is likely you are not in the midline. Enlarge the incision as above, and retract the tissues under a gauze swab, and palpate the cricoid & trachea. *Do not waste time trying to arrest the bleeding at this stage!*

42.4 Penetrating neck wounds

For stab or gunshot wounds of the neck, the same immediate priorities (42.1) apply. However, outcomes of penetrating are different to blunt injury. The most common cause of death is either asphyxia or blood loss, so this is what you need to concentrate on initially.

Whilst you need to give to the cervical spine special attention in blunt injury (54.1), *this is not the immediate priority in penetrating trauma* (though blast injuries may give severe 'blunt' trauma (46.15) with neurological damage to the spine).

N.B. Don't put on a cervical collar because this helps nothing, and obstructs access to wounds and may add to neck compression.

ANATOMICAL CONSIDERATIONS
Several vital structures meet in the neck, in the triangle in front of the cervical spine, and are surrounded by the inelastic deep cervical fascia.
The major vessels in the anterior lower neck are partially protected by the clavicle & 1st rib, but major damage can occur if these bones are fractured, especially by a high-energy projectile.

The neck is sufficiently narrow that even a high energy bullet will make a through-&-through wound (46-44A). This usually has an 'all or nothing' result: a survivor probably has no vital structure injury. However, haemorrhage from a smaller vessel may cause asphyxia because of limited space within the subfascial compartment.

The airway is relatively rigid, so when hit by a projectile, suffers a defect, which can be of variable size.

The oesophagus is a hollow organ, resistant to stretch on account of its elasticity: *small entry & exit wounds may therefore not be easily visible by endoscopy.*

Posteriorly, a projectile has a much greater chance of hitting bone: the mandible, vertebral column, or the skull base.

In about half of survived injuries, major damage is seen; notably:
(1) ~30% of carotid artery lesions are accompanied by signs of stroke (cerebral ischaemia),
(2) an isolated vascular injury is only likely if the cause is a small fragment projectile.
(3) 50% of laryngeo-tracheal wounds also have injury to the pharynx or oesophagus,
(4) projectiles may also cause damage in the chest or head.

N.B. Catastrophic haemorrhage is rare unless the victim is brought in very quickly for emergency help.

If digital pressure has controlled bleeding, take the patient immediately to theatre (with the first aider's hand included in the operating field).

If haemostasis is inadequate, tamponade it with a large (Ch20) Foley catheter into the entry wound, inflate it with saline, clamp the drainage outlet, fix the catheter firmly to muscle or skin, and close the wound with a continuous suture. Then immediately intubate the victim's airway *to prevent asphyxiation.* If tamponade is successful in proximal carotid or vertebral artery injuries, leave the catheter *in situ* for 48h before removing it *in theatre.*

NEVER TRY BLIND CLAMPING IN THE DEPTHS OF A WOUND !

MANAGEMENT
(a) Airway
Symptoms and signs of airway damage are usually obvious: stridor, hoarseness, dyspnoea & haemoptysis, with tracheal deviation, instability or tenderness on palpation. More subtle signs are loss of 'clicking' of the larynx on pushing it laterally, loss of thyroid prominence, and bruising of the overlying skin. You may see blood 'bubbling' out, or crackling from subcutaneous emphysema, which may extend to the scalp (43-28) or abdomen and into the mediastinum, pericardium or pleura!

If the wound is very small, lie the victim in the lateral position with the head down, so that blood can trickle out of the mouth.

If there is airway compromise, perform a needle cricoidotomy (42-13), before converting this to a formal tracheostomy (29.15) in theatre.

If there is a very large tracheal defect, pass a suture through the inferior lip of the tracheal wound, and fix this to the skin. Then insert a tracheostomy tube & inflate the balloon (29-17).

If there is copious bleeding from the tracheal wound, pass a tracheostomy tube so that its balloon can occlude the bleeding vessel, and avoid blood trickling down the airway: use a Sengstaken-Blakemore tube to do this if you can.
Whatever you do, make sure the airway is patent!

(b) Breathing & Circulation
Palpate the carotid & superficial temporal pulses, and measure the BP in *both arms.*
If you suspect a major venous injury, put up an IV line in the contralateral arm or lower limb!
N.B. you may need a vein graft from one leg *so don't use both for IV lines!*

N.B. Shock may be neurogenic (44.5)*, rather than haemorrhagic!*

Lung injury may result in pneumo- or haemothorax, and need an intercostal drain (43-15). Haemoptysis can occur with injury anywhere in the airway or lungs; haematemesis from anywhere from mouth to stomach.

(c) Disability
A central lesion (hemiparesis, hemiplegia, aphasia or loss of consciousness) is almost always due to carotid artery insufficiency; this may be temporary if the artery is in spasm (from the pressure wave of a passing bullet). If there is no carotid injury, a direct brain injury is likely.

A peripheral lesion is due to direct injury of:
(1) cervical spine: tetraplegia, neurogenic shock
(2) cervical plexus: Horner's syndrome
(3) brachial plexus: neurological deficit in the arm
(4) VIIth nerve: drooping of corner of the mouth
(5) VIIIth nerve: auditory loss
(5) IXth nerve: altered swallowing & gag reflex
(6) Xth nerve: hoarse voice
(7) XIth nerve: sternomastoid weakness
(8) XIIth nerve: tongue deviation

N.B. Direct auditory loss in blast trauma (46.15) is common from pressure wave effects.

Injury to the pharynx & oesophagus often present late with fistula formation & infection. *Always suspect these if there is an airway injury.*

Drainage of milky fluid suggests damage to the thoracic duct.

Give a conscious patient diluted methylene blue or gentian violet to drink. Otherwise, once the airway is secured, inject some down the pharynx to find the site of the leak.

PROCEDURE
Be careful not to dislodge any haematoma before you are ready. Don't pass a nasogastric tube till the patient is well sedated.

If in doubt about the airway, perform a tracheostomy!

Explore all wounds which penetrate the *platysma,* & those in the middle of the neck, *even in the absence of clinical signs. Avoid exploring those above the level of the mandible* as a conservative approach is best here.

Remember, ligation of an artery is easier than repair. Most times ligation of the carotid artery is justifiable (49.3); likewise subclavian or axillary vessels, *but obviously not the braciocephalic trunk!* You can ligate the internal jugular vein, *but not on both sides!*

Remember, insertion of a shunt (49-5) can get you out of a big difficulty!

Where access below the skull is very difficult, as for the proximal carotid or vertebral arteries, you can use bone wax or crushed muscle (or chewing gum) to stuff the skull foramen from which these vessels emerge.

Don't think you need to do the definitive surgery in the emergency situation. Do only what is necessary to save life or limb!

PREPARATION
Make sure blood is cross-matched. Prepare equipment for autotransfusion (5.3, 44.4)
Place the patient supine with the arms tucked in alongside the chest, and a small roll under the shoulders to extend the neck. Put the head on a ring (or doughnut pillow) to stop it rolling around, and turn it to the side away from the wound. Keep the head tilted 10^{o} up to reduce bleeding.

N.B. ***If there is massive blue (venous) bleeding****, put the head down 15^{0} to prevent air embolism!*

Put 2 towels under the head, and fold the top one over the face as in thyroidectomy (25.7). Sterilize from the chin to the groin, and include one leg for possible venous harvest.

For a lower neck injury (zone I), you may well need proximal control, so a simple supraclavicular incision for the subclavian artery (49-7) needs a median sternotomy extension (44-11).

For a middle neck injury (zone II) extend an incision along the medial border of *sternomastoid* for the carotid artery (49-6) to the median sternotomy.

You may need an anterolateral thoracotomy extension on the right for damage to the upper or mid-oesophagus, or the right hemidiaphragm and retrohepatic injury; on the left for lower thoracic oesophageal damage.

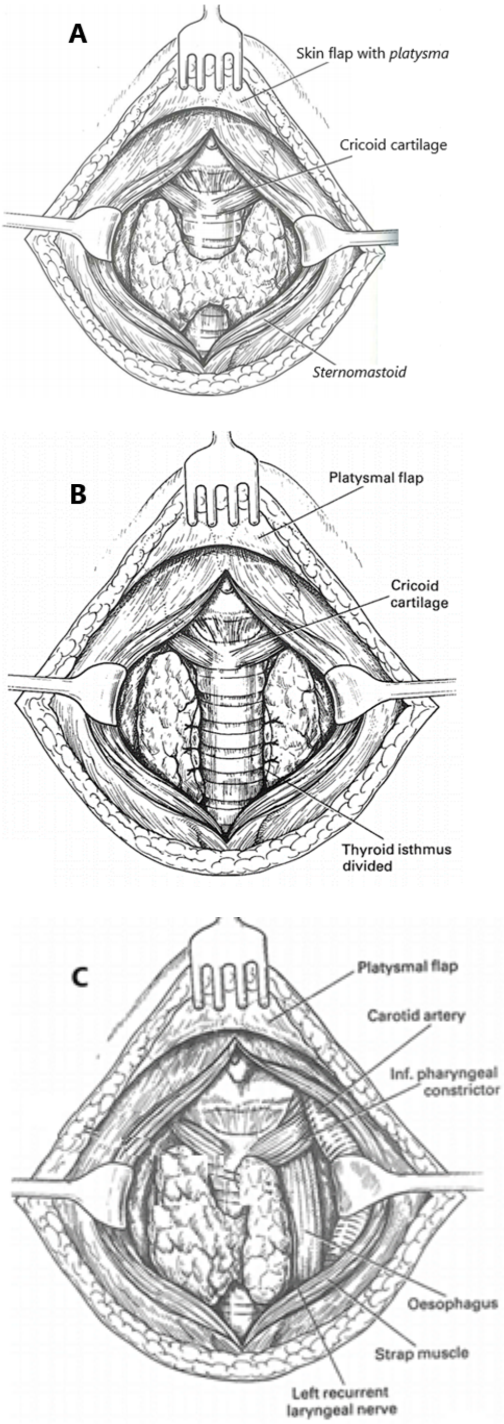
Expose the wound and try to assess the damage. You may be able to get an on-table arteriogram to help you. If necessary, get an assistant to keep on pressure digitally. Gently lift off clots and try to gain control on both sides of a vascular injury.

42.5 Laryngeal & tracheal injury

INTRODUCTION
Blunt injury may not be noted early, but may present with a stenosis much later. Causes are usually blows on the anterior neck (mainly in motor vehicle crashes), more rarely falling against a taut wire, through assault (attempts at strangling included), and sports, smoke burns or iatrogenic injury (especially rigid bronchoscopy, 29-16, or aspiration of oil).

Penetrating injury (42.4), however, is usually obvious. In half of cases there is also damage to the pharynx or oesophagus.

ANTERIOR NECK EXPLORATION



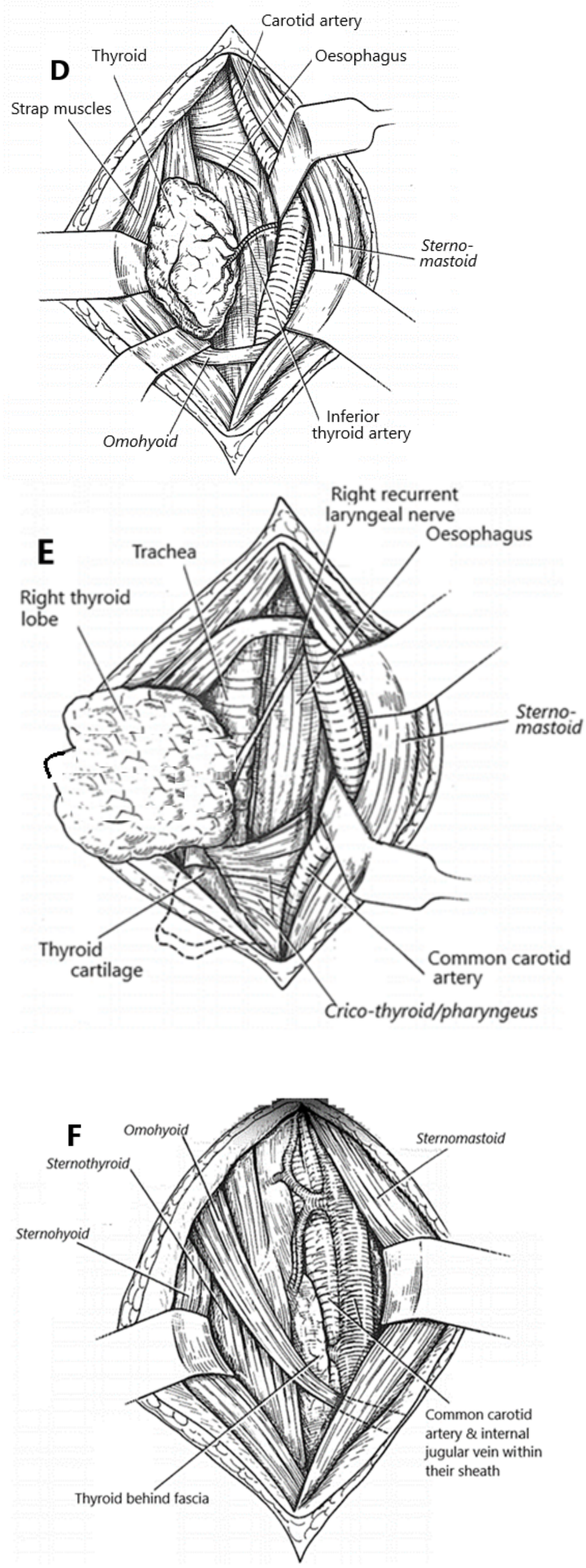


Fig.42-14 ANTERIOR NECK EXPLORATION. A, retract the *sternomastoids* to expose the thyroid. B, divide the thyroid isthmus. C, retract the thyroid lobe to the left using your finger. D, divide the inferior thyroid artery. E, divide the omohyoid & preserve some as a flap if necessary. F, take note of the recurrent laryngeal nerves, especially the right which crosses the oesophagus. *After Snyder WH III, Carder HM in Rob & Smith's Operative Surgery Trauma Surgery Part 1, Butterworths, 4th ed 1983.*

Injuries in children are rare, because the larynx is higher up, and partially protected by the mandible.

You must keep a high index of suspicion in all cases, and if in doubt, have a look, preferably with a flexible bronchoscope. Even if the mouth & pharynx show no damage (*e.g.* in a burn), the larynx may still be affected.

MANAGEMENT
Obtain a chest radiograph as a baseline. Make sure the victim is able to breathe humidified oxygen or air. Keep the head up. Steroids may help against oedema in the 1st 12h. Start chest physiotherapy.

Minor oedema with no mucosal disruption needs only repeated observation, and usually a follow-up bronchoscopy after 24h.

Significant oedema with only minimal mucosal disruption & no exposed cartilage needs early & late follow-up bronchoscopy; be prepared to fashion a tracheostomy if there are signs of deterioration.

Severe oedema threatening to occlude the lumen, mucosal tears, exposed cartilage, and vocal cord disruption, all require an urgent tracheostomy. Try to repair lacerations carefully.

Injury to the trachea from a wire is particularly hazardous, as the upper larynx gets pulled upwards, and the distal part disappears behind the sternum. Make a low vertical incision for this injury & *don't hesitate to divide the manubrium to get good access!*

ANTERIOR NECK EXPLORATION (GRADE 3.4)
Make a collar incision 2cm above the manubrium, divide the *platysma* and develop superior and inferior flaps just as for a thyroidectomy (25.7). Divide the middle cervical fascia between the *sternomastoids* and develop the plane around the thyroid (42-14A). Divide the thyroid isthmus between clamps: you can best achieve haemostasis by a continuous overlapping suture (42-14B). Then retract the left thyroid lobe gently with a finger (42-14C) to expose the oesophagus.

Retract the *sternomastoid* laterally to expose the carotid artery; then ligate & divide the inferior thyroid artery & middle thyroid vein (42-14D). You will now have good views of the oesophagus and, by retracting the thyroid further to the left, of the trachea.

Divide or retract the *omohyoid* which crosses the middle cervical fascia: *N.B. you may need some of this muscle to buttress a tracheal or oesophageal laceration!* (42-14E)

N.B. Beware of the right recurrent laryngeal nerve, which crosses over the oesophagus from inferolateral to superomedial (42-14F). The left recurrent laryngeal nerve rests in the groove between the trachea & oesophagus. *Take care not to damage either of these nerves!*

If you suspect a hole in the trachea but you can't find it, cover the wound with sterile water and look for air bubbles coming out of a hole.

Cricoid or thyroid cartilage fractures need fixing with a special plate: try to refer such patients. You can fix the hyoid with wire.

You can preserve the lumen by introducing a home-made stent for 2wks: fill a finger of a sterile surgical glove with gel foam and pierce this making a sufficient air passage, to improvise.

N.B. A small mucosal tear can produce alarming subcutaneous emphysema

If there is a tracheal defect, introduce a cuffed tracheostomy into the defect (42.4) till you can arrange surgical closure. Repair the wound as accurately as possible, leaving knots on the outside. Buttress the repair with a small flap of muscle.

Make sure your nurses know how to look after tracheostomy patients! (29.15)

Speech therapy is important in the recovery period.

42.6 Pharyngeal & cervical oesophageal injury

INTRODUCTION
Oesophagael injury is usually from ingestion of sharp objects, such as fragments of meat bone, a safety pin, ill-fitting dentures with metal hooks, or iatrogenic (especially from rigid oesophagoscopy (30.2). Caustic fluids (acid or alkaline) may also cause severe oesophageal mucosal damage.

In some areas particularly in Niger & Nigeria, traditional uvulectomy is still carried out, mainly on children, with primitive instruments. (It is not done to prevent snoring!) Frequent complications are haemorrhage, pharyngeal infection, including tetanus, and aspiration of the excised uvula, all of which can be fatal.

Penetrating injury which damages the oesophagus also injures the trachea in over 50% of cases. As with the airway, you must keep a high index of suspicion in all cases, and if in doubt, have a look, preferably with a flexible endoscope (13.2).

Oesophageal perforation often presents late with disastrous septic complications; depending where the perforation is, drainage may occur into the neck, mediastinum, pericardium or pleural space.

MANAGEMENT
Check if the airway is patent; in any doubt, get the patient to sit up or lie with the head down, and suck out the mouth and clear the airway (42.4).
Obtain a chest radiograph as a baseline. Look especially for effusions, mediastinal air and the presence of a foreign body.
N.B. A coin stuck in the oesophagus will appear 'flat on' on a radiograph, whereas one in the bronchus will appear 'side on'.

Foreign bodies may rarely penetrate the oesophagus: try to remove them without damaging the oesophageal lining! (30.2). Likewise oesophageal corrosive may, in severe cases, cause necrosis and perforation; try to mitigate this by early protective measures (30.3).

LATERAL NECK EXPLORATION

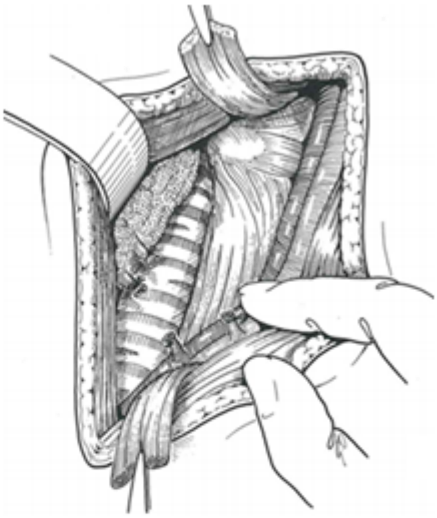


Fig.42-15 LATERAL NECK EXPLORATION. Exposing the oesophagus.

LATERAL NECK EXPLORATION (GRADE 3.4)
Make an incision along the anterior border of the left *sternomastoid*. Follow anterior neck exploration (42-14D,E) to let you examine the oesophagus.
N.B. Be careful not to damage recurrent laryngeal nerves by attempting to view the back of the oesophagus!

Close any perforation with 2 layers of interrupted sutures, buttressed by a flap of *omohyoid*. Always leave a drain for a leak which usually presents as a salivary fistula and normally heals on conservative treatment.

In perforating injuries, look carefully for associated damage to the trachea, major vessels, & thyroid.

42.7 Drowning

Drowning can be classified as cold water (<20^{o} C) or warm water (20^{o} C or higher), fresh water or salt water, in natural water or man-made collections of water. The protective effect of ice-cold water in young people (the so-called mammalian diving reflex) is nullified by prolonged immersion. Hypothermia (45.2) is a problem with both cold and warm water drowning, as is rhabdomyolysis (49.7) due to intense shivering.

Long-term infectious complications are primarily related to whether the victim was submersed in a natural or a man-made body of water.

Drowning from diving-board accidents are often associated with cervical spine injuries. Be sure to protect the spine until a fracture has been ruled out.

Terms such as 'wet drowning', 'dry drowning'", 'active or passive drowning', 'near-drowning', 'secondary drowning', and 'silent drowning' are not helpful, so are not used here.

TREATMENT
If a child has fallen into water and cannot swim, laryngeal spasm may occur (a 'gag reflex'). If this is prolonged, hypoxia results. You should initiate CPR (44.9) immediately. Results are often surprisingly good even after prolonged efforts. *So, don't give up before 20mins!*

The most critical measure is prompt correction of acidosis & hypoxaemia; the degree of the latter is often underestimated.

Administer pure oxygen and monitor the patient closely with pulse oximetry if possible. Monitor vital signs, temperature and conscious level. Intubate and use positive end-expiratory pressure (PEEP) with mechanical ventilation in any patient with poor respiratory effort, altered conscious level, severe hypoxaemia, severe acidosis, or significant respiratory distress.

Rehydrate the patient with isotonic crystalloid (20mL/kg) and await correction of the acidosis. *Don't administer sodium bicarbonate*. Hypothermia may exacerbate hypoxaemia, acidosis, and bradycardia.

Warm the patient (50.13), but if the victim remains comatose, don't *actively warm to temperatures >32º-34°C.*
Treat any seizures. Check the blood glucose level frequently, and correct hypoglycaemia.

Ventricular dysrhythmias (typically, ventricular tachycardia or ventricular fibrillation), bradycardia, and asystole may occur as a result of acidosis and hypoxaemia rather than electrolyte imbalance.

Insert a nasogastric tube to remove swallowed water and debris. Pass the tube by mouth if there is head or facial injury.

You may need bronchoscopy (29.14) to remove foreign material, such as aspirated debris or vomitus plugs, from the airway.

N.B. Remember there may be associated head, chest or limb injuries!

43 Chest Injury

43.1 Management of chest injury

Chest injuries can be terrifying to both patient and physician – but most injuries just need at most the placing of a chest drain into one or both sides of the thorax. You must learn this skill and be ready to use it earlier in chest trauma rather than later (43.2). Only 5–10% of chest injuries will need the chest opened (thoracotomy). This is major surgery which is unlikely to be feasible in your setting. *You should learn to recognize those injuries which require referral – and prepare for it early in the course of treatment.*
You must also accept that some injuries (*e.g.* an aortic rupture) are unlikely to be salvageable. They are not even likely to survive the journey to your hospital.

Before you are overwhelmed by the idea of serious chest trauma, *you must realize there is a great deal you CAN do to help these patients*. Try by all means to get a pulse oximeter if you don't have one.

The aim is to make sure that the lungs are well ventilated, these are things you should do:
(1) Secure the airway, and encourage coughing to clear it. It is easily obstructed, especially in a child, and can only too easily be filled by inhaled blood, secretions, or stomach contents. Avoid this by: (a) aspirating the secretions, (b) passing a nasogastric tube, (c) arranging a bronchoscopy, or (d) tracheal intubation, or occasionally (e) tracheostomy, which will reduce the dead space and make a tracheal toilet easier.
(2) Administer oxygen.
(3) Insert a needle for a tension pneumothorax.
(4) Remove air or blood by pleural drainage.
(5) Close an open or sucking chest wound.
(6) Stabilize a flail chest (43-24).
(7) Assist ventilation with a self–inflating bag.
(8) Start a blood transfusion.
(9) Prevent infection.
(10) Relieve cardiac tamponade by pericardial drainage.
(11) Start physiotherapy (11.10)
(12) Monitor the patient carefully.

The great danger with all chest injuries is that retained secretions will cause infection, lung collapse, and ultimately death. *Only active physiotherapy will prevent this consequence.*

N.B. Don't forget that burns can cause significant injury to the airways & lungs through inhalation of smoke! (50.3)

Blunt and penetrating injury vary in the pattern of damage they cause. Unlike a penetrating injury in the abdomen which usually requires a laparotomy, a penetrating wound of the chest does not mandate a thoracotomy.
Remove knives, spears, arrows and foreign bodies embedded in the chest only in the operating theatre!

If the penetrating instrument has already been taken out, you may have great difficulty deciding how deep is the stab wound, or which organs in the chest have been pierced or are bleeding.

If there is air or blood in the pleural cavity, put in a needle or chest drain (43.2).
Remember a penetrating wound of the chest may cause damage in the neck or abdomen as well! *The most important priority in all trauma cases is the airway* (42.1). *Don't skip this step, no matter how dramatic the chest injury may be*.
During the primary trauma survey (42.1), the goal is to identify and treat life-threatening conditions first.
In the chest, this list includes:
(1) Tension pneumothorax (43.2)
(2) Open sucking pneumothorax (43.3)
(3) Flail chest and respiratory distress (43.2)
(4) Massive haemothorax (43.2)
(5) Cardiac tamponade (44.7)

Other injuries which are not life-threatening tend to show up a bit later (often not being obvious on a quick physical examination):
(1) Simple pneumothorax (43.2)
(2) Smaller haemothorax (43.2)
(3) Pulmonary contusion (43.2)
(4) Diaphragm injury (43.4)
(5) Fractured sternum & ribs (43.5)
(6) Blunt cardiac injury (43.7. 44.6)
(7) Traumatic aortic disruption (43.6)
(8) Blunt oesophageal rupture (30.7, 43.6)
(9) Tracheo-bronchial tree injury (43.6)

RAPID ASSESSMENT OF A CHEST INJURY

If the airway is obstructed, clear it (42.1).

If air is going in and out, but breathing is distressed, there may be multiple fractured ribs or severe abdominal pain.

If there are great respiratory efforts, **but the patient is still hungry for air**, think of a flail chest or pneumothorax.

If there is cyanosis in the presence of an adequate airway, there may be a badly damaged lung, a flail chest, or a pneumothorax.

Administer oxygen. Always think whether you need to put a needle or drain into the chest! You will very rarely cause any damage and the act may well be life-saving. Monitor the oxygen saturation, if you can. (Try by all means to get a pulse oxymeter!)

TENSION PNEUMOTHORAX

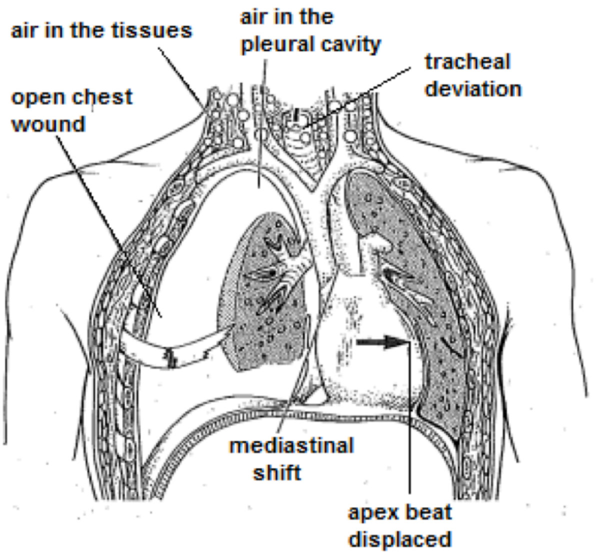


Fig. 43-1 TENSION PNEUMOTHORAX. This causes obstruction to venous return to the heart and is a surgical emergency, needing a needle thoracostomy. (Air in the tissues is known as 'subcutaneous emphysema')

NEEDLE THORACOSTOMY

If there is hypotension, tracheal shift, and a contralateral lack of air entry, a hyperexpanded hemithorax, hypoxia and ribs pushed apart from each other *or any one of these signs*, there may well be a tension pneumothorax: quickly insert a 4-6cm long 14G cannula into the 2nd intercostal space in the mid-clavicular line. If air hisses out, or blood spurts out, insert a chest drain as soon as you can (43.2).

FINGER THORACOSTOMY

If shock persists, insert a chest tube into the 5th intercostal space anterior to the mid-axillary line (53.2). *Don't waste time getting a radiograph done!*

If a patient cannot maintain his own breathing, and you can intubate him, connect him to an intermittent positive pressure ventilator (IPPV), and monitor his oxygen saturation, or keep him ventilated with a self-inflating bag.

(a) History:

Obtain a history of the mechanism of injury, if you can. Assess the force of impact carefully. The greater the force (including being thrown from a vehicle, the height of a fall, a crushing injury, a head-on-collision), the greater the chances of a severe injury, both in the chest and elsewhere.

Find out when the injury occurred. Get some information, if possible, about the victim, especially related to alcohol, drugs, and the past medical history. Ask where the patient has pain: beware if there is back pain because this may suggest an aortic injury (43.2).

(b) Examination

If a patient is conscious, and is now breathing easily, strip him to the waist, and ask him to describe his pain and show you exactly where it hurts. If vertebral injury is very unlikely, and the neck is protected in a rigid collar, you can sit him up (holding his head straight and having 2 assistants to lift the shoulders) so that you can examine the back of the chest.

If a patient is unconscious, remove the clothes and examine the chest carefully. *Don't fail to turn him* (log-roll him with at least 2 assistants maintaining a straight alignment of the spine).

(c) Inspection

Assess the rate and depth of breathing. Broken ribs will soon provoke sharp pain at the fracture site.

Look for evidence of bruising or crepitus at the site of pain (which may be due to air rather than blood). Note bruising due to a seat belt or the imprint of the steering wheel.

Check if both sides of the chest move equally. Look carefully for any areas of diminished chest movement, which may be in one area only, or involve the whole of one side. Look at the chest from the sides and from the head and foot of the patient.

CAUTION! Look carefully for paradoxical movement. This is due to a flail chest (fracture of two or more ribs in two or more places causing the portion of the chest wall to have independent movement).

Look at the movement of a normal area, then compare it with the possibly abnormal one. Is it moving in or out when the normal side is doing the opposite?

Such paradoxical movement may be difficult to see when a patient is shocked and respiratory movements are shallow; it may only appear later, after proper resuscitation.

N.B. Don't mistake this for the indrawing of the lower costal margin common in mild respiratory obstruction, especially in children!

Is one side of the chest hyper-expanded compared to the other (look from the foot of the patient)? Do the ribs seem further apart from each other on one side compared with the other?
Is there cyanosis? Look at the mucous membranes and fingernails. Monitor oxygen saturation if you can.

N.B. Anaemic patients (<50g/l) don't become cyanosed, and may die of anoxia without showing cyanosis.

N.B. Patients with carbon monoxide poisoning (especially from fires) *may still show normal oxygen saturation.*

Is there an open chest wound? Is it sucking in air? *Beware! A bullet may pass into the chest via the neck, abdomen, arm or back!*

Are the jugular veins abnormally distended? This can be caused by anything which impedes the venous return to the heart, *i.e.* tension pneumothorax, mediastinal shift, and especially cardiac tamponade.

N.B. A hypovolaemic patient will not show jugular venous distension.

(d) Palpation:
If a patient is conscious, start palpation in a pain-free area, and then move towards the injured zone. Feel for:(1) tenderness, (2) crepitus when fractured ribs move with respiration, and (3) the crackly feeling of surgical emphysema (due to movement of air in the subcutaneous tissues).

Is there a mediastinal shift? Check if the apex beat in its normal place? Feel the suprasternal notch if the trachea is displaced to one side or the other. (This may be hard to be sure about and will usually require a radiograph to confirm).

If the patient does not complain of pain, gently spring the chest between your hands from front to back, or from side to side. If this causes severe pain, there are probably multiple broken ribs. Feel for the tender fracture sites, which may be easier to feel than see on a radiograph.

(e) Percussion: Tap the chest in all lung fields, especially the lower, comparing one side to the other. Dullness indicates a collection of fluid or lung collapse, and hyperresonance suggests a pneumothorax.

(f) Auscultation:
Listen for breath sounds in all lung fields, noting if they diminished in some area? Note especially: (1) clicking sounds from fractured ribs, (2) coarse crepitation of surgical emphysema, (3) reduced or absent breath sounds on one side, compared to the other, suggesting air or fluid in the pleural cavity, or lung collapse.
If the patient is lying supine, you will only hear this on the sides posteriorly (43-8).

N.B. There is often much noise around the drama of a chest trauma victim: tell those around to keep quiet!

If you don't have imaging, especially in the triage setting, perform a *diagnostic* thoracocentesis. Puncture the pleura through the 4th or 5th intercostal space in the mid-axillary line, and aspirate. If you find blood, this patient needs a chest drain.
Don't try to drain a haemothorax by repeated aspiration on a needle: it takes too long and the blood will clot!

Other signs: Examine *the abdomen* carefully. Note whether it moves with respiration (55.2,3). Note any tenderness, rigidity or distension.
Where the lower left ribs are fractured posteriorly, suspect a ruptured spleen (55.6). If there is tenderness in the right upper abdomen, suspect a ruptured liver. If there is central abdominal tenderness, think of rupture bowel.

Pulse: **Is the pulse stronger on inspiration than on expiration** (*pulsus paradoxicus*)? This a rare but classic sign of cardiac tamponade (44.7). In aortic dissection, there may be a difference in BP between both arms.

N.B. **If there is a focal neurological deficit & no head injury,** think of an ***air embolism*** (blunt or penetrating lung damage allowing air to pass through branches of the great vessels to the brain). This is a dire situation; tough it is an indication for thoracotomy and removing the damaged area of lung, you are unlikely to get this far in resuscitation!

IMAGING IN CHEST INJURIES

NORMAL ULTRASOUND PLEURAL IMAGES

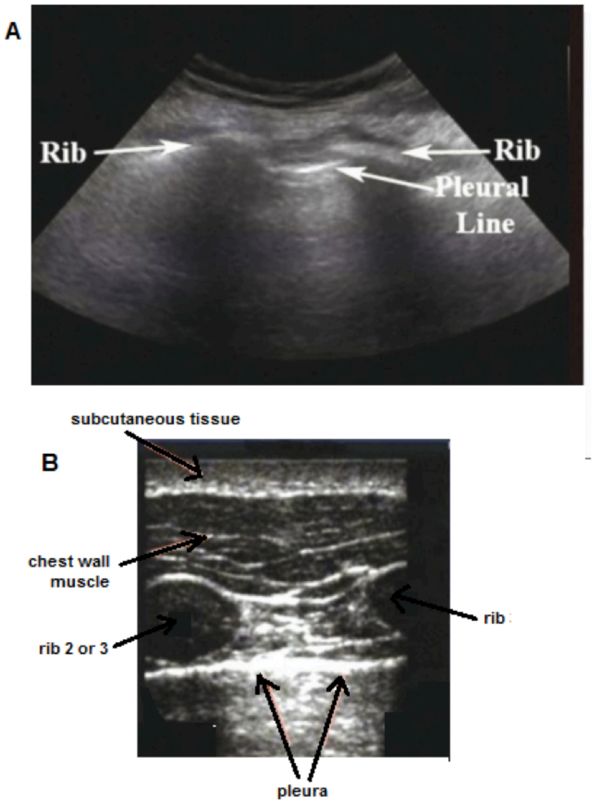


Fig. 43-2 NORMAL ULTRASOUND IMAGES OF THE PLEURA. A, with the probe below in the mid-clavicular line between the 2nd & 4th ribs, the pleural line shows as a bright white line below the ribs. B, the bright pleural line shows a 'wiggle' effect as the pleural surfaces move over each other with normal breathing.

ULTRASOUND IN CHEST INJURIES
Ultrasound is often more reliable in chest injuries than radiography; it is quicker and much more sensitive. You should learn this skill. It is *not* difficult.

ULTRASOUND IN PNEUMOTHORAX:

Air will rise to the uppermost part of the chest. When a patient lies supine, this corresponds to the anterior chest at the 2nd-4th intercostal spaces, below the clavicles, in the mid-clavicular line.
Scan the patient therefore in a supine or near-to-supine position. Place the probe in a longitudinal or transverse position.
Identify the landmarks of 2 ribs with posterior shadowing behind them and visualize the pleural line in between them. If you can't see the ribs, move the probe slowly in a caudal direction (towards the perineum) until 2 ribs appear on the screen. Between these you will see the 2 layers of pleura, parietal and visceral, sliding or 'wiggling' across one another.

NORMAL M-MODE IMAGES

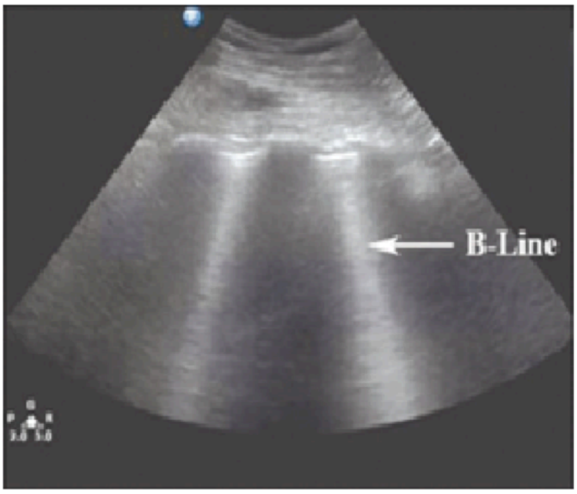


Fig. 43-3 NORMAL M-MODE IMAGES. Artefacts behind the pleural lines disappear in a pneumothorax.

CONTRASTED M-MODE IMAGES

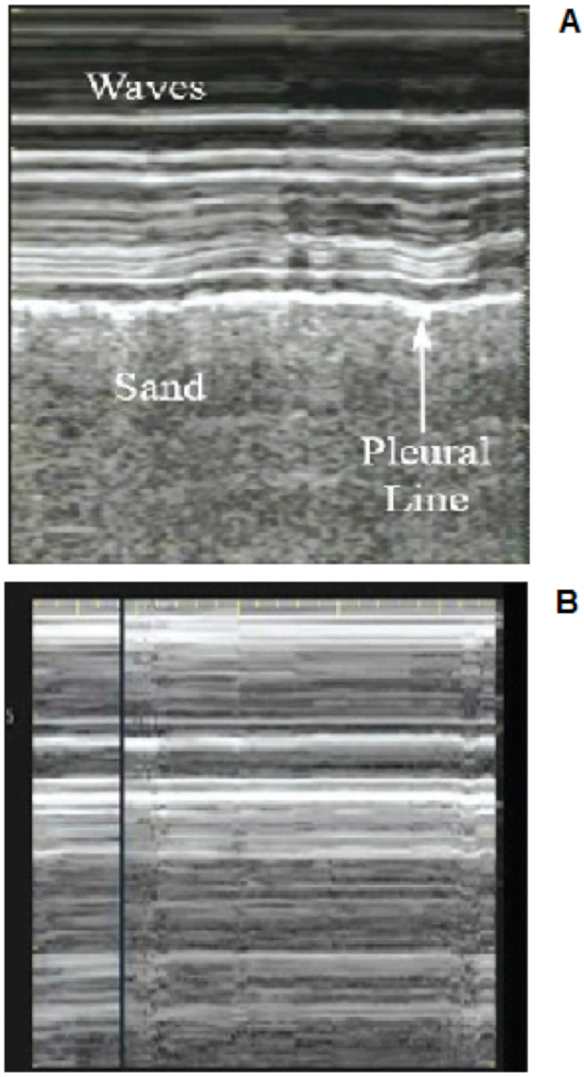


Fig. 43-4 M-MODE IMAGES CONTRASTING NORMAL & PNEUMOTHORAX. A, the normal image where the pleural line represents the 'seashore'. B, a 'Bar Code' image of a pneumothorax.

(1) The normal wiggle (36.1), seen as a bright line below the dark rib, of parietal and visceral pleura sliding on each other with normal respiration is lost with a pneumothorax (43-2). This is the most reliable sign. By moving the probe, you may be able to determine where the limit of the pneumothorax lies.

(2) In the M-mode, 'comet tail' or reverberation artefacts, which arise from the deeper visceral pleura, should normally move with the lung during respiration (43-3). This likewise disappears when a pneumothorax is present.

(3) M-mode detects motion between the 2 pleural lines in the normal situation, much as waves against a seashore, whereas in a pneumothorax, there is no motion, creating the same pattern throughout (43-4)

ULTRASOUND: A LEFT HAEMOTHORAX

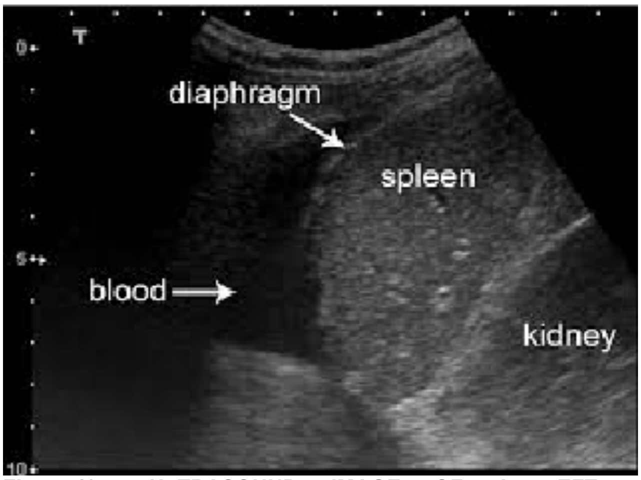


Fig. 43-5 ULTRASOUND IMAGE OF A LEFT HAEMOTHORAX. Blood shows as a dark homogenous zone; you will not be able to differentiate this from other types of effusion.

ULTRASOUND: A RIGHT HAEMOTHORAX

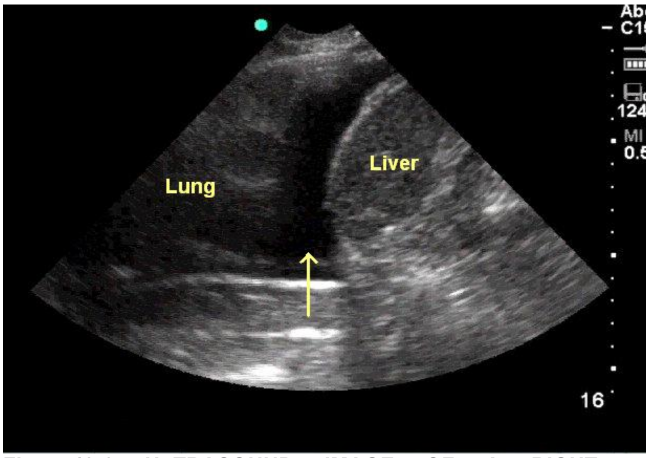


Fig. 43-6 ULTRASOUND IMAGE OF A RIGHT HAEMOTHORAX. Blood shows as a dark homogenous zone between the diaphragm and the lung.

ULTRASOUND IN HAEMOTHORAX

Place the probe at both lower quadrants of the chest, and look for the edge of the diaphragm. Free liquid appears as a homogenous dark zone between the diaphragm and other structures (43-5,6). Check also the anterior quadrants, in case of localized fluid effusions.

ULTRASOUND FOR FRACTURED RIBS

Place a linear probe along the suspected broken rib a little distance away from the site of maximal tenderness. Verify that you can see the rib clearly. Move it towards the point of tenderness. Look for a break in the cortex of the bone, and liquid around it. Then turn the probe 90º and check again for a discontinuity of the cortex (43-7), or ossification from a healing fracture.

ULTRASOUND: RIB FRACTURES

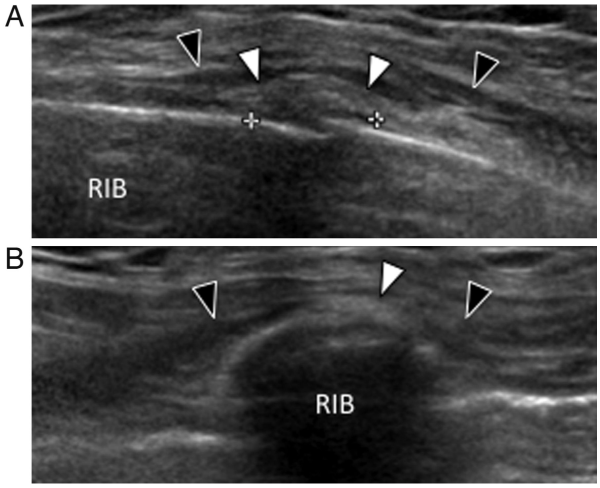


Fig. 43-7 ULTRASOUND IMAGE OF A BROKEN RIB.
A clear break in the cortex of the rib is easily visible.

Figs 43-2-7 After Husain LF, Hagopian L, Weyman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. J. Emerg Trauma Shock 2012; 5(1):76-81.

ULTRASOUND: STERNAL FRACTURE

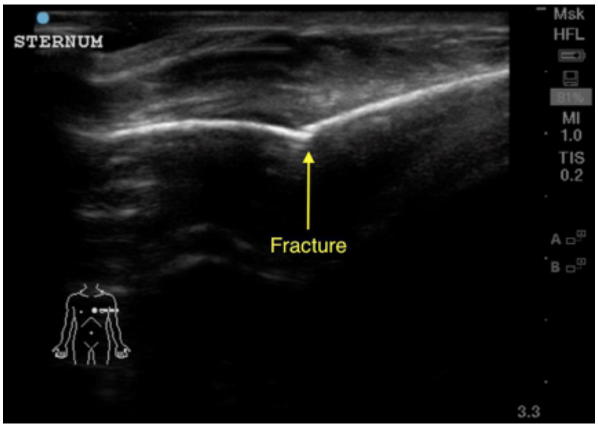


Fig. 43-8 ULTRASOUND IMAGE OF A STERNAL FRACTURE. The irregularity in the edge of the sternum is clearly visible.

Ultrasound can diagnose unossified rib fractures in children, breaks in costal cartilages in the anterior chest, which are *not* visible on radiographs. However, the ribs covered by the scapula and the infraclavicular portion of the first rib are not visible by sonography.

N.B. Don't confuse a fracture for the sterno-manubrial angle or the xiphisternal junction!

ULTRASOUND FOR STERNAL FRACTURES

Place a linear probe along the sternal edge a little distance away from the site of maximal tenderness. Verify that you can see the sternum clearly. Move it towards the point of tenderness. Look for a break in the cortex of the bone. Then turn the probe 90º and check again for a discontinuity of the cortex (43-8).

RADIOGRAPHS IN CHEST INJURIES

Obtain chest radiographs after the primary survey in all patients you suspect of having a serious chest injury. They are often unhelpful and unnecessary to show fractured ribs, or a fractured sternum (which needs a lateral view), though may be useful to check for complications.

Try, if possible, to get an erect or semi-erect image of the chest. You may need to support the patient to obtain such pictures.
Radiographs taken supine are notoriously difficult to interpret. You may easily miss a large haemothorax (which often looks like 'ground glass').

SOME RADIOGRAPHIC FINDINGS

(a) Pneumothorax and sucking chest wound (36.1, 43.2):
The lung markings don't reach all the way out to the edge of the thoracic cage. The pleural edge is visible as a faint line (36-1C,D). *Don't confuse the inner edge of the scapula with this line.*

If the mediastinum (and trachea) are shifted to the opposite side, the outline of the hemidiaphragm flattened, and the ribs appear wider apart than the other side (36-1A), *stop looking at this picture and immediately insert a 14G cannula in the midclavicular line between the 2nd-4th ribs!* This is a **tension pneumothorax**, which has been missed! *Act fast or the patient might die!*

Likewise, for a **bilateral pneumothorax** where no lung vessel markings visible, the trachea is central and the heart has 'disappeared' (36-1B). *Insert a cannula as above on both sides!*

(b) Haemothorax (43.2):
There is a diffuse opacity in a lower lung field, which is more easily seen in an erect film (43-9A).

HAEMOTHORAX

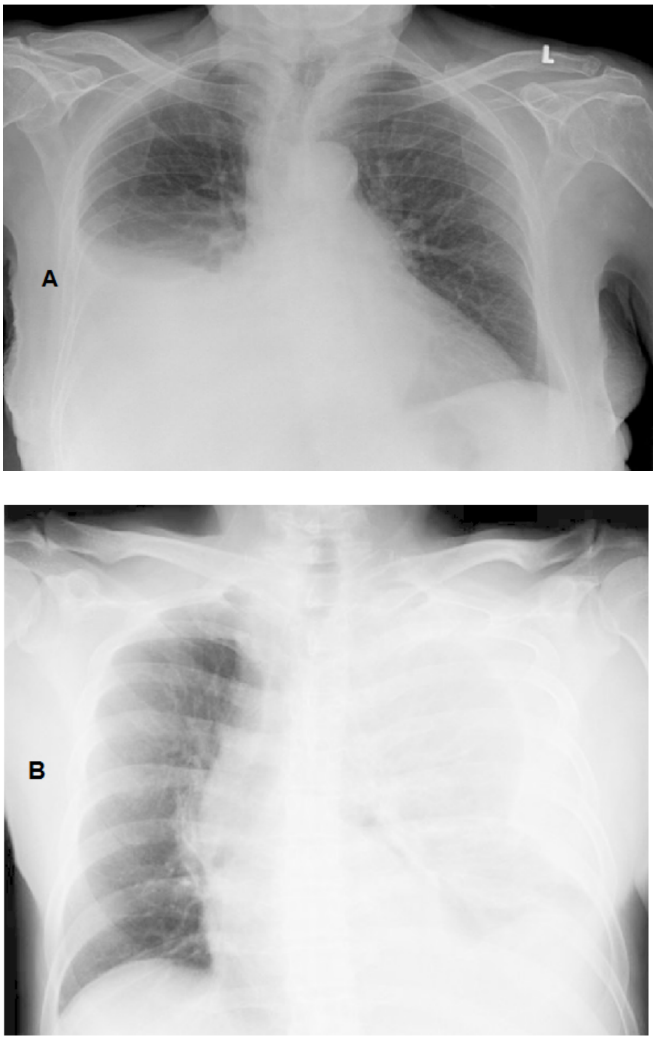


Fig. 43-9 RADIOGRAPHIC SIGNS OF FLUID IN THE CHEST. A, in a semi-erect film, fluid makes a curved interface with air at the pleural edges. B, mediastinal shift in a left tension haemothorax.

A massive haemothorax can fill the entire chest, producing a 'white out' appearance. *Don't confuse this for a lung collapse or the routine postoperative image of a pneumonectomy!*

Rarely there may be so much fluid in the hemithorax that it pushes the mediastinum to the opposite side as above.

This is **a tension haemothorax** (43-9B). *React as for a tension pneumothorax, but use a bigger cannula!* This is a sign of life-threatening bleeding and needs a very urgent chest drain or 2nd one (and possible thoracotomy).

A smaller haemothorax may not be very visible radiologically, especially if you take the picture with the patient supine.

N.B. Remember, in rare cases, a patient may have a pre-existing pleural effusion (from TB, or tumour) *before the injury!*

(c) Cardiac tamponade (44.7):
The only (late) sign is a widened, but typically globular, cardiac shadow.

(d) Fractured ribs and flail chest (43.5):
Identify each of the upper ribs anteriorly and follow them around and back to the vertebral column. Look for any disruption of the cortical layer. The lower ribs are usually identified best posteriorly and followed anteriorly.

Remember that the anterior ribs are cartilaginous and not visible on radiography. Fractures are almost always in adjacent ribs. If you identify a fracture in ribs 3 & 5, there almost always is one in rib 4.

A flail chest is defined as a segment of at least 2 ribs separated from the rib cage. Each rib must therefore be broken in at least 2 places. This segment may move independently, especially 24h after injury, and therefore fails to support proper lung expansion.

(e) Pulmonary Contusion (43.2)**:**
Diffuse mottling with dense patches is visible in the affected lung field, usually below the impact of trauma. These patches may condense in the days following trauma before clearing.

PULMONARY CONTUSION

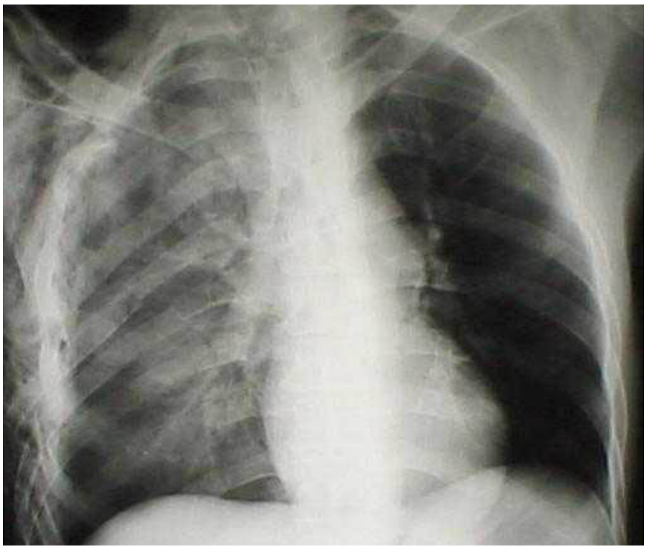


Fig. 43-10 RADIOGRAPHIC SIGNS OF PULMONARY CONTUSION. Mottling may be subtle. Note the rib fractures, and subcutaneous emphysema.

Contusion is usually associated with obvious rib fractures in adults, but may be seen in children without, since their ribs are compliant so that they bend rather than break.
Contusions are frequently found in explosion injuries.

(f) Traumatic diaphragm injury (43.4)**:**
There is a loss of the distinct demarcation of the hemidiaphragm (most often on the left side), with fluid or gas in the left hemithorax; there may be an elevated hemidiaphragm on the right. A nasogastric tube, if passed, will be visible at the oesophageal hiatus below the diaphragm and then curve back into the left hemithorax, if the stomach has herniated into the left chest. There is an elevated gastric gas bubble usually. *Don't confuse this with a haemopneumothorax!* The small bowel (unmistakable) or spleen may find their way into the hemithorax. *Don't confuse this with pulmonary contusion!*

Often the increased volume of content in the hemithorax may provoke a mediastinal shift.

TRAUMATIC DIAPHRAGM RUPTURE

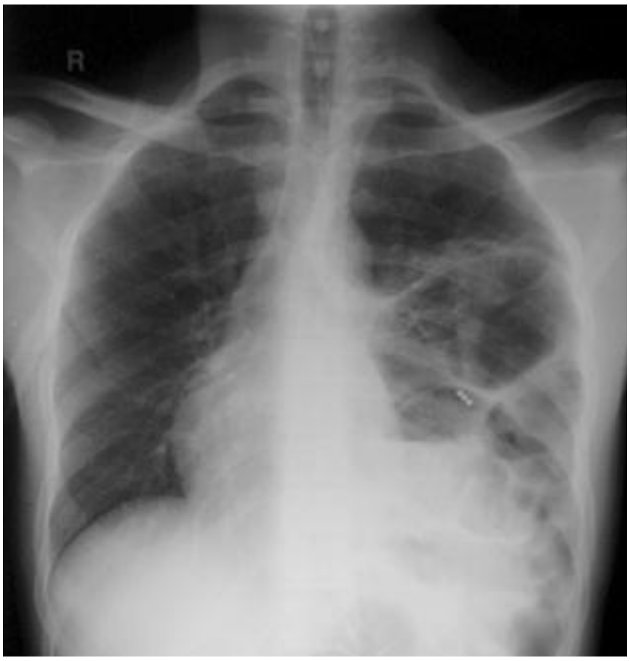


Fig. 43-11 RADIOGRAPHIC SIGNS OF DIAPHRAGM RUPTURE. Note the gas bubble (with the nasogastric tube tip) & bowel in the left hemithorax. There is some mediastinal shift to the right.

(g) Aortic injury (43.6):
Look for a widened mediastinum >8cm in a supine film (or >6cm in an erect film). This is quite a subtle diagnosis: you may need to repeat the radiograph after a while if you are not sure.

You can estimate of the size of the aortic knob (and associated hematoma) by passing a nasogastric tube; measure the distance from the radiopaque line of the tube to the pleural side of the mediastinum. Other signs are listed (43.6).

AORTIC INJURY

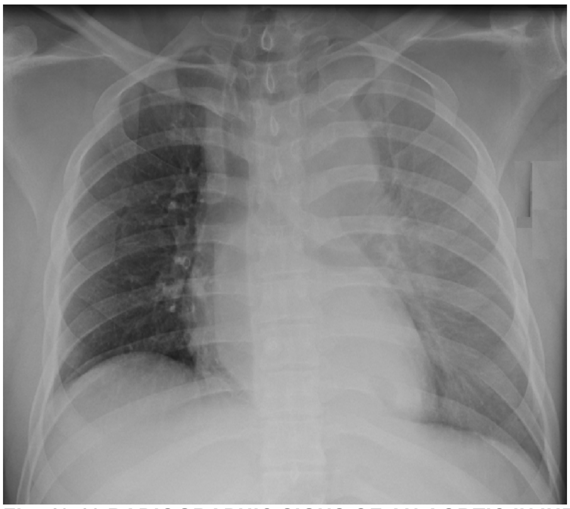


Fig. 43-12 RADIOGRAPHIC SIGNS OF AN AORTIC INJURY. A supine film: note the widened mediastinum, right tracheal deviation, flattened left main bronchus and ground-glass appearance of blood in the left hemithorax.

OESOPHAGEAL INJURY

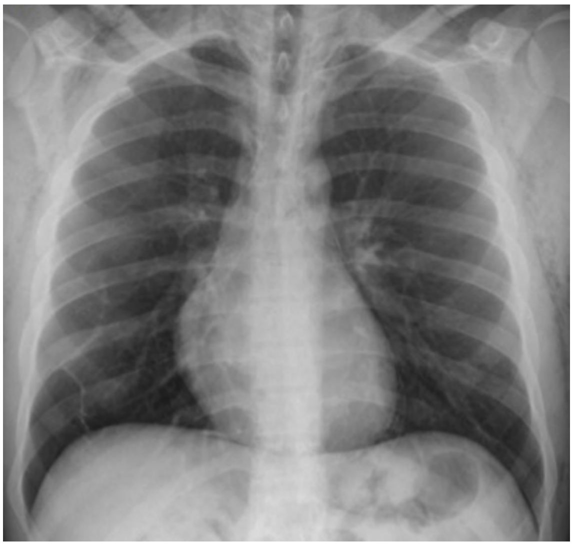


Fig. 43-13 RADIOGRAPHIC SIGNS OF OESOPHAGEAL INJURY. Note the air in the mediastinum (a black line around the heart border) and the subcutaneous emphysema, usually best seen in the neck (43-14).

(h) Blunt oesophageal rupture (30.7, 43.6)**:**
Look for subcutaneous emphysema in the neck or upper chest wall, air in the mediastinum (may be very subtle), around the heart, with or without a small pneumothorax or, rarely, a pleural effusion usually on the left side.
You may confirm the diagnosis by a gastrograffin oesophageal swallow (*don't use barium*).

N.B. The oesophagus can easily be damaged by rigid oesophagoscopy (30.2).

SUBCUTANEOUS NECK EMPHYSEMA

Fig. 43-14 RADIOGRAPHIC SIGNS OF AIR IN THE NECK TISSUES. A, AP view. B, lateral view a copious subcutaneous emphysema in the neck, which can arise from a pneumothorax, perforated airway or oesophagus. *Kindly contributed by Dhananjaya Sharma.*

TRACHEO-BRONCHIAL INJURY

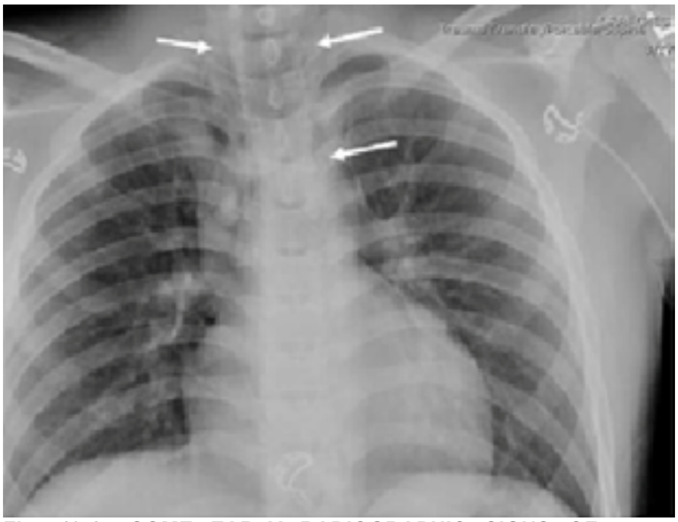


Fig. 43-15 SOME EARLY RADIOGRAPHIC SIGNS OF TRACHEO-BRONCHIAL INJURY. There is cervical surgical emphysema (air in the soft tissues) in the neck & mediastinum, but no pneumothorax. *After Jennings A Joe M, Karmy-Jones R. Tracheobronchial Trauma. JSM Burns Trauma 2017;2(1): 1011.*

(i) Tracheo-bronchial tree injury (43.6)**:**
Look for a large pneumothorax, air in the mediastinum, emphysema in the upper chest, neck or face (depending where the rupture is situated) and sometimes lung collapse. It is more common on the right than on the left; air will continue to bubble out of chest drains despite suction.
It may be difficult to differentiate from, and exist in addition to, oesophageal injury, especially in burns (50.3). You may see the lung apex at the level of the carina.

We assume CT scanning is *not* available. *Don't be tempted, however, to scan a haemodynamically unstable patient!* He is at great risk of dying before you can treat what you might find on the images.

(j) Subdiaphragmatic gas (12.1)**:**
Unless the chest radiograph is taken erect, you are unlikely to see free air under the diaphragm (from a ruptured hollow viscus); this is occasionally visible on a lateral decubitus film.

(k) Foreign bodies:
In penetrating injuries, look carefully for a bullet or other foreign body. It may be obscured behind the heart shadow, so get a penetrated ('hard') film. *Remember that an entry & exit wound don't always mean the same object that has entered has also exited! Remember also that you may find the foreign body far outside the chest!*
Occasionally a large, especially a jagged, foreign body warrants removing electively.

43.2 Emergency measures

INSERTING A CHEST DRAIN (TUBE THORACOSTOMY) (GRADE 1.4)
The pleura should be kept empty. We describe the classic technique for use in the emergency situation. Concentrate on mastering this, use adequate anaesthesia. Ketamine & LA are ideal. *Never use targeted guidewire and trocar-guided chest tube insertion:* they are dangerous.

INDICATIONS
(1) any type of pneumothorax,
(2) haemothorax,
(3) haemopneumothorax,
(4) chylothorax,
(5) a penetrating chest wall injury, in a patient who has been intubated or is about to be intubated for ventilation.

N.B. Not all patients with fluid in the chest need a chest drain. Correct a bleeding disorder as quickly as you can, *but don't delay inserting the chest drain.* Avoid puncture sites where there is a burn wound or skin infection, or where you know there are pleural adhesions. You should put in a chest drain *before* the trachea is intubated!

PREPARATION
Get all you need ready before starting to insert the drain; sterile drapes, disinfectant, LA, a #10 blade on a blade holder or handle, curved Mayo scissors, large & medium Kelly clamps, 2/0 silk sutures on cutting needles, a needle holder, gauze & tape.

Where there is a larger wound to debride or another procedure to perform, or in a very anxious patient, use ketamine as a sedative.

Choose the correct sized drain (for blood):
(1) adult male: Ch28-32
(even 36 for a large haemothorax)
(2) adult female: Ch24-28
(3) child: Ch12-24
(4) infant: Ch12-16
(5) neonate: Ch10-12.

If you are only draining air, you can use a narrow Ch10-14 tube but in trauma patients, there may well be blood with a pneumothorax, so a larger drain is safer.

N.B. Make sure the tube is at least 8cm long to penetrate the thoracic cage!

INSERTING A CHEST DRAIN

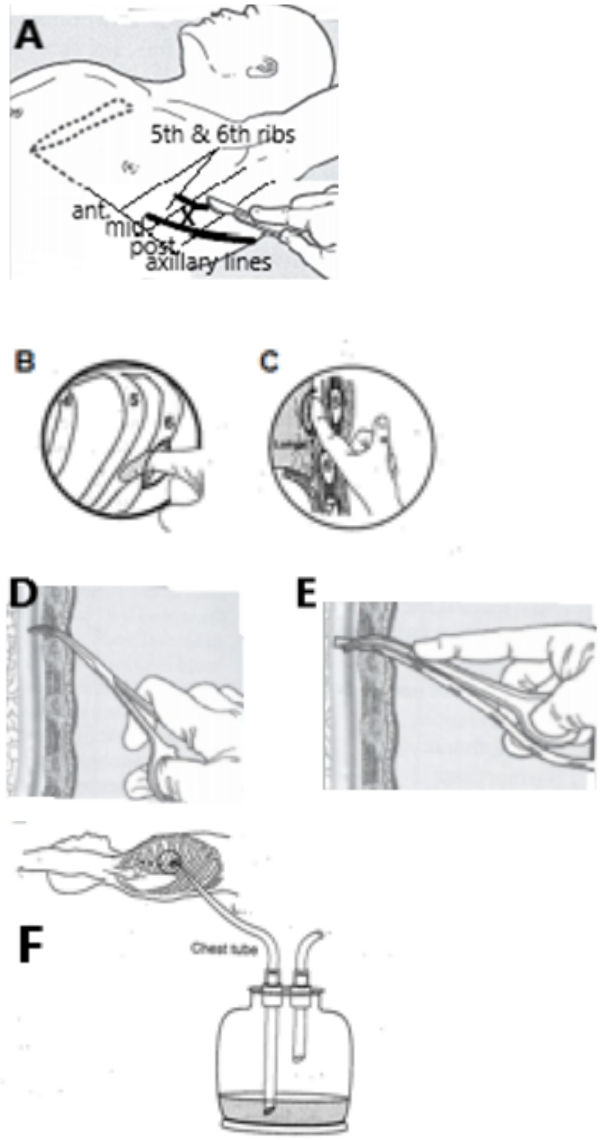


Fig. 43-16 INSERTING A CHEST DRAIN. A, X marks the drainage site (in the 5th intercostal space in the mid- axillary line). B, palpate to confirm you are above the rib. C, palpate inside the pleural space & break down light adhesions, if any. D, increase the size of the hole in order to insert the drain. E, insert the drain held on a Kelly clamp. F, connect the drain to an underwater seal. *N.B. Use the 2nd intercostal space in a child.* *After Nicol A, Steyn E. Handbook of Trauma for Southern Africa, OUP Cape Town 2004*

Prepare a collecting bottle with sterile water & 10ml chlorhexidine inside and a bung with 2 holes. Make sure the collecting tubing fits the chest drain tube, or that you have adaptors which fit.

N.B. Don't use iodine to sterilize the bottle as the colour masks blood.

***If you suspect a large haemothorax and you might need auto-transfusion**, put saline in the chest drain bottles as water causes blood to haemolyze.*

Obtain consent from the patient if time allows.
Position the patient in either the supine with the head up at 45º. This helps against the risk of placing the chest drain below the diaphragm but is not always possible in the trauma patient, especially if he is hypotensive.
Double check the correct side where you intend to insert the drain, and mark the site of insertion with a permanent marking pen.

This is anterior to the mid-axillary line in the 5th intercostal space, in the triangle formed by the anterior border of *latissimus dorsi*, the lateral border of *pectoralis major* (which forms the anterior axillary line) & a line superior to the horizontal level of the nipple (in a male). It has its apex below the axilla (43-17).

N.B. In children, use the 2nd intercostal space!

This is the safest area, although sometimes you might need to place a chest drain elsewhere (43-20).

THE SAFE TRIANGLE FOR CHEST DRAINAGE

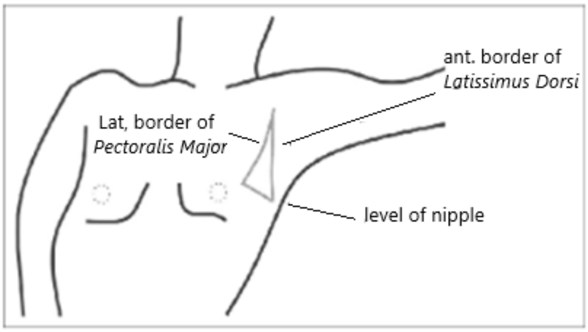


Fig. 43-17 THE SAFE TRIANGLE where you should put in a chest drain. Its edges are the lateral border of *pectoralis major,* the level of the male nipple, & the anterior border of *latissimus dorsi.*

Have atropine available in case the patient has a vasovagal attack when you insert the tube.
Consider using ketamine if a patient is very frightened. *There is no need for LA in an unconscious patient!*
It is best to inject LA before you prepare the equipment for inserting the chest drain, in order to give the drug time to work. Use a long (3-4cm) needle.

Infiltrate LA in the subcutaneous tissues, and then redirect the needle towards 5th rib and inject c.10mL into the periosteum (if you hit bone), muscle in the 5th intercostal space, and pleura.

"Walk" the needle off the rib as you keep injecting LA. Keep drawing back on the needle to check you are not in a blood vessel.

If you aspirate air, fluid, pus, or a mixture of these, your needle is inside the pleural space. Remember the depth and direction of the needle.
Monitor the patient during the procedure and afterwards. Provide oxygen by mask or nasal prongs: (*a serious trauma patient should already be inhaling oxygen!*)

Put on a sterile gown, and sterile gloves: *treat this procedure as any surgical intervention*. Place 4 sterile drapes (or 1 drape with a hole) to isolate the area where you intend to introduce the drain.
Get all your equipment ready (open the packets, and select the size of chest drain you want to use. Fix the blade on the blade-holder, and a long clamp through the eye of chest drain to hold it.

Make a 3-4cm incision along the 6th rib, through skin and subcutaneous fascia (43-16A).

Then use a medium Kelly (or sharper-pointed) clamp to create a track in the subcutaneous tissue *above* the 6th rib (in order the avoid the intercostal nerves and vessels). Aim towards the head.

Open the clamp widely to separate the muscle: (you may find that turning the clamp over so its curve is upward rather than downward helps). This might need some force: the track needs to be big enough for your index finger and for the clamp holding the drain.

When you have reached the top of the rib, palpate with your sterile finger to confirm where you are (43-16B,C). Add more LA at this stage into the deep tissues, and into the pleura.

Put the closed clamp back into the same tunnel, advance it gently but firmly repeatedly. You will eventually enter the pleura (43-16D).

N.B. Don't damage the lung! Make controlled movements! Use your non-dominant hand against the patient's chest wall to hold the clamp as you work it with your dominant hand; this prevents the tip from plunging into the pleura. Once you have entered the cavity, bring the tip of the Kelly clamp back to the level of the inside of the ribs (the pleural level) and spread the clamp wide enough to pass the chest drain easily, *but not too wide to cause a leak!*

Put the index finger of your non-dominant hand into the track to make sure it is above the diaphragm: (check to feel for the liver, spleen or stomach!) Feel inside the pleura 360º to break down any light adhesions.
If you feel dense unbreakable adhesions, choose another site to insert the chest drain, unless you can be certain that you can go round a localized area of adhesions.
Leave your finger in the track. (In obese patients, this may be impossible.) With your other hand, grasp the clamp holding the chest drain. (This is why you must get it ready beforehand!)

Place the curve of the clamp parallel the end of the drain and streamline its entry as much as possible by guiding it along the index finger already inside the track. Insert the drain at least 5cm inside the pleural cavity. Hold the drain as you withdraw your finger and release the clamp, *so the drain does not come out as well.*
Advance it posteriorly and superiorly (for air) or inferiorly (for blood) until *all of the holes in the drain are inside the pleural cavity*.

Make sure all the holes of the chest drain are inside the pleural cavity (usually the last hole is indicated by a break in the radiolucent line of the drain), or else air will collect in the tissues. Fold the sterile drape round the drain with a towel clip to stop it falling onto the floor. Connect the drain to the drainage tubing with an appropriate adaptor.

Don't clamp the drain! Look to see if there is a rush of air, condensation on the inside of the drain, or fluid coming out with bubbles.
You should see a swing in the fluid level of the drainage device with each respiration.

Secure the drain (4-14M). Close the skin with 2 separate simple interrupted sutures on each side of the chest drain, to prevent the patient's routine movements from dislodging the chest drain. *Don't use a purse string round a drain.*

Leave the ends long and tie each suture around the chest drain twice in opposite directions, producing slight indentation (like a roman sandal) on the tube. Mark the depth of insertion of the chest drain on the dressing.

Dress the insertion site with gauze, having an opening made by cutting a "Y"-shaped fenestration in it and securing this with wide adhesive tape to the chest wall. Strap the emerging chest drain on to the lower trunk with a 'mesentery' fold of adhesive tape, as this avoids kinking of the drain as it passes through the chest wall. It also helps reduce wound site pain and discomfort for the patient.

Tape all the tube connections in their long axis to avoid disconnections. *The tape over the connection should not prevent you from examining it:* it is quite possible for the tape to look secure, but the junction to leak. You can use a tongue depressor to splint the connection to hold it in place. Connect the chest drain to an underwater seal.
Avoid using a Y-connector for 2 drains, because it can appear that both drains are working when only one is.

Obtain a chest radiograph to confirm the position of the drain. Make sure all the tube holes are inside the pleura (the outer-most hole is usually marked with an interruption in the radiolucent line). Repeat a chest radiograph to confirm that the lung is fully expanded before removing the drain.

MONITORING

Make sure you check the patient in the 1st h after putting in the chest drain, and then 4hrly till he is stable; note:
(1) that fluid in the drain is coming out or air is bubbling out,
(2) the type of fluid draining,
(3) the vital signs, and pulse oximeter readings,
(4) the pain or discomfort score,
(5) the ability to cough,
(6) the depth of breathing.

MANAGEMENT

Keep the patient in a semi-sitting position.
Don't raise the level of the drainage bottle above the chest!
Encourage deep chest respirations. (*There is no contra-indication to patients walking around with their chest drain bottle hanging down.)*
Provide analgesia (intercostal nerve blocks, NSAIDs, & non-opioids) & chest physiotherapy.
Administer antibiotics for open wounds for 4-5 days.

PVC CHEST DRAINAGE BAG

Fig.43-18 Plastic chest drainage back, with air vent. This can also be used for autotransfusion (44-12). It is known as a Raina Romo bag.

UNDERSTANDING CHEST DRAINAGE SYSTEMS

There are 1,2, & 3-bottle systems. You can also use adapted plastic bags (43-18) which work on the same system, are cheaper and not breakable!

A 1-bottle system has a top with two drains coming out of it. The chest drain connects to the longer drain which reaches a point near the bottom of the bottle. Make a water seal by pouring sterile water into the bottle until 2cm of the drain is underwater. This prevents air from going back up the chest drain into the pleural cavity. The bottle acts as a reservoir for any fluid drainage (43-19A).

This system works well for a simple pneumothorax and small effusions, but if too much fluid drains into the bottle, it requires more and more intra-pleural pressure to force the air out and can prevent complete evacuation of a pneumothorax.

SIMPLE CHEST DRAINAGE SYSTEMS

To solve the problem of evacuating large volumes, use a 2-bottle system. Interpose a 2nd collection bottle between the chest drain and the water seal bottle (43-17B). The tubes coming out of the top of this bottle don't go down very far.

TWO BOTTLE SYSTEM

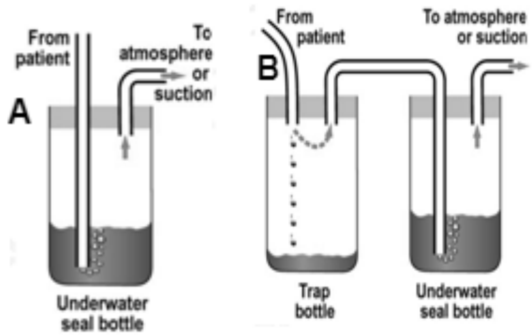


Fig. 43-19 UNDERWATER SEAL DRAIN SYSTEMS. A, a simple 1-bottle system. B, a 2-bottle system, which is ideal if you have a high-volume suction machine which has a method to regulate the degree of suction needed. Without suction, it serves as a simple water-seal with an entire bottle for a reservoir.

If you need to put a 2-bottle system on suction to continue to drain air or blood, and cannot regulate the amount of suction, add a 3rd bottle.

THREE-BOTTLE SYSTEM

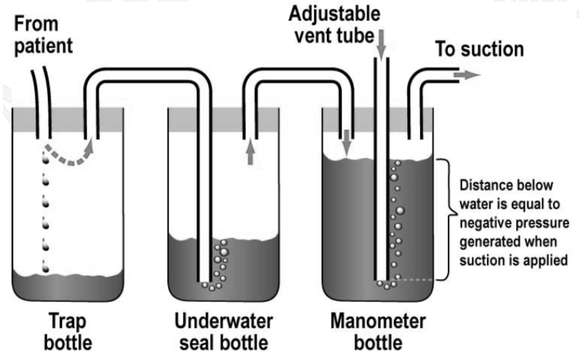


Fig. 43-20 3-BOTTLE UNDERWATER SEAL DRAIN SYSTEM. The stopper on this system has 3 drains: the 1st goes to the water-seal bottle, the 2nd to the unregulated suction source and the 3rd to a point near the bottom of the bottle. Add water until there is 10-20cm (as desired) between the surface of the water and the bottom of the longer tube.

Suction is rarely needed, except for a bronchopleural fistula (36.1), *and it can be dangerous.*

The 3 glass bottles with the appropriate tops and drains can be heavy, difficult to walk around with, and are at best clumsy. There are commercially available collection devices which are designed to accomplish all 3 functions.
Some need you to add a pre-measured amount of water to a chamber to create a water seal; some have mechanical one-way valves built into them and you just add the water to assess whether the drain is still working.
The manometer regulating the suction pressure may require water in a separate chamber; this is so you can use the drain system if there is no machine to regulate the negative pressure you want. These devices are convenient and light-weight but you cannot safely clean them & re-use them; *they are not really worth the expense*.

DON'T CLAMP A CHEST DRAIN !

Never routinely clamp a chest drain, especially if it is bubbling out air, except in the rare case of rapid re-expansion syndrome (36.1). *Always stay with a patient if you do, e.g. when changing a bottle.*

If a chest drain bottle needs to be changed, get ready with the connections, new tubes and bottles, and put on the clamps only whilst you rapidly switch over the units.
Don't clamp a drain to see if it is still needed: it can be dangerous if a pneumothorax recurs while the drain is clamped. If you are not sure if the chest drain is needed, check the bottle several times over 12-24h; if there is no bubbling or <50ml draining, remove it.
N.B. Beware if the drain has been put in the chest where there is a diaphragm rupture! Only remove the drain in theatre at laparotomy.

DIFFICULTIES WITH CHEST DRAINS

If the drain is too far inside (and touches the mediastinum or the heart), **or in a lung fissure,** take down the dressings, cut the securing sutures, and withdraw it an appropriate distance. *Don't pull it out too far so that the tube holes are now outside the chest!*

If the lung does not fully re-expand, and the pleural collection does not empty properly, remember, it is re-expansion of the lung that pushes out what is inside the pleura, so exercise or chest physiotherapy may be all that is necessary, but see 43.7. Check that the patient does not sit tilting to the side and so compress the chest drain: he needs more analgesia!

If the chest drain starts bubbling madly, or air continues to bubble out after 48h, there may be a fistula (36.1). In this case, if the patient is haemodynamically stable, check if the tube is properly in place and its connections airtight. If that is the case, apply suction up to 20cm H_2O.

If the patient is haemodynamically unstable, insert a 2nd chest drain, the actual site being determined by the site of the remaining collection.

N.B. Large haemothoraces or high-flow pneumothoraces often require 2 drains; the air may leak from a torn lung, a ruptured bronchus, or a lacerated trachea (43.6).

If the fluid inside the drain in the underwater-seal bottle does not swing back and fro with the respiratory cycle or with coughing, the drain may be blocked. *This is not uncommon; a non-functioning drain serves no purpose* and provides a route of bacterial migration, so get it working or remove it!

First, take down the dressings and ***make sure that the drain is not kinked*** at any point, especially at the entrance point into the chest. If it is, straighten it out and re-strap it to the chest. ***Then check that the tube is not disconnected.***

If the drain is blocked by semi-solid contents (*e.g.* blood clot), try 'milking' the tube. Clamp it proximally, and try to massage the tube to dislodge the stuck contents out of the tube into the bottle. Or, disconnect the drain and pass a guide-wire up it to dislodge the blockage. Some diluted heparin may help if this is a blood clot.

N:B: If you have connected 2 chest drains to a single drainage source (especially if you are using suction), one drain can continue to function and the other block off.

If the drain has partially come out, you should be able to check how much it has come out by what is marked on the dressing. An important sign is if room air is being drawn into the pleural cavity through a hole in the tubing which is now outside the chest. *Don't push the drain back in*, because you risk introducing infection. Remove the drain and replace it aseptically, as below, if it is still needed.

If the drain has fallen out completely, decide if it is still necessary. If it is, use an aseptic technique as before, cleaning the drain track. Introduce a new drain through this same track. *Do this whenever a patient becomes distressed before a repeat chest radiograph demonstrates his need.*

N.B. If the drain was placed originally for a tension pneumothorax, place a needle thoracostomy (43.1) in the 2nd interspace before you try to reinsert a new drain.

If (a glass) chest drain bottle has broken, cut off the tubing leading from it, and place a sterile glove over the end of the tube, and secure it in place. Cut one finger of the glove off.
This will then act as a Heimlich (one-way) valve (43-21), and give you time to set up the tubing system as before. An alternative is a urine bag with a hole cut in its side.

N.B. Don't clamp a chest drain!

ONE-WAY HEIMLICH VALVE

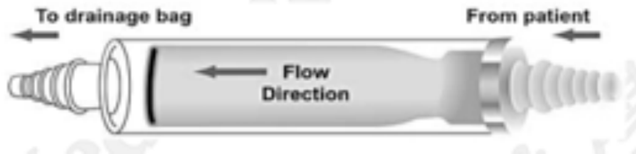


Fig. 43-21 A ONE-WAY VALVE. You can make an effective valve but cutting the finger end of a rubber glove, and tying it onto the end of a chest tube.

If the patient starts to cough (continuing for >15mins)**, complains of severe discomfort, and becomes haemodynamically unstable,** lung oedema may be developing. This is the **rapid re-expansion syndrome.** *It is rare (<1% of cases), but it can be deadly*. It usually occurs in young patients with a large pneumothorax or large pleural effusion (>3l), especially of >7days' duration, rapidly drained, particularly with suction, within the 1st h of drainage.
Clamp the drain, get the patient to breathe 5l/min pure oxygen, monitor and sedate him.

REMOVING A CHEST DRAIN
INDICATION
Remove a chest drain when no more air or <250mL serous fluid drains over 24h, *and* the chest radiograph demonstrates complete lung expansion. Wait till 12h after you turn off any suction.

TECHNIQUE
Remove the dressings, and identify any anchoring sutures. Use these for closing the drain hole. Instruct the patient to take a deep breath and hold it, bearing down without letting air escape from the mouth or nose. Gently, firmly and relatively quickly, withdraw the chest drain in a single motion.
Tie the sutures, or close the hole with a new suture while applying direct pressure to the site. Compress with a dressing for at least 2mins or until bleeding/drainage have subsided.
Try to prevent air being sucked back into the chest, if the skin gapes. Obtain an upright chest radiograph to make sure there is not a recurrent pneumothorax.

COMPLICATIONS OF CHEST DRAINS.
(1) Injury to intercostal nerves:
Lack of local sensation normally recovers.
(2) Injury to intercostal vessels:
The resulting haemothorax usually settles, but if there is a bleeding disorder, you may need to explore the wound to obtain haemostasis. This needs GA and quite a big incision.
(3) Wound infection:
Avoid this by using a sterile technique. *Don't put a chest drain through a penetrating injury*.
(4) Empyema.

Replacing a pneumo- or haemo-thorax by an empyema is a disaster! Always use a sterile technique! Don't push a dislodged drain back!

PNEUMOTHORAX
If a patient has respiratory distress, shock, with lack of air entry, hyperresonance, over-expansion of the hemithorax, and tracheal deviation to the opposite side (this may be hard to be sure about)**, and a displaced apex beat, *this is a dire emergency.***

This is a tension pneumothorax and is a clinical diagnosis. *(All these signs may not be present!) Don't wait for a radiograph* to confirm it: insert a cannula through the 2nd intercostal space in the mid-axillary line *immediately*.

You can diagnose a moderately sized pneumothorax by poor respiratory movements, hyper-resonance to percussion, and poor air entry on the affected side. The patient may not be very dyspnoeic, and may not have much pain. Subcutaneous emphysema may be present.
Ultrasound is better and easier in making the diagnosis than a chest radiograph (43-2,3).

A small pneumothorax may not be symptomatic. The air in the pleural cavity is slowly absorbed and needs no treatment.

If there is >3cm air from the chest wall rim on an erect chest radiograph, it is better to drain a pneumothorax. *A pneumothorax may become massively larger under positive pressure ventilation.* So insert a chest drain on all such patients *before starting artificial ventilation*.
N.B. **If the patient is intubated**, manual ventilation will require increasing pressure on the bag to inflate the lungs properly. The development of a tension pneumothorax may then not be otherwise obvious.

A pneumothorax from a serious chest injury may well be a haemopneumothorax, and so deserves formal drainage.
N.B. You should advise a patient to avoid non-pressurized air travel till the pneumothorax is completely resolved, and to avoid smoking and deep sea diving permanently.

HAEMOTHORAX
Bleeding from the lung, chest wall or mediastinal structures can cause blood to collect in the chest. Usually, you find diminished expansion, dullness on percussion and loss of breath sounds on the affected side. Look for associated signs of rib fracture or open wounds.
Tracheal deviation doesn't occur unless there is a massive (tension) haemothorax (43-9B).

This is also a dire emergency. Perform an immediate tube thoracostomy (43.1). Remember to use a large size drain.

N.B. Ultrasound is better and easier in making the diagnosis than a chest radiograph (43-5,6).

Small amounts of blood are very hard to see on chest radiographs. Usually it takes as much as 400-500mL to obliterate the costophrenic angle on an erect chest radiograph (43-9A).
A lateral decubitus film may show layering of fluid consistent with a small haemothorax.

There is no fluid level seen on a supine film as the fluid layers spread out posteriorly throughout the entire hemithorax.

Where you have a good suspicion of a haemothorax in a chest injury, don't hesitate to insert a chest drain. *Delay may prove fatal for the patient!* Record the amount of on-going bleeding.

If the patient remains haemodynamically stable, monitor and observe him. The colour of the blood is also important: dark, venous bleeding is more likely to cease spontaneously than bright red arterial bleeding.

An immediate drainage of 800-1500mL of blood from a hemithorax is *not necessarily* an indication for thoracotomy. The initial volume of blood drained is not as important as the amount of continued drainage. However, if this is >250mL/h and not reducing over 4-5h, a thoracotomy is indicated (43.6). *Make sure the tube is not blocked, kinked or in the wrong place!* Get another radiograph! *Remember drained blood can be used in auto-transfusion* (5.3)*!*

N.B. If you have facilities to refer such a patient, and you don't have the means to perform a thoracotomy, refer the patient earlier than later.

If a haemothorax does not completely drain after 48h, insert a 2nd Ch32–36 drain guided by the repeat chest radiograph. Place this somewhat lower and aimed posteriorly if possible (aiming the drain is not always successful). Repeat the radiograph to determine the result.

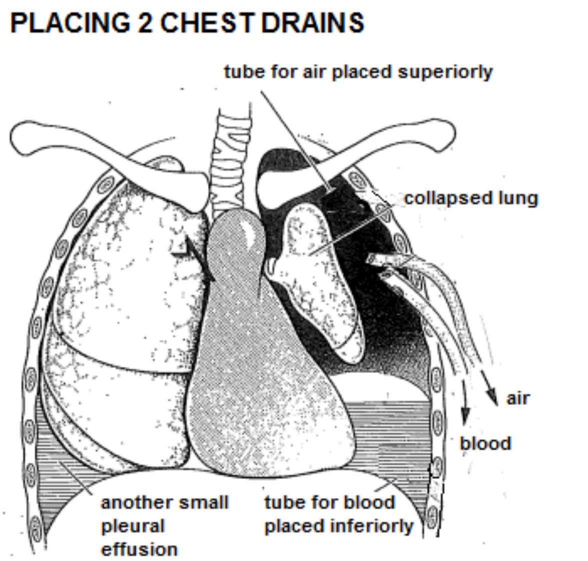


Fig. 43-22 DRAINING A HAEMOPNEUMOTHORAX. 2 drains are often better than 1, although both air & fluid will come out of each. *Kindly contributed by James Cairns.*

A retained clotted haemothorax can result in the development of a constrictive peel around the lung and if that peel is not removed, it can diminish lung function for the rest of the patient's life. *Don't wait too long to insert a 2nd drain;* do so while the blood is still liquid.

If you don't drain a haemothorax adequately in time, a decortication may be necessary, usually 3–7days after the injury.

MECHANISM OF FLAIL CHEST

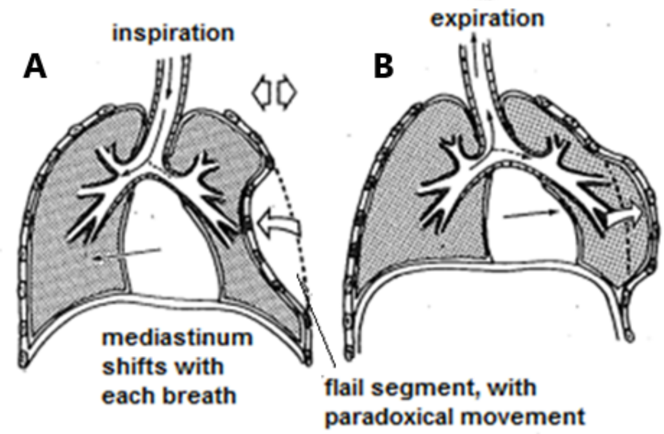


Fig. 43-23 MECHANISM OF A FLAIL CHEST. A, at inspiration, the flail segment sinks in, and the mediastinum shifts to the uninjured side. B, at expiration, the reverse happens, some air passing uselessly from one lung to the other. *Adapted from Netter FH, CIBA collection of medical illustrations.*

TRACTION FOR A FLAIL CHEST

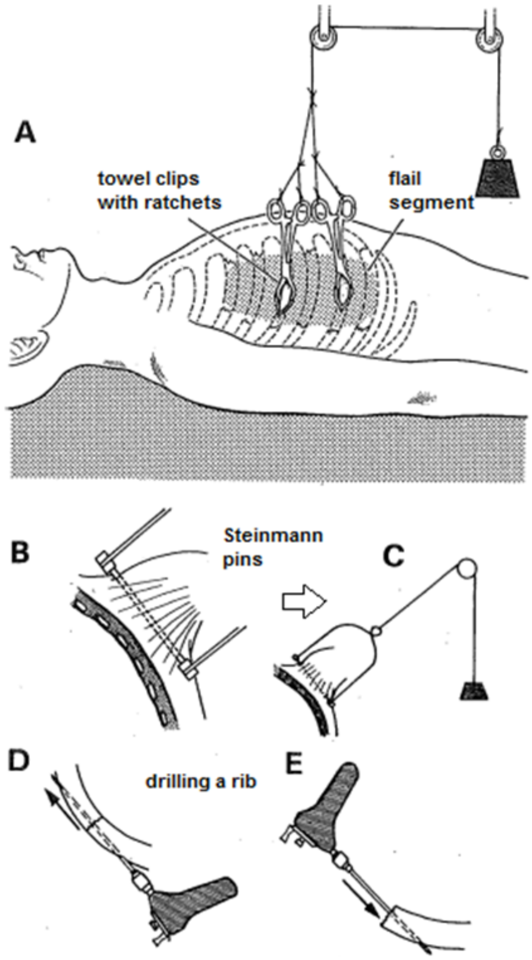


Fig. 43-24 TRACTION FOR A FLAIL CHEST. A, towel clips are usually the most convenient method. B,C, method using a Steinmann pin and stirrup. D, if the injury is open, try drilling into the rib and passing a K-wire. *Adapted by Peter Bewes, after de Palma, Management of Fractures & Dislocations; An Atlas, Saunders 1970 with kind permission.*

FLAIL (STOVE-IN) CHEST

A flail chest is defined as having ≥2 ribs fractured in ≥2 places. It is often caused by collision with a car steering wheel or by a lateral force, breaking the ribs both anteriorly and posteriorly.

This flail portion then moves paradoxically, *i.e.* it bulges outward during exhalation and inward during inspiration.

This causes hypoventilation and difficulties in the exchange of sufficient air, resulting in elevation of CO_2 in the blood. *Most flail chests are associated with pulmonary contusion.* The force breaking the ribs simultaneously crushes the lung. As a result of pulmonary contusion the exchange of oxygen at alveolar level is impaired and so levels of O_2 in the blood fall.

The flailing portion of the chest only rarely needs attention; it is the underlying pulmonary contusion that causes the greatest risk to life. Most patients just need good pain control and good pulmonary toilet (ketamine is useful); they rarely need mechanical ventilation. Use this for those who still have respiratory insufficiency after control of the pain or who have respiratory depression because they need too much opiate for pain control.

This means you may have to intubate such a patient and that will mean a referral if you don't have a ventilator and the capability to monitor the vital signs properly.

A chest drain is almost always necessary for the associated pneumo- or haemo-thorax.

Don't strap the ribs: it adds little and can diminish respiratory excursion. Intercostal blocks (43.5) will help.

A single intravenous morphine injection may make a mildly blue, anoxic, sweating patient quiet and pink. Administer it cautiously and titrate the dose needed.

N.B. Don't use more than is necessary but administer it frequently enough (often every 1–2h), but have naloxone readily available to reverse the opiate as necessary. This means careful monitoring in an intensive care set-up.

If you can't manage this, or refer the patient, you may be able to stabilize the floating segment of the chest wall by applying some form of traction for several weeks. Bilateral flail chest is usually fatal without mechanical ventilation.

But a patient with a unilateral flail chest, provided he has no serious injuries inside the thorax, and he survives the immediate injury, may be a good indication for chest traction.

TRACTION FOR A FLAIL CHEST (GRADE 3.3)

You probably will need to intubate the patient and use a self-inflating bag. A tracheostomy may help with pulmonary toilet, but this is not generally necessary straight away. *The goal is to prevent paradoxical chest movement.*

Using ketamine & intercostal nerve blocks, choose any of the following methods to apply traction to 1, 2, or more points on the floating part of the rib cage.

(1) Grip the flail ribs or sternum with several towel clips, or suitable forceps, and then tie these together with string. The clips or forceps must have a ratchet so that they remain closed (43-23A).

(2) Pass wire or strong sutures under the ribs or sternum.

(3) Screw some sterile cup hooks into the ribs or sternum.

(4) Pass a Steinmann pin under the pectoral muscles close to the ribs (43-24B,C)

(5) Attach cords to any of these traction points, pass them over pulleys, and then tie weights to the cords. Usually, 500g per traction point is enough. You may need 5kg on either side. Fix the pulleys to a frame (58.4), as for fractures.

Continue traction until the chest moves as one piece when the weights are temporarily lifted. This may take several weeks.

MANAGEMENT

Pay great attention to the patient's breathing. Encourage coughing to clear the respiratory tract.

If there are loud rhonchi, this shows that fluid is accumulating, so perform a tracheostomy (29.15, 42.4) to make bronchial suction easier.

If breathing is 'rattly' and coughing feeble, suck out the pharynx. If this fails to clear the airway adequately, perform a bronchoscopic suction (29.14).

If breathing becomes very weak and shallow, apply a self-inflating bag, especially during the 1st 24h.

If >800mL blood is still draining after 24h, or >200ml/h, a thoracotomy is indicated.

If there is a diaphragm rupture, injury to the great vessels or traumatic cardiac tamponade, perform a thoracotomy (44.6)

PULMONARY CONTUSION

Concentrate on treatment of the damaged lung, not the overlying broken ribs (beyond good pain control). Associated haemoptysis may block the airways. The main problem is usually inadequate oxygenation, not problems with CO_2 exchange.

Administer oxygen to all patients (maintaining a saturation of c.94% on a pulse oximeter). If you can, use intermittent positive pressure and positive-end-expiratory pressure ventilation. This may mean you need to try to refer such a patient.

Remember that pulmonary contusion can occur without rib fractures, especially in children (where the ribs bend but don't break) and also in explosions (blast injury).

Be careful in the amounts of fluid you administer. Use enough to treat shock but *don't overload the patient with fluid*. It will make the hypoxia from the contusion worse.

Keep the airways and bronchi clear with frequent suction. A tracheostomy (29.15, 42.4) may be very useful.

43.3 Open chest injury

When there is an open chest wound, air from outside is sucked into the pleural cavity (which is normally at subatmospheric pressure). If the air is sucked in, but cannot escape, the lung collapses, and a tension pneumothorax may arise.

There may be a sucking noise each time he breathes, or froth from the injured lung may come out of the hole in the chest.

An open pneumothorax occurs when the hole in the chest wall allows free passage of air between the outside and the pleural cavity in both directions. This will produce all the signs and symptoms of a simple pneumothorax (43.1): shortness of breath and perhaps hypoxia, but does not get worse.

A sucking chest wound can cause a tension pneumothorax. This can occur when the diameter of the hole in the chest wall approaches 12mm (⅔ the width of the trachea).

To prevent air being sucked in, but allowing it still to come out, stick an occlusive dressing to the hole in the chest but leave it open on 1 side.

N.B. ***If the dressing does not stick properly*** in a diaphoretic patient with a bleeding and bubbling wound, suture it in place.

N.B. A sucking wound under the scapula may only allow air in intermittently depending on the position of the shoulder.

Insert a chest drain (43-16) as soon as you can*, through a separate incision*. An open chest wound needs debridement and closure of the pleura and deep muscle layer. This may mean a limited thoracotomy. Leave the other layers open as a thoracostomy. Once the wound is sealed and the chest drain has stopped bubbling, you can remove it.

43.4 Diaphragmatic rupture

This can be a hard diagnosis to make. Diaphragmatic rupture is uncommon in blunt abdominal trauma, and it may be overlooked because the dominant clinical symptoms or radiographic findings may be related to other associated injuries. *Always think about this possible diagnosis.*

N.B. The diaphragm rises to the 5th intercostal space on deep inspiration.

Patients can be relatively asymptomatic or in great distress from the loss of lung volume owing to herniated abdominal contents.

The mechanism is a lateral compression or crush injury. Most (80%) diaphragmatic ruptures occur on the left side, largely because the liver protects it from the shearing forces on the right. Furthermore, the liver rarely herniates into the right hemithorax, and stops other organs from doing so. A right diaphragmatic injury is indicative of a much greater force and is associated with a higher mortality. Lacerations from penetrating injuries may be anywhere in the diaphragm but those from blunt injuries are usually at the musculo-tendinous junction.

Therefore, insert a chest drain (43.1) in the left hemithorax in cases of severe trauma with extreme care, so as not to injure any abdominal viscera which have herniated up through a ruptured diaphragm. Ultrasound is helpful to guide you.

N.B. Unrepaired ruptures may lead to incarcerated hernias and strangulation, sometimes diagnosed only years later.

DIAGNOSIS

On a plain chest radiograph, look for the loss of a distinct (usually left) hemidiaphragm, fluid or gas in the left hemithorax, or an elevated hemidiaphragm on the right (43-11).

A nasogastric tube inserted beforehand will go down below the diaphragm at the oesophageal hiatus and then curve back into the left hemithorax. It will also relieve some of the symptoms.

Diaphragmatic rupture is uncommon and the radiographic pattern is *easily confused with other conditions (haemo-pneumothorax on the left, and haemothorax on the right, or contusion)*, so keep these diagnoses in mind.
Gastrograffin studies will later demonstrate the herniated organs and constriction at the hernia site. An expert with ultrasound can demonstrate the rupture.

REPAIR FOR DIAPHRAGM RUPTURE
(GRADE 3.4)

Organize an exploratory laparotomy. Make sure a nasogastric tube is passed before anaesthesia. You may need to perform auto-transfusion (5.3). Have a chest drainage set ready. Ask the anaesthetist to use a long endo-tracheal tube and put it down the right bronchus (initially).
Make a midline or oblique incision extending over the anterior left hemithorax.

Inspect and palpate the entire diaphragm meticulously. The diaphragm is rarely injured alone. Other viscera, especially the spleen, stomach and small bowel may be injured, either in the abdomen, or in the left hemithorax.

The mechanism of injury may have sufficient force that pelvic fractures, haemopneumothorax, head injury and long-bone fractures are commonly associated.

Reduce the viscera that have herniated into the left hemithorax into the abdomen. *Don't pull on these organs*, but rather pass a hand into the chest, and ease the organs down from above.
Inspect these organs for injury, and make sure you make a systematic survey of all the abdominal organs as well.
Insert a left chest drain *after all the viscera are out of the chest (opening the abdomen may have created a pneumothorax)*.

If there has been gastric or bowel spillage, proceed to a thoracotomy to clean & wash out the left hemithorax. *You cannot do this properly from the abdomen!*

Grab the edges of the ruptured diaphragm with long Allis forceps and get your assistant to pull these towards you. Repair the diaphragm with continuous figure of 8 #0 non-absorbable sutures, pulling on the suture to prevent the wound from inverting. If there is a massive hole, use a non-absorbable polypropylene mesh to close the defect.

Monitor the patient carefully postoperatively. Ventilation for 24h may be necessary.

ABDULLA (41yrs) was hit in the left flank by a passing car. He had a cold nose, a fast, weak pulse, and a normal blood pressure. The left flank and lower left ribs were tender. A radiograph showed bowel in the chest. He was in the OT in 20mins, by which time 2 IV infusions had improved him considerably. A right upper paramedian incision was made and a hand passed up to the diaphragm. This revealed a hole. The skin incision was therefore extended up into the 8th left intercostal space. It was now seen that the spleen, although not actively bleeding, had been badly lacerated. Splenectomy was easy through the enlarged incision. The diaphragm was repaired with interrupted figure–of–8 sutures in one layer, and the chest closed with two layers of continuous monofilament. He recovered.
LESSONS: (1) Opening the chest, when you have to, may make surgery much easier. (2) Better results follow early intervention.

JABULANI (27yrs) was a lorry driver in a head-on collision which occurred at 6am. He was haemodynamically stable on arrival in hospital, where the junior doctor diagnosed a ruptured diaphragm because he heard bowel sounds in his left chest. (The x-ray machine had broken down.) Because of a problem with the municipal water supply, no sterile instruments were to hand, the last laparotomy set having been used in the night.
Laparatomy was therefore delayed till 2pm, by which time more bowel and the stomach had herniated into the chest, producing a tension effect. The patient had become unconscious in shock. The abdomen was opened without anaesthesia, and a hand passed through a large hole in the diaphragm. The spleen, many loops of bowel, and the stomach were reduced into the abdomen, and the heart manually massaged from within! A regular heart beat returned, and the patient was then quickly closed, by this time sedated with a little ketamine.
LESSON: Much is possible even *in extremis*.

If a chest drain has been inserted into the stomach, (the radiographic images being confused with a haemopneumothorax, and insufficient palpation of the pleural cavity), ***don't remove it except in theatre!*** Wash out the hemithorax copiously: gastric acid is very toxic to the chest. It is best to leave 2 chest drains *in situ* and irrigate the pleural space through these the drains postoperatively (43-20).

43.5 Rib & sternal fracture

RIB FRACTURES

Rib fractures are usually due to a blow, fall or crush injury. Older people and those with osteoporosis or metastases tend to break ribs; remember that some of the fractures are of the rib cartilage and you won't see them on a radiograph (but you can on ultrasound!).

Children may flex their ribs but not break them (however, this increases the amount of the force which is transmitted to the underlying lung and this may result in a pulmonary contusion).

Even if you cannot see rib fractures on a chest radiograph or on an ultrasound, assume if a rib is tender to the touch and hurts with every move of respiration, it is actually broken.

Fractured ribs may be associated with a pneumo- or haemothorax, but more often by pulmonary contusion. They may be a sign of more serious chest or abdominal injury, and of cardiac contusion (44.5)

Fractures of the 1st & 2nd rib are a sign of high force may be associated with major vessel injury.

Fractures of lower ribs may be a sign of liver or splenic injury. It is uncommon for broken ribs alone to be the source of a large haemothorax.

A chest wall injury may bleed profusely from intercostal and mammary vessels. These may be difficult to find.

DIAGNOSIS
Physical examination can often be very accurate. Radiographs are not particularly sensitive (and miss 50% of cases). Delayed images taken after a few days (when decalcification of the fracture line has occurred) may be helpful if documentation and a diagnosis are still necessary.
Regular chest radiographs are still useful in diagnosing underlying injury, although this may be seen better on ultrasound (43.1). If there is a sternal or scapular fracture, look carefully also for rib fractures and soft-tissue injuries.

Treatment. Like most broken bones, ribs hurt and take time to heal, and so may limit good respiratory movements. *Don't be sparing with analgesia to help a patient to breathe properly!* Use NSAIDs. Opioid analgesia depresses respiration and is therefore not ideal, but may allow respiratory excursion without too much discomfort.

Adequate pain control is important to decrease chest wall splinting, prevent alveolar collapse and assist in clearing pulmonary secretions by coughing.
Use intercostal nerve blocks with long-acting LA (*e.g.* bupivacaine) will provide pain relief without affecting respiratory function.

Use the Omoigui diffusion technique: put your left middle & index fingers on the superior and inferior borders of the rib to stabilize it, at a site proximal to the area of pain. Direct a 3 cm 25G, needle onto the midpoint of the rib and inject 2 mL long-acting LA over the rib. *Don't attempt to place the needle in the subcostal groove.* This way you remove the risk of introducing a pneumothorax or damaging intercostal vessels.

Introduce 1 nerve block for each broken rib and the ribs above and below. (You will not exceed the maximum dose of 0·5% bupivacaine for 10 ribs!)

INTERCOSTAL NERVE BLOCK

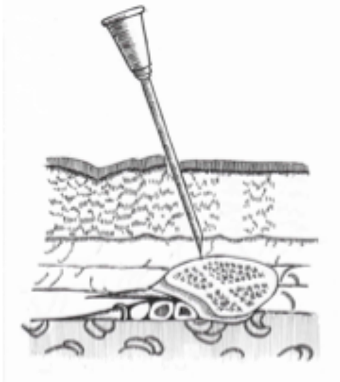


Fig. 43-25 INTERCOSTAL NERVE BLOCK. This is not used enough as analgesia for rib fractures. *Omoigui Diffusion Technique of Intercostal Nerve Block. After Omoigui S, Do Y, Adewumi PA. J Aneasth Clin Res 2013;4:344.*

N.B. Don't bind ribs with strapping: this reduces chest expansion and may lead to lung collapse. *Don't try to fix the ribs,* except occasionally for a flail chest (43-22).

Very few rib fractures don't heal, even though a fibrous capsule may envelope the fracture. A non-union may present months to years after injury and can cause discomfort with respiration due to movement of the fracture site.

N.B. Rib fractures in children represent serious impact, so are associated with greater pulmonary contusion! Think of child abuse if there are multiple fractures of different ages. (47.1)

LIGATING INTERCOSTAL ARTERIES

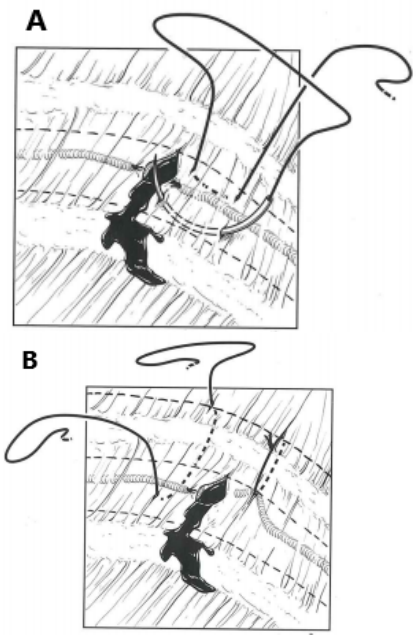


Fig. 43-26 LIGATING BLEEDING INERCOSTAL ARTERIES. (GRADE 3.1) **A, place a figure-of-8 suture with a large needle *parallel* to the ribs. B, make a cerclage of the rib on either side of the bleeding point *(N.B. this will trap the nerve, but it is a small price to pay for haemostasis).*** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If the chest wall is bleeding furiously, expose the wound (*though you may find you have to extend the incision to reach the vessels 1-2 spaces above or below*) and ligate any bleeding vessel you can see. The intercostal artery needs a figure-of-8 suture *parallel* to the ribs (43-26A), or rarely a cerclage of the whole rib on both sides of the bleeding site (43-26B).

Occasionally a large injury needs packing, and a large perforation may require inserting a balloon and inflating it to create a tamponade effect.

STERNAL FRACTURE

Although uncommon, an anterior force (such as a steering wheel) may fracture the sternum, especially in the elderly and those with osteoporosis. There is pain at the fracture site, worsened by deep breathing. Very rarely, the sternum can be separated from all the ribs, but such victims rarely survive.

DIAGNOSIS
This is easy with ultrasound, otherwise you need a lateral chest radiograph. *Don't confuse a late ossification centre at 16-18yrs* which can look like a sternal fracture.

TREATMENT
If you can, monitor such patients and get an ECG to detect cardiac contusion (44.5). These patients need adequate analgesia as the fracture is very painful. *Don't try to strap the sternum!*

43.6 Oesophageal burn

Corrosive burn of the oesophagus occurs as the result of swallowing caustic soda (for making soap), sulfuric (battery) acid, or some other corrosive chemical. It also occurs after eating the tropical beach apple (manchineel), which has a number of highly irritant toxins. Occasionally this is the result of a suicide attempt. Burns to the oesophagus may also arise with laryngo-tracheal burns from inhalation of smoke (50.3).

Acid ingestion, as compared to alkali, causes greater injury to the stomach than oesophagus because antral spasm leads to accumulation of acid in the antrum increasing the burn effect. '*Acid licks the oesophagus but bites the stomach*'.

The extent of damage may be misleading at first; redness of the pharynx and mouth is not always present if the victim has taken a large gulp of fluid.

Initial management includes haemodynamic stabilization and ensuring airway adequacy, necessary, by a tracheostomy (42.4).

In a severe case, a plain chest radiograph may reveal air in the mediastinum (43-13) or below the diaphragm suggesting esophageal or gastric perforation. A gastrograffin swallow can confirm and localize a perforation; (*don't use barium which is very irritant to tissues*).

Try to refer for a CT scan (ideal for assessing transmural damage and the extent of necrosis), therapeutic stenting or oesophageal resection.

After the initial injury has settled, perform a fiberoptic OGD within 48h, to determine the extent of damage, to assess the initial damage. Take great care during this procedure, stop if you see a circumferential oesophageal burn. *Don't make any attempt at dilatation or bougienage*. It is much safer to deal with any subsequent oesophageal stricture later.

Treat with a PPI to lessen the risk of reflux oesophagitis and further scarring. Check for this during the next 6-12wks.

If the oesophageal injury is likely to be severe (you can sometimes tell early by the bleaching caused in the mouth and pharynx), *don't hesitate to construct a feeding jejunostomy. Don't make a gastrostomy* as the stomach may be needed later for oesophageal replacement.

N.B. Never administer neutralizing agents (alkali for acid or vice versa): this will cause a chemical reaction producing heat, and so worsen the burn!

43.7 Serious chest injury

A thoracotomy is indicated:
(1) if blood drains >250mL/h over 4-5h from the chest.
(2) if there is a penetrating wound of the heart or the great vessels at the root of the neck.
(3) if >800mL blood continues to drain >24h.
(4) if a haemothorax has clotted.
(5) for air embolism.

There are 3 major types of chest injuries that will be beyond your scope in a district hospital. Try to stabilize these patients and transfer them if you can at the earliest possible time:
(1) Aortic disruption.
(2) Tracheal-bronchial injury.
(3) Oesophageal rupture.

An emergency thoracotomy (needed by <5% of patients) will depend on the resources available, your skill & experience, and that of your support staff. You must decide whether heroic measures are justified, but you should also not just let a patient die because you haven't seen operated on or even such a case before! *Fortune favours the bold!* However, perform such surgery in the theatre *not in an emergency room!*
Don't operate on someone with non-reactive dilated pupils!

SEVERE CHEST INJURY ALGORITHM

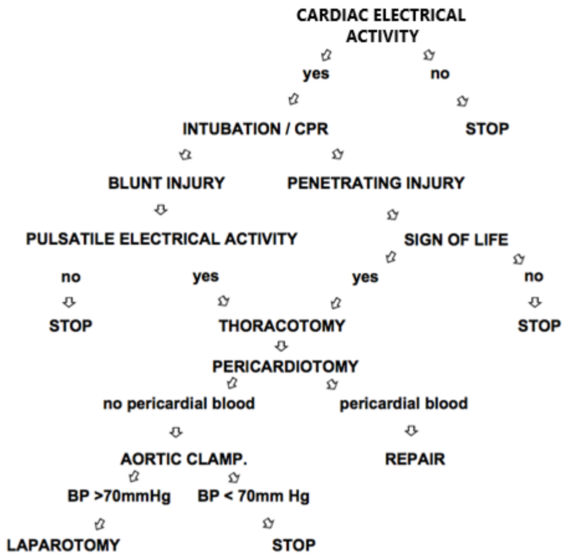


Fig. 43-27 SEVERE CHEST INJURY ALGORITHM. Treat this as a good guide.

AORTIC DISRUPTION
This is due to rapid deceleration (*e.g.* a car hitting a tree, or falling from a horse). The intima of the aorta is torn, usually just distal to the *ligamentum arteriosum*. Most such patients die at the scene because of massive haemorrhage.
In some victims, the amount of bleeding around the aorta may be limited. Such patients may look surprisingly well. They complain of severe upper back pain. The circumference of the neck may enlarge dramatically in 2-3h. The BP may be different in both arms.

DIAGNOSIS
Look carefully for the following signs on chest radiography (43-12):
(1) a widened mediastinum (>8cm when supine, or >6cm when erect),
(2) an indistinct or abnormal aortic contour,
(3) deviation of the trachea or nasogastric tube to the right,
(4) depression of left main bronchus,
(5) loss of the aortopulmonary window,
(6) a widened paraspinal or paratracheal stripe,
(7) a left apical cap,
(8) a left pulmonary hilar haematoma.

If you suspect this condition, administer analgesia, insert a left chest drain, and transfer the patient urgently, preferably with a qualified person. *You must discuss such a case with the referral hospital before sending a victim!*

EMERGENCY THORACOTOMY
Get as much help as possible, especially an anaesthetist, and members of your resuscitation team!
Splash antiseptic over the chest, and proceed as quickly as possible to open the chest. You can do this through the sternum or *via* an antero-lateral thoracotomy (44.6)

MASSIVE HAEMOTHORAX
If there is an initial >2L blood, or >250ml/h in a chest drain, especially if the blood coagulates, prepare for a thoracotomy.

N.B. You will not see a haemothorax from a stab wound of the heart in a patient still alive!
You may find that bleeding is not coming from the lung at all but from the chest wall, this can be very brisk, difficult to find and to control (43.5).

LUNG INJURIES
Perform a lateral thoracotomy (44.6) and find which part of the lung is injured.

If there is a peripheral injury which is bleeding, isolate this, preserving as much healthy lung as you can. Apply 3/0 non-absorbable mattress sutures proximal to where you want to cut the lung, and remove the bleeding portion. A linear stapler is very useful for this (43-28). *Don't use a braided suture!*

PERIPHERAL PULMONECTOMY

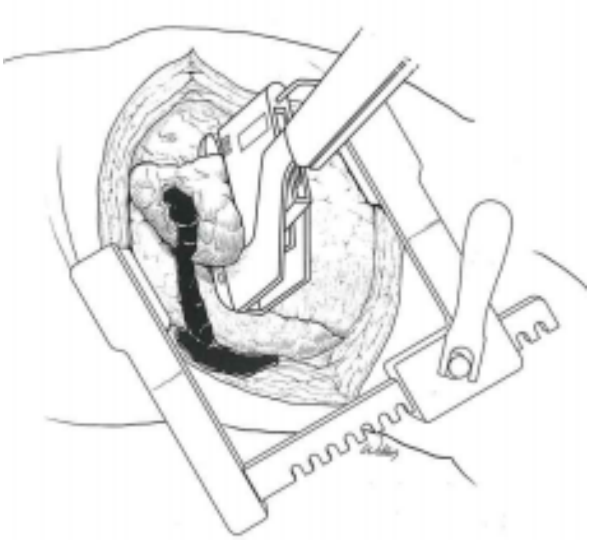


Fig. 43-28 PERIPHERAL PULMONECTOMY (GRADE 3.5**). Remove the injured part of the lung: a linear staler is ideal for this.** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If there is a penetrating wound through the lung, pass clamps (or the linear stapler) through the track to expose the concealed bleeding lung vessels which you can then suture-ligate with 4/0 non-absorbable (43-29).

TRACHEO-BRONCHIAL INJURY
Most victims present with haemoptysis, mediastinal or subcutaneous emphysema, or tension pneumothorax.
Dyspnoea, respiratory distress hoarseness, dysphonia and stridor are common.
Air leaking as a result of a penetrating wound in the neck implies an airway laceration.
In intrathoracic injuries, pneumothorax, often with high volume leakage (seen after insertion of a chest drain) is common; it may be under tension. Look for subcutaneous emphysema in the neck, and signs of lobar or full lung collapse.

HAEMOSTASIS IN A PULMONARY MISSILE TRACK

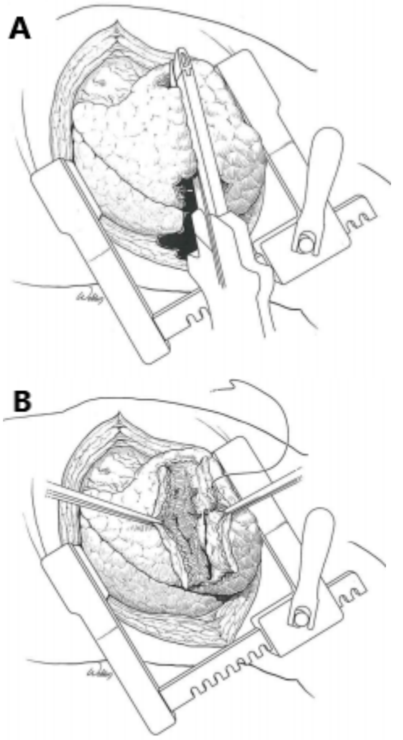


Fig. 43-29 HAEMOSTASIS IN A PULMONARY MISSILE TRACK. A, opening the track. B, suture-ligating the bleeding vessels. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If there is massive bleeding from the pulmonary hilum, quickly mobilize the lung and grab it from behind and front with your non-dominant hand to squeeze it (43-30). You may just be able to repair the hole in a major vessel.

DIAGNOSIS
Radiographic signs are a large pneumothorax, air in the mediastinum, and emphysema in the chest, neck and face, often with lung collapse (43-15). This may be difficult to differentiate from oesophageal rupture, where the pneumothorax is usually small, and there is usually a pleural effusion associated.

A *careful* flexible bronchoscopy *by the surgeon who can repair the injury* is probably the best option.

GRASPING THE PULMONARY HILUM

Fig. 43-30 GRASPING THE PULMONARY HILUM. This might just enable you to close a hole in a major vessel. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Most penetrating injuries of the tracheobronchial tree occur in the neck. On the other hand, most blunt injuries occur in the distal trachea and right main bronchus within 2·5cm of the carina.
There are often additional injuries, which have priority for repair.

If you suspect this condition, administer analgesia, insert a left chest drain, and see if you can transfer the patient urgently, preferably with a qualified person. *You must discuss such a case with the referral hospital before sending him!*

OESOPHEAL RUPTURE
Trauma is responsible for only 10% of cases of oesophageal rupture and most are related to penetrating trauma.

A pleural effusion (more often on the left than right) is common. Rarely, you will see air under the diaphragm on an erect chest film. Air in the mediastinum takes at least 1h after injury to accumulate, and may not be present at all (43-13).
N.B. Endoscopy is unreliable in making the diagnosis. Perform a gastrograffin swallow to look for an oesophageal leak.

Administer broad spectrum antibiotics. If there is a pleural effusion, insert a chest drain and test the effluent for amylase (from the salivary gland). This can confirm the diagnosis.
Repair may be complex, but needs to be done early.

COMMON COMPLICATIONS IN CHEST INJURIES:
(a) Lung collapse.
If part or all of the lung fails to expand, 'lung collapse' has occurred. This is often due to retained secretions, which is why getting a patient with a chest injury to cough is so vitally important, painful although this may be.

First try chest physiotherapy (11.10). Encourage deep breathing and coughing. Aspirate the secretions as much as you can. If this does not help, pass a sterile rubber catheter or bougie into the unanaesthetized larynx to start coughing.
If this also fails, perform a bronchoscopy (29.14) within 1h, to suck out what is blocking the bronchi.

If you need to perform >2 bronchoscopies, perform a tracheostomy (29.15, 42.4), so that you can aspirate secretions regularly and more efficiently with a fine catheter. *Oxygen is of no value if it cannot reach the lungs! Antibiotics at this stage are also of little help.*
Lung collapse may complicate *any* chest injury, however apparently minor.

(b) Traumatic asphyxia.
If the face, neck and upper arms are covered with petechial haemorrhages, violent chest compression has forced blood to extravasate from venules in the skin. There may also be retinal and conjunctival haemorrhages. In a child, respiratory insufficiency is likely, so institute intensive care.

If there is associated drop in GCS level, this suggests cerebral haemorrhage as well. Normally the petechial haemorrhage is not serious. A semi-erect position and oxygen helps.

(c) Subcutaneous (surgical) **emphysema.**
Air may leak into the tissues, causing quite alarming facial swelling (43-31). The skin makes a crackly sound on palpation. This is common in pneumothorax or pneumomediastinum, but is seldom serious in itself, and soon disappears.

The swelling may extend from pelvis to forehead. If the eyelids are swollen and there is difficulty seeing, you can 'milk' the air elsewhere away from them. *Treat the underlying cause: insert a chest drain where there is a pneumothorax.* Apart from a pneumothorax, check whether there is evidence of tracheal, bronchial or oesophageal injury.

If severe coughing, by raising intrathoracic pressure, risks enlarging a pneumothorax, perform a tracheostomy (29.15, 42.4).
Subcutaneous emphysema may look very alarming in the face, but the air is absorbed quickly.

To speed the process, you can insert a size 4 infant feeding tube (with spiral fenestrations cut into it) into the subcutaneous space, and attach this to a low pressure (10-15cm H_2O) suction.

SUBCUTANEOUS EMPHYSEMA IN THE FACE & NECK

Fig. 43-31 SUBCUTANEOUS EMPHYSEMA may be so severe as to close the eyelids and obscure features of the neck.

(d) Chylothorax.
Rarely, the thoracic duct is ruptured. A large amount of fluid (up to 2L/day) may collect in the pleural cavity. You can recognize chyle by it leaving a creamy upper layer on standing. It goes clear when mixed with ether. Its protein content is 20-30g/l. If the patient drinks dairy cream with a lipophilic dye, the drainage fluid will show this dye. The drainage usually stops after 5-7days, but the patient needs a high protein diet to replace the losses. If the drainage is >2L/day, the thoracic duct tear probably needs surgical closure. If you can't arrange this, you can try talc pleurodesis (as for recurrent pneumothorax, 36.1).

44 Shock

44.1 Assessment of shock; hypovolaemia

Shock is any abnormality of the circulatory system that results in inadequate organ perfusion and altered energy metabolism. It is dangerous to depend on any particular blood pressure figures to make the diagnosis because people can be in shock and still have relatively normal BP and pulse rates (this is called "compensated shock").

The delivery of oxygen to the issues (and its subsequent utilization producing energy) is dependent on multiple factors: haemoglobin levels, haemoglobin oxygen saturation levels, systemic cardiac output (in turn dependent on blood volume, heart rate and heart contractility), regional blood flow (vasoconstriction) and the integrity of the cellular metabolic system (which can be affected by toxins and energy status). Disruption of any one of these can cause cellular-level shock (altered oxygen and energy metabolism).

You can classify shock as follows:
(a) Haemorrhagic (hypovolaemic) shock: from loss of circulating volume, by far the most common type in trauma & burn patients.

(b) Cardiogenic shock (44.5): arising from heart dysfunction such as cardiac contusion, or occluded venous inflow owing to cardiac tamponade or tension pneumo- or haemo-thorax (49.1). Myocardial infarction is uncommon in trauma, *but may be caused by reduced perfusion*.

(c) Neurogenic shock (44.5): *is not shock associated with head injury*. A spinal cord injury (often associated with vertebral fracture) may result in hypotension owing to loss of sympathetic vasomotor tone.

(d) Septic (distributive) shock (44.5): arising from septicaemia, rare in the initial stages of trauma but may occur within hours of injury, especially with abdominal injuries. In pregnant women, amniotic embolism causes a pattern of distributive shock.

(e) Anaphylactic shock is similar in its appearance.

HYPOVOLAEMIC SHOCK.
In hypovolaemic shock, the loss of circulating fluid volume causes a progressive vasoconstriction of the arteries and emptying of the venous capacitance vessels resulting in a diminished blood return to the heart. Tachycardia is the earliest sign (but may not be obvious in athletes and older patients on beta-blockers).
The resulting drop in cardiac output results in tissue hypoperfusion and that in turn, causes metabolic (lactic) acidosis.

MANAGEMENT
Administer oxygen by mask to all hypovolaemic patients and attempt to restore their circulating volume with isotonic fluids (Ringers lactate or 0.9N saline) and/or blood.

Here are some important guiding principles:
(1) ***Presume shock in trauma to be hypovolaemic until you have proved it isn't.***

(2) The most urgent need **is to *locate the source of bleeding & stop the bleeding*** and at the same time, restore the circulating volume and therefore venous return to adequate levels. *Failure to stop ongoing bleeding leads to the lethal triad of acidosis, hypothermia and coagulopathy, which ultimately ends in death.*

(3) ***Don't pour in blood or IV fluids if the systolic BP is >80mmHg till you have controlled the bleeding!***

(4) ***Don't diagnose 'shock' by looking for specific BP values:*** recognize inadequate perfusion and the clinical signs of shock. *Any injured patient who is cool, has tachycardia, and poor peripheral perfusion is in shock until proven otherwise*. It is very possible to be in shock with a normal BP.

(5) In acute bleeding, the **Hb and haematocrit values will *not* fall until you or the body system restore the circulatory blood volume**; therefore initial values will only tell you about pre-existing anaemia but *not* tell how much blood has been lost. ***A patient with anaemia before injury will often need blood transfusion sooner.***

Follow ABC:
Check the airway.
Ensure the patient is breathing normally
Put up an IV line. Stop the bleeding!

N.B. Don't use the Trendelenburg (head-down) position because it is uncomfortable for the patient, causes cerebral congestion and impairs respiration by making diaphragm movements hard work.

Place 2 large-bore intravenous cannulae (14-18G for adults) in peripheral veins *or if you fail*, insert intra-osseous needles (tibia, femur, iliac crest, sternum or humerus), especially in children, if you have them.

Consider a cut-down (the saphenous vein anterior to the medial malleolus of the ankle is often a good option) or inserting a central venous infusion.

The femoral vein is perhaps the safest if you are not experienced. *Don't use the same femoral vein site again* because of the risk of infection and thrombosis. Inserting subclavian or internal jugular central lines carries a risk of pneumothorax, so place them on the side where you might have to insert a chest drain! The external jugular vein is an alternative.

Use ultrasound to help you guide the needle, if you can.

N.B. Central IV infusions don't allow flow as fast as peripheral lines because the length of the IV line increases the resistance and diminishes the flow rate (Poiseuille's law). They should be your last resort. Intra-osseous lines or short peripheral catheters are a better option.

Begin the 1st bolus infusion (1L for adults or 20mL/kg for children) of warmed isotonic crystalloid fluid (0.9% normal saline or Ringers lactate).

Check the glucose level and type and cross-match blood. Collect the patient's own blood, if it is feasible to do so for possible autotransfusion (44.4), while looking for sites for intravenous access.

DEGREE OF HAEMORRHAGIC SHOCK

Degree	**I**	**II**	**III**
BP	<20%	<20-40%	<40%
Pulse	Normal	Vol ⇓	Weak
Temperature	Normal	Cool	Cold
Colour	Pale	Pale	Mottled
Circulation	Slow	Slow	Sluggish
Thirst	Normal	Definite	Severe
Urine	Normal	Vol ⇓	Oliguria
Mentation	Distressed	Apathetic	Comatose

Fig. 44-1 GRADING SHOCK. *After Blackburn G, Field Surgery Pocket Book, Min Defence, HM Stationery Office, London. with kind permission.*

HOW SHOCKED IS THE PATIENT?

Don't rely on one sign only: assess the overall picture. Check the BP, the pulse rate and its quality, the skin colour, the peripheral temperature, and the presence of sweating. Ask about thirst and assess the mental state.

Later, the amount of urine passed (ml/h) will be your best guide to the degree of shock (44-1).

How full are the peripheral veins?
Empty any convenient superficial vein by pressing it between 2 fingers. Remove your more peripheral finger, and see how fast the empty vein fills up. (It should do so immediately)

How fast is the capillary return in a nailbed?
Apply pressure on the nailbed. If it takes ≥2sec for the colour to return after releasing pressure, this is suggestive of shock.

Is there mottling of the skin? This is a sign of severe acidosis.

What is the interstitial fluid pressure?
Look for: (1) sunken eyes, (2) loss of skin elasticity, (3) lowered eyeball tension, and (4) in severe cases, the classic Hippocratic facies (sunken eyes and temples, pinched nose, and tense hard skin suggestive of impending death). These are late signs.

If the respiration is shallow and rapid (air hunger), there is severe shock.

If you have the means, and if you are sufficiently skilled, insert a central venous line and measure the CVP. This will be useful for monitoring treatment.

INSERTING A CVP LINE

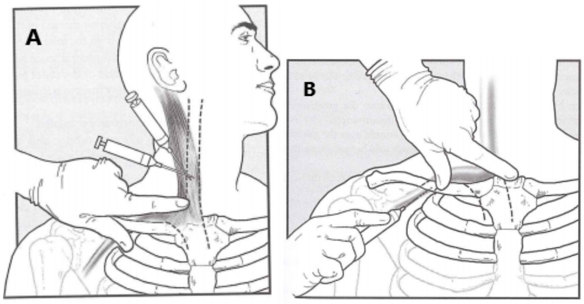


Fig. 44-2 INSERTING A CENTRAL VENOUS LINE. A, using the internal jugular route (direct puncture of the internal jugular vein is shown). B, using the subclavian route.

INSERTING A CVP LINE (GRADE 1.4)

Access may be difficult in a trauma patient, especially if the neck is injured. (In this case, femoral access is preferable, if you have the equipment). Place the patient in 15^0 of head down tilt. Ultrasound is very helpful as a guide. Identify the junction of the subclavian & internal jugular veins, which lies in a triangle formed by the 2 heads of *sternomastoid* & the medial ⅓ of the clavicle.

Introduce the needle in the centre of this triangle at 30^0 to the frontal plane, directing it toward the midline, to a depth of 1-2cm *(but never >4cm).* When blood flows freely into the syringe, advance the guidewire (if you have one) or the long cannula.

N.B. It is useful to have an ECG monitor to check for disturbances of rhythm.

Once connected to a 1L bag, lower this to the floor to check if there is free flow back into the tubing. Fix the CVP line with a suture and get a chest radiograph to check the position of the CVP line, and to rule out a pneumothorax.

An alternative route (44-1A) is directly into the internal jugular vein through the mid-point of the *sternomastoid* advancing the needle at $30\text{-}45^0$ to the frontal plane, or inserting it at the lateral border of the *sternomastoid* ⅓ of the distance from clavicle to mastoid process, and aim for the sternal notch, advancing it at 45^0 to the frontal plane & 45^0 to the border of the muscle.

DIFFICULTIES WITH CVP LINE INSERTION

The most dreaded complication is air embolism, which presents as a sudden drop in cardiac output. You may hear a continuous heart murmur with distended jugular veins.

Turn the patient on his side, administer 100% oxygen, and aspirate the air from the right atrium using the CVP line you have just inserted.

Other complications are:
(1) Pneumo-, Hydro- or Chylo-thorax,
(2) Subclavian artery injury, or AV fistula,
(3) Embolization of catheter fragments,
(4) Phrenic nerve or brachial plexus injury,
(5) Cardiac dysrhythmias
(6) Local infection or bacteraemia.

CAUTION!
(1) A falling blood pressure is a late sign of increasing shock.
(2) Don't administer vasopressor drugs (adrenaline or noradrenaline) ***before IV fluids.***

ORTHOSTATIC HYPOTENSION TEST

A simple way to identify patients with impending haemorrhagic shock is to take the BP and radial pulse while the patient is lying flat), and then again when sitting up. If there is a sharp fall in BP and an increase in pulse rate, the blood volume is depleted. This test may be very useful if you suspect bleeding in a patient who has no other obvious sign.

CORRECTION OF HAEMORRAGIC SHOCK

Generally, administer 1L *warmed* crystalloid IV fast and another if the vital signs have not improved. (This takes a total of 15mins if you use a 14G cannula.) At that point, there is already ≥40% drop in blood volume and when you have restored the fluid deficit, the haematocrit will have dropped by ≥40%.

N.B. Colloids, starch, and hypertonic saline are expensive and have significant risks (such as fluid leak into the tissues and electrolyte disturbances. *They have no advantage over isotonic crystalloids* (0.9% saline or Ringer's lactate solution)

After you have infused 2L of fluid, transfuse whole blood (group-specific, if confirmed, or O-ve). Do this earlier if the patient was previously known to be anaemic.

For children, infuse boluses of 20mL/kg warmed isotonic crystalloid fluid at a time. This reflects 20% of their blood volume.
Children with normal haematocrit can tolerate 3 such boluses before blood is needed, but anaemic children need blood after the 2nd bolus.

N.B. Children who are severely malnourished don't tolerate large boluses of fluid well: infuse 10mL/kg of crystalloid and then carefully examine for signs of volume overload or capillary leakage (liver enlargement, pulmonary and peripheral oedema) before adding another bolus.

Estimate the amount of blood lost by the response to the amount of fluids infused (44-5). Those with Class I haemorrhage and some with Class II will respond rapidly with the fluid bolus and will then maintain their blood pressure. These are people who have lost 15 -20% of their circulating volume. They are called **'rapid responders'**.

There are intermediate groups, Class II & III, who will respond initially to boluses of fluid (often ≥2L) but then relatively rapidly become hypotensive and tachycardic again as they continue to bleed and the fluid equilibrates between the intravascular and interstitial compartments. They are called **'transient responders'**. They will need blood in addition to the crystalloid fluid and, very often, will need an operative procedure to control their bleeding.

Non-responders have Class IV haemorrhage: they fail to restore their blood pressure and drop their pulse with fluids. *They always need blood* and almost always need surgery to control ongoing bleeding.

CAUTION! Be aware of the '3 for 1' rule. Because of a continued equilibrium between the intravascular and the interstitial compartment, crystalloid infused into the vascular compartment will continue to shift into the interstitial space until it reaches an equilibrium.

Practically, this means you need 300mL of crystalloid to replace 100mL blood lost. The fluid that shifts can cause significant oedema, which is particularly a problem in the brain & lungs.
You must monitor the patient closely to avoid over- and under- replacement. In some conditions, even more fluid will be needed to maintain the intravascular volume.

MANAGEMENT OF HYPOVOLAEMIC SHOCK
At this point, you should have finished your primary survey (41.1), taken blood for cross matching, and set up at least 1 (preferably 2) good intravenous infusions, controlled any external bleeding (49.1), added tranexamic acid 1g IV and administered oxygen.

HOW MUCH FLUID TO INFUSE AND HOW FAST?
If possible, replace the volume of blood you calculate is lost. In every class II shock (44-5), infuse 1L in 5mins. If there is class IV shock infuse 2-3L, but *if you don't arrest the bleeding or transfuse blood,* you will make the patient profoundly anaemic!

If the patient is fit and has no cardiac problem, you can transfuse at the most rapid convenient rate until the systolic BP reaches 90mm Hg. *If you push the BP up higher, bleeding may start again!*

If you cannot get venous access in a child <6yrs, try the intra-osseous route (44-3).

INTRA-OSSESOUS ACCESS

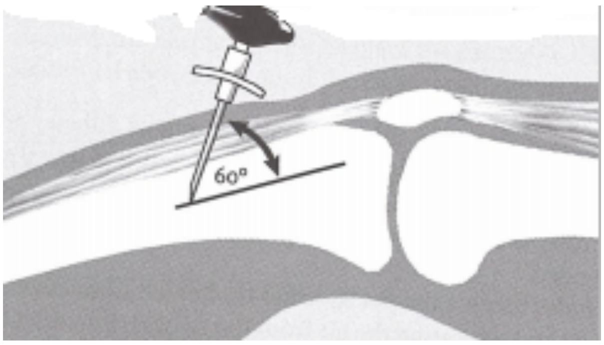


Fig. 44-3 INTRA-OSSEOUS ACCESS. Introduce the needle at a 60^0 angle 3cm below the tibial tubercle through its flat antero-medial cortical surface with a twisting motion into the bone marrow. *After Nicol, A, Steyn E. Handbook of Trauma for Southern Africa. OUP Cape Town 2004.*

Place a pillow under the knee and flex it to 30°. Infiltrate LA, and then introduce the intra-osseous needle at right angles to the periosteum 3cm below the tibial tubercle. Then angle it to 60°, making sure you are inferior to the epiphyseal plate, and twist it into the bone marrow. Aspirate and flush the needle with saline; *check there is no swelling of subcutaneous tissues.* Connect the needle to a fast-flowing IV line and push the needle into the bone & fix it securely with tape.

SAPHENOUS VEIN CUT-DOWN

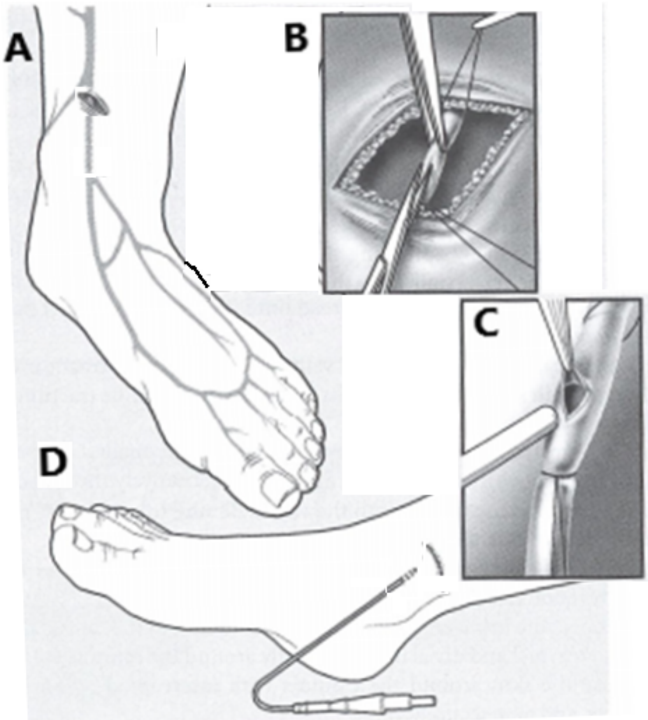


Fig. 44-4 SAPHENOUS VEIN CUT-DOWN. A, the incision 3-4cm above the medial malleolus. B, dissecting out the vein until 2-3cm is visible & passing 2 ligatures under the vein; C, opening the vein cleanly. D, close the incision and fix the cannula securely with tape and a bandage *After Nicol, A, Steyn E. Handbook of Trauma for Southern Africa. OUP Cape Town 2004.*

If you cannot access a suitable upper limb vein, try a saphenous vein cut-down. This is more reliable than trying to cannulate the vein blind. After infiltrating LA, make a 2cm transverse incision 3-4cm above the medial malleolus. Pass 2 ligatures under the vein and use the proximal one to lift it up. Tie the distal one. If you have small scissors, make a neat cut into the vein and dilate it with artery forceps & introduce the biggest cannula that will fit. Otherwise transfix the vein with a needle, and cut adjacent to this with a sharp knife to open the vein. Fix the cannula with both previous sutures, and close the incision. Tape the cannula in place and secure it with a bandage (and POP if necessary).

A QUANTITATIVE (ADULT) FIGURES FOR SHOCK & ITS MANAGEMENT

	Class I	Class II	Class III	Class IV
Blood loss	500-750 ml	750-1250ml	1250-2000ml	≥2000ml
(% blood volume)	<15%	15-25%	25-40%	≥40%
Pulse rate	< 100/min	> 100/min	> 120/min	>140/min
Blood pressure	normal	normal	decreased	decreased
Pulse pressure	normal or increased	decreased	decreased	decreased
Capillary refill time	<2 sec	>2 sec	<3 sec	<5 sec
Respiratory rate	14-20/min	20-30/min	30-40/min	>35/min
Respiratory effort	normal	accessory muscles	rib retraction alar flaring	grunting apnoeic attacks
Urine output	≥30 ml/h	20-30 ml/h	10-20 ml/h	negligible
Mental status	slightly anxious	mildly anxious	anxious & confused	confused or lethargic
Skin appearance	pale	grey	dusky	mottled

B QUANTITATIVE (CHILD 3-8YRS) FIGURES FOR SHOCK & ITS MANAGEMENT

	Class I	Class II	Class III	Class IV
Blood loss	up to 300 ml	300-850ml	850-1500ml	≥1500ml
(% blood volume)	up to 15%	15-25%	25-40%	≥40%
Pulse rate	>100/min	> 120/min	> 140/min	<50/min
Blood pressure	normal	normal	decreased	collapsed
Pulse pressure	increased	decreased	much decreased	absent
Capillary refill time	>3 sec	>4 sec	<5 sec	none
Respiratory rate	20-25/min	30-35/min	40-45/min	10-20/min
Respiratory effort	accessory muscles	rib retraction alar flaring	grunting apnoeic attacks	feeble
Urine output	≥40 ml/h	20-40 ml/h	10-20 ml/h	anuria
Mental status	drowsy	confused, irritable	lethargic	coma
Skin appearance	pale, dusky	grey, cyanosed	mottled	mottled, cold

C QUANTITATIVE (TODDLER, 1-3YRS) FIGURES FOR SHOCK & ITS MANAGEMENT

	Class I	Class II	Class III	Class IV
Blood loss	up to 250 ml	250-450ml	450-750ml	≥750ml
(% blood volume)	up to 15%	15-25%	25-40%	≥40%
Pulse rate	>100/min	> 120/min	> 140/min	<50/min
Blood pressure	normal	normal	decreased	collapsed
Pulse pressure	increased	decreased	much decreased	absent
Capillary refill time	>3 sec	>4 sec	<5 sec	none
Respiratory rate	20-30/min	30-40min	40-50/min	10-20/min
Respiratory effort	accessory muscles	rib retraction alar flaring	grunting apnoeic attacks	feeble
Urine output (ml/h)	≥40 ml/h	20-40 ml/h	10-20 ml/h	anuria
Mental status	sleepy	inconsolable	seizures, asymmetric pupils	coma
Skin appearance	pale, dusky	grey, cyanosed	mottled	mottled, cold

D QUANTITATIVE (INFANT, <1YR) FIGURES FOR SHOCK & ITS MANAGEMENT				
	Class I	**Class II**	**Class III**	**Class IV**
Blood loss	up to 50 ml	50-100ml	100-250ml	≥250ml
(% blood volume)	up to 15%	15-25%	25-40%	≥40%
Pulse rate	>100/min	> 140/min	> 170/min	<50/min
Blood pressure	normal	normal	decreased	collapsed
Pulse pressure	normal or increased	decreased	decreased	decreased
Capillary refill time	>3 sec	>4 sec	<5 sec	none
Respiratory rate	30-40/min	40-50/min	50-60/min	20-30/min
Respiratory effort	accessory muscles	rib retraction alar flaring	grunting apnoeic attacks	none
Urine output (ml/h)	≥30 ml/h	20-30 ml/h	10-20 ml/h	anuria
Mental status	sleepy	inconsolable	seizures, asymmetric pupils	coma, dilated pupils
Skin appearance	pale, dusky	grey, cyanosed	mottled	mottled, cold

E QUANTITATIVE (NEONATE <1 MONTH) FIGURES FOR SHOCK & ITS MANAGEMENT				
	Class I	**Class II**	**Class III**	**Class IV**
Blood loss	up to 30 ml	30-50ml	50-80ml	≥80ml
(% blood volume)	up to 15%	15-25%	25-40%	≥40%
Pulse rate	>120/min	> 160/min	> 190/min	<50/min
Blood pressure	normal	normal	decreased	collapsed
Pulse pressure	normal or increased	decreased	decreased	decreased
Capillary refill time	>3 sec	>4 sec	<5 sec	none
Respiratory rate	40-60/min	50-70/min	60-80/min	30-40/min
Respiratory effort	accessory muscles	rib retraction alar flaring	grunting apnoeic attacks	none
Urine output	≥20 ml/h	10-20 ml/h	anuria	anuria
Mental status	sleepy	inconsolable	seizures, asymmetric pupils	coma, dilated pupils
Skin appearance	pale, dusky	grey, cyanosed	mottled	mottled, cold

Fig.44-5 AMOUNTS OF BLOOD LOSS & RESPONSE TO FLUID REPLACEMENT. A, adults. B, children. C, toddlers, D, infants, E, neonates. *Modified from Classification and Management of Haemorrhagic Shock, ACS ATLS Student Course Manual 9th ed with kind permission.*

N.B. (1) In non-adults*, bolus replacements IV are better than infusions.*
(2) Premature neonates have 90-100ml blood/kg (*more than term neonates).*
(3) Obese patients have lower blood volumes per weight (ml/kg).
(4) Measure systolic BP with a cuff 40% the circumference of the upper arm.
(5) In children, a normal systolic BP = [2 x age(yrs)] + 65.

RESPONSE TO INITIAL FLUID REPLACEMENT (2l in adults; 20 ml/kg in children)			
	Rapid Response	**Transient Response**	**No Response**
Vital Signs	Return to normal	Show transient improvement; ↑BP and ↓HR, then ↓BP and ↑HR	Remain abnormal
Estimated blood loss (% blood volume)	Minimal (10 – 20%)	Moderate & ongoing (20 – 40%)	Severe (>40%)
Need for more crystalloid	Low	High	High
Need for blood	Low	Moderate to high	Immediate
Blood preparation	Type & cross-match	Type-specific	Emergency blood transfusion
Need for operative intervention to control ongoing bleeding	Possible	Likely	Almost certain

Fig.44-6 RESPONSE TO INITIAL FLUID REPLACEMENT. *Modified from Classification and Management of Haemorrhagic Shock, ACS ATLS Student Course Manual 9th ed with kind permission.*

If the patient is old, hypertensive, or has cardiac disease, infuse repeated rapid boluses of 100 mL, watching the jugular venous pressure carefully between each infusion. Do this until there are signs that the cardiac output is normal. *A change in the JVP or CVP is more important than its absolute value.* Listen to the bases of the lungs for crepitations, indicating overload.

If there is a +ve gag reflex and no abdominal injury*,* you can resuscitate a patient with oral fluids: diluted cereal porridges based on local foodstuffs are ideal.

MONITORING THE URINARY OUTPUT:
It is best to attach a condom catheter (or more reliably, insert a urinary catheter) to measure the output. *There is no point doing this if no-one is going to collect the urine & record the output!*

If you suspect a urethral injury, insert a suprapubic catheter (55.1). *Don't try to pass a urinary catheter into a damaged urethra!*

Aim to get an output of ½mL/kg/h (1mL/kg/h for a child, 2mL/kg/h for an infant, and 3mL/kg/h for a neonate). This is the most useful indication that you have treated hypovolaemic shock adequately.
Examine the first urine from this catheter. Look at its colour, murkiness & especially for blood and, if possible, culture it.

If, later, no urine appears in the bag, make sure that the catheter is not kinked, and the system is open and properly functioning.
If the catheter only produces a little urine and some blood, suspect that there is a bladder or urethral injury (55.17).

Start a FLUID BALANCE CHART.

WHEN HAVE YOU INFUSED ENOUGH FLUID TO A SEVERELY SHOCKED PATIENT?

The skin should become warm, dry, and the mucosa, nailbeds and palms will become pink, instead of being cold, damp and white. The nail beds should fill up in <2secs and the nose tip becomes warm.

Don't overinfuse fluids, because if secondary bleeding occurs, the patient will have used up all his reserve! It is a good idea to aim at 80mm Hg systolic pressure; *perfusion may still be inadequate* as the patient's blood is now diluted.
Loss of consciousness will not occur from volume loss unless the BP drops <60mm Hg; it will take only 1-2h of severe hypotension to cause irreversible kidney damage.

MONITORING THE CVP:
Inserting a central venous line is a skill made much easier by ultrasound guidance. This will enable you to measure the central venous pressure (CVP).

If a patient is hypovolaemic, you can infuse fluid safely and rapidly until the CVP rises to 12cm H_2O. If it is >15cm, you are overinfusing fluid, or the heart is failing.

If the CVP rises, but the BP and peripheral circulation don't improve, you may have to use IV 5µg/min noradrenaline, *but this needs a pump and careful monitoring.*

METABOLIC ACIDOSIS
In shock, metabolic acidosis results from inefficient anaerobic metabolism of pyruvate to lactic acid. *This is a more reliable sign of shock than blood pressure*. It is best to use arterial blood gas measurements to get an accurate pH value. Correction of shock allows pH to normalize; you very rarely need to administer IV bicarbonate, even if the pH < 7.2.

CAUTION! Acidosis causes coagulation problems.

BLOOD TRANSFUSION
Warm the blood you transfuse. *Don't infuse it thawed (but still cold) straight from the fridge:* (it may cause ventricular fibrillation). A safe way to warm blood is to pass it through 2 IV drip sets connected together through a water bath at 37°C, measured with a thermometer.

Slowly infuse 5mL 10% calcium chloride, or 10mL 10% calcium gluconate IV for every 4 units of blood you transfuse. *N.B. Rapid infusion may produce vasodilation, bradycardia, cardiac arrhythmias, syncope, hypotension & cardiac arrest*

44.2 External bleeding

CONTROL OF ONGOING BLOOD LOSS IS YOUR HIGHEST PRIORITY!

You *must* determine where the bleeding is coming from. To find the source of the bleeding, remember the mnemonic:

'Blood on the floor and four more'

Blood on the floor:
100 mL of blood covers c. 1000cm^2 (or 1ft^2). 1L covers c. 1m^2. The most likely sources are scalp injuries, large lacerations and broken bones.

'Four More' are the chest, abdomen, pelvis and long bones (44.3)

EXTERNAL BLEEDING (49.1)
It is difficult to judge the amount of external blood loss accurately but always remember that significant blood loss may have occurred at the scene of the injury. The history from the patient or from the first-responders will be of some help.

CONTROL OF EXTERNAL BLEEDING:
CAUTION: Don't let dramatic external bleeding draw your attention from Airway and Breathing as your first priorities.

Methods you can use are:
(a) Elevation
If a limb is bleeding, raise it. This will usually control venous bleeding. If the wound is in the upper part of the body, sitting the patient up may help, but be careful that it does not cause fainting.
(b) Pressure
Your gloved finger (or someone else's) is usually the best option to stop external bleeding. Adequate localized pressure stops almost all kinds of external bleeding. For arterial bleeding, this works best at certain sites (49.1)

ISRAELI BANDAGE

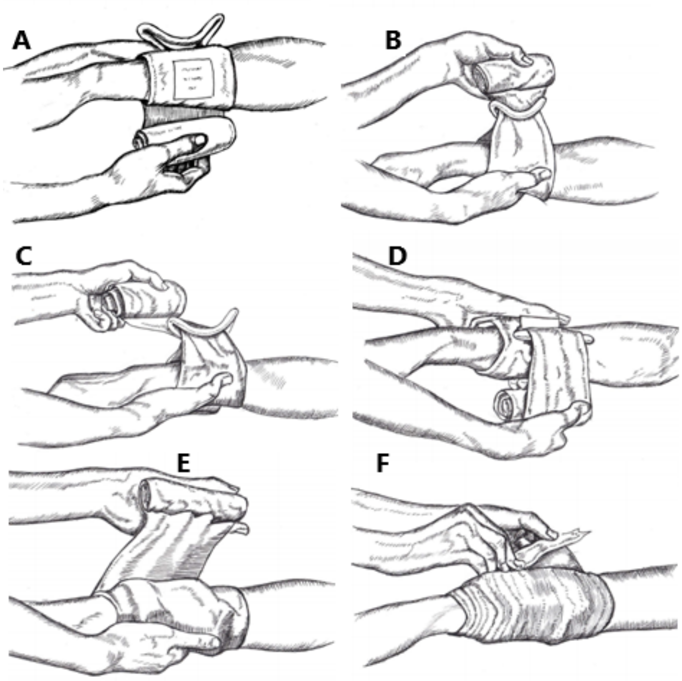


Fig. 44-7 CORRECTLY APPLYING AN ISRAELI BANDAGE. A, Place the bandage with the non-stick pad (opposite the label which states 'other side') on the wound, and wrap it round. B, insert the bandage into the clip (pressure bar). C, tighten the bandage. D, reverse direction of the bandaging, forcing the clip down against the pad. E, wrap the bandage round fully covering the pad. (You can twist the bandage for greater pressure, *but this might convert this into a tourniquet!*) F, Secure the system by hooking ends of the closure bar onto the elastic bandage.
After Bar-Natan, B. The Emergency Bandage 1995.

N.B. The bandage comes in 3 different sizes: 10,15, 20cm wide.

Compression dressings, as traditionally used, are notoriously ineffective on non-extremity wounds. They often soak up & hide bleeding more than they stop it. They fail on trunk wounds because they don't apply focused pressure; the bandage often sits ineffectively on top of the skin rather being put circumferentially.

An elasticated bandage is essential, the most effective type, especially in combat situations, is the 'Israeli Bandage', This has a non-adhesive bandage pad sewn in, which prevents re-bleeding when you remove it. *Don't do anything more until you have waited for at least 5mins by the clock*, unless a torrent of blood pours from the dressing (which will only occur if you have applied the Israeli bandage incorrectly, or you have used inadequate pressure). If bleeding stops, be thankful and *don't meddle with the dressing*.

N.B. A tight dressing might act like a tourniquet, so note when it was applied, and remove it before too long!

(c) Packing
Use this to control deep inaccessible bleeding. Use broad strips of folded gauze (soaked in benzoin for its sealant effect, or iodine for antisepsis), and place these systematically in the wound, *not as a rolled up wodge.* If necessary, hold the pack in place with deep sutures. Here you can make good use of haemostatic agents, if they are available.

SUBFASCIAL PACKING with proximal compression can arrest severe bleeding from high-energy penetrating injuries and amputation wounds.

BALLOON TAMPONADE
Where haemorrhage is welling up from a deep knife wound or gunshot track, put a Foley urinary catheter (or sterilized condom) into the track as far as possible, and inflate the balloon, and then apply traction to it. Suture it in place if necessary, and close the skin hole, as a temporary measure.

N.B. You can also use this in the cervix or uterus for gynaecological haemorrhage (22-10).

(d) Tourniquet
Use a tourniquet in massive exsanguination *but remember it causes ischaemia & the danger of reperfusion injury*. *Don't use it unless direct compression is ineffective*. Take the victim to the operating theatre as soon as possible afterwards.

Tourniquets are useful in a mass casualty setting; it is better to lose a limb and save a life! They may also have a temporary role in an overstretched and understaffed emergency situation.

A FIELD TOURNIQUET
Improvised tourniquets don't usually work well. Replace an improvised or makeshift tourniquet by a commercial, or pneumatic one, *as soon as possible.*

N.B. Direct pressure on the brachial artery (in mid-humerus) or femoral artery (at the groin) may temporarily slow distal bleeding, but ties up one rescuer. If you are alone, put pressure on the mid-arm or groin with your knee as you kneel over the patient while getting ready to put on the tourniquet.

AN EFFECTIVE TOURNIQUET needs:
(1) Material: this is a band of some sort to wrap around the extremity. Good options are 3-4cm wide: tie, scarf, bandana, any fabric long enough to wrap around limb, nylon webbing or elastic bandage, and 10-20cm long.

N.B. Poor choices include: belts, cables and other narrow devices. Narrow belts require more pressure and can cause more damage, especially to nerves.

Don't try to tighten it with the buckle itself: this will not work. The material needs to be loose enough to slip a windlass under it to twist.
(2) Windlass: this is a rigid object used to twist the material (*hand tightening is ineffective*) so that the grip tightens. It should be sturdy and ≥15cm long. Good options are: a car jack handle, sturdy stick, or shortened broom handle.
(3) Securing mechanism for the windlass: this is something to keep the windlass from unwinding after you have tightened the tourniquet. It must secure the windlass to the band by slipping around the windlass. Suggested options are: another strip of cloth with or without a rubber band, hair band or ribbon, zip-tie, key ring, carabiner, plastic ring from an opened water bottle, etc.

THE COMBAT APPLICATION TOURNIQUET (CAT) is the most popular tourniquet for out-of-hospital use. It is made of a self-adhering band with a windlass strap, a rod and a clip. It costs c. US$15. To use it properly, you should:
(1) first put direct pressure on the bleeding site for 5mins, if possible. If the wound is still bleeding, proceed to place the tourniquet,
(2) place the band 5-8cm proximal to the wound (or at the level of the lowest compressible tissue),
(3) pull the strap through the buckle and pull it snugly (44-8B); double it back, using the hook-and-loop to fasten it,
(4) turn the windlass in either direction (44-6C) until the bleeding stops and the distal pulses are no longer palpable. *Don't turn it >5 times!* (Each turn may deliver 100mm Hg pressure),
(5) hook the windlass under the clip (44-6D),

(6) close the clip and **record the time of application** on the limb or the tourniquet (44-6E), with a permanent marker, and
(7) **check for absence of distal pulses.**

You must always do the last 2 things!!

DIFFICULTIES WITH TOURNIQUETS
Wider compression straps at lower pressures produce less injury to nerves, blood vessels & tissue than narrow tourniquets (*e.g.* cables, ropes, narrow belts) at higher pressures.

Don't use more pressure than is necessary to stop arterial bleeding and obliterate distal pulses. Use a wide-enough band as the tourniquet.

If the tourniquet is not effective, *use a 2nd tourniquet proximal to the 1st* rather than tightening the 1st one further.

If you still need the tourniquet on arrival to the hospital, replace it with a wider pneumatic tourniquet. Place it proximal to the most proximal bleeding site where tissue compression is possible: *not as "high and tight" as you can*.

SECURING A COMBAT TOURNIQUET

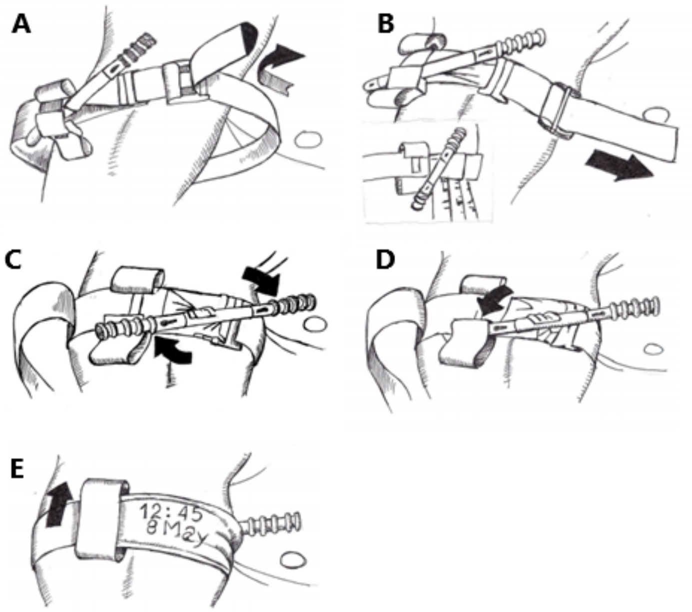


Fig. 44-8 SECURING THE COMBAT APPLICATION TOURNIQUET. A, pull the strap through the buckle, and B, pull it snugly so you can't pass 3 fingers under the strap. C, double the strap back through the clip. D, turn the windlass till distal pulses are no longer palpable, and hook the it under the clip. E, replace the band through the clip over the windlass & record the time of application. *After Crown E, US Army Medical Materiel Agency Public Affairs, Fort Detrick, Maryland, USA.*

N.B. Tourniquets can be life & limb savers when properly used but you MUST use them properly.

INDICATIONS FOR TOURNIQUET USE
(1) life-threatening or multiple bleeding wounds in a limb,
(2) a wound which is not accessible (*e.g.* patient is trapped in a vehicle),
(3) lack of time because of other severe problems,
(4) failure of simpler measures.

If you use a pneumatic cuff, put soft cotton to protect the skin surface. Pump the cuff slightly higher (not >80 mm Hg) than the patient's systolic blood pressure. Bleeding will stop if you have applied the tourniquet properly.

CAUTION! If it only impedes venous backflow (not enough pressure!) bleeding will increase.

CAUTION! Never use a tourniquet when simple pressure or a pressure dressing can control the bleeding. Multiple bleeding sites, major arterial bleeding, traumatic amputation and multiple fractures are likely to be indications for their use.

CAUTION! Never partially apply a tourniquet! Always apply with sufficient constriction to occlude arterial bleeding completely. *If it does not occlude all bleeding, take it off after you have put another tourniquet more proximally.*

CAUTION! Never forget you have applied a tourniquet. Always time the application & remove it as soon as safely possible.

CAUTION! Systolic blood pressure may increase with effective resuscitation and result in re-bleeding. You may need to re-apply the tourniquet.

CAUTION! You may need to perform a fasciotomy (49.8) *later*.

CAUTION! ***If you leave a tourniquet for ≥6h,*** *the limb involved is at great risk of ischemia and/or nerve damage and eventual amputation.*

CAUTION! Don't loosen the tourniquet periodically! This worsens ischemia-reperfusion injury.

CAUTION! ***Don't leave a tourniquet >1½h on the arm or >2h on the leg. (30min & 45min respectively for thin adults & children.)***

If the accident-to-definitive-care time is <2h, leave the tourniquet in place the entire time. However, under good conditions, remove it <2h if possible. Ischemic tissue damage begins around this time.

If the patient is no longer in shock, let down the tourniquet if:
(1) bleeding is controlled and you can observe the victim;
(2) a haemostatic dressing is effective;
(3) evacuation is prolonged >6h; or
(4) you can relocate the tourniquet more distally to preserve extremity length.

Don't let the tourniquet down before definitive care if (1) there is an amputation or known arterial injury, (2) the tourniquet has already been in place ≥6h, or (3) to let the tissues 'recover'. *Intermittent release of a tourniquet increases the risk of myoglobinaemia, myoglobinuria & renal shut down!*

Proceed quickly to vascular control or repair (49.1)

ALWAYS NOTE THE TIME WHEN YOU HAVE APPLIED THE TOURNIQUET!

Don't forget analgesics: a correctly applied tourniquet is always painful!

The scalp can bleed profusely. Stapling or rapidly closing the skin with a running haemostatic suture is useful. You may need to make a more definitive exploration later when the patient has stabilized. The same applies to the face.

Never try to use diathermy in the emergency situation: it causes further necrosis to the tissues.

Never use haemostatic (arterial) forceps blind: they can easily cause damage to nerves, veins and other issues.

If, however, you can see a bleeding vessel clearly, try to isolate it and clamp or ligate it.
N.B. Haemostatic agents are expensive, and don't take the place of a pressure dressing.
This means you must know how to dissect out vessels correctly, control them, and know whether to ligate them or attempt a shunt or repair (49.5). This may also mean an amputation at the appropriate level (60.1) or a fasciotomy (49.8).

44.3 Internal bleeding

The 'Four More' causes of bleeding:

BLEEDING IN THE CHEST
The chest can easily hold 3L blood or more. A patient can lose all his blood easily into the thorax.

Suspect a haemothorax if air entry is poor, the chest is dull to percussion, there is clinical evidence of rib fractures, or an ultrasound scan or chest radiograph suggests this (43.2).

Insert a large chest drain (Ch32-36) and if there are large volumes of blood to drain, a 2nd drain.
If you are uncertain, put in a drain! Use the blood from chest drains for auto-transfusion (5.3). Simply attach a collecting bag (*e.g.* a urine bag) to the chest drain tube *via* a 2-way tap, and re-transfuse the blood.

BLEEDING IN THE ABDOMEN
The abdomen can easily hold 3L of blood or more. A patient can lose all his blood easily into the abdomen.

Since bleeding is not visible and you may well not know what the abdomen looked or felt like before the injury, you must always suspect abdominal bleeding in a shocked patient.

Abdominal distension and marks from the seat-belt or steering wheel are the most common signs of significant intra-abdominal bleeding in motor crashes.
A doughy consistency of the abdomen may indicate bleeding. Peritoneal irritation may suggest an associated visceral injury (which often causes some bleeding).

Remember that the liver and spleen are under the rib edge; obvious trauma to the lower chest and ribs may damage these structures, especially if there has been significant impact, *e.g.* against a steering wheel, a seat, a seat-belt, or the handlebars of a cycle.
However all these signs take some time to be obvious. *Always keep re-evaluating the patient!*

N.B. Unrecognized or missed intra-abdominal injuries remain amongst the leading causes of potentially preventable trauma deaths worldwide.

ULTRASOUND
The FAST (Focused Assessment with Sonography in Trauma) examination is a skill you can easily learn. Fluid shows up black on the scan. Use a low-frequency (3.5MHz) curvilinear transducer. If some views are not good (particular those through the ribs), it is sometimes necessary to switch to a small cardiac probe to see between the ribs. There must be 200mL blood in the peritoneal cavity for this test to be positive.

However, if you only find such small amounts of fluid, this is *not* the cause of hypovolaemic shock; keep looking for another reason.
Repeat examinations at various intervals if you suspect ongoing bleeding.
N.B. Clotted blood will not show up as fluid, and blood in the retroperitoneal space is not readily visible. Also injury to solid or hollow organs is difficult to visualize.
Use 4 views (called acoustic windows):

(1) Place the probe in the sub-xiphoid area (below and to the right of the xiphoid process), looking toward the heart. Look for a fluid collection in **pericardium** outside the heart. If this view does not give good images, try a sagittal (longitudinal) parasternal view of the heart.

(2) Place the probe over the posterior axillary line over the 10^{th} rib. Orient the probe as before. Look for a fluid collection between spleen and kidney (**perisplenic** area).

(3) Place the probe in the right mid-axillary line (a **perihepatic** view of Morrison's pouch). Orient the probe to get a coronal view looking somewhat up). Look for a fluid collection between liver and kidney.

(4) Place the probe transversely over bladder (**pelvic**): look for a fluid collection outside the bladder. *Make sure to do this before there is a catheter in the bladder*. In females, fluid usually collects in the pouch of Douglas behind the uterus. This FAST examination is positive if you find free fluid in *any* of the 4 acoustic windows, negative if you see no fluid, and indeterminate if you cannot assess any of the acoustic windows. **If you are uncertain**, repeat the scan after 10mins.

If the FAST scan shows free fluid in the abdomen, take the patient to theatre. *Do this urgently without delay!* Even if the patient is haemodynamically stable, you should still explore the abdomen, *rather than wait for shock to occur!*

FAST SCAN

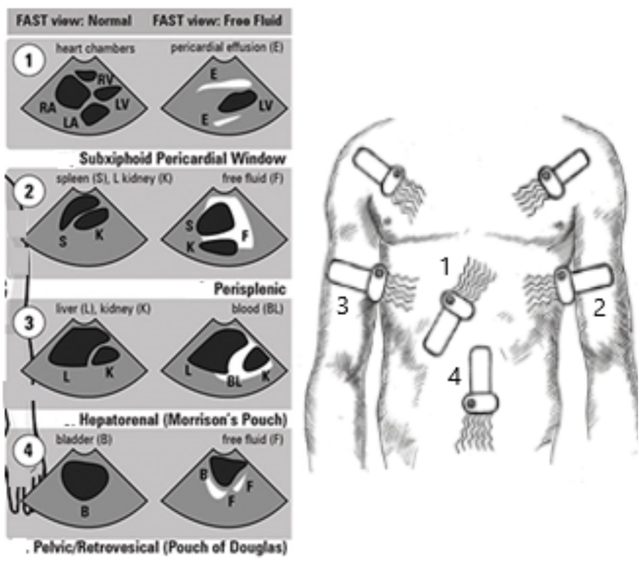


Fig. 44-9. FOCUSED ABDOMINAL SCAN: The four key windows for FAST and their schematic ultrasound views. 1, pericardial (subxiphoid). 2, perisplenic, 3, perihepatic. 4, pelvic. *Hui A. www.ashleyhui.com/Toronto-notes- 2015 with kind permission*

N.B. FAST does not readily show injuries to the pancreas, diaphragm, or an isolated perforated hollow viscus. Views may be restricted by the presence of excessive gas in the bowels, obesity, massive ascites, and surgical emphysema.

If the ultrasound scan is unhelpful or not available, and the patient is haemodynamically unstable, check for blood loss elsewhere (44.2) before proceeding to a diagnostic peritoneal lavage.

DIAGNOSTIC PERITONEAL LAVAGE (DPL) (GRADE 1.4)
This is also valuable in settings where ultrasound is not available N.B. This is not suitable for perforating abdominal injuries!

INDICATIONS
Patients with a spinal cord injury.
Multiple injuries and unexplained shock, and you need to assess priorities.
(3) Intoxicated patients or those with impaired conscious level with possible abdominal injury.
(4) Patients with potential intra-abdominal injury who are having anaesthesia for another procedure.
(5) Indeterminate FAST examination.

RELATIVE CONTRAINDICATIONS
(1) morbid obesity,
(2) 3^{rd} trimester pregnancy,
(3) previous lower abdominal surgery,
(4) advanced cirrhosis
(5) coagulopathy.

DIAGNOSTIC PERITONEAL LAVAGE (DPL)

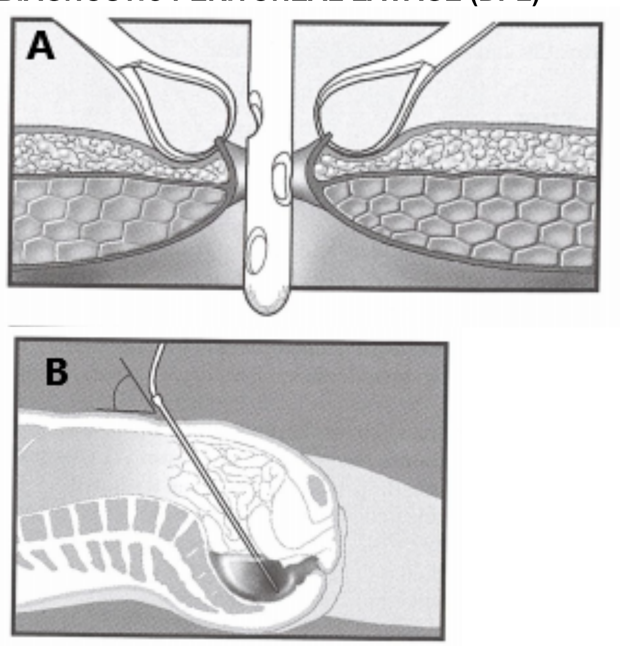


Fig. 44-10 DIAGNOSTIC PERITONEAL LAVAGE (DPL). A, Elevate the edges of the abdominal sheath, and make a small incision in the peritoneum in order to insert the peritoneal catheter under direct vision. B, Guide the catheter at 45^0 into the pelvis. *After Nicol, A, Steyn E. Handbook of Trauma for Southern Africa. OUP Cape Town 2004.*

TECHNIQUE OF DPL

Check a pelvic radiograph to see whether the patient has a pelvic fracture before starting. A false-positive result can occur if you use an infra-umbilical approach in a patient with a pelvic fracture, because you may enter the haematoma in the preperitoneal space anteriorly.

Insert a urinary catheter and a nasogastric tube to empty the bladder & stomach. Prepare a warm 1L bag of sterile IV 0.9% saline (you can use sterile water *in extremis*), attached to a collecting bag. Infiltrate LA down to the peritoneum & use a sterile technique. Make a 3-5cm sub-umbilical midline incision, extended to and through the *linea alba*. Place haemostats to control any skin bleeding. Make sure this control is perfect.

N.B. In the pregnant woman, place the incision above *the umbilicus.*

Open the peritoneum under direct vision and insert the peritoneal tubing (which can be a catheter or IV line) towards the pelvis. Place a purse string in the peritoneum to close the hole and avoid leakage. First use a large syringe and attempt to aspirate free intraperitoneal blood from the tube.

If you obtain ≥10mL of grossly bloody aspirate *before* you start lavage, the test is +ve. Proceed then to laparotomy in the operating theatre.

If you aspirate nothing or <10mL thinly blood-stained fluid, run 1L of warm fluid that you have prepared rapidly into the abdomen through the tubing, gently agitate the abdomen for 2mins (or tilt the patient up & down and side to side) and then lower the empty collecting bag onto the floor. Fluid will run out through the tube.

If you see blood-stained fluid, the test is +ve. You may need laboratory analysis to check the results, which are positive if the siphoned lavage fluid has:
(1) >100 RBCs/mL,
(2) >500 WBCs/μL,
(3) amylase >20IU/L,
(4) bile,
(5) bacteria,
(6) bowel content or vegetable matter,
(7) urine.

In the meantime, try to read newspaper print through the IV tubing. If you cannot, the test is almost certain to be +ve.

If the DPL is taking time to set up and the patient is becoming shocked, abandon it and proceed to laparotomy!

COMPLICATIONS OF DPL include:
(1) bleeding from the incision
(2) bleeding from insertion of the tube
(3) infection in the wound or peritoneum
(4) injury to intra-abdominal viscera
These complications may increase the chance of false-positive studies.

DPL is very accurate, sensitive and specific, but apart from the risks described, it may be so sensitive, you may end up performing an unnecessary laparotomy. Only c. 30mL blood makes the DPL test positive. So if bleeding from the procedure contaminates the fluid, it can produce a false-positive result. *Even so, a –ve result does not mean there cannot be an abdominal injury.*

If peritoneal lavage fluid comes out of a chest drain or urinary catheter, perform a laparotomy!

RETROPERITONEAL & PELVIC BLEEDING

Bleeding in the retroperitoneum is very difficult to detect by examination or ultrasound.

Abdominal pain, abdominal distension, the presence of an abdominal mass, severe back and lower quadrant pain and femoral neuropathy are all nonspecific signs and symptoms.

Ultrasound may pick up <50% of cases. Bruising in the flanks (Grey Turner's sign) or the umbilicus (Cullen's sign) are usually delayed for several hours to days.

PELVIC FRACTURES, especially open-book fractures, can cause life-threatening bleeding. Examine the pelvis only once as *repeat examinations will only increase bleeding*. Use a bed sheet as a binder to close the 'open book'. Place the sheet at the level of the hips (greater trochanters), *not higher*.
Apply and tighten the sheet carefully, at least until you get a radiograph. You may worsen bleeding from lateral compression fractures if you apply excessive force.

BLEEDING IN LONG BONES

Multiple fractures or fractures in the femur are the most likely source of severe blood loss from bones. The average adult blood loss in closed fractures is:
(1) Radius & ulna: 150-250mL
(2) Humerus: 250-500mL
(3) Pelvis: 1½-3L
(4) Femur:1-2L
(5) Tibia and fibula: ½-1L
Appropriate splinting or traction is the best method of reducing further blood loss until more definitive treatment is possible.

You can therefore calculate the revealed total blood loss: *e.g.* if there is a haemothorax of 1.5L, and a fractured femoral diaphysis (1L), and you have transfused 5 units of blood, but the patient is still hypovolaemic, it is likely that there is another source of blood loss which you have missed. This is likely to be abdominal or pelvic.

N.B. Bleeding inside the head of an adult can never account for enough blood loss to cause hypovolaemic shock: you must look elsewhere. The situation is quite different in a small child, where the size of the head is proportionately much larger compared with the rest of the body.

THE CHEST RADIOGRAPH
We have deliberately left this till last, as the benefit from X-raying the chest in trauma is not very high for the effort and time incurred. Unless you can take a radiograph in the resuscitation area, *don't bother with it for the shocked patient!*

The ultrasound scan is more sensitive in detecting free liquid in the chest and abdomen.
These are the features to look for, which suggest abdominal injury may be present:-
(1) A positive FAST
(2) Fractures of the lower ribs
(3) Free air under the diaphragm (erect film)
(4) Foreign bodies (*e.g.* bullets)
(5) Fluid or air in the pleural spaces
(6) Abdominal viscera in the thorax.
(7) A 'ground glass' appearance between loops of bowel.
(8) Fractures of the pelvic bones
(9) A raised hemidiaphragm
(10) A dented or displaced gastric shadow

Many of these are subtle signs, and not very reliable, which you must add to your clinical impression.

44.4 Autotransfusion

Blood from clean traumatic injuries of the chest or abdomen, or from an ectopic gestation, is ideal for auto-transfusion; it can be life-saving. Also, it is warm and has all the necessary clotting factors and carries no risk of hepatitis or HIV, and it will be perfectly cross-matched.

Autotransfusion may be life-saving even more in the operating theatre scenario (5.3). Rapid blood loss of ≥1L blood should make you start thinking of autotransfusion, especially if cross-matched blood is not available or in short supply.
You don't need sophisticated equipment. A simple collection bag system (44-11) is ideal. Re-infused blood recovers its clotting capacity within 24-72h.

Blood from the thorax is defibrinogenated and so does not clot, unless it is from the major vessels (when there isn't enough time for defibrinogenation), and so you can use it up to 72h after injury! One filtration is usually adequate.

N.B. **If the blood has been lying in the thorax or abdomen for >12h**, and the patient has compensated haemodynamically, IV crystalloids are probably needed rather than this blood auto-transfused, although you can still use it for blood transfusion.

However, blood from the abdomen and the limbs needs filtering through 6-8 gauze layers (5-1).

Blood from the thorax does not need anti-coagulant, but blood from the abdomen needs a half dose of citrate (in blood transfusion bags) or 1000 units of heparin per 500ml of blood, although this is not absolutely necessary if not available.

(a) Thorax
In extremis, the simplest method is to drain blood from the thorax into a sterile chest drain bottle containing 100mL normal saline. Then disconnect this, invert it, and connect it to an IV giving set. At the same time connect both chest drain bottles and repeat the process.

If you have a lesser degree of urgency, drain the blood from the thorax or abdomen through 6-8 layers of sterile gauze, into a sterile bottle, or better, an empty 1L bag. Then infuse this, preferably through a standard blood transfusion filter of 150-200µm.

(b) The abdomen
Ladling blood through a funnel (5-1) is time-consuming and inefficient; it is better to use suction *at low pressure*, as the higher the pressure the greater the haemolysis. *Keep the sucker under the fluid surface*, so as not to suck up air and cause frothing and risk of more haemolysis & air embolism.

In *extremis,* if you have no alternative and the blood is contaminated with gastric juice, bile, faecal, or foreign matter, *remove the gross contamination manually & filter out the particulate matter* (because this is the cause of DIC). Then pass the blood through 2 filters, as before, and administer broad spectrum antibiotics IV simultaneously. *Don't get glove powder mixed in with the blood!*

Whilst there are risks of fever, clotting disorder, renal failure (from haemolysis), sepsis & ARDS, the advantages of autotransfusion when blood transfusion is necessary far outweigh its risks.

AUTOTRANSFUSION EQUIPMENT

Fig. 44-11 AUTOTRANSFUSION EQUIPMENT. A sterile 2L abdominal drainage (or even urine) bag can collect the blood through one port and re-infuse it through the other (drainage) port, using a blood giving set with a filter. *After Kothari R, Pandey N, Sharma D. A simple device for whole blood autotransfusion in cases of hemoperitoneum and hemothorax. Asian J Surg 2019; 42: 586-587.*

44.5 Septic & other kinds of shock

SEPTIC SHOCK
Septic shock is a life-threatening condition caused by a severe localised or system-wide infection causing organ failure that requires immediate medical attention.

This is a type of distributive shock, caused by loss of normal arterial vasomotor tone, which leads to an alteration in the afterload. As the systemic vascular resistance drops, the cardiac output must increase in compensation (in contrast to other types of shock).

Sepsis, anaphylaxis and amniotic embolism may all have similar physiologic presentations, despite differing aetiology.

Cytokines and bacterial toxins generally cause disruption of capillary cell integrity, resulting in a secondary leakage of fluid from the intravascular space into the tissues. This results in hypovolaemia and oedema. It can be difficult to differentiate between septic and hypovolemic shock.

Only patients in early sepsis will have a normal circulating volume, modest tachycardia, warm skin, nearly normal systolic pressures and a wide pulse pressure.

Septic shock in trauma patients is uncommon and usually occurs usually in patients with peritonitis who have a delayed presentation.

ADEQUATE FLUID RESUSCITATION
Infuse ≥30mL/kg IV crystalloids (*i.e.* 1.5-3L) within 1h of making the diagnosis. Be aggressive with this; *several patients will need much more fluid*.

Aim for a urine output of ≥30mL/h. The normal 2:1 ratio between the interstitial fluid volume & the vascular compartments may increase to 10:1.
Fluid may leak not only into the tissues but also into the lungs, which may then require post-pressure ventilation.
Watch the Na^+ & especially the K^+ levels; if you can, correct them.

Don't try to obtain 'normal' BP values as long as the brain is being well perfused (normal conscious level) *and urine output is adequate*. A systolic pressure of 80mm Hg may still be adequate.
N.B. The BP may not respond well to vasopressors. Start noradrenaline to target a mean arterial pressure of 65mm Hg.

ANTIBIOTIC TREATMENT
Antibiotics and drainage of any source of infection is critical (6.1). Take blood cultures and culture pus from any possible source.

Cover Gram negative & positive organisms and anaerobes. Choose drugs depending on known antibiotic sensitivities at your hospital.

If you don't know the antibiogram at your hospital, try these suggestions. Use large doses of ≥3 bactericidal antibiotics, if possible IV, as bolus injections, every 3h, & every 10 units transfused.

Choices for Gram-positives include:
(1) Chloramphenicol 1g (12.5mg/kg in children) qds IV, or streptomycin 500 mg qds.
(2) Ceftriaxone 2g (50-80mg/kg in children) od slowly IV. This covers most Gram-negatives except *Pseudomonas* and *Acinetobacter.*
Don't use it with Ringer's lactate as it calcifies in the veins.

Choices for gram-negatives include:
(1) Gentamicin 5-7mg/kg od slowly IV. (In renal failure increase the interval between the doses.)
(2) Amikacin 15mg/kg bd (up to 22.5mg/kg tds) slowly IV. Use 7.5mg/kg bd in children.
For anaerobes, use metronidazole 1g tds PR, or bd IV. For a child use 7.5mg/kg tds either PR or IV.

N.B. Avoid quinolones & glycopeptides.

Control the fever with tepid sponging and oral or rectal antipyretics. Support the hypermetabolism which occurs with oxygen by a mask.

PULMONARY OEDEMA
This is characterized by poor oxygen saturation, crackly lung sounds, and frothy sputum. Use large doses of furosemide (100-200 mg bd or tds) but *be warned that they may not be effective*.

If acute left ventricular failure develops despite vasopressors, try digoxin at 0.125-0.25mg PO/IV od; you may rarely need to increase these doses up to 0.375-0.5 mg/day.

For patients with impaired renal function or low lean body mass, use low doses. If a pulse deficit (difference in apex beat & pulse) develops, he has excess digoxin.

If cardiac output remains low despite high CVP, add a dobutamine infusion, if you can, at 10-20µg/kg/min to any vasopressor in use.
Don't use dopamine in low doses.

Steroids in sepsis *are of doubtful value.*
This is a last ditch effort: use hydrocortisone 50mg IV qds, a dosage designed to replace normal adrenal function.

ANAPHYLACTIC SHOCK
This is another type of distributive shock where vasomotor tone is affected.
Use adrenaline IM 0.01mg/kg (maximum 0.3 mg in a prepubescent child, and 0.5mg in a teenager/adult) into the *vastus lateralis* muscle of the thigh.

N.B. Many people with allergies have this medication (as an 'epipen') in a pocket or handbag. Remove the source of the antigen if known.

In addition:
(1) Use nebulized adrenaline for laryngospasm.
(2) Use nebulized albuterol or salbutamol for bronchospasm
(3) Use histamine-1 & 2 blockers together, *e.g.* diphenhydramine or hydroxyzine; plus ranitidine or cimetidine.
(4) *Corticosteroids have no immediate effect!* However, administer them early to prevent a potential late-phase reaction (biphasic anaphylaxis). Use prednisolone at 1mg/kg in divided doses and, in children, 0.5-1mg/kg per day. *A tapering regimen is not necessary unless the patient has been taking steroids chronically*.

AMNIOTIC FLUID EMBOLISM
Similar treatment as for septic shock is needed with large volumes of IV fluids as well as vasopressors. Correcting coagulopathy may not be possible with your resources.
A Caesarean section is indicated at 23/40 gestation if the mother bleeds profusely without stopping, but these are heroic last ditch efforts.

FAT EMBOLISM
This is the dreaded complication of pelvic & closed long bone fractures, usually in young well-built adults, or sickle disease children (58.16).

It can also occur in pancreatitis, liver injury, during orthopaedic surgery, or liposuction, and in decompression injury. The victim becomes confused, without neurological signs, restless and hypoxic as fat globules pass to the lungs from long leg veins.

You may see tell-tale signs of petechiae on the chest & in the mouth & conjunctivae, and fat globules in the urine, sputum & veins on retinoscopy. There may also be 'cotton wool' exudates and retinal haemorrhages. Human albumin IV may help. Renal & respiratory function deteriorate; high-flow oxygen with ventilatory support is usually necessary, and the outcome is fatal in up to 50% of cases. *Don't use heparin!*

ARTERIAL GAS EMBOLISM
When a diver resurfaces too quickly from a longer period in the depths, the inert gas (nitrogen & helium) which has dissolved in the blood at high pressures below the water surface rapidly comes out of solution. It literally bubbles into the blood, and so blocks its flow.

This is also known as barotrauma or decompression sickness. It is more common the longer or deeper a diver has been, and the quicker he surfaces. Most recommendations are to surfaces at rates <10m/min.
The risk is greater in people with diabetes, cardiovascular or chronic airways disease, and especially those with a patent *foramen ovale* (which may be quite small, and undiagnosed)

Symptoms are classically pains in elbows, knees and ankles, known as 'the bends', but can be associated with central or spinal neurological deficit: nausea, dizziness, extreme fatigue, confusion, fits, or paralysis.
Treatment is to supply 100% oxygen through a re-breathing system for 12-24h.

CARDIOGENIC SHOCK
This refers to any intrinsic cardiac condition which diminishes cardiac output. In trauma, cardiac contusion (43.5), very rarely in snake bite (46.11) or, less rarely, an associated myocardial infarction or ventricular rupture will diminish cardiac contractility.

Any pre-existing condition may be the cause: dysrhythmias, cardiomyopathy, toxins and medications.
In severe deceleration impact, a cardiac valve replacement may rupture and so cause acute left-sided heart failure (if aortic) or right-sided (if mitral).

Try to get an ECG done, and cardiac ultrasound, if possible

Oxygen, fluid restriction and ionotropic agents may be indicated.

Obstruction to outflow, or diminution of inflow, can occur in cardiac tamponade (44.6), tension pneumothorax (43.2) and rarely tension haemothorax, as well as pulmonary embolism. Extended FAST ultrasound scan can make a quick diagnosis: immediate emergency treatment may be life-saving.

NEUROGENIC SHOCK
Remember that ***isolated intracranial injuries don't cause shock in adults.***

Neurogenic shock occurs in patients with cervical and upper thoracic spinal cord injuries which cause a loss of sympathetic vasomotor tone.
As cardiac reflexes are also disrupted, tachycardia *does not occur*.
Neurogenic shock is, however, a diagnosis of exclusion.

Treat for hypovolaemia first! Only after you are sure that you have adequately restored the fluid volume, should you add vasopressors.
N.B. Differentiate this from so-called **spinal shock,** which is a temporary disruption of normal spinal cord function but *not associated with hypotension*. The speed of functional recovery is highly variable.

ELECTRIC SHOCK
A high current can stop the heart: remember *it is amps that vamps and volts that jolts!*

Lightning delivers c.50Kamp + 100Gv over 10-100msec at a temperature of 30,000ºC. One metre away from where lightning has struck reduces the voltage by c.1Kv, but is obviously still significant. There may also be a side flash.
Immediate results may include:
(1) Asystole
(2) Apnoea
(3) Blast lung injury
(4) Cerebral haemorrhage

If the victim survives, it is essential to administer external cardiac massage (44.9) and continue till there is a resumption of spontaneous cardiac activity. *Don't give up till at least 30mins!*

Look for signs of a pneumothorax (43.2) and insert a needle if you suspect one.

An ECG may show ventricular tachycardia, which may respond to 1mg adrenaline IV, atrial fibrillation or just prolonged QT intervals.
Later, check for pulmonary damage on a chest radiograph, evidence of other blunt trauma, neuropathy, hearing loss, cataract, burns, or limb compartment syndrome (49.8). The victim may suffer a prolonged ileus.
Similar sequelae may follow an electric current shock.

44.6 Cardiac tamponade

The pericardium can fill up with fluid, pus (9.3) or blood. This may be due to blunt, but more likely penetrating trauma. A stab wound to the anterior left chest (or upwards through the abdomen) must always suggest a heart injury. *This is not always immediately fatal.*

Tachycardia, muffled heart sounds and distended neck veins are the classic signs (Beck's triad), but sudden hypotension (especially in a young male stabbed in the chest, where personal violence is common) must ring alarm bells.

You may not have time to perform a rapid ultrasound scan to confirm the diagnosis; *do this only in a haemodynamically stable patient!*

If a victim arrives still alive with a stab wound of the heart, the only way he will survive is if you open his chest!

Bleeding into the pericardial cavity prevents the heart filling normally, which: (1) raises the jugular venous pressure, (2) makes the heart sounds faint, (3) causes *pulsus paradoxus* (a peripheral pulse stronger on expiration), and (4) hypotension.

The clinical signs depend on the speed at which fluid fills up the pericardial cavity. If this is relatively slow, owing to a puncture of the right atrium (whose pressure is <10mm Hg), the amount of fluid may still allow some cardiac output.

A chest radiograph shows a round, globular heart shadow (44-12), but this is not very specific, and a late sign. Ultrasound is much clearer (44-13-15).

PERICARDIAL TAMPONADE

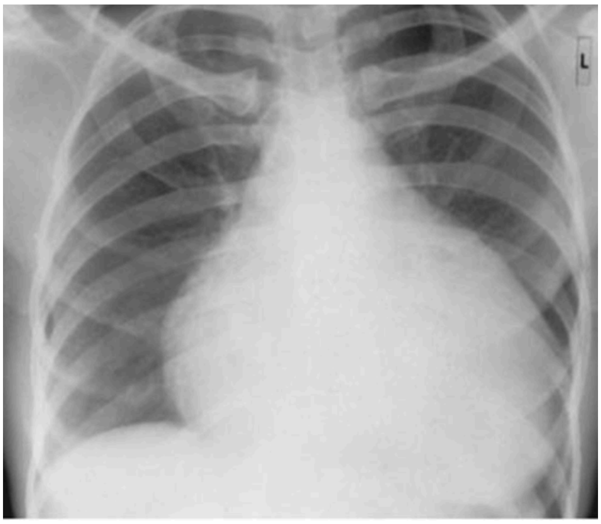


Fig. 44-12 RADIOLOGICAL SIGN OF PERICARDIAL FLUID. A globular shaped heart needs a considerable amount of liquid to give this shape, so is a late sign.

ULTRASOUND: CARDIAC TAMPONADE

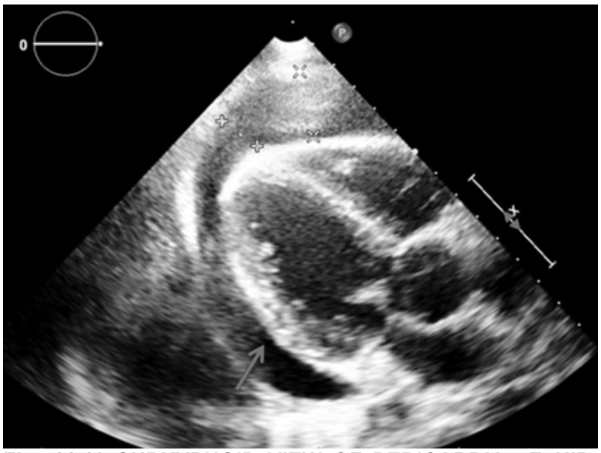


Fig. 44-13 SUBXYPHOID VIEW OF PERICARDIAL FLUID. There is a uniform blackness around the heart. Flocculation suggests clotted blood, or pus.

ULTRASOUND: PERICARDIAL FLUID

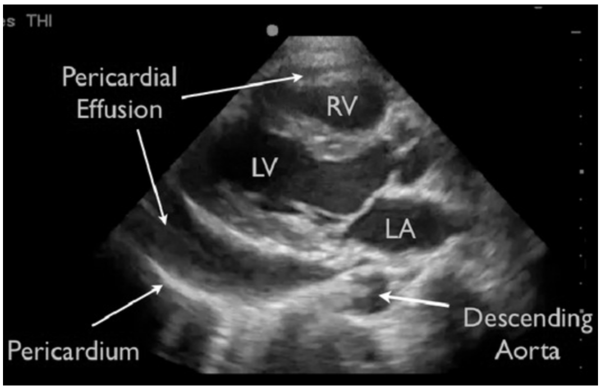


Fig. 44-14 PARASTERNAL VIEW OF PERICARDIAL FLUID. The pericardial effusion is anterior to the descending aorta.

ULTRASOUND: PLEURAL FLUID

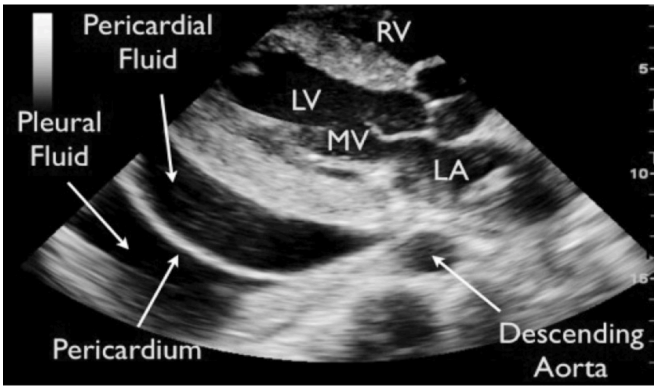


Fig. 44-15 PARASTERNAL VIEW OF PLEURAL FLUID. The pleural effusion is posterior to the descending aorta.

PERICARDIAL TAP (GRADE 2.3)
You might buy time by draining the pericardial cavity. *However, this is inadequate for a perforating cardiac injury.*

Insert a 16G 12cm needle from just under the xiphoid (if possible, with ultrasound guidance), aiming towards the left shoulder and leave a cannula *in situ* (9-4). Watch for an injury pattern from the ECG attached to the needle (or on a monitor). If you see this, withdraw and redirect the needle slightly.

Attach the cannula to a 3-way tap, and aspirate what you can but removal of even relatively small amounts (15-20mL or more) of blood may relieve the pressure on the heart. Leave the cannula in place. Prepare for a thoracotomy urgently.

EMERGENCY THORACOTOMY (GRADE 3.4)
This can, almost miraculously, transform a moribund patient into one who the next day is asking for his breakfast!

The aim is simply to close the (presumed) perforation in the right atrium (or much more rarely, in another heart chamber). Though this may sound daunting, a simple suture will suffice.

You obviously need to open the chest. Do this either through the sternum, or the left chest. A sternotomy needs either a Gigli wire, circular saw, or a Lebsche knife; you should use this only for precordial stab wounds. If you don't have the equipment, or the injury is more complex (particularly gunshot wounds), opt for a left thoracotomy. The difficulty with this is stretching the ribs apart.

(a) Median Sternotomy
You may (initially) need no anaesthesia! Ketamine is the ideal choice.
Make a midline incision from the sternal notch to just below the xiphoid. With your fingers, create a plane for 2-3cm under the sternum both inferiorly and superiorly (44-11).

Hook up the sternum at the lower end, and cut through it along its middle. Put a self-retaining retractor between the two halves of the sternum.

(b) Anterolateral left thoracotomy
Tilt the patient slightly to the right with a pillow under the right shoulder; make a bold incision in 3 strokes through the 4th or 5th intercostals space (below the nipple in a male and along the inframammary fold in the female) from the costochondral junction anteriorly to the mid-axillary line laterally.

OPENING A RETROSTERAL PLANE

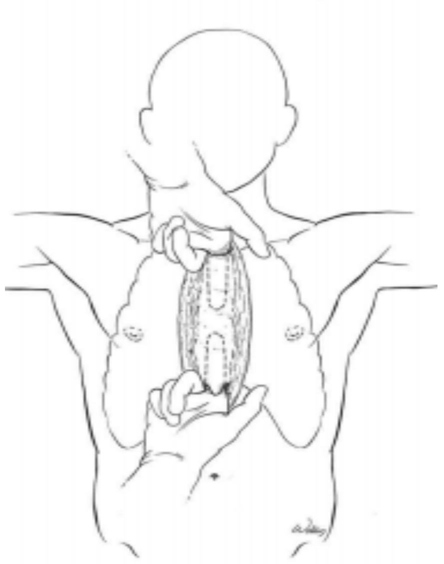


Fig. 44-16 OPENING A RETROSTERNAL PLANE using your fingers prior to a sternotomy. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

In the 1st stroke, incise the skin & subcutaneous tissue along the upper border of the lower rib, in the 2nd, divide the pectoralis fascia & *serratus anterior* posteriorly, and in the 3rd, get into the pleural space. Break down any adhesions with your fingers.

Then divide the intercostal muscles with strong scissors. Avoid *trapezius* & *pectoralis major*.
Insert a Finochietto retractor to spread the ribs apart. You may need an assistant to retract the lung laterally. You will now see the pericardium right in front of you. It may not be bulging but still hide a tamponade!

N.B.
(1) Bright red blood pooling in the thorax is usually from the chest wall (43-22).
(2) Blue blood is from a pulmonary hilum injury.
(3) A mediastinal haematoma means a large vessel injury.
(4) Blood with air bubbles is from a lung injury.

Open the pericardium superiorly, avoiding the innominate vein & phrenic nerve, and expose the heart. Some blood will gush out; get your assistant to aspirate it. Put a finger over the hole in the heart to occlude it, or a Foley catheter (if it is bigger) and pull on this. Occasionally you can use a Satinsky vascular clamp for an atrial laceration.

If the situation suddenly becomes calm, the patient might even wake up at this stage, so use anaesthesia with ketamine, if you have not done this already!

Repair the heart (but *not* full thickness) with a figure-of-8 2/0 deep non-absorbable suture on a large round-bodied needle which, ideally, you have passed through a small pledget of pericardium; *avoid the coronary arteries!* (44-17) *Don't tie the sutures too tight,* or they will cut out. If the muscle is friable, use mattress sutures.

N.B. The right heart is a low pressure system with thin muscle, so be careful not to let your sutures cut out (tie gently & use pledgets). The left heart is a high pressure system with thick muscle and so is more resilient.
N.B. You may find moving in rhythm with the heart makes it easier to place the sutures.

Check if there is a perforation posteriorly by gently passing your hand under the heart. *Don't lift it up* as this will cause a dysrhythmia!

REPAIR OF A CARDIAC PEFORATION

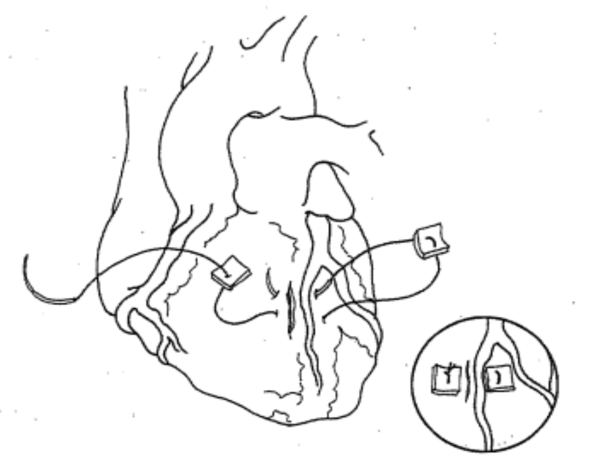


Fig. 44-17 REPAIRING A CARDIAC PERFORATION. Use pledgeted sutures, and avoid the coronary arteries (if they are in the way). *After Szul AC, Davis LA (eds) Emergency War Surgery. Dept Defense 3rd US rev 2004.*

If the heart has stopped, start cardiac compressions with both hands (*not the thumbs)* before attempting to close the perforation. Insert a soft pericardial drain & loosely approximate the pericardium with absorbable sutures. Insert a pleural chest drain, & close the pleura with absorbable sutures.
Close the sternum with wire c. 2cm from its edge, or round the whole bone in the intercostal spaces.
Close discrete muscle layers with absorbable sutures, then close the skin.

N.B. Don't attempt to perform these procedures for blunt or gunshot cardiac injury. Remember to ligate the mammary arteries after a lateral thoracotomy!

44.7 Venous thrombosis prophylaxis

Pulmonary embolism (PE) is the scourge of surgery, because it can affect anyone. It can be suddenly fatal. However, certain types of surgery and certain patients are more prone to develop deep venous thrombosis (DVT), and therefore are more at risk of pulmonary embolism, than others.

In order to assess the risk of developing deep venous thrombosis, you can score various factors:

Risk Factor Point Score	0-1	2	3-4	5+
DVT Incidence	2%	10-20%	20-40%	40-80%
Risk Level	Low	Moderate	High	Very High

The following score **5 points** if <1 month previous there was:
(1) Major lower limb joint surgery
(2) Hip, pelvis, or leg fracture
(3) Cerebrovascular accident (stroke)
(4) Multiple trauma
(5) Spinal cord injury with paralysis

These score **3 points**:
(1) Age >75yrs
(2) Previous or family history of DVT or PE
(3) Past history of MI, CCF or COPD
(4) Thrombocytosis

These score **2 points**:
(1) Age >60, but <75yrs
(2) History of malignancy, current chemotherapy or radiotherapy
(3) Surgery lasting, including tourniquet >45mins
(4) Being confined to bed >72h
(5) Having a leg cast <1month

These score **1 point**:
(1) Age 41-60yrs
Minor surgery
Pregnancy within 1 month
Varicose veins or leg swelling
Inflammatory bowel disease
Obesity (BMI >25kg/m^2)
Use of oral contraceptives, or hormone replacement therapy

Only 10% of those with DVT extend to PE.
Don't use prophylaxis when the score is <2.

Knee- or thigh-length graduated compression (elastic) stockings prevent DVT to some degree, but *are not as effective as anticoagulants in moderate or high-risk cases.*

(a) Moderate risk patients (score 2 points).
Use standard (unfractionated) heparin 5000 U SC 2h before surgery, and then bd for 7 days or till ambulant, as well as stockings.

(b) Higher risk patients (score >3 points) Use low molecular weight heparins, heparinoids or fondaparinux, which is a factor X inhibitor. These are expensive, but effective, so you should consider their use before committing a patient with high risk to major surgery (especially elective).
N.B. Heparin may cause thrombocytopenia (an immune reaction) *or hyperkalaemia* (by inhibiting aldosterone) *as well as haemorrhage.*

CAUTION! Don't use low-dose aspirin alone as a prophylactic agent for any patient group.

CAUTION! Warfarin is effective but has a long-lasting effect and needs monitoring.
It can, however, be reversed by vitamin K. The goal is an INR target of 2.5 for DVT prophylaxis. Start it the night before surgery and continue it postoperatively during the discharge period. You won't usually reach INR target levels until postoperative day 3.

HEPARIN OVERDOSAGE
This is reversible with protamine sulphate, which itself is an anticoagulant. 1mg can neutralize c.100U of heparin activity. You must infuse it very slowly IV over 10mins to a maximum of 50mg.

Time Elapsed Since Heparin Dose	Dose of protamine (mg) to neutralize 100 units of heparin
<1/2 h	1-1.5mg protamine per 100 units of heparin
30-120 min	0.5-0.75mg protamine per 100 units of heparin
>2 h	0.25-0.375mg protamine per 100 units of heparin

Because heparin is rapidly cleared from the circulation, the amount of protamine needed decreases rapidly. Titrate the final dosage according to coagulation studies, or by the scheme above.

44.8 Protecting the kidneys

The kidney is similar to the brain in that the secondary insult often causes more damage than the initial damage. Rapid correction of shock causing hypoperfusion is the single most important thing you can do to spare the kidneys a long-term insult.

If you don't resuscitate a patient in severe hypovolaemic shock rapidly and adequately (with fluid and blood), immediate death occurs, or the cortices of the kidneys necrose and the kidneys fail. Post–traumatic renal failure is thus the major complication of hypovolaemic shock.

Although a period of acute hypovolaemia can injure the lungs, the heart or the liver, it is the effect on the kidneys that is so marked and so preventable.

The more severe the hypovolaemia and the longer it lasts, the more likely are the kidneys to shed their tubular cells and stop functioning. Days or weeks may elapse before they recover.

During that time, a patient can die from uraemia, potassium intoxication, or infection. Prevent these disasters by treating hypovolaemic shock quickly and adequately. *A patient may require a lot of blood and fluid!*
Acute renal failure may also complicate extensive burns, crush injuries, severe muscle wounds (especially if they are heavily infected), causing rhabdomyolysis (49.9) or transfusion & drug reactions, causing haemolysis.

If a patient passes no urine, check first that the catheter is neither kinked nor blocked, and that the urinary tract is not obstructed. If the amount passed is <20mL/hr (for a child, <0.5–1mL/kg/h), suspect that there is post-traumatic renal failure.

Before diagnosing this, consider these other possibilities:
(1) There is still hypotension due to hypovolaemia. If the BP is still <80mm Hg systolic, or the peripheral circulation is still severely constricted, the glomerular filtration rate will be low. Once you correct the hypovolaemia and restore the blood pressure, the urine output may increase, provided that hypotension has not lasted long enough to damage the kidneys.

(2) There is an expected metabolic response to injury owing to increased ADH secretion. This may reduce the urine output for 8-36h.

Don't rely on this being the right diagnosis unless the condition is stable in other respects, the urine is chemically normal and its specific gravity is high. The practical consequence of making this diagnosis is that you should not infuse more fluid to increase the urine output if all other signs are satisfactory.

If you have excluded these 2 conditions, and there is <20mL/h of urine over 12h, this is probably acute post-traumatic renal failure.

Diagnose it early, before the blood urea starts to rise, if: (1) the urine specific gravity is <1.016 in the absence of glycosuria or albuminuria, or (2) there is pigment or protein in the urine, whatever its specific gravity.

If the patient recovers, there are then 2 phases to pass through:

(a) An oliguric phase during which the kidneys cannot correct for the water and electrolyte intake, and so these need to be restricted. During this phase, a danger is that excess potassium will enter the plasma from dead or dying tissues. Try to minimize this.

Unfortunately, you cannot diagnose the earlier phases of hyperkalaemia clinically: you have to use laboratory tests frequently. *Don't use potassium-containing solutions such as Darrow's or Ringer's lactate* in this phase.
This phase may be followed gradually or suddenly by the next phase, diuresis.

(b) A **diuretic phase** during which the kidneys may pass 6-9L/day of urine, regardless of the fluid intake. While this phase lasts, the danger is of loss of electrolytes and dehydration.

Replace the electrolytes and the water lost. It is difficult to know when to stop adding large volumes of fluid input. If you keep adding fluid, the patient will go on excreting fluid, so you won't know if they are needed or not!

TREATMENT IN THE OLIGURIC PHASE
(a) Correct hypovolaemia & electrolyte deficit: chart what has been lost and what you have administered. Correct the calculated water and electrolyte deficit before you start the period of fluid restriction.

(b) Administer the measured output of water, plus an estimate of the insensible loss. Give it as water by mouth, or as 5% dextrose IV.

N.B. Don't use any electrolyte solutions, except those necessary to replenish losses, because he cannot excrete any excess.

The measured output is the total volume of urine, vomit, or watery diarrhoea. The insensible loss in a temperate climate is c.500mL (6-7 mL/kg), and may rise in hot climates, or in fever to 1000mL (12 mL/kg) or more.

CAUTION!

(1) *Don't include blood, plasma, or plasma substitutes in these estimates.*
(2) *Don't allow thirst to influence the intake volume*. Watch that the patient does not overhydrate.
(3) The dose of many antibiotics, especially gentamicin and other aminoglycosides, needs to be modified in the presence of renal failure.
(4) *Don't use diuretics*.

(c) Minimize hyperkalaemia.

(1) Remove all dead and dying tissue with a really thorough wound toilet.
(2) Avoid hypoxia. If he needs an anaesthetic, use ketamine or LA.
(3) *Don't add potassium in any form*. There is potassium in milk and fruit juice, soup and meat, Darrows and Ringer's lactate, and in many drugs.
(4) Minimize catabolism by providing a high energy, no protein diet. If there is no nausea, gastric suction, nor intestinal pathology, include ≥400g/day of glucose or lactose, or, failing these, sucrose, by mouth or by nasogastric tube.

This will provide 1,600 kcal/day. Add 20mL of 50% glucose with 10U of soluble insulin into a large vein, preferably the vena cava (by a central line), qds.

(d) Weigh the patient daily. There should be c.500g weight loss daily after the initial fluid replacement. If there is weight gain, this will be retaining fluid from being overhydrated.

TREATMENT IN THE DIURETIC PHASE

In every 24h during this phase, add 1500mL of maintenance fluid on top of the volume of urine output over the previous 24h.

Infuse 1L 0.9% saline plus 1L 5% dextrose and the balance as ½-strength Darrow's solution. This contains 17mM of potassium. The normal potassium requirements are c.35mmol/day. A total of 6-10L/day of fluid may be needed. Check the potassium level in the laboratory, if possible.

If the urine specific gravity is still very low after 4days, you are probably over-infusing. Start cautiously to reduce the fluid intake.

CAUTION! Don't start protein feeding until ≥1500mL/day of urine is passed, and the blood urea is <25mmol (2.5g/l). *Starting it too early increases the danger of uraemic complications.*

44.9 Cardiac massage & defibrillation

ASYSTOLE

When the heart stops and there is no rhythm, this is a sign of death. *Asystole is not a dysrthymia. It is not treatable by an electric shock.* You must reverse the causative events quickly for any hope of success.

First of all, you and your team must continue CPR while you determine whether the asystole is real.

Connect the patient to a monitor (if not already wired up), then:
(1) check the leads to make sure they are connected,
(2) change the gain on the monitor to make the ECG lead look larger on the screen, and
(3) use the selector knob to change the leads from position II (where it usually is) to another lead.

Check possible causes that you might be able to reverse.

N.B. This might well be too late, but go through them with this mnemonic: 6H4T:.

(1) **Hypovolaemia**: infuse 0.9% saline.
(2) **Hypoxia**: administer oxygen and ventilate.
(3) **Hypoglycaemia**: check a finger-prick test immediately, and administer 200mL 10% dextrose IV if <2mmol/L.
(4) **Hydrogen ion excess** (acidosis): *don't administer bicarbonate!*
(5) **Hypothermia**: cover with warm blankets, use a heating fan, and warm IV fluids. *Don't move the patient if the temperature is <28⁰C.*
(6) **Hypo- or hyperkalaemia**: you may well not be able to check this quickly, but slow infusion of 10mL 10% calcium gluconate is the best option for reversing hyperkalaemia.
(7) **Tension pneumothorax** (43.2): insert a needle into the 2nd intercostal space in the mid-clavicular line.
(8) **Tamponade** (cardiac, 44.7): perform a pericardiac tap (9-4), or open the chest!
(9) **Toxins**: a hard diagnosis to make unless you have evidence of an empty bottle (of alcohol or medicines) or a labelled syringe. You can only reverse a few overdosages. If the cause is opiates, use naloxone; if benzodiazepines use flumanezil; if β-blockers use adrenaline,
(10) **Thrombosis**, pulmonary or coronary.

The success of cardiopulmonary resuscitation (CPR) is relatively poor, even in tertiary hospitals, but it is zero if nothing is done.

Most cardiac arrests in LMICs are not from heart attacks, they occur because an acute respiratory, septic or other condition has deteriorated to the point of no return.

This is why prevention is so necessary by good attention to the critical ill and the course of their illness; prevention beats the best CPR.

This is especially true in children (who make up 50% of the population in many countries), because their strong compensatory physiology means they are very often severely metabolically deranged when they hearts stop.

Respiratory problems are more common than cardiac events in children; the reverse is true in adults. Therefore concentrate on the AB of ABC.

There are many cultural and educational issues which may interfere with the timely recognition of impending death, preventing intervention. It is important to teach your team who is at high risk of arrest, and of the need for prevention.

For effective CPR, you need a motivated, trained team. You should gather any necessary equipment ahead of time and keep it at a central location on a 'crash cart'. Ideally, each main unit of the hospital (including the emergency department and the operating theatre) should have its own cart.

Ensure that your team knows how your AED (automated external defibrillator) or independent defibrillator and monitor works.
For the latter, know how to switch from unsynchronized defibrillator mode to synchronized cardioversion mode. Also, know how to turn the pacer on and change both heart rate and amperage to that you can capture the runaway heart. *The time to learn these things is NOT during the middle of a cardiorespiratory arrest.*

Assign 2 persons to be responsible for checking each day (and after each usage) that the supplies are all present or replaced and all electrical items are working (including rechargeable and disposable batteries).

EQUIPMENT IN ALL CARTS
(1) Basic airway equipment including different sizes of self-inflating bag valves and masks, oral and nasal airways, oxygen masks, nasal cannulas, & Magill forceps.
(2) Intravenous access equipment including venous catheters, IV tubing and IV fluid.

If intraosseous access is available, include a drill motor and/or needles.

(3) An automatic external defibrillator: keep this charged! (This might be the least necessary equipment)
Have fresh disposable batteries if any equipment needs them, and a check list of all supplies.

ADVANCED LIFE SUPPORT EQUIPMENT
Add these items to the cart and checklist:
(1) Adrenaline, amiodarone and lidocaine.
(2) Adenosine, diltiazem, metoprolol and atropine.
(3) Methylprednisolone and diphenhydramine.
(4) Laryngoscopes with various sizes of straight and curved blades (adult and paediatric), various sizes of ET tubes and perhaps laryngeal mask airways, or supraglottic airways.
(5) Nitro-glycerine spray or 0.4mg tablets
(6) Naloxone

BASIC LIFE SUPPORT
You should have a system in place to recognize and activate a 'crash call'
Teach team members how to recognize that a person is unresponsive, not breathing or breathing ineffectually (gasping), and know how to call for help, ideally by pressing a 'crash button'

(a) Check the airway
(b) Check the breathing (40.1)
(c) Check the pulse for ≥5secs but ≤10secs at the carotid or femoral in adults; in infants, at the brachial in the mid-upper arm.

If the pulse is absent, start CPR compressions at cycles of 30 compressions and 2 breaths. Hook up the monitor and run the checks. If there is a 2nd rescuer, increase the 30:2 ratio to 15:2 in pre-pubertal children.
If there is bradycardia <60 beats/min in a child, continue compressions at 15:2 as before.

(d) Effective compression means pushing down on the lower half of the sternum in adults; *don't deviate off the midline*.

In infants stay high enough to avoid pushing on the xiphoid. *Push hard and push fast.* Maintain a rate of at least 120 beats/min.

	Neonate <1 month	Infant <1yr	Child <7yrs	Adult
Compression detail				
Place	Centre of sternum			lower ⅓ of sternum
Depth	⅓ of chest diameter			5-6cm
Rate	100-120 beats per minute			
Method	1 finger	1-2 fingers	palm of 1 hand	palms of both hands

Your compressions should be ≥5cm in adults and ⅓ the antero-posterior diameter in children & infants (c. 5cm & 4cm respectively). *Be sure to allow the chest to recoil fully* between compressions (to allow venous return).

Change rescuers every 2mins: compressing the chest is tiring if done right! Minimize any interruptions to compression *(never stop for ≥10secs!)*

(e) Blow in 2 breaths with the airway clear.
Tilt **t**he head with the chin lift or the jaw thrust (especially if neck trauma is suspected).

N.B. You may need to put a pad under the thorax to avoid hyperflexion of the airway in small children (with their outsized occiput).

Use a one-way mask (this should be on your crash cart) to give the breaths. Each breath should be just enough to see the chest rise. Introduce the air in >1sec: *don't overinflate the chest*. Allow 1–1.5secs for exhalation before giving the 2nd breath.

If the chest does not rise, return immediately to compression and prepare to suction the airway. Consider introducing an oropharyngeal airway or improve the position of the head before your next attempt to give 2 breaths.

Continue this cycle until help arrives. Stop to check pulses every five cycles (every 2mins). Stop if a spontaneous perfusing rhythm is present. **If you find none, continue CPR.**

N.B. Defibrillation is very rarely an option in the district hospital setting, and is not described here.

CARDIOPULMONARY RESUSCITATION (CPR)

Fig. 44-18 CARDIOPULMONARY RESUSCITATION. Follow this scheme if the victim is in public, after making sure you & he are in a safe place. *N.B. This applies to a person likely to have suffered a 'heart attack'*, the priority for a patient who is bleeding is to *STOP THE BLEEDING!*

ADVANCED LIFE SUPPORT

Pulseless electrical activity is the presence of cardiac arrest in the presence of an organized cardiac rhythm (of any type) which is *not* accompanied by a pulse. It can look like normal sinus rhythm or any one of a hundred variants. Treat it like asystole. Remember to look for reversible causes.

***Only one drug is indicated*: adrenaline**. For adults, administer 1mg IV (or intra-osseous) every 4mins (*i.e.* between every other cycle of compressions). Use a 20mL saline flush after each dose and elevate the arm.
For children, use 0.01mg/kg.

If you don't have venous access, squirt 2mg in 10mL saline down the endotracheal tube.

If you have no IV or intra-osseous access, you can spray 10 x the above dose of adrenaline down the tube.

If you see ventricular fibrillation or unstable ventricular tachycardia, only 3 drugs are indicated:
(1) Adrenaline, as above, or:
(2) Amiodarone 300mg bolus with a 2nd dose of 150mg if needed 4mins afterwards.
For children, use 5mg/kg and you can repeat this dose twice every 24h, or:
(3) Lidocaine 1-1.5mg/kg as a bolus, with a 2nd dose in 5-10mins if refractory.

N.B. For children, use 1mg/kg loading dose and 20–50µg/kg/min infusion.

If you see a bradycardia <50 beats/min, determine whether there are signs of distress or hypoperfusion (mental confusion, ischaemic chest pain, hypotension, diminished capillary refill, heart failure, administer atropine 0.5mg IV as a bolus. Repeat this as necessary every 3–5mins up to a maximal dose of 3mg (6 doses).

In children, use 0.02mg/kg (minimum dose 0.1mg; maximum single dose 0.5mg). You can repeat this once. The maximum total dose for a child is 1mg; for an adolescent 3 mg (6 doses), as an adult.

Maintain the airway (assisting with bag valve mask if necessary, administering oxygen if hypoxic)

N.B. Don't start futile resuscitation if the pupils are already dilated and fixed.

WHEN SHOULD YOU STOP RESUSCITATION?
There is no one right way or wrong way, but here is one possible conversation you might have with your team (with the family listening in or not).

"Right, we are on the 5th cycle of CPR and good ventilation. We have run through the H's and T's and found nothing we could reverse. We have given 1mg of adrenaline at 4 & 8 mins. We have given amiodarone 300mg without effect. There is asystole, which we have checked. I think we have done all we can. You have all done a good job. Does anyone have any suggestions?"
After listening to comments, continue, "So, our next check is in 2mins. We know that almost no one lives or regains brain function after this long. If it shows asystole again, we will stop. I am sorry, but thank you very much for all your efforts."

This shows good communication, appreciation, compassion and a professional approach, to both the team and anyone else who is listening.
The only thing left to do is to document what transpired and to have a debriefing meeting later in the day.

COMMON PROBLEMS DURING CPR
(1) You can't achieve IV or intraosseous access. Remember some drugs can be absorbed from the lung *via* an endotracheal tube: lidocaine, adrenaline, atropine and naloxone.
(2) *Don't wait for others to start the CPR:* yell for help and start immediately!
(3) Well-done CPR requires practice. You must push deep enough, fast enough and not stop for >10secs once you start, no matter what.
(4) Most (>90%) who survive do so with completion of the 1st or 2nd cycles of compression; remember to look for reversible reasons within these 1st 4mins.
(5) *Don't waste time trying to put in an endotracheal tube* if you are ventilating well with a bag-valve mask
(6) Make sure the crash cart is regularly checked, drugs are replaced and batteries are charged or replaced.
(7) Make sure you know how to use your equipment: *the middle of a CPR is not the place to learn.*
(8) Assign roles during CPR who does what. Make sure orders are clear & repeated back to you, as the leader. *Don't forget to ask for ideas, but be polite if someone is doing something wrong.*
(9) *Don't forget to keep the family informed*.
(10) Do a debriefing after the event. Support those who have taken it hard. Figure out what was done well, and what not so well, so that, as a team, you can do better next time.

N.B. Limb Compartment Syndrome (49.8)
N.B. Abdominal Compartment Syndrome (11.10)

45 Functional Disability

45.1 Assessment of consciousness; secondary survey

The Secondary Survey means that you have done a primary survey of the patient (41.2). *Proceed only to the secondary survey when the patient is haemodynamically stable* and you have organized the tests you want done (41.3).

CAUTION! If at any point, the patient deteriorates, return to the primary survey (ABC)!

Complete the medical history getting as much detail as you can, using the patient, witnesses or family members if present. *You must perform a complete physical examination looking for other, non-life-threatening injuries. Don't rush this!* You may not need to put a finger or tube in every hole the patient has – but consider if such intervention will give you useful information *(e.g. a rectal examination to determine anal tone).*

Repeat this examination in 6 & 12h, or as needed: remember patients' conditions rarely stay static, and may deteriorate alarmingly quickly.

After you have treated or stabilized the main problems, the patient may now report others, especially neurologic and orthopaedic injuries.

Assess the **disability (neurologic status)**: at the very start of your initial assessment, you should have used the AVPU scale:

A – **A**wake
V – **V**erbal Response (to questions)
P – **P**ain Response (reacts to pain: press over the supraorbital nerve, sternum, or the nail beds)
U - **U**nresponsive

Now make a more specific neurologic evaluation assessing the level of consciousness, pupillary size and reaction, lateralizing signs and spinal cord injury level.

Remember that 5% of brain-injured patients have an associated spine injury, *so always protect the spine* (54.1).

Vital signs (hypertension with bradycardia) present only late with significantly raised intracranial pressure. *Except in children, bleeding in the head does not cause hypotension, although bleeding from the scalp may do so!*

Observe for spontaneous movements and look for one-sided weakness in the limbs or face: an abnormality suggests an intracranial mass lesion.

Check direct and consensual pupillary reflexes: response to light should be brisk. Pupils should be equal within 1mm in size.

Evaluate the conscious level using the Glasgow Coma Scale (45-1), and observe the patient closely for changes in this score. This means you must get your nurses to record the values carefully over time. If the score drops by >2 points, this indicates a neurological deterioration.

N.B. Use the score from the *best* side, if the patient's examination is different from one side to the other.

GLASGOW COMA SCALE			
Best motor response	Obeys		M 6
	Localizes		M 5
	Withdraws		M 4
	Abnormal flexion - decorticate posture		M 3
	Extensor response - decerebrate posture		M 2
	No movement		M 1
Best Verbal response	**Adults**	**Paediatric**	
	Oriented	Appropriate words or social smile, fixes and follows	V 5
	Confused	Cries, but consolable	V 4
	Inappropriate words	Persistently irritable	V 3
	Incomprehensible sounds	Restless, agitated	V 2
	None	None	V 1
Eye opening	Spontaneous		E 4
	To speech		E 3
	To pain		E 2
	None		E 1

Fig. 45-1 THE GLASGOW COMA SCALE (GCS). Though not initially described for trauma, this is the most widely used scale. Absolute values give an idea of the neurological status, but it is changes in scores that are important, and show if a patient is improving or deteriorating.

A minor head injury scores 13-15, a moderate injury 9-12 and a severe injury ≤8. *These latter patients cannot protect their own airway.* The lowest possible score is 3. The lower the score, the worse the expected outcome: *only 7% of those with GCS 3-4 have a good recovery* or only moderate disability; about ⅔ of those with GCS 8-10, and 80% of those with GCS >11.

Most pre-hospital trauma-related deaths are the result of brain injury. Of those who arrive at your hospital, some 75% will have minor injuries, 15% moderate and 10% severe. These are the primary injuries.

Most head injuries deteriorate because of poor oxygenation; it is therefore vital that you always clear a patient's airway, and make sure his breathing is unimpaired. *You must try to prevent secondary brain injury* by allowing enough oxygen to reach the brain through patent air passages, good lung function, and adequate blood pressure.

Remember to look beyond a head injury. Don't assume alcohol or drugs are the result of drowsiness in a head injury patient. Record GCS scores every 15 minutes, and if the patient deteriorates, exclude treatable causes.

You should also try to identify an extradural or subdural haemorrhage that requires evacuation (51.9): typical signs are unequal or dilated pupils. The Cushing response (bradycardia, increased BP and decreased respiratory rate) is a late sign with poor prognosis.

A generalized convulsion is not necessarily a bad sign, but will require anticonvulsant therapy. *A focal (localized) convulsion is sign of a more sinister lesion.*

N.B. Non-barbiturate anticonvulsants don't alter the GCS score.

Maintain a moderate IV fluid input with diuretics (don't overload pure head injury patients, but make sure the BP is adequate if there is bleeding elsewhere). Cerebral oedema may respond to mannitol 0.25mg/kg IV over 30mins, *but you must exclude an intracranial haematoma first!*

Nurse the patient with the head propped up 20^0 to the length of the body, lying supine.

Prevent hyperthermia (45.3).

If you need to transport a patient with a significant head injury (GCS <12) without full medical attention & capacities, *perform a tracheostomy* (42.3) *beforehand*.

ULTRASOUND

A simple way of checking intracranial pressure is to measure the optic nerve sheath diameter by placing an ultrasound probe gently on the globe of the closed eye, *provided there is no direct eye injury*.

At a distance of 3mm from the posterior border of the globe, a measure >5.2mm is significant indication of intracranial pressure raised >20mmHg.

ULTRASOUND SCAN OF OPTIC NERVE SHEATH DIAMETER

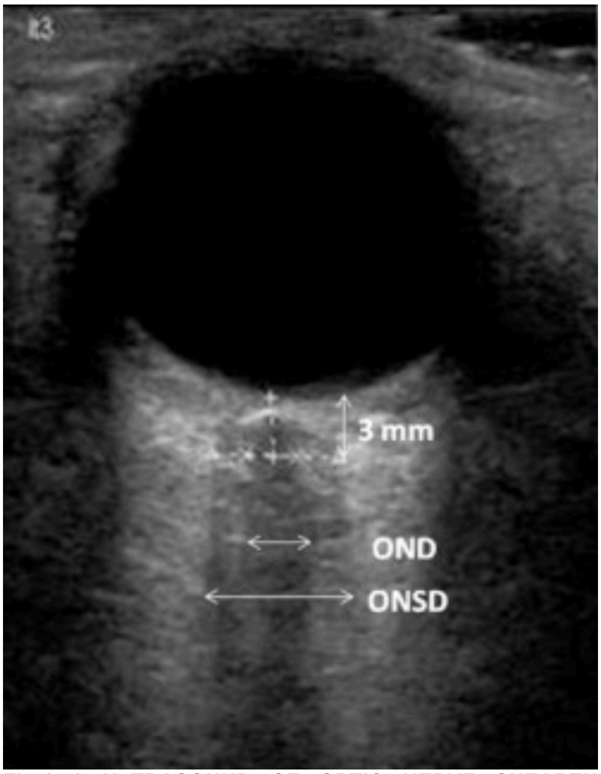


Fig.45-2 ULTRASOUND OF OPTIC NERVE SHEARTH DIAMETER can give you early indication of increased intracranial pressure. Measure it 3mm behind the vitreous.

You can carry out this examination repeatedly as it is non-invasive. *Don't press hard or take a long time* or else you may damage the eye.

45.2 Hypothermia

Accidental hypothermia occurs more frequently than you might suspect, even in the heat of the tropics, and certainly in colder climates, or higher up, or at night, and in any case of drowning. It can even occur inside the hospital.

Ironically, such 'indoor hypothermia' is more likely to occur in patients with significant medical comorbidity (alcoholism, sepsis, hypothyroidism, and hypopituitarism) and tends to carry worse outcomes than exposure hypothermia.

You need to be alert to the possibility of hypothermia in any patient that you encounter.

When conditions are dry, radiation causes the majority (55-65%) of heat loss; conduction and convection account for 15%, and respiration and evaporation the remainder.

Conductive and convective heat loss, or direct transfer of heat to another object or circulating air, respectively, are the most common causes of accidental hypothermia.
Patients lose heat up to 30x faster when wet than when dry.

CAUTION! Remove all wet clothing and keep a trauma patient covered with warmed blankets. Always used warmed intravenous fluids if possible.
CAUTION! Make sure that your clinical thermometers can actually measure significantly lower than normal temperatures (as low as 25ºC).

Measure core temperatures using a low-reading oesophageal, rectal, or bladder thermometer. *Tympanic thermometers are unreliable* in profound hypothermia. *A rectal probe inserted into stool may yield falsely low readings*.

Normal hospital thermometers will not be useful, so order one specially and guard it carefully, not allowing its routine use on the wards.

Hypothermia is classed as mild (32–35°C), moderate (28–32°C), or severe (<28°C). Systemic hypothermia may also be accompanied by localized cold injury (50.13).

Accidental hypothermia increases oxygen consumption (through shivering), blood loss (through coagulopathy). Mortality from traumatic brain injury is increased, especially in the aged, those presenting late, those severely injured, those hypovolaemic and with alcohol (or drug) intoxication.

MILD HYPOTHERMIA (32–35ºC)
Signs and symptoms between 34-35°C include shivering, tachycardia, tachypnoea, and vasoconstriction. Mental changes may predominate, with mood change, irritability, poor judgment, and lassitude. Slurred speech and ataxia may mimic a stroke, alcohol intoxication, or high-altitude cerebral oedema.

As the temperature drops below 34°C, there is altered judgment, amnesia, and slurred speech. The respiratory rate may increase.

At c.33°C, ataxia and apathy may develop.

In hypothermia, CNS metabolism decreases in a linear fashion as the core temperature drops. At core temperatures <33°C, brain electrical activity becomes abnormal; between 19-20°C, an electroencephalogram (EEG) may appear consistent with brain death.

Patients are generally stable haemodynamically and able to compensate. You may observe hyperventilation, tachypnoea, tachycardia, and cold diuresis as renal concentrating ability is compromised.

MODERATE HYPOTHERMIA (28-32°C)
Shivering disappears (≤31°C) and there may be dysrhythmias, bradycardia, and an altered level of consciousness, even stupor. Oxygen consumption decreases, and the CNS is further depressed: hypoventilation, hyporeflexia, decreased renal flow, and you may notice paradoxical undressing (severely hypothermic persons remove their clothing in response to prolonged cold stress) or rhythmic or repeated motion such as rocking. Reduced muscle perfusion leads to tissue ischaemia, cell death & rhabdomyolysis (49.7).

Between 28-30°C, the pupils may dilate markedly and become minimally responsive to light, a condition that can mimic brain death. Mortality approaches 40%.

At 30°C, risks of dysrhythmias, especially atrial fibrillation and other ventricular dysrhythmias become more likely. The pulse continues to slow progressively, and cardiac output is reduced. You may see a J wave (45-2) on an ECG.

J (or OSBORN) WAVE

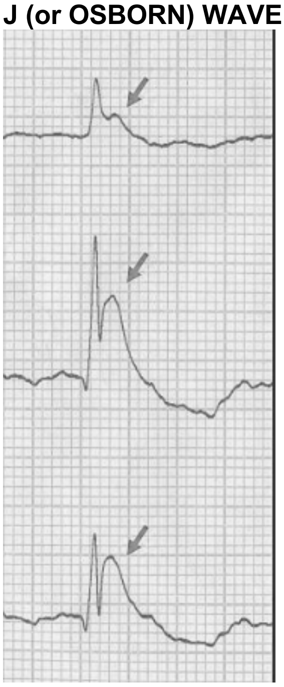


Fig. 45-3 J WAVE IN HYPOTHERMIA. A similar wave may appear in hypercalcaemia.

SEVERE HYPOTHERMIA (<28°C)
At 28°C, the body becomes very susceptible to ventricular fibrillation and further myocardial depression. Coma or cardiac arrest may follow.

Pulmonary oedema, oliguria, hypotension, pulselessness, rigidity, apnoea, areflexia, unresponsiveness, fixed pupils, and decreased or absent brain activity (as seen on EEG) may result.

Many patients are hypovolaemic because of 'cold diuresis'. A haematocrit levels may be deceptively high. Haematocrit levels may increase 2% for each 1°C drop in core temperature. Electrolyte levels can fluctuate wildly and unpredictably. However, a hyperkalaemia ≥12mm is associated with a very low likelihood of recovery.

CAUTION! The usual classic changes on ECG seen with hyperkalaemia may be diminished or absent.

Acute hypothermia may result in hyperglycaemia, while chronic or secondary hypothermia usually presents with hypoglycaemia.

Coagulation studies (performed at 37ºC) may be near normal, and will not reflect the serious coagulopathy seen clinically and which is caused by many factors.

In similar fashion, arterial blood gas examinations done at 37ºC may report falsely elevated oxygen and carbon dioxide levels and lower pH values.
Aspiration pneumonia and pulmonary oedema are common findings.

CPR IN HYPOTHERMIA

N.B. Remember:
"You are not dead until you are warm and dead". Hypothermia may be the only cause of a GCS <3.

Obviously, you have to apply some practical tests. **If a patient presents with a frozen chest**, he is dead. From a practical standpoint, there must be some way to rewarm the patient actively while CPR continues; without warming, CPR is a waste of time. *Don't attempt CPR wnen the patient's temperature is <30^{0}C!*

If there are no signs of life and the core temperature is >32°C after a period of CPR, further attempts are likely to be futile.

Furthermore, the principles of triage must apply: do you have the resources to dedicate to this patient at the expense of all the others you must take care of?

Ventricular fibrillation in a very cold patient is a desperate event. Try defibrillation x3, despite the fact that it is generally ineffective at very low temperatures.
Intubate any patient whose breathing is failing.

GENERAL TREATMENT PRINCIPLES
(1) Prevent further heat loss,
(2) Rewarm the body core temperature
(3) Avoid precipitating ventricular fibrillation or other malignant dysrhythmia.

The risk of ventricular fibrillation is greatest if the core temperature is <22°C, and inadvertent jerky movement of the patient may provoke this.

Most other dysrhythmias will correct with warming alone. *Don't use any anti-dysrhythmic medication till the temperature is >30°C*. Amiodarone is probably the most useful.
Remove wet clothing, and replace it with dry blankets or sleeping bags.

Start administering warmed, humidified, oxygen; provide heated intravenous saline; and place warmed blankets or heat lamps around the patient. Add external heat packs (*e.g.* hot water bottles, chemical packs) placed in the axillae, on the groin, and on the abdomen. Avoid causing a burn.

N.B. Surface rewarming is ineffective in very low body temperatures and carries an additional risk of peripheral vasodilation and 'core temperature afterdrop'.

Administer warm fluid IV in those patients who have been hypothermic for >45-60 mins. *Don't use inotropic agents, such as dopamine*.
N.B. In the field, IV fluids freeze in 10mins! Use intra-osseous boluses. *A warmed ampoule of adrenaline refreezes in 1min!*

N.B. Rapid rewarming, e.g. by inserting heated fluids through nasogastric, chest or peritoneal tubes, may cause nerve damage. Aim to raise the temperature by ≤2°C/h.

If you need to intubate a victim, *don't use relaxants!*

Probes for pulse oximetry are better placed on the ears or the forehead than the fingers.

Look out for local cold-induced injuries. Frostbite may result in deep tissue damage. Surgical exploration and debridement may be necessary. Amputate affected parts if gangrene with a clear line of demarcation develops.
Treat rhabdomyolysis (49.6) early.

N.B. An avalanche of snow 50m wide & 150m long weighs 100-1000 tons and can move at >50km/h. Mortality is 50% if someone is fully buried, usually through asphyxia. Secondary phase injury occurs 30-90mins after the event.

45.3 Hyperthermia

Hot weather, excessive exercise, lack of hydration, wearing excess clothing (including protective gear), and being locked in a hot space may all lead to temperatures that the body can no longer regulate properly. When the temperature reaches 40ºC, there is significant mortality. Such 'heat stroke' occurs more swiftly in children; classically, if left in a locked vehicle in the sun, temperatures may rise above 70ºC inside, and a child may die within 1h because of their greater body surface area and less efficient thermoregulation.

Hyperthermia is common amongst improperly prepared marathon runners; consumption of alcohol beforehand makes matters worse!

PRESENTATION
Apart from the high temperature, those at risk have dry hot skin (having used up their capacity for sweating), may have nausea and diarrhea, and become confused or aggressive.

TREATMENT
Remove the clothes, and cool the body surface down by sponging with cold water; if you can, put the person in a bathtub of cold water. Encourage drinking of cold fluids. Put on fans to cool the room air.

N.B. The notion that very cold water causes vasoconstriction does not reverse the effects of cooling!

If the temperature is >39⁰C, or the patient is losing consciousness, infuse cold saline IV, perform a gastric lavage with cold water, and consider haemodialysis (if possible).

N.B. Beware rhabdomyolysis (49.9) *in severe cases!*

MALIGNANT HYPERTHERMIA, which is associated with muscle rigidity and tachycardia, may also occur:
(1) As a reaction to succinyl choline or halothane during anaesthesia,
(2) In the 'malignant neuroleptic syndrome' with psychotropic drugs,
(3) After a stroke,
(4) With anticholinergic drugs,
(5) In malignant hyperthyroidism.

HYPERTEHERMIA

Fig. 45-4 HYPERTEHERMIA. Temperatures >39⁰C are dangerous.

45.4 Monitoring

During any resuscitation, monitor the heart, oxygen tension and blood pressure frequently. An oximeter is essential.
When the patient is stabilized, after the secondary survey, consider if naso- or oro-gastric tubes, bladder catheter and CVP lines are necessary.

N.B. Beware if there has been serious nasal or urethral injury, because passing a tube may further damage these fine structures.

Now get the necessary scan or radiographs done (45.5).

Take a break to see other patients or have a cup of tea and come back to re-assess the trauma victim thoroughly at definite intervals in order to observe any changes in his condition. Such changes will be more obvious than if you had stayed with the patient, yet they often precede a catastrophic fall in blood pressure.

If you have even a simple intensive care unit, this is the place for a patient who is seriously ill, before and after his operation.

Get a specific nurse to record the respiratory rate, pulse, blood pressure, CVP reading, GCS level, fluid input and output.
Make sure that the nurses who complete these charts know that their role is life-saving.

CAUTION! Watch out carefully for the development of a silent pneumothorax. Percuss the lungs twice daily.

Consider monitoring the optic nerve sheath diameter by ultrasound (45.1)

46 Soft tissue wounds

46.1 Wound assessment & basic principles

Wounds represent damage to the surface of the body, most parts of which (apart from eyes & nails) are protected by the skin. This is the largest organ in the human body. As a physical barrier, it prevents infection, helps regulate body temperature, and protects underlying delicate structures. Along with subcutaneous fat and fascia, the skin is a resistant, but *soft*, tissue.

Any breach of the skin allows entry of microbes and can damage underlying structures. A major wound of the skin, such as a large burn, also puts into question the regulation of body temperature (50.1). You must also do everything possible to prevent infection and diagnose the severity of the wound (46.2).

To assess the general seriousness of trauma to the body, you use the *physiological* parameters of the C-ABCDE algorithm (41.1). To assess the wound, you must look to the *anatomical* parameters of the extent of tissue injury and the anatomic site.

How can you determine the seriousness of wounds then?

(1) Consider the anatomy of the underlying structures; what are the underlying structures: organs, artery, bone, nerve or tendon?
(2) Determine the history of the injury, including its age and mechanism;
N.B. Tissue damage after a knife stab wound is not the same as a bullet, or after a crush injury, or a fall at speed.
(3) Look at your patient's vital signs, and deal with any serious problem (41.1), particularly acute bleeding;
(4) Examine the damage carefully (which often means removing clothing, foreign material, dressings, and much else!), but *don't pull out a penetrating object immediately*;
(5) Look at the rest of the body;
(6) Make a specific assessment of distal neuro-vascular function;
(7) If appropriate, take a photograph.
(8) Score the wound, if penetrating (46.15)

Classically, a very small penetrating missile may be immediately fatal in the head, but leave hardly a trace on the skin; conversely a large skin degloving injury may produce little physiological effect.

Big wounds and small ones

In general, the larger the wound the more contaminated it is and the easier for bacteria to enter. Dead or devitalised tissue is an excellent culture medium for bacteria.

In a small wound, the body's natural defence mechanisms (macrophages, white blood cells, antibodies etc.) can usually overcome the bacteria present.

In a large wound, the amount of tissue damage and bacterial colonisation can easily overcome these mechanisms and, therefore, the importance of wound debridement. There is also the greater chance of injury to deeper structures.

However, even small wounds can be dangerous. A small puncture wound can overlie an important structure. A deep puncture wound can be anaerobic in its depths, creating the best culture medium for *Clostridia tetani*.
N.B. Make sure your patient is vaccinated against tetanus.

Wound examination (40.2)

Make a mental picture in your mind what is underneath. Note how big the wound is, how much it is soiled, and how deep. Are there >1 wounds? Is there torn fascia and muscle? Does the wound enter the head, thorax or abdomen?

Don't forget to look at the back of the victim!

Don't forget the soft tissue wounds after you have dealt with more serious neck, chest or abdominal injuries.

In the limbs, where most trauma occurs, think of the distal arterial supply, distal innervation, and joint functions.

Check for peripheral pulses (with Doppler if you can & need to), & look for the six P's of acute compartment syndrome: pain, pallor, paraesthesia, paralysis, poikilothermia, & pulselessness, (49.2).

Check nerve sensation and motor power in the distal limb (48.1) & tendon function (49.3).

46.2 Wound management

A wound can heal in 2 ways. Either it can heal by '1st intention' (1° closure), *i.e.* quickly, with no sepsis and a minimum of scarring. Or, it will heal by '2nd intention' (2° closure), slowly by granulation, perhaps with discharge of pus, and eventually with much scarring. Unfortunately, when you see a wound you often will not know what will happen. If you bring together the wound edges immediately by primary suture, will it heal elegantly by first intention, or will it break down and pour out pus?

Answering this question depends on understanding the physiology of wound healing. After a major injury in a shocked patient, the body's priority immediately is to maintain the circulation to the brain (44.1), at the expense of less essential organs, which include the skin, muscles and bones. Once shock is overcome, the priorities change and the blood supply to a wound will increase to prepare better for healing. This process of post-traumatic inflammation has 2 phases: exudative and proliferative.

Meanwhile, bacteria which have entered at the time of injury have their own time scale. Their survival depends greatly on the nature of the wound, and on how much foreign material and dead tissue there is in it, especially dead muscle, and the body's reaction.

Platelets are the first to be active within a wound, acting in the 1st 2sec, stimulating a coagulation process and releasing factors to attract white cells. As epithelial cells advance from the wound edges in single layers, the white cells eat up (phagocytose) bacteria, foreign and dead tissue cells. This outpouring of white cells & serum (the exudative phase) occurs from the 1st h up to 3days.

If there is too much dead tissue or too many bacteria, after 6h, monocytes arrive, and differentiate into macrophages. This 2nd phase lasts up to 10days.

The base of a wound produces tiny blood vessels from which more platelets and white cells leak. This produces a highly active granulation tissue which is the body's main process of healing (the proliferative phase). Where there is excessive dead tissue and bacteria, white cells are unable to cope, and produce pus.

SEVERE WOUNDS ARE ACUTE EMERGENCIES

These factors influence wound healing:
(1) the mechanism of injury (clean straight cut, ragged laceration, animal bite, gunshot, blunt injury, burn);
(2) the extent of injury to underlying tissues, especially muscle;
(3) contamination with foreign material, especially dirt, earth, clothing;
(4) the general condition of the patient (nutritional status, anaemia, diabetes, steroid use, HIV positivity, TB, vitamin C or zinc deficiency).

If you see a dirty or potentially dirty wound, or one with obvious systemic or local signs of infection, or maggots, *debride this wound immediately!*

N.B. Some maggots digest live tissue!

If you see a clean wound, without reason to suspect contamination, without systemic or local signs of infection and no sign of dead tissue*, consider if the wound would benefit from closing***.** If no, leave it alone. If yes, you may close it provided it has not been exposed to a dirty environment. If you are not sure, leave it open for 3-5days for delayed primary closure.

If you see a wound that has been neglected, assume it is chronically infected wound and treat it as such (46.4). Time is critical. A grossly contaminated wound is an acute emergency, and every hour's delay makes the chances of an uncomplicated recovery less likely.

SITES TO AVOID PRIMARY SUTURE

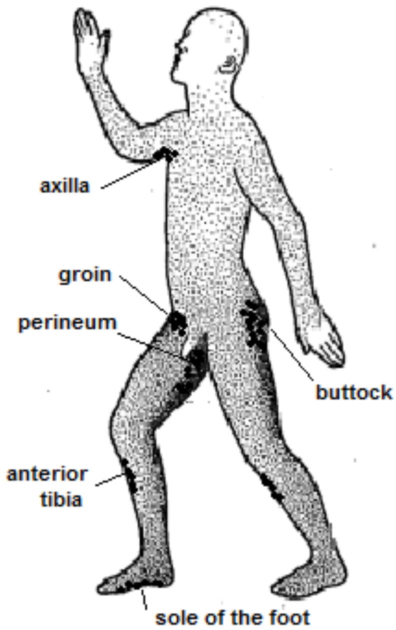


Fig. 46-1 SITES WHERE TO AVOID PRIMARY SUTURE. The darker the area, the more risky it is to close a wound by primary suture.

MANAGING WOUNDS
All wounds need some kind of cleaning (toilet). The simplest toilet is ordinary washing and exploring to remove obvious dirt. Many wounds need more than this, some very much more. The more the dead tissue, the more thorough must be the cleaning.

If there is *any* contamination, debridement (getting rid of all foreign, dead or non-viable tissue) is mandatory. For example, if a patient treads on a nail, *don't merely treat with antibiotics* and hope for the best. Instead, excise the puncture wound, curette the track, and leave it open. *Suspect contamination if a wound smells!*

Don't hesitate to admit a patient, even if the wound is quite minor, especially if it ison the anterior tibia, in the buttock or perineum, or the sole of the foot. *Don't forget: other soft tissues and bone may have been damaged* and still require treatment.
Examine thoroughly to check if there might be injury to nerves (48.1), tendons (47.1), or blood vessels (49.1-5). Do this while the patient is conscious; (much more reliable than poking about in a wound after anaesthesia!).

Consider if the wound may be non-accidental! (40.12)

See specific wounds: chest (43.3), scalp (51.10), face (53.1), abdomen (55.2) or hands (64.1).

RADIOGRAPHS. Use the X-ray beam in 2 planes to locate a foreign body or view a fracture. Glass is usually radio-opaque. Stick a radio-opaque marker *(e.g.* an opened paperclip with its end positioned at the wound entry point) to locate the foreign body. If you suspect it to be deep, attach further radio-opaque markers in different planes to identify the depth and orientation of the foreign body.
ULTRASOUND is often very helpful to localize an embedded foreign body.

EQUIPMENT.
A minor operation set,
2 *fairly soft* nailbrushes,
2 skin hooks,
soft rubber tubing for a finger tourniquet, or a pneumatic tourniquet.
Several litres of clean water, which need not be boiled: (if you can drink it, you can put it into a wound).
Soap and aqueous chlorhexidine or povidone iodine.
A good light.
N.B. If the wound may be complex, use the main theatre.

ALL WOUNDS NEED CLEANING: DETERMINE THE NEED OF THE WOUND

TOURNIQUET (3.4).
This is necessary if the wound is actively bleeding (49.1), and often useful if the wound is complex. It makes distinguishing between living and dead tissue more difficult, though. So, release the tourniquet as soon as you can.

SMALL FOREIGN BODIES such as splinters and needles may be very hard to find. Identify their position as above, and make a small incision *at right angles* to their long axis.
For a needle, grasp it with forceps and push its end out through the skin to retrieve it.
For a splinter, grasp it likewise, but cut down onto it along its length to draw it out *intact* through the incision; *otherwise you risk leaving fragments behind.*
For cactus spines, briars and the like, use fine forceps to withdraw them. If you suspect some remain embedded apply a gauze with non-toxic household glue or magnesium sulphate. When it dries, remove the gauze and the foreign body will usually come out on its own.
Occasionally, you can cut out a small foreign body with the skin in which it is embedded.
N.B. Don't make an incision across a neurovascular bundle or tendon!

FISHHOOKS have barbs, so *don't try pulling them out!* Occasionally you can introduce a needle to catch and cover the barb, and pull both out together. Alternatively, you may be able to push the barb out of the skin entirely, or else cut its barbed end off with pliers, and then withdraw the other end of the hook. If neither of these tricks is feasible, enlarge the wound under LA and extract it under direct vision.

ANTIBIOTICS. *A thorough wound excision is more important than any antibiotic.* Administer a single use prophylactic antibiotic (46.7) for heavily contaminated deep wounds before surgical debridement in the dark areas of 46-1.

TETANUS PREVENTION. *Do not forget to check if the patient is protected* (46.7).

ANAESTHESIA. *Don't hesitate to anaesthetize a patient*, even if the wound is quite small. You cannot debride adequately if the patient is in pain. Use ketamine for large wounds, or LA in the surrounding tissues for small wounds.

MAKE A PLAN
Choose the most appropriate method:
(1) **Immediate wound debridement,**
(2) **Immediate primary suture** (46.3)**,**
(3) **Delayed primary closure** (46.3)
(4) **Serial debridement** (46.4)
(5) **Secondary closure** (46.5)

WOUND TOILET

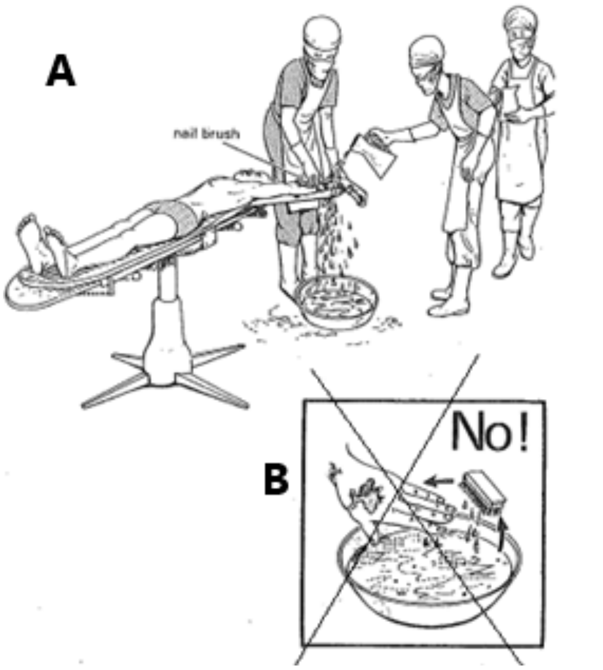


Fig. 46-2 SOCIAL WOUND TOILET. Pour on plenty of clean water over a dirty wound; *don't soak the wound in a basin. If necessary, get a 2nd or 3rd brush!*

TREATING THE WOUND
There are 2 parts to cleaning a wound properly: social toilet and surgical debridement.

(a) Social Wound Toilet
Do this in 2 stages before you drape the patient; first clean the surrounding skin, then the wound itself. You may need ketamine to do this properly.

First, pack the wound with a sterile swab to keep it dry while you scrub the skin around it with tap water, ordinary soap, and a soft nail brush.
Ask your assistant to pour clean tap water over the wound (46-2), until the skin is perfectly clean. You may need many litres; *dabbing with a wet sponge is simply inadequate! Don't hesitate to use a nail brush*; it is the best way to remove ingrained dirt, such as occurs when a limb is dragged along a road.

Now anaesthetize the wound or use GA.
Remove the swab & clean the wound itself.
If the dirt is ingrained, use a fresh soft, boiled nailbrush and gloved or scrubbed hands. Push the nailbrush directly into the dirty tissues of the wound with gentle rotating movements.
Don't damage tissue with vigorous side-to-side scrubbing movements. Put a basin under the wound, so that your assistant can pour clean water over it continually. *Don't immerse the wound in a basin*, where the dirt you have cleaned out will only contaminate the water!

(b) Surgical Wound Debridement
(GRADE 2.3)

Paint the skin round the wound with cetrimide, chlorhexidine, or povidone iodine. Drape the patient.

Gently explore the wound digitally; *be careful of jagged bone fragments*. *Just probing for foreign material is inadequate*.

Excise damaged tissue with a scalpel or scissors; adapt your excision to the severity and site of the wound. You only need all the measures described for the severest and most disadvantageously sited wounds (46-1). At one extreme, a recent clean, incised, knife wound of the scalp needs a social toilet only, and no surgical excision. Panga knife wounds, on the other hand, have crushed edges that must be excised. At the other extreme, you need to remove all dead muscle and severely contaminated tissue from a grossly dirty wound. If the wound is large and very dirty, debridement may take >1h. *Don't try to rush this:* the time saved is not worth it!

EXTEND THE WOUND and open it widely, if necessary, in the length of a limb to look into its depths.

If you have to open up a joint flexure, make an S–shaped incision (46-3).

If nerves or vessels have been injured, extend the wound to reach them. Remove all blood clots and join up all wound cavities into one, so that they drain readily.

CAUTION! Treat the tissues kindly. Don't grab them with large artery forceps, or swab them violently; this injures them, and increases the damage!

FOREIGN BODIES.
Remove any contaminating organic foreign body, such as grass, leaves, soil, a splinter of wood, or a piece of cloth, as part of the wound debridement. Use non-toothed forceps to extract pieces of dirt and foreign material; cut away all ingrained mud or soot. Flush smaller foreign bodies out of the wound with sterile water in a 50 ml syringe, or an ear syringe.

Inorganic foreign bodies, such as bullets, nails or needles are a different matter. For sharp objects, aim to remove them, especially if they are not clean. *Put on double gloves! Beware that you do not injure yourself!* For bullet or bomb fragments, remove them if you come across them, but *don't go searching for them* (46.14,15).

INCISIONS FOR EXTENDING WOUNDS

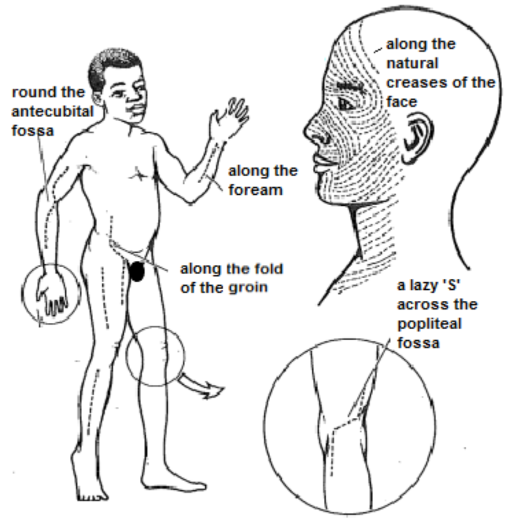


Fig. 46-3 INCISIONS FOR EXTENDING WOUNDS. A, follow the crease lines on the face. B,C, note S-shaped incisions at the elbow and popliteal fossa.

For the best results, and in order not to miss any dead tissue, perform the wound excision layer by anatomic layer, from skin down to the depths.

INJURED SKIN
With the scalpel, cut away 2-3 mm of the skin margin all around the wound, (46-4A). Skin is elastic and has a good blood supply, and you will need it for closing the wound later, so *be conservative in skin excision*. *Don't undermine the skin edges*.

INJURED FAT
This readily becomes necrotic and dirt sticks to it, so cut it back freely with scalpel or scissors until you reach healthy yellow fat which is not bruised: *be radical with fat!*

INJURED FASCIA
Cut away all torn fascia and open up the fascial planes (46-4B). Put retractors in the wound so that you can see inside it. If you need better exposure of the depths of the wound, extend the skin and fascia incisions through healthy tissue. *Be radical with exposure!*

INJURED MUSCLE
Cut away all dead muscle (46-4C) layer by layer, all the way around, from superficial to deep muscle according to its colour, consistency, circulation, contraction (4 C's). Dead muscle looks darker and bluish and loses its firm texture, becoming friable; it does not contract when pinched with forceps and it does not bleed or ooze when cut.

N.B. **If you are using a tourniquet**, living muscle will not bleed! So release it. If bleeding is severe, obtain haemostasis (49.1).

SURGICAL TOILET

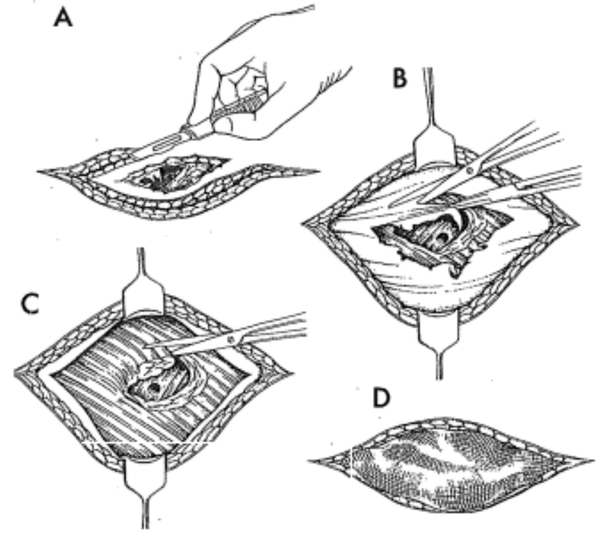


Fig. 46-4 SURGICAL DEBRIDEMENT. A, excise 2mm of skin edges. B, excise torn fascia. C, remove dead muscle. D, pack the wound and leave it open. *After Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone, 7th ed. 1976 with kind permission.*

Snip away dead muscle until you reach healthy muscle which contracts and oozes where you cut it. *Be radical with muscle!* (Dead muscle is an ideal culture medium for clostridia). If the muscle does not bleed, you have not yet reached viable tissue, *so you have not cut away enough*!

If there is viable muscle nearby, use this to cover the exposed bone. This is usually easy with the femur, radius, ulna, or humerus because reduction will reposition the exposed bone into the depth of the wound.

If the wound is extensive, pack one part of it while you clean another. Use copious amounts of clean water to wash the wound under gentle pressure. Then apply a vacuum dressing (11-20).

If you are in doubt as to whether muscle is alive or dead, *cut it out!* There will be usually minimal functional deficit.

Injured periosteum. This is important for new bone formation if there is a fracture. The periosteum has a good blood supply and is robust. Carefully excise any discoloured or ragged edges only: *be conservative with periosteum!*

If there are loose bone fragments not attached to periosteum or muscle, they are ischaemic and will die. Remove them, no matter how big they are. *Don't try to save loose bits of bone!* Leave pieces which are still attached to periosteum. *Don't scrape live muscle or periosteum from the surface of a bone*, because the bone under it may die.

If bone or fracture fragments are exposed in

the wound, manage them as follows:
(a) if they are clean but stripped bare, place them back in the periosteal and muscle bed.
(b) if they are dirty but still covered by soft tissue, scrape and curette the contaminated parts only; *don't scrape off clean, live muscle or periosteum!*
(c) if they are dirty and stripped bare, remove the dirty cortex with a bone nibbler or rongeur, and gently curette the marrow until there is fresh bleeding.

If the exposed area of bone is large, often the case with the tibia, cover it with moist gauze. Wet it with sterile saline several times daily and change the gauze daily. If the periosteum is intact, put on a split skin graft. If this later falls off, leaving white dry bone, or if there is no periosteum present, chisel away the white shiny cortex until you reach red cancellous bone. Apply a vacuum dressing (11-20); wait 3-4days till suitable granulations form and then apply a split skin graft.
N.B. Open fractures (58.12) and open joint wounds, (58.9) need special attention.

If tendons lie exposed, see if they are covered by paratenon (the normal fine vascular covering of a tendon). *A split skin graft will not take on naked white or dry tendons*, but it will usually take if they are still covered by paratenon.
For extensor tendons covering by a groin flap (64.27) works well.
N.B. Tag ends of tendons with a coloured non-absorbable suture for repair later (48.4), as they tend to retract & might be difficult to locate later.

If nerves or vessels are exposed, cover them with adjacent tissue, or a simple flap (46.5).
N.B. Tag injured nerve ends as above (48.1), or clean the ends carefully and suture the epineurium approximating the ends accurately.

If major vessels are injured, consider ligation, shunting or repair (49.1)

If you are not sure if tissue is alive or dead: check if it bleeds or blanches on pressure. If you are still not sure, inspect the wound at 48h and remove more dead tissue if necessary. This is wiser than waiting for infection and is termed a planned *serial debridement*.

If the tissues of the injured limb are very swollen and show any tendency to burst out of the wound, perform a FASCIOTOMY (49.3); open up the deep fascia longitudinally down the whole length of the muscle compartment involved.

46.3 Wound closure

Decide whether you should close a wound immediately or after a period of delay.

If you see a clean wound, without reason to suspect contamination, without systemic or local signs of infection and no sign of dead tissue, primary closure is indicated.

Make sure there is no doubtfully viable tissue, and that you can suture the wound without undue tension. Most wounds of the face, and neck, and small clean wounds on the hands, arms, and scalp, are suitable for immediate primary suture because their blood supply is so good.

Close wounds of the dura, pleura, peritoneum and joint capsule by immediate primary suture. If necessary, you can leave the soft tissues over them for delayed suture.

If you cannot bring the skin edges together without exerting tension, you may still be able to close the wound primarily by skin grafting (50.12) or a local rotation flap (46.5).

If there is much contamination, dead tissue or debris, after debridement, it is wiser to leave it for delayed primary closure on the 3rd–5th day.

The wound will still heal by 1st, and not 2nd intention, just as it would have done if you had sutured it immediately, but the risk of infection will be much reduced.

Plan *delayed* primary closure for:
(1) Wounds with dirty or damaged tissue.
(2) All severe wounds, crush injuries and bites, either human or animal.
(3) Wounds in severely shocked patients whose peripheral circulation is so poor as to compromise wound repair.
(4) Wounds with a large loss of skin, *e.g.* degloving injuries, especially those with a distally based blood supply (46.4). These usually need skin grafting.
(5) All open fractures (57.12).
(6) Most open joint wounds (57.9).
(7) Wounds unlikely to receive close attention.
(8) Where antibiotics are in very short supply (and you cannot justify their use by taking a gamble on a wound closure).
(9) *ALL war wounds,* especially missile wounds.
(10) Chronically debilitated patients.
If you are in any doubt, leave a wound open for closure on the 3rd–5th day

A COMMON MISTAKE IS FOR WOUND DEBRIDEMENT *NOT* TO BE THOROUGH ENOUGH

There are 3 basic methods of delayed primary closure: direct suture; skin grafting; and a local rotation flap.

C*ommon mistakes are*:
(1) Not to do an adequate wound excision.
(2) Not to leave a wound open for delayed primary closure.
(3) To imagine that antibiotics can treat contamination: *there is no such thing as an 'antibiotic deficiency syndrome'*!.

Neglect of these principles actually delays wound healing, and may result in osteomyelitis, amputation or death. *The temptation to close a wound is great* because a neat wound looks much tidier. Unfortunately dirt, dead tissue and bacteria may all hide under a beautifully sutured wound.

If, therefore, a patient presents with a wound inadequately cleaned or debrided, *don't hesitate to re-open it and clean it thoroughly!* (46.4)

IMMEDIATE 1° SUTURE (GRADE 1.1)
Aim to close a wound at all points and in all planes. Suture it so as to obliterate all dead space in which blood and exudate can collect (46-6B). If you allow fluid to collect in such a space (46-6F,G), the wound may readily become infected because bacteria thrive on this protein-rich fluid. When the wound finally closes, it will have a thicker scar. Cause as little trauma to skin & tissues as possible by using sharp needles and fine monofilament sutures.

N.B. Avoid heavy toothed forceps, and blunt scissors on the skin edges. Never put haemostats on the skin!

Before you start to close a wound, try to control bleeding adequately. *Do not try to suture blindly in a sea of blood!*

If bleeding is from the edge of the wound*,* especially on the scalp, a continuous suture will usually arrest it. Close fascia with *interrupted absorbable* sutures and skin with *interrupted non-absorbable* sutures. Insert these at 90° to the skin.

If a wound is shallow and the cosmetic result is important, *e.g.* on the face, use subcuticular sutures (53-1)

WOUND SUTURE

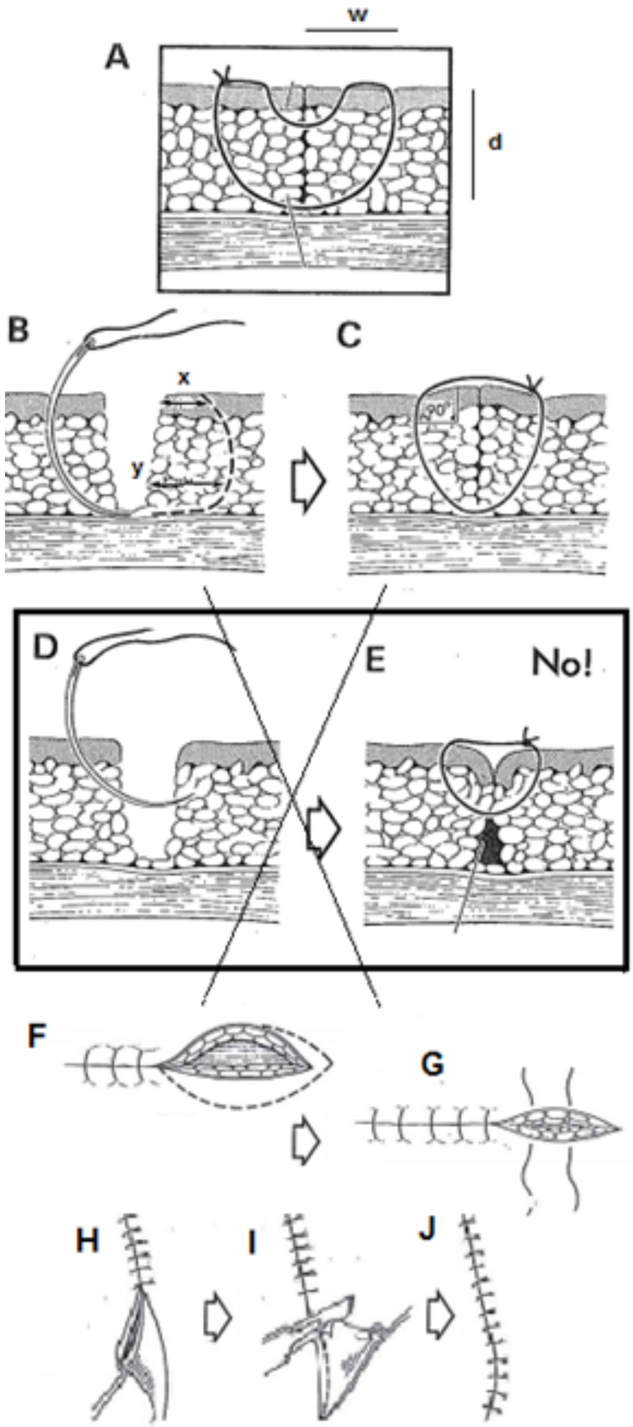


Fig. 46-5 WOUND SUTURE. A, vertical mattress everting suture; the depth (d) should equal the greater bite distance (w) from the wound edge. B,C, correct depth and apposition of a suture; if x<y, the edges will evert, if x>y, they will invert. D,E, suture too superficial and fluid trapped deep in the wound. F,G, cut along the dotted line to remove a 'dog ear'. H,I,J, alternatively cut off the 'ear'
From various sources, partly Dudley H, Hamilton Bailey's Emergency Surgery, Butterworth 9th ed. 1976 with kind permission.

If the wound is deeper, use interrupted vertical mattress (46-6A). The large bite closes space deep in the wound, and the small bite everts the skin edges.

N.B. Make sure the depth of the suture is equal to the distance of suture entry to the wound edge.

Don't drain a simple wound unless the patient is very obese or if you expect much discharge.

If closure tends to form a 'dog ear', remove the extra skin (46-5F,G)

If the wound is superficial, adhesive strips are adequate.

CAUTION! (1) *Don't make the sutures too tight:* the aim is to approximate the edges, not tighten them together!

(2) Don't put sutures too close together, as this may result in ischaemia of the edges or accumulation of exudate under the skin.

UNDERMINING WOUND EDGES

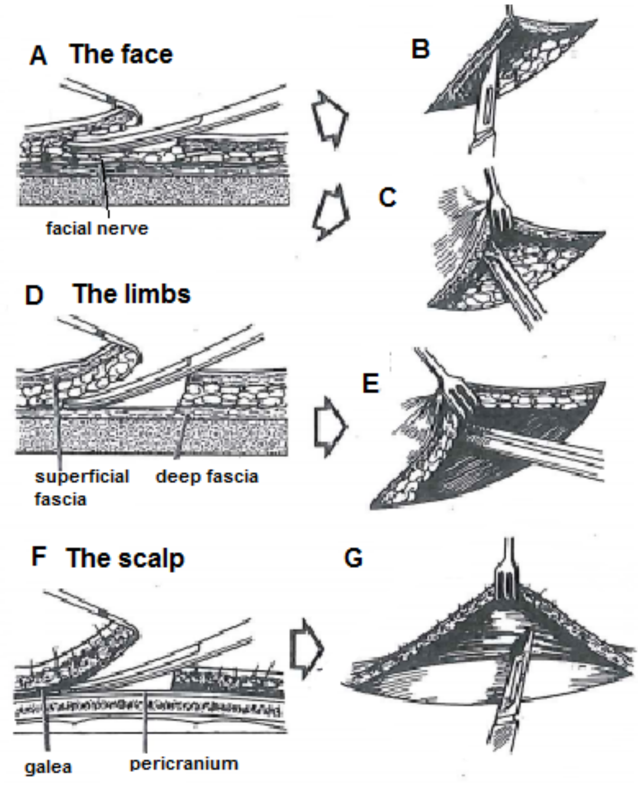


Fig. 46-6 UNDERMINING WOUND EDGES. A, in the face, just deep to the dermis, superficial to the facial nerve. B,G, using a scalpel. C,E, using scissors. D, in the limbs, between superficial & deep fascia. F, in the scalp, between galea & pericranium. *After MacGregor IA. Fundamental Techniques of Plastic Surgery. Churchill Livingstone, Edinburgh, 7th ed 1980 with kind permission.*

If you cannot bring the skin edges together without tension, try to mobilize them by 'undermining' their attachment to subcutaneous tissue. Where you do this, is important:
(1) in the face (46-6A), just deep to the dermis (53.1).
(2) in the limbs, between the superficial and deep fascia (46-6D).
(3) in the scalp, between the galea and the pericranium (46-6F).

Otherwise use a skin graft or use a local rotation flap (46.5).

CAUTION! Beware of haematoma formation if you undermine >1cm. *Always leave some subcutaneous fat:* if you undermine skin too superficially, it will necrose.

DIFFICULTIES WITH A SUTURED WOUND

If a wound bleeds within 24h (reactionary haemorrhage), a ligature has slipped, or a clot has become dislodged. Bleeding is sudden and may be massive. Prevent it by putting careful double ligatures or transfixion sutures on larger vessels.

If a wound bleeds after 24h (secondary haemorrhage), sepsis has probably eroded a blood vessel. There may be a small warning bleed before a large vessel bursts.
Try to control bleeding with pressure dressings. Take the patient to theatre, remove the dressing and open the wound gently, and ligate the bleeding vessel.

N.B. Don't use 3% hydrogen peroxide more than once in a wound; otherwise it damages small vessels and causes *more* bleeding!

If you cannot find the source of bleeding, pack the wound again to create a tamponade effect (you can secure the pack with sutures). Remove it in theatre 2-3days later. In the case of secondary haemorrhage, further excision of dead tissue (a second debridement) to control infection is necessary.

If the wound fails to heal, or leaves a sinus, think first of a foreign body (46.2). Explore the wound.

IBRAHIM (6yrs) was admitted in severe shock with a gross open fracture of the tibia and a bad laceration of the anus. The wound was carefully debrided, and the leg amputated below the knee. The stump was closed by primary suture and drained. The anal wound was treated by wound excision, and a proximal defunctioning colostomy was made. He was treated with antibiotics, but the amputation stump became so badly infected that the leg had later to be amputated above the knee.

IF YOUR ARE IN DOUBT,
DON'T CLOSE A WOUND IMMEDIATELY

MUSTAFA (46yrs) had a minor fracture of the fibula, and a wound over the medial side of the ankle, away from the fracture. A wound toilet and excision was done and the wound was sutured, as the doctor who was caring for him said, "to convert a compound fracture into a simple one". He was then transferred to another hospital and was treated with antibiotics. Nevertheless, sepsis had spread within the ankle joint so severely that its ligaments sloughed, it fell open and the surrounding bone necrosed. He required 5 more operations, including sequestrectomy, drainage, and skin grafts. Finally, he was left with an ankylosed ankle.

LESSONS. Both patients had a social toilet and a surgical debridement. The errors were to suture their wounds too early. The boy would probably not have lost the knee if the original amputation stump had been closed by delayed primary closure. Both wounds should have been left open, and only closed when they showed signs of healing.

KAMAU (35yrs) had a bad injury to the right hand. He was treated in another hospital but discharged himself when he was told, "when the suppuration is over we will amputate your hand". The hand was indeed seriously injured, with its palm torn open. It was debrided under a tourniquet and bleeding controlled with packs. The wound was then left wide open under a gauze pack. Within 6days it was granulating well and ready for grafting. The grafts took, and he is now using the hand normally.

NJOROGE (25yrs) was a bus driver with a severely torn forearm. Lacerated tendons, crushed muscle, bruised torn fat, and damaged ischaemic skin lay ingrained with mud in the depths of the dirty ragged wound. All damaged tissue was cut away, and even some of the tendons, until only healthy bleeding muscle, fat, and viable skin were left in the wound. Packs took 20mins to control bleeding, but only a few small arteries needed tying off. The wound was left widely open under a gauze dressing covered with absorbent cotton, and it, too, was ready for grafting in 6days. All the grafts took, and he is now again driving his bus.

JACK (51yrs) was standing in cattle manure and slurry when he had both his legs torn off by a farm machine. Manure was deeply ingrained in what was left of the calf muscles. A wound toilet was done using about 15 litres of water.

This was followed by a thorough surgical debridement and bilateral knee amputations, using long flaps and delayed primary suture. Both knee joints were saved, and he is now walking on bilateral below knee prostheses.

LESSONS. These are good examples of very effective ways of managing wounds. A patient usually needs no antibiotics; if he does, one dose of gentamicin and metronidazole is usually enough. If you are in any doubt about whether to close a wound, wait to see what happens. *Delay in closing a wound will not lengthen a patient's stay in hospital, but an unwise decision to close it immediately may cause disaster.*

DELAYED 1° CLOSURE (GRADE 1.2)

This is the most reliable way of closing a wound. It means closing a wound between the 3rd & 7th day, usually on the 3rd-5th.

It is during this interval that the wound changes from its exudative to proliferative phase of inflammation. *It does not mean waiting for 10days until granulations have formed*; that is 2° closure.
Wounds naturally heal by granulation; immediate primary suture is a human intervention. Delayed primary closure thus occurs in animals.
It makes good use of a universally available chemical which is lethal to the anaerobes causing gas gangrene and tetanus: oxygen in the air.

Alike to immediate closure, there are 3 main methods of delayed primary closure: direct suture; skin grafting; and a local rotation flap.

If there are no signs of infection, close the wound by the same methods as for immediate primary closure. Disturb it as little as possible, irrigate it with sterile water to remove blood clot. Clean its edges, but *don't freshen them.* If necessary, undermine them. Bring them together without tension and use interrupted monofilament sutures. Apply a pressure dressing and, if necessary, splint the limb as before.

CAUTION!
(1) Control all bleeding. Use packs and avoid ligatures if you can. A haematoma will ruin the chance of success.
(2) *Don't close the wound under tension*.

If you cannot bring the edges together, and the gap is >6cm, close the wound by skin grafting. If the wound is on the forearm, hand, or calf, use a local rotation or transposition flap.

If there are signs of infection or any necrotic tissue, the 1st operation was inadequate. Perform a 2nd debridement and leave it open again. Go back to look at the wound after 3days.

2° CLOSURE (GRADE 1.2)

If wound closure is delayed beyond 10days, granulation tissue will cover it and it will heal by secondary intention. By now, the wound edges will be indurated and will be difficult to bring together, so a skin graft will be necessary. This is secondary closure.

Apply a tourniquet where possible. Undermine the new epithelium at the edge of the wound, and gently freshen the granulation tissue on the surface of the wound. This should be a rosy matt red colour, not shiny, or heaped up. Remove any thin layer of exudate. If this is purulent, scrape it off, and postpone the operation for 2-3 days. If the wound is very small, leave it to epithelize on its own.

POST-OPERATIVE MANAGEMENT

DRESSINGS.

Cover a sutured wound with a simple gauze compress. After extensive wound debridement, use fluffed gauze. Cover this with bulky absorbent cotton to absorb the exudate (46-4D). Aim for dryness and coolness. Loosely bandage the cotton in place, making sure the bandages do not restrict the circulation. Dress a skin graft as in 50.12.

IMMOBILIZE a severe limb wound. Skeletal traction is safest (especially for the femur). A plaster back-slab is best while waiting for delayed 1º closure. If you use a circular cast (for the tibia, humerus, or forearm), bivalve it immediately; *a slit down one side is not enough to prevent compartment syndrome*. Elevate the limb.

Begin PHYSIOTHERAPY and mobilization of the patient immediately the day after wound debridement. *Do not wait for till wound closure*.

REMOVE SKIN SUTURES after 4-14days, depending on the site. 3days is enough for the face, 5 for the neck and 7 for the scalp. 10-14days may be necessary on the lower leg, feet, and toes. Leave them longer in old people.

If there is increasing pain, redness or purulent discharge, open the wound widely, and debride it (2.10).

WOUNDS WHICH LEAVE FLAPS
The apex of a Y-shaped laceration may necrose. *Don't strangulate this part;* use a suture which passes through all 3 sides of the apex (46-7).

APICAL SUTURE FOR Y-SHAPED WOUNDS

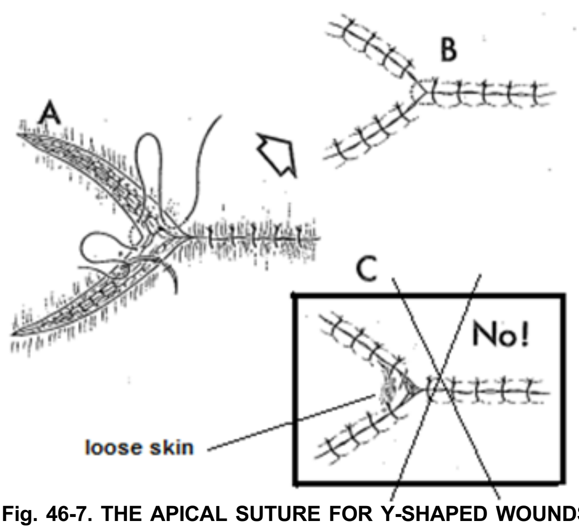


Fig. 46-7. THE APICAL SUTURE FOR Y-SHAPED WOUNDS. A, B make a 3-way suture at the apex.

With larger flaps, you can reposition it, excise and discard it, or excise it and use it to make a graft.

Retain a flap provided:
(1) its edges bleed,
(2) it becomes pale when you press on its base and colours again when you let go.
(3) its base is wider than its length.
(4) the wound under it is clean.
Otherwise, excise it.
If you decide to keep it, hold it in place with adhesive strapping rather than sutures.

TRIMMING FAT OFF A SKIN FLAP

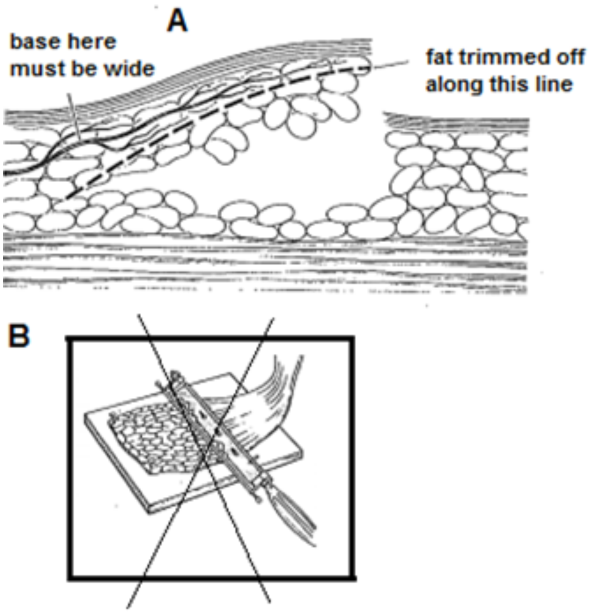


Fig. 46-8 TRIMMING EXCESS FAT OFF A FLAP.
A, preserve the blood supply at the base of the dermis.
B, *don't use a Humby knife for this,* as it will remove the vessels.

Trim off fat from under the flap (46-8).

If a flap is very thick, trim it so that it has a thinner margin and a thicker base, preserving its blood vessels. Make sure that the patient does not lie on top of the graft.

46.4 Degloving or avulsion injury

A large flap of skin may tear off its underlying tissues. This can occur if a vehicle runs over the leg (46-9A). If the skin is hanging loose (46-9B), the diagnosis is obvious; but if it is merely separated from the tissues underneath by a haematoma (46-9C), the diagnosis is not so easy. To begin with the skin may look quite normal, and only necrose later. If you are in any doubt, feel it carefully, to make sure it is attached to the tissues underneath, and look at it again 48h later.

If you suture a large piece of degloved skin back in place, it will die, so manage the patient as described below.

If there is no skin wound, aspirate the underlying haematoma, or incise the skin and explore to see how much undermining there is, (46-9C,D). Turn back the skin flaps, and excise or replace them as described below.

If the patient has an open skin wound, excise any grossly damaged skin.

DEGLOVING INJURIES

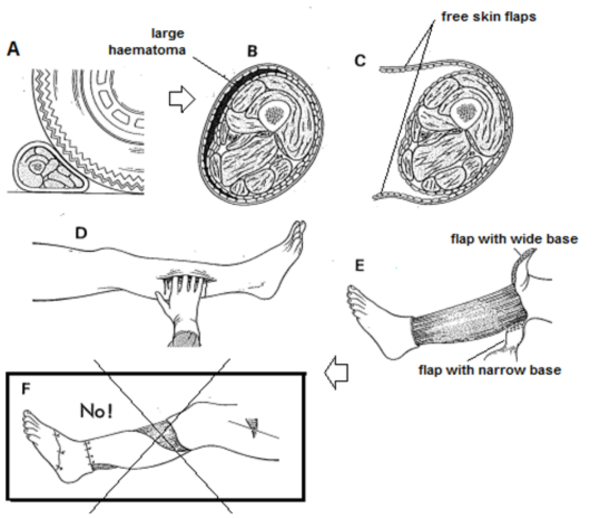


Fig. 46-9 DEGLOVING (AVULSION) INJURIES. A, vehicle tyre crushing a limb. B, undetached degloving injury with a large underlying haematoma. C, free skin flaps. D, exploring a haematoma and evacuating it. E, flaps with wide and narrow bases. F. *the narrow based flap will necrose!* *After London PS, A practical guide to the care of the injured, E&S Livingstone, Edinburgh 1967 with kind permission.*

If the base of the flap is wider than its length, preserve it, trim its subcutaneous fat (46-8) and reapply it immediately.

If a piece of skin is free or has a base which is too narrow to let it survive as a flap, or has a distally based blood supply, excise all the degloved skin and fat. Take split skin grafts from the avulsed flap and apply them immediately, if the base is clean and well-vascularized (as with muscle). If it is not, take the grafts, and store them (50.13), and cover the wound with dry dressings. At 3-5days when granulations are forming, remove the dressings, and any dead tissue, and apply the stored graft.

CAUTION! (1) **If there is a tyre mark on the skin**, there will certainly be a degloving injury under it. (2) *Never replace any skin flap whose length is longer than its base*.

46.5 Various flap techniques

If a wound has as its base bare bone, tendon, nerve or vessels, no skin graft will take on such a surface. You need to act quickly within 2days. Tissue to cover such a defect should 'bring skin with it'. This is called a flap, and this may be of various types: somewhere adjacent (transfer), having a central blood supply (axial pattern) or be of random pattern. In the particular case of the hand, you can use tissue from the groin (a type of transfer flap, 34.12), anterior chest wall or abdominal wall.

Firstly, mark the margin of the flap to be slightly greater than the defect. The ratio of its base and length must be equal (1:1).

You can also tubularize the flap (46-11B)

Always carefully clean and debride the wound. If the wound is granulating, excise its edges radically, down to sound tissue.

(1) FINGER-ABDOMINAL FLAP (GRADE 2.5)
For the palmar site of the hand or a single finger, especially for a degloved thumb with open bone or tendon, use an abdominal flap**.**

N.B. Don't make the fat layer of the flap very thick.

Use GA. Measure the size of flap that the degloved finger needs by wrapping a piece of paraffin gauze round it. Lay this on the lower abdomen in the position that the hand would be in if it were in a trouser pocket. Cut a flap the size and shape of the gauze with its base downwards (46-12), leaving only a little fat under the skin.

Make holes in the proximal end of the fingernail with a strong cutting needle. Wrap the flap round the degloved finger, leaving the nail outside it. Suture the base of the finger to the flap, & leave its upper border free. Dress the flap and hold the forearm in position with tight bandages round the trunk.

Change the dressing after 5days, but check the circulation of the flap daily (especially with a hand-held Doppler), more often during the 1st 24h.

After 3wks, new vessels from the flap should have grown into the finger. Check this by placing a broad soft tissue clamp at the flap base. See if disconnecting the blood supply to the flap for some minutes makes any difference to the skin on the finger. If not, leave it for longer periods. After 4wks, cut the pedicle and finally close the wound.

You can usually close the abdominal wound primarily.

CAUTION! Start active finger exercises immediately !

If you need a longer pedicle, close the open back of the flap with a split skin graft.

CHEST WALL TRANSFER FLAP

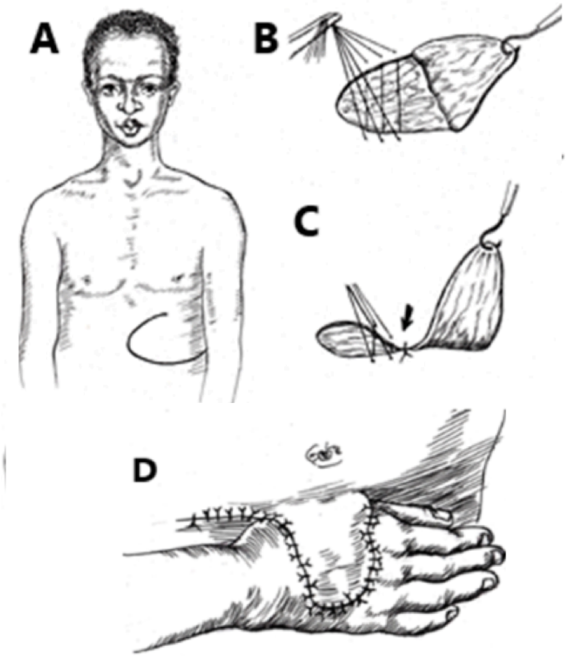
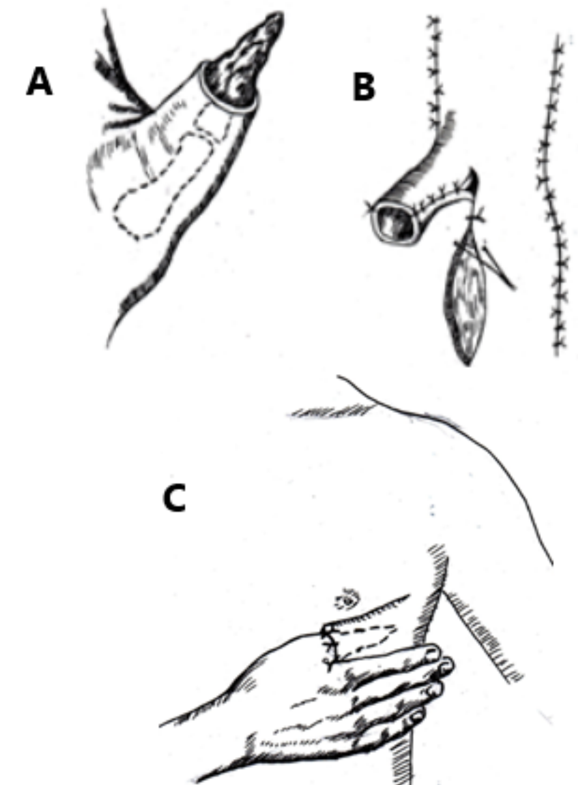


Fig. 46-10 Trunk transfer flap. **A, donor site. B, mobilizing the flap. C, closing the donor site primarily. D, suturing the flap onto the hand.** *After Grabb WC, Smith JW, Plastic Surgery, Little Brown, Boston 1979*

THUMB FLAPS



46-11 Various flaps to the thumb. A, degloved thumb tip. B, fashioning a tube out of 2 flaps of chest wall skin. C, inserting the thumb. *After Wachsmuth W, Wilhelm A, Operationen an der Hand, Sp ringer, Berlin 1977*

ABDOMINAL WALL FLAP FOR A FINGER

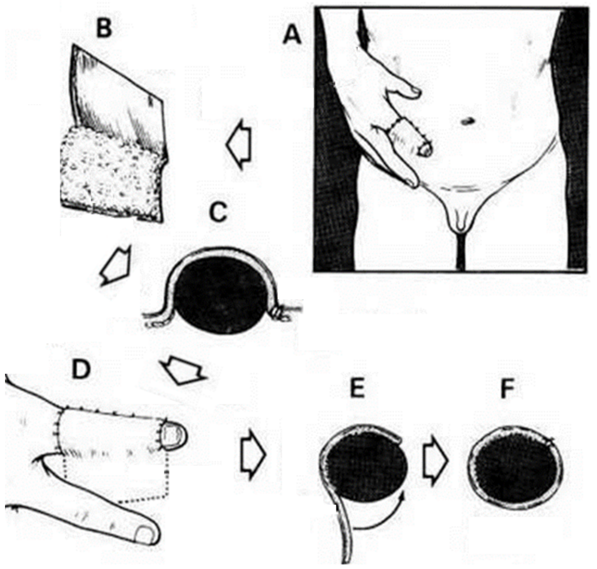


Fig. 46-12 AN ABDOMINAL FLAP FOR A FINGER is an alternative to amputation in degloving injuries. It needs care! A, strap the hand to the abdomen. B, cut the flap leaving only a little fat. C, suture the flap round the finger. D, divide the flap after 3wks, leaving enough (E) to cover the volar surface of the finger. F, suture the flap. *Kindly contributed by Mamdur Tahir*

GROIN FLAP FOR THE HAND

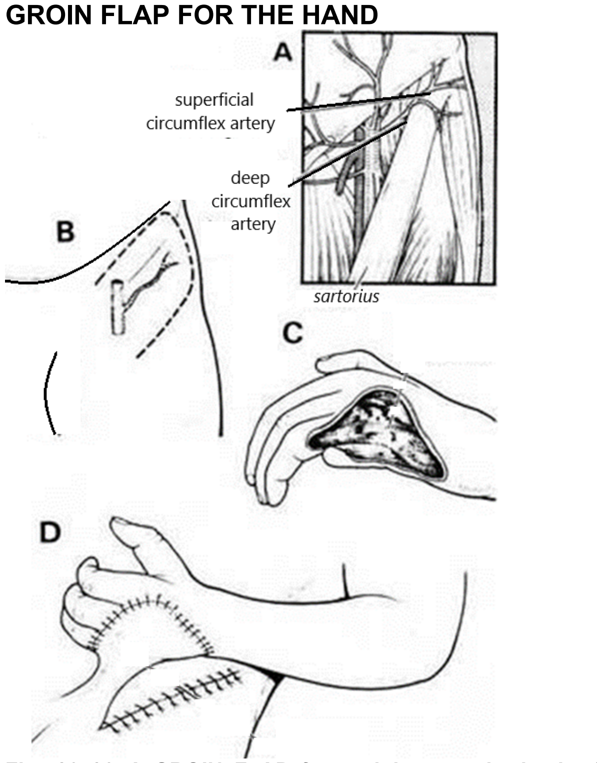


Fig. 46-13 A GROIN FLAP for an injury on the back of the hand. A, the anatomy of the superficial circumflex iliac artery. B, the anatomy of the flap. C, the defect in the hand. D, the graft sewn in place, the pedicle tubed, and the defect closed by suture with the patient's hip flexed. *Kindly contributed by Ian McGregor.*

(2) HAND-GROIN FLAP (GRADE 2.5)
For exposed tendons on the back of the hand use a groin flap (46-13).

Mark out the anterior superior iliac spine, the pubic tubercle, and the inguinal ligament running between them. Palpate the line of the femoral artery. Mark the origin of the superficial epigastric artery 2.5cm below the mid-point of the inguinal ligament. Draw the line of the superficial circumflex iliac artery parallel to the inguinal ligament and mark its point of entry into the flap where it crosses the medial border of the *sartorius*.

Raise the flap to include the artery, which need not necessarily lie along its axis. The usual width is 10cm, but you can use extremes of 6cm and 19cm in an adult and 14cm in a child successfully. The maximum length of the flap is uncertain, but if you extend it beyond the anterior superior iliac spine, make the part beyond it square with an equal length to breadth ratio.

Raise the flap at the level of the deep fascia starting laterally. At its upper margin, divide the superficial epigastric vessels. Raise the flap in a plane deep to these vessels to be sure to include the superficial circumflex artery and vein, since they lie in the same plane. The key point in raising the flap is the virtually constant branching of the artery at the medial border of *sartorius*. When you reach this muscle, incise the fascia over it, and strip the muscle bare to just short of its medial border, preserving the deep branch of the artery. Then stop, knowing that the main part of the artery is safely out of the way in the flap.

Suture the edges of the flap to the defect in the hand. Try to suture the edges of the bridge segment together into a tube.
CAUTION! Make sure the fingers are exercised as much as possible, to prevent stiffness and oedema.

Close the defect in the groin by flexing the hip and try to make a primary repair. If this is too tight, graft the exposed area.

(3) *GASTROCNEMIUS* FLAP (GRADE 3.1)
For an open knee joint or a defect in the proximal lower leg, use the *gastrocnemius* muscle flap, either on the medial or lateral side. The blood supply of both *gastrocnemius* muscle bellies comes from the popliteal artery upwards from the knee-joint gap (46-14A), so this is an axial pattern flap.

When raising the flap, incise mediodorsally (or lateraldorsally) from the knee up to ½ the lower leg.

Start preparing the muscle at its transition to the *Achilles* tendon. Here cut the medial or lateral belly of the muscle, and look for its very strong middle segment. Now lift the muscle flap step by step from its base. *Be very careful near the knee, not to damage the feeding sural & popliteal arteries*. If you need more length in the flap, cut the muscle at its insertion; in this way, it will never contract. After its transfer, cover the muscle directly by a split skin graft.

You can also use the *gastrocnemius* flap together with its skin island as an axial pattern flap in the cross-leg flap (46-17). Prepare the skin-fascia-muscle flap in the same way and transfer it to a defect on the other leg.

***GASTROCNEMIUS* FLAP**

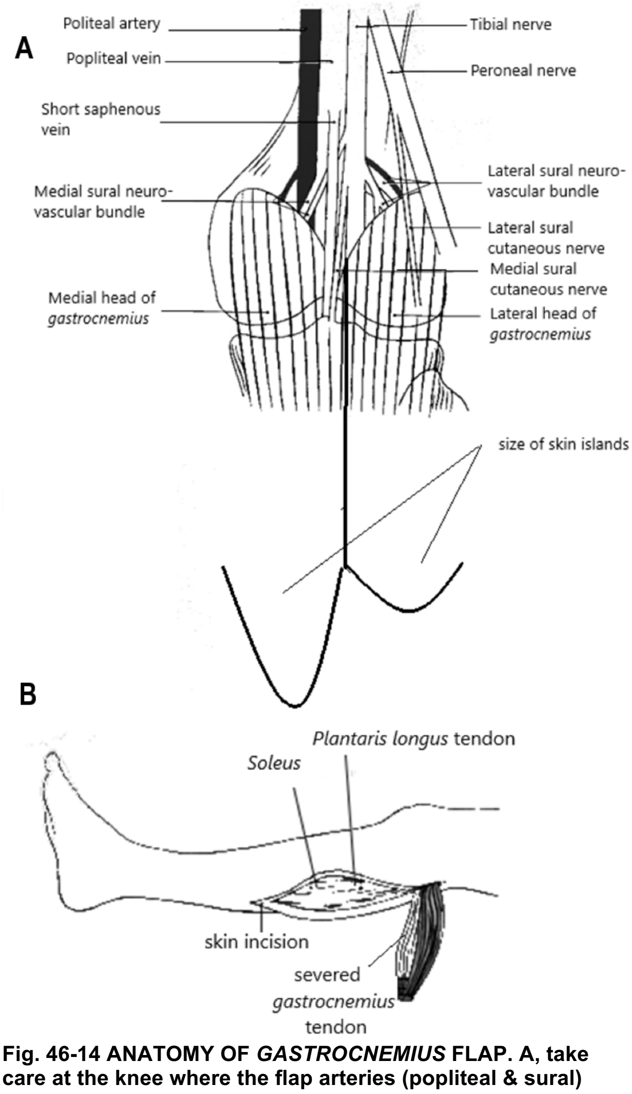


Fig. 46-14 ANATOMY OF *GASTROCNEMIUS* FLAP. A, take care at the knee where the flap arteries (popliteal & sural) originate. B, Medial view. Use a skin graft to close the defect.
After Geishausen, Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995

(4) SURAL FLAP (GRADE 3.2)

If there are problems in the distal part of the lower leg, which the *gastrocnemius* flap cannot reach, use the sural flap. Its blood supply is served by perforator arteries 5,10 & 15cm above the medial malleolus, and its sensitivity by the sural nerve.

The pivot of the flap lies just proximal to the last perforator artery. The pedicle *must include* the fascia. *Note that the blood supply of this flap comes from below!*

Make an incision in the posterior calf and, at the same level, of the fascia. Look for the sural nerve and the short saphenous vein at the proximal border of the flap and, ligate and cut them (46-15).

Be careful to avoid separating fascia from subcutis and skin. The pedicle, beginning at the distal border of the skin flap, should be a strip of 2-3cm of the crural fascia together with nerve and vein.

SURAL FLAP TO THE HEEL

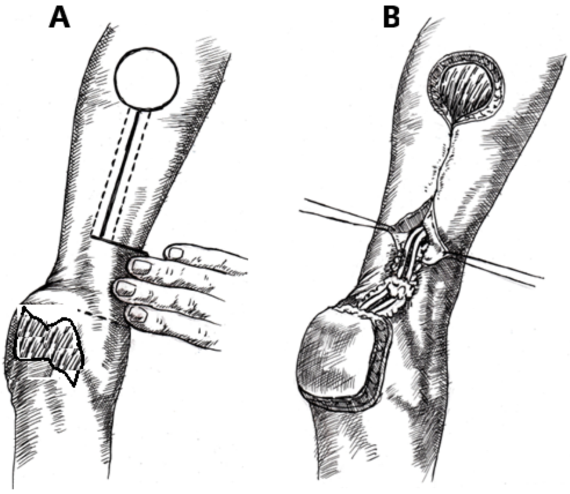


Fig. 46-15 SURAL HEEL FLAP. A, Incision. B, rotation on long pedicle and insertion into defect enlarged from debrided wound.

(5) PERFORATOR-BASED ROTATIONAL FLAP (GRADE 3.2)

If the flap cannot reach the defect, or because of kinking at the vascular pedicle, or bad 'dog-ears', use the perforator flap.

Pre-operatively, use a handheld Doppler to locate the dominant perforator in the vicinity of the defect. Keep the perforator preferably in its centre, forming the pivot point of the flap. Measure the proximal limit of the flap by the distance between the perforator and the distal edge of the defect, and the width of the flap by the width of the defect. Then add 1–1.5cm to allow for primary flap contraction.

Use an arterial tourniquet, and operative magnification spectacles if possible. Make an exploratory subfascial incision on one margin of the flap, in such a way that it does not violate a possible adjacent flap, which you may need in case the reconstruction fails. The aim of this incision is to locate one good perforator free of scar or granulation tissue. If you can't find such a perforator, you need to re-design the flap.

The most reliable perforators are 6-10cm from the tip of the medial malleolus, and you can raise the flap within 10cm of the popliteal skin crease. Where there are multiple perforators, select the largest suitable distal artery and place single clamps on all the others; if flap perfusion is reliable, ligate these.

Skeletonize the selected perforator completely if its length is 3cm. Then raise the rest of the flap, thus creating an island. Rlease the tourniquet and check for flap perfusion. Then rotate the flap into the defect in the most favourable direction, but *don't rotate it >180⁰* (46-16).

PERFORATOR-BASED PROPELLER FLAP

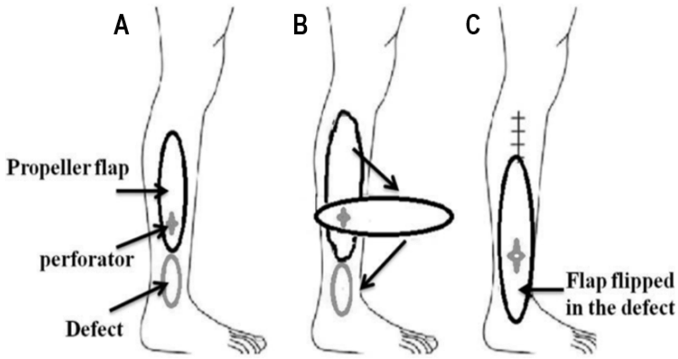


Fig. 46-16 PERFORATOR ROTATIONAL FLAP. A, position of the flap. B, flap rotated. C, flap covering the defect. *After Yadav P, Thakur S, Agarwal P, Sharma D, Kukrele R. Perforator-based prpeller flap. Trop Doc 2021.*

Close the donor site primarily, if small, or if large, by a skin graft. Check the dressing on the 2nd day post-operatively and then on alternate days for a week. Remove sutures on the 8th day.

(6) CROSS LEG FLAP (GRADE 3.1)

For the middle of the lower leg, where you can neither use a *gastrocnemius* flap nor a sural flap, you can use a flap from the other leg.

Lift a cutaneous (46-17) or, better fascio-cutaneous, or musculo-fascio-cutaneous flap from the calf of the other leg, *e.g.* a *gastrocnemius* flap (46-18).

Using its axial vessel, you can take it as long as you need to cover the critical skin defect over the other leg. However, the biggest problem is the need for absolute stability of the donor pedicle. A cast is one option, but an external fixator is better. Check the blood flow in the flap regularly. *Avoid any kinking of the vessel in the pedicle and any tension*.

After 3wks, if there is no infection, start 'training' the flap by occluding its pedicle, as before. -
When you are sure that the blood supply within the flap is good enough, cut the pedicle.

After this, wait some days until definitively closing the flap rim to the defect.

N.B. You may encounter some necrosis at the edges of the pedicle, but hopefully this will be Illimited.

SUPERFICIAL CROSS LEG FLAP

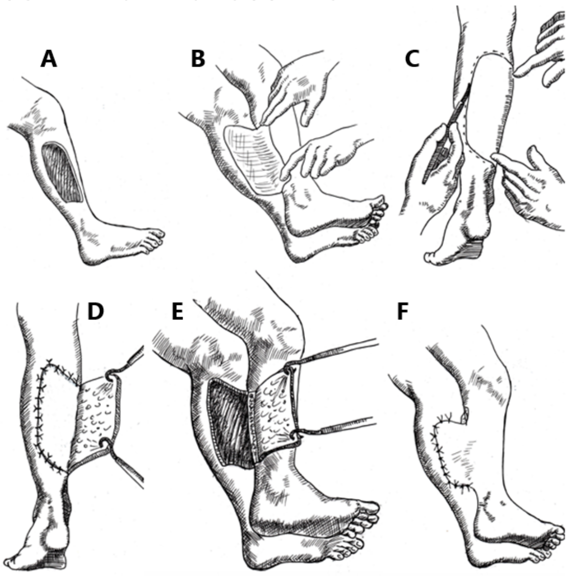


Fig. 46-17 CROSS LEG FLAP. A, defect on the lateral right lower leg. B, making a template with paraffin gauze. C, measuring the size of flap needed. D, detaching the flap on 3 sides. E, fixing the flap to the other leg. F, final result before flap division. *After Converse et al, Reconstructive Plastic Surgery Philadelphia1977*

DEEPER CROSS LEG FLAP

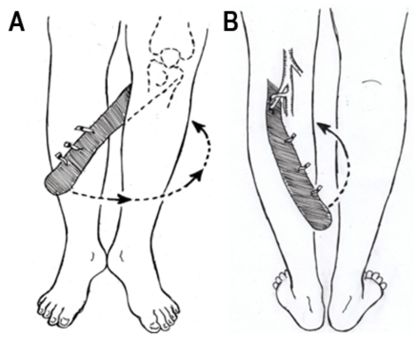


Fig. 46-18 CROSS LEG FLAP. *After Mathes-Nahai 1: Clinical Atlas of muscle and musculocutaneous flap, St. Louis 1979*

N.B. Don't attempt cross-finger flaps: stiffness of fingers usually results.

(7) *LATISSIMUS DORSI* FLAP (GRADE3.2)
For bigger defects in the breast, neck, upper arm and shoulder, the *latissimus dorsi* flap is suitable.

Its pedicle is based on the thoraco-dorsal artery, and its length is ≤12cm (46-19). You can use the overlying skin island for an area ≤20x40cm. If the donor side is >10cm, close it with a split skin graft.

With the patient on the side, & the arm supported, start cutting the margin of the skin island (46-20). Prepare the flap in a proximal direction towards its pedicle vessel.

ARTERY SUPPLY OF *LATTISIMUS DORSI* FLAP

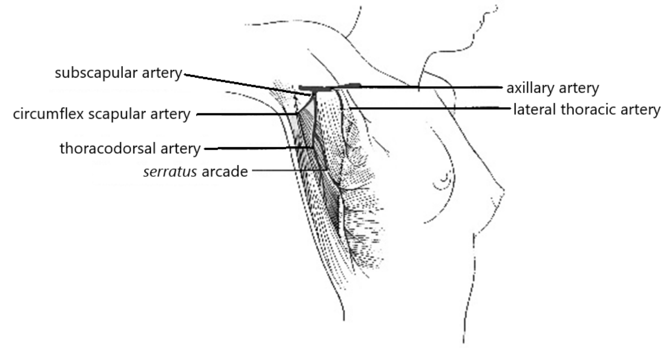


Fig. 46-19 *LATISSIMUS DORSI* FLAP. *After Geishauser/ Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

Incise the fascia as well as the skin, at the limit of your proposed muscle cut. Loosen the muscle insertion of the *latissimus* part without damaging the vessels (46-21). Usually you need only part of the muscle, so use the part you need at the distal end, with skin and fascia. *Be careful not to loosen the connection between fascia and subcutaneous tissue;* you may need some sutures to fix them together.

***LATISSIMUS DORSI* FLAP DESIGNS**

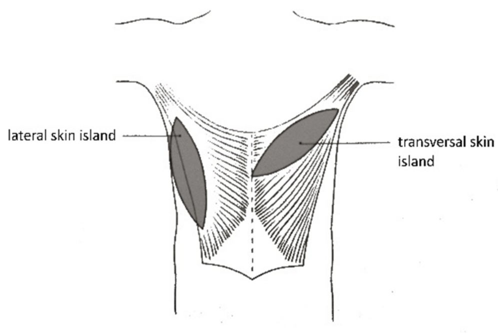


Fig. 46-20 *LATISSIMUS DORSI* FLAP. Possible skin islands. *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

Take the flap to cover the defect, and suture the muscle and subcutaneous tissue in place.

CONSTRUCTION OF *LATISSIMUS DORSI* FLAP

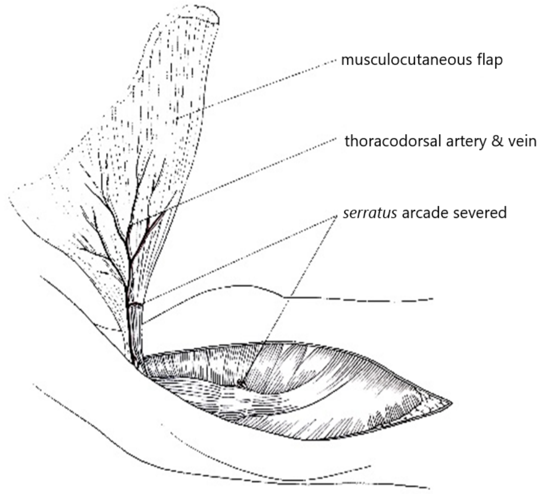


Fig. 46-21 *Latissimus dorsi* flap. *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

(8) *PECTORALIS MAJOR* FLAP (GRADE 3.2)
To cover bigger defects in the face, especially combined with some soft tissue defects, the *pectoralis maior* flap a good solution. It is also possible to use it to reconstruct defects of the thoracic wall, neck and upper arm, usually as a pedicle-island flap.

The 3 parts of the *pectoralis maior* muscle have their origin at the clavicle, the sternum and the rectus sheath. It is possible to take only one part of the muscle for the transfer. The muscle insertion is at the humeral tubercle.

The blood supply of the muscle comes from the thoraco-acromial artery, which arises closely medial of the origin of *pectoralis minor*. It is 7cm long (46-23).

***PECTORALIS MAJOR* FLAP DESIGNS**

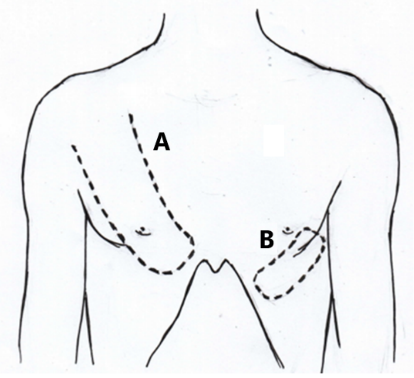


Fig. 46-22 *PECTORALIS MAJOR* FLAP. DESIGNS A, vascular pedicle flap. B, an island flap. *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

For covering areas at the sternum, it is possible to use it as turn-over-flap with a medial pedicle.

Prepare most the skin island with the distal margin at the distal end of the pedicle vessel, beginning near the clavicle (46-23). The more distal you make the end of the flap, the longer must be the pedicle vessel.

For transfer of a skin island, it is necessary to take a part of the muscle around the artery. You lenthen its arc of rotation much by this manoeuvre. If more volume is needed, take more muscle. *Fix the margin of the skin to the fascia very carefully.*

***PECTORALIS MAJOR* FLAP**

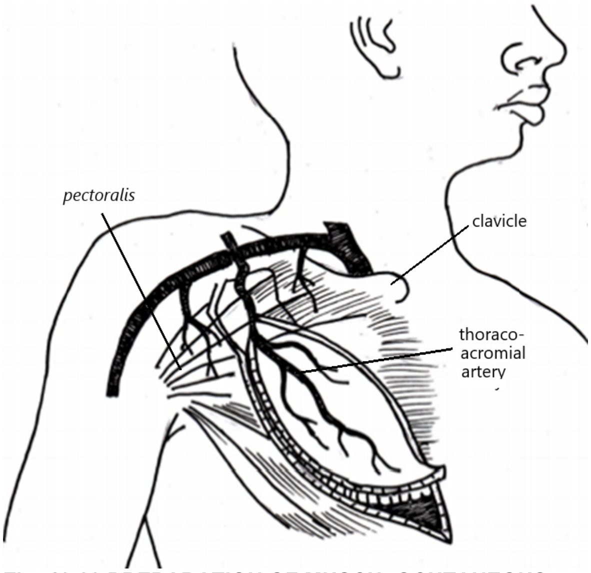


Fig. 46-23 PREPARATION OF MUSCULOCUTANEOUS *PECTORALIS ALIS MAJOR* FLAP *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

(9) *GRACILIS* FLAP (GRADE 3.2)
For perineal defects, the *gracilis* flap is ideal. Its pedicle is based on the medial circumflex femoral artery. The gracilis muscle can easily be sacrificed without significant deficit to leg function.

***GRACILIS* FLAP**

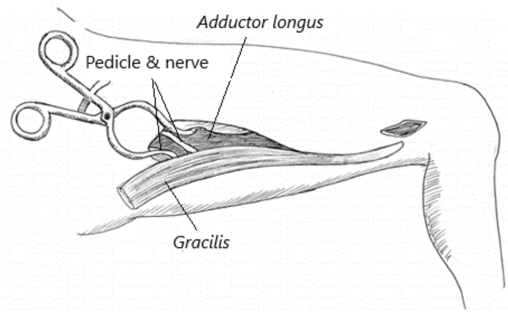


Fig. 46-24 *GRACILIS* PEDICLE separated from *Adductor Longus.* You can make a separate incision near the knee to divide the tendon if you need full length.

With the patient's thigh abducted and knee flexed, mark the axis of *Gracilis* 5cm posterior to the *adductor longus*. You can find the pedicle c. 10cm below the ischium (46-24).

Make an incision longitudinally down to fascia, and elevate this off the muscle anteriorly. Separate *gracilis* from *adductor longus* superior to it. Transect the muscle distally depending on how much length you need ; you can use a separate cut near the knee to transect the distal *gracilis* tendon. Then swing the flap into the defect you wish to close ; its length is up to 7cm, but you can extend its reach by another 4cm by tunneling it under *adductor longus.*

46.6 Antibiotic prophylaxis

PROPHYLACTIC ANTIBIOTICS *only* have a role as an *adjunct to proper wound toilet* and debridement in preventing septic complications. *A severely contaminated wound is already infected!*

You must avoid these 4 common errors of antibiotic therapy:
(1) Using antibiotics when they are not needed;
(2) Not using antibiotics when they are needed;
(3) Using antibiotics for too long;
(4) Selecting the wrong antibiotic;
(5) Relying on antibiotics without wound cleaning;
(6) Using antibiotic to which the patient is allergic.

(a) When *not* to give antibiotics:
If a wound is clean and suitable for primary suture after wound toilet. *Don't risk primary closure of a doubtfully clean wound* by prescribing a course of antibiotics 'to be on the safe side'! *It is better to leave the wound open and do a proper debridement.*

DO NOT GIVE ANTIBIOTICS FOR CLEAN WOUNDS

(b) When to use antibiotics for contaminated wounds, *in addition* to wound toilet and surgical debridement (46.2)**:**
(1) highly contaminated soft tissue wounds with necrotic or devitalised tissue,
(2) war wounds,
(3) wounds caused by explosions,
(4) high velocity gunshot wounds,
(5) farming accidents (especially with soil contamination),
(6) open fractures (except fingertip injuries),
(7) wounds involving joints,
(8) animal and human bites (46.10)
(9) abdominal wounds penetrating bowel,
(10) wounds involving the brain or spinal column.

WHAT ANTIBIOTICS TO USE?
Many different protocols and recommendations exist. You will have to make a choice depending on your resources and the situation you are working in.
The antibiotic you choose should cover skin germs and staphylococci such as *Staph. aureus*.

For very deep, contaminated or penetrating injuries (*e.g.* gunshot wounds) it should cover *Clostridium perfringens* which can cause gas gangrene (6.24).

To be effective as prophylaxis, antibiotics must reach high tissue concentrations *as soon as possible after injury***.** Therefore, IV preparations are best.

Any antibiotic use can have potentially serious side effects and increases the risk of antimicrobial resistance. *They are not an alternative to proper debridement, wound toilet and delayed closure of contaminated wounds* (46.2,3)

IF INDICATED, START ANTIBIOTICS EARLY!

In many scenarios, *penicillin G* is still a valid option for wounds that involve only soft tissue. However, resistant strains of *staphylococci* are common, and so penicillin is less effective especially in open fractures.

A 1st generation IV cefalosporin such as *Cefazolin* is an alternative with better activity against staphylococci.

You can use *Cefazolin* for all indications listed above except for human or animal bites, which require broader cover (46.10).

If the patient has an open fracture, use cefazolin.

For a deep wound soiled with faeces, or an **abdominal injury with bowel penetration** or a **brain injury,** add *metronidazole.*

For a heavily soiled, open fracture or an abdominal injury with spillage of faeces, consider the addition of gentamicin as well to provide prophylactic coverage against Gram-negative germs.

In case of documented beta-lactam allergy, use *clindamycin* instead; *you don't need to add metronidazole*.

SAVE NEWER BROAD-SPECTRUM ANTIBIOTICS FOR COMPLICATED INFECTIONS!

EYE INJURIES
Most antibiotics do not penetrate well into the eye; see (52.1) for how to prevent infection.
Typical dosage recommendations for adults are:
(1) penicillin G: IV 5 MIU qds,
(2) cefazolin: 2g IV td
(3) metronidazole: 500mg IV tds
(4) clindamycin: 900mg IV tds
(5) gentamicin: slow IV 5 mg/kg over 30 min
CAUTION! Reduce the dose or avoid Gentamicin in patients with renal insufficiency.

(c) How long should you give prophylactic antibiotics?
For prophylactic use, *a single dose* is sufficient in most cases. You can apply this for low-grade open fractures and major soft tissue injuries that are clean *after* debridement, and also to **abdominal injuries with penetration of the gut** *if you see and operatein such patients promptly.*

For a high-grade open fracture or a highly contaminated soft tissue injury, *the wound is already infected,* so continue antibiotics for up to 72h after debridement, or until wound closure, *whichever is sooner*.

For open brain & spinal column injuries (with penetration of the dura; 51.10): use cefazolin & metronidazole for 5days, or until the CSF leak stops.
N.B. Closed basal skull fractures do not require prophylactic even if there is a liquor leak.

46.7 Tetanus prophylaxis

Tetanus is caused by *Clostridium tetani*. It can follow any minor wound but the risk is especially high in burns, frostbite, deep puncture wounds and other contaminated injuries.

Prevention of surgical tetanus depends on:
(1) A thorough wound debridement (46.2)
(2) Active immunization with tetanus-toxoid-containing vaccines (TTCV).
Other methods at the time of the injury are:
(3) Active immunization or a booster of an existing immunization with tetanus toxoid (TT) or TTCV,
(4) Passive immunization with human tetanus immunoglobulin (HTIG) to provide immediate protection.
N.B. Don't rely on antibiotics to prevent tetanus!

Vary your regime according to the patient's vaccination status and the nature of his injury and follow your national recommendations for prevention and immunization against tetanus. Toxoid is cheap, widely available, and seldom causes reactions. When they do occur, they are unlikely to be serious, so there is no need to test for sensitivity. The disadvantage of tetanus toxoid is that it does not provide immediate cover. If a non–immune patient has a high risk wound, give human tetanus immune globulin (HTIG) *and* tetanus toxoid.

CAUTION! Don't use horse anti-tetanus serum! It only has a half-life of 1-2 days and carries a much higher risk of anaphylactic reactions.

A patient is fully immunized when he has received ≥3 doses of tetanus toxoid.
If the last dose was given >5yrs before, administer one dose (0.5ml) of tetanus toxoid.

If the patient is not fully immunized (<3 doses), **no prior vaccination, or the immunization status is unknown**, always give tetanus toxoid AND administer human tetanus immunoglobulin (HTIG) in high-risk wounds (*e.g.* all wounds except small, clean, superficial wounds).

People with HIV infection or severe immunodeficiency who have contaminated wounds should *also receive* HTIG, regardless of their history of tetanus immunizations. The usual dose IM is 250 IU for adults and children. In wounds that are already infected or wounds older than 24 h, double the dose to 500 IU. Use different syringes in different sites.

If you don't have access to human immunoglobulin, focus on a thorough wound debridement and give antibiotics and tetanus toxoid as described previously, add metronidazole for all contaminated wounds that receive antibiotics.

IF IN DOUBT, ADMINISTER TETANUS TOXOID TO ALL PATIENTS WITH WOUNDS

AZIZ (26 years) fell drunk from a second floor verandah and dug both his forearm bones into the earth. His wound was closed by primary suture without a wound toilet. 5 days later he developed tetanus and died. At post mortem a quantity of earth was found in his wounds. LESSON The critical step in preventing tetanus is a thorough wound toilet.

FOLLOW UP IMMUNIZATION Immunize a patient on the indications given above. If necessary complete active immunization with toxoid with a second dose after at least 4wks and a 3rd dose after at least 6months. To protect a patient throughout life, WHO recommends that an individual receives 6 doses in total, or 5 if the immunization was started in adulthood.

46.8 Malaria prophylaxis & special considerations

In endemic areas, it is wise to administer prophylaxis against malaria, Leishmaniasis, Leptospirosis, Brucellosis & Filariasis in cases of severe injury or burns, particularly for children.
A splenectomy reduces immunity and needs special protection (55.6).

46.9 Rabies prophylaxis

A rabid dog may behave oddly with an abnormal gait, but does not always show any rage. In fact such a dog may show no abnormal signs at all. But a fox, skunk or bat in broad daylight, showing no fear of humans is behaving abnormally. The only real guarantee that a dog does not carry rabies is if it has been properly vaccinated. Therefore stray dogs carry a particular risk.

N.B. Other animals such as cats, ferrets and especially bats may also carry rabies.
Bites, or licking of broken skin, or contamination of mucous membranes constitute exposure risks, and so demand treatment.

N.B. Symptoms may present up to 1 month after exposure!

POST-EXPOSURE TREATMENT
Wash wounds thoroughly with clean water for 15mins. Then use disinfectant.

Administer human (or horse) immunoglobulin IM on the day of exposure at 20 IU/kg (or 40 IU/kg for horse IG) into the deltoid or thigh (*not the buttock*) or up to 7days afterwards, if presenting late.

Also administer vaccine on days 0, 3, 7, 14 & 28, or 2 doses into opposite limbs on day 0, and the one on days 7 & 21, at a point distant from the IG injection.
An alternative, if available, is to administer 0.1mL of the vaccine intradermally.

For those previously vaccinated, but where the vaccine used is suspect, or in immunosuppressed individuals, use one dose of vaccine.

If there is a severe injury, especially of the face, instil IG around into the wound site (after cleaning it thoroughly), if necessary diluted x2-3, leaving the remaining amount for IM administration as above.

Do not forget tetanus & antibiotic prophylaxis!

If the animal culprit has been captured, but shows no signs of illness after 10days, rabies prophylaxis is unnecessary.

46.10 Animal bites & injury

Consider all animal bites as serious. At least they transmit simple bacterial infection, and at worst may introduce rabies, or cause serious tissue damage. Worldwide, the majority of bite injuries are caused by dogs, followed by snakes (46.11), cats and humans.
The highest risk population for dog bites is children. Up to 50% of urban populations may suffer a bite injury during their lifetime.

Large animals obviously may cause much more damage than small; no animal can really be called tame, and all may decide to attack, especially if they feel threatened.

The tendency is to over-estimate injuries by large animals, and under-estimate those by small ones.

Exploding populations in some parts of the world encroach into wild animal kingdoms, with inevitable conflicts. However, most animal injuries are from domesticated beasts. Nonetheless, many of these, particularly dogs, may be stray. Dog bites make up 96% of all animal bites seen in India.

In most cases, an animal will bite just once: this may result in an abrasion, puncture wound, avulsion, laceration, with vessel, nerve or tendon damage. If the animal (such as a cat) has sharp teeth, there may be deep penetration without obvious external injury.

Most small animals cause injuries to the feet, lower limbs, and hands used to ward off the animal, typically on the extensor surface of the mcp joints. In children, the face may be at the same level as an animal's mouth; in crawling infants, the whole body is at risk: for example, a child's buttocks & head are often attacked by a hyena. In some regions affected by many years of conflict, carnivores became used to dead human bodies scattered in the bush, and acquired a taste for human flesh. Hyenas were not only attacking lonely children in the bush but also entering huts in villages to attack people.

Rodents, which include bats, beavers, chipmunks, gerbils, guinea-pigs, hamsters, lemmings marmots, mice, opossums, raccoons, rabbits, skunks, squirrels, rats, and voles may also attack humans, and pass on viral disease as well as worms.
Clasically rats can produce fever, leptospirosis & scrub typhus. Their bites are usually unnoticed, and found by blood marks on bed sheets, especially on persons with peripheral neuropathy on both lower legs and feet (rarely the sole).

You will see painless multiple separate bleeding abrasions with linear sharp or serrated edges of varying length. Administer doxycycline or azithromycin.

Larger animals may cause crush injuries, fractures, and deep soft tissue damage.

Whilst most patients will volunteer that they have been bitten by an animal, they may ignore or deny being *bitten by a human!* However, human bites are common where biting is a recognized means of fight or attack. They transfer more bacteria compared to dog and cat bites as the human mouth has a wider variety of germs (c. 10^8 bacteria/ml saliva).

All animals' mouths contain quantities of germs of different species, including anaerobes. They may transmit tetanus (46.7), and rabies (46.9), but also flea-borne typhus, plague and ticks, which themselves may be carriers of haemorrhagic fevers!. The infection rate is higher from cat (20-50%) than from dog bite (3-20%), but may be similar to human bite (10-50%). Some 40% of hand bites develop infection.

Injuries may be abrasions, lacerations, crush or degloving injuries.

RESULTS OF PRIMARY CLOSURE OF A DOG BITE

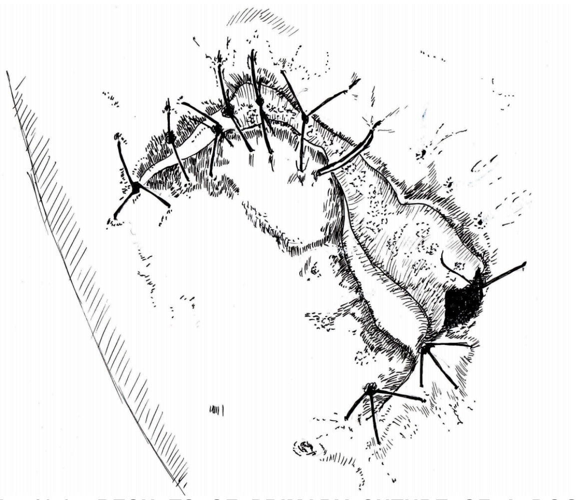


Fig 46-25 RESULTS OF PRIMARY SUTURE OF A DOG BITE. There is septic dehiscence of the wound, further tissue damage, and risk of life-threatening sepsis.

The golden rule is to clean an animal bite wound thoroughly, if necessary by opening it further, and leaving it open. *Be careful to remove all foreign bodies.*

DON'T CLOSE ANIMAL BITE WOUNDS PRIMARILY

Even on the face, it may be best to leave wounds open for 24-48h. *You must carry out a very thorough and meticulous lavage before risking closing a facial wound.*

N.B. Never apply herbs, chalk, or spices!

FIRST LINE ANTIBIOTIC TREATMENT
Use co-amoxiclav for 5-7 days. For deeper wounds of the hand, wrist or foot, and for human, cat, pig, wild carnivore and monkey bites, administer at least 2 antibiotics:-
(1) Dog & human: clindamycin 500mg bd (15mg/kg in children) and/or ciprofloxacin 500mg bd (10mg/kg in children) 3-5days, with metronidazole 400mg tds (7.5mg/kg in children) 5-7 days
(2) Cat & rodent: doxycycline 100mg bd (or cefuroxime 15mg/kg bd in children) + metronidazole 400mg (7.5mg/kg in children) tds 5-7days.

Use IV antibiotics for serious wounds, *i.e.* those with:-
(1) deep puncture,
(2) crush injury,
(3) inflammatory, venous or lymphatic swelling,
(4) involvement of bone, tendon or joint,
(5) neurovascular damage & tissue loss,
(6) an immune-compromised host.

N.B. This is not prophylaxis: these wounds are already infected!

N.B. Don't irrigate fluid into *the tissues to clean a wound!*

N.B. Transmission of HIV & Hepatitis is more likely, in human bites, to occur from the victim to the aggressor than vice versa.

Distinguish, especially in the face, between wounds where there is significant tissue loss, and superficial injuries. The former may need special attention (53.7)

Animals may also transmit diseases apart from tetanus & rabies: typically dogs carry fleas, cats *Bartonella* (causing cat-scratch disease) for which azithromycin is best, rabbits Tularaemia (best treated by gentamycin) & many cats, dogs, rabbits, cattle & pigs *Pasteurella* (best treated by co-amoxyclav).
The dog or fox may transmit hydatid disease (15.12) with sheep, cattle & pigs as secondary hosts.

SEPTIC DOG BITE OF THE HAND

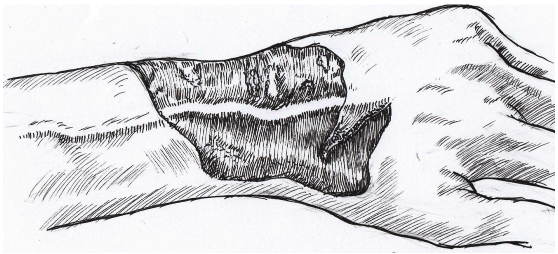


FIG 46-26 SEPTIC HAND AFTER A DOG BITE. The hand is often swollen; extension of the fingers will be painful or impossible. This needs exploration & lavage. *N.B.* There is also an extensor tendon injury of the little finger *(but don't try to repair this when the hand is septic:* just reduce the dislocation and splint the finger!)

BITES TO THE FACE

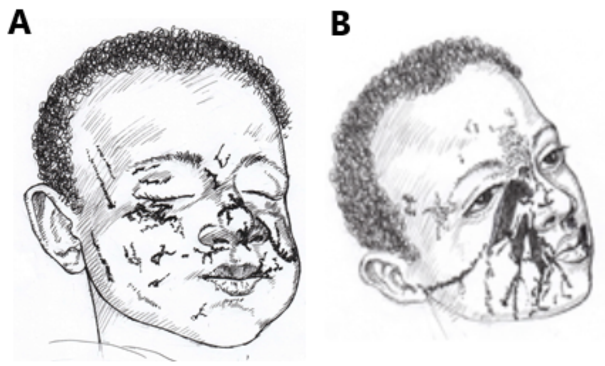


Fig. 46-27 BITES TO THE FACE. Distinguish between A, superficial injuries & B, tissue loss.

DOG BITE
By far the most common, these cause significant infection in 15-20% of cases. Some dogs are effectively medium-sized animals, and are carnivores. Several are by nature hunters (*e.g.* hounds, terriers, setters) and have powerful jaws with ferocious teeth.

The worst implicated are (in order of danger): Pitbull, Cocker Spaniel, Rottweiler, Mastiff (including the Great Dane), Wolf dog (including the German Shepherd, Husky & Malamute), Dobermann & Bulldog (46-28A-H). The Chihuahua, though seemingly small & innocuous, is also a biter (46-28I). However, rather than breed, a dog's training is a much clearer link to its readiness to bite.

N.B. Dogs may unexpectedly attack, and may do so in packs. The 'painted' dog & dingo is properly wild, and behaves as such.
Many dogs carry *Pasteurella* & A-haemolytic *streptococci* in their mouths. Cellulitis can easily develop quickly.

Whilst bites may occur anywhere, as dogs orientate themselves by an acute sense of smell, they may particularly bite the scrotum or perineum in adults & the head & neck in children.

If a victim has had a splenectomy, he may suffer rapid fatal septicaemia from *Capnocytophaga*, so treat with IV co-amoxyclav.

Bites of the hands or joints can readily lead to tenosynovitis or septic arthritis. Bites of the face quickly lead to septicaemia or meningitis. They may cause permanent disfiguring of the nose, ears, lips and eyes. Bites of the scrotum can result in Fournier's gangrene (6.21). Bites of the leg often heal slowly.

N.B. A large dog can take a child's entire head into its jaws!

DANGEROUS TYPES OF DOGS

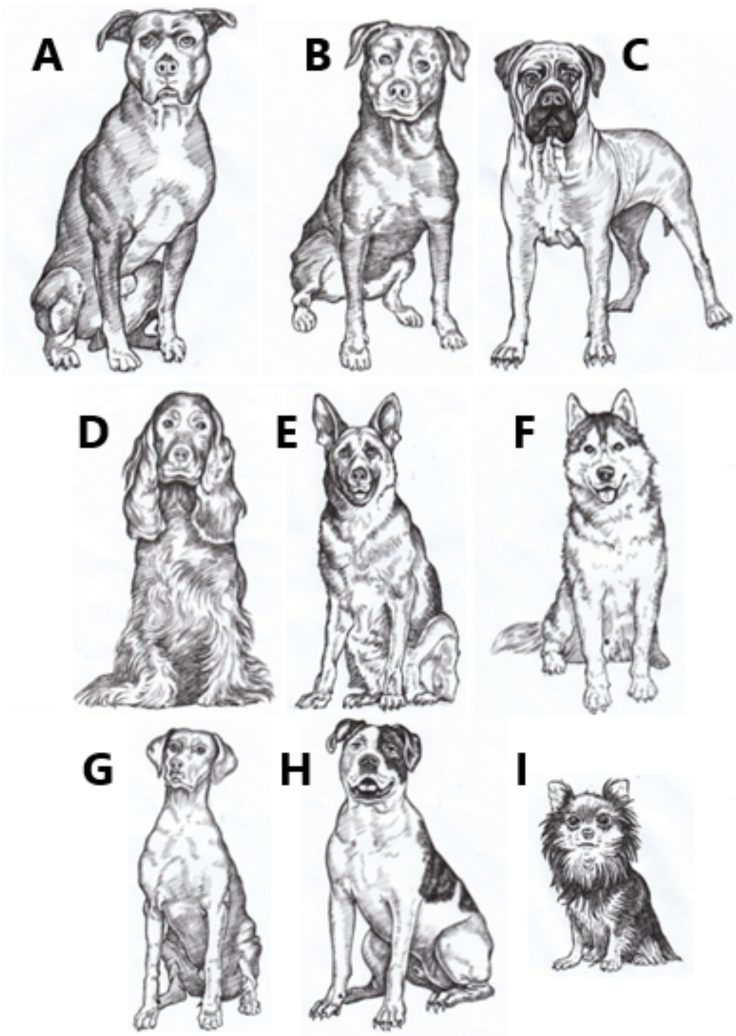


Fig. 46-28 DANGEROUS DOG TYPES OFTEN KEPT AS PETS: A, pitbull. B, rottweiler. C, mastiff. D, cocker spaniel. E, German shepherd. F, husky. G, dobermann. H, American bulldog. I, chihuahua. *(Not to scale)*

TO AVOID DOG ATTACKS
(1) *don't pet strange or chained dogs,*
(2) *don't let children play alone with dogs,*
(3) *don't run from a dog or scream,*
(4) *don't disturb a dog sleeping, running or feeding,*
(5) *don't look a dog straight in the eye,*
(6) *don't teach a dog aggression,*
(7) *don't tease an animal in pain,*
(8) *don't put a hand in a dog's mouth,*
(9) *don't put your face close to a dog,*
(10) *don't let a dog sleep in your bed.*

To try to prevent injury: *curl into a ball, and use a barrier (e.g. a shoe, a bag, a rolled up coat) to ward off the animal.*

N.B. Postmen are prone to injury from putting letters through door latches.

CAT BITE & SCRATCH
Second most common are injuries from domestic cats. Owing to their sharp pointed slender teeth and claws, puncture wounds tend to be small but deep. In contrast, scratches may be extensive.
N.B. Larger cats, such as the ocelot, cause different types of injury, but even small cats have the instinct to attack at the neck & head, and this may be catastrophic for children. If a cat holds by the neck, puncture wounds of the oesophagus & larynx are possible.

Pasteurella is found in 50-70% of healthy domestic cats. Some 80% of cat bite wounds become septic if untreated. *Bartonella* is found in fleas and rats that cats may catch; if such cats scratch, fever is very frequent after 10-14 days. Treat this with azithromycin.

The classic cat bite injury involves the dorsum of the hand, where the extensor tendons run just below the skin. A resultant tenosynovitis or septic arthritis can be a real disaster.
Don't under-estimate such injuries, but explore them, open up the skin & lavage the wounds scrupulously under GA, *as well as* treating with antibiotics.

WORKING ANIMAL INJURY
Amongst working (as opposed to domestic) animals are the camel, cow, horse, donkey, pig, goat, & sheep. The elephant is a special beast on account of its size (for which it is usually harnessed).

(a) The camel can bite aggressively if handled roughly: it attacks the head & arms. Its long mandibular jaw with incisors & canine teeth makes its crushing grip a deadly weapon. It can spit saliva or spew the foul contents of its rumen 2-3m. The camel may also crush or lift a person into the air and throw him forcefully down. It also has a powerful kick, and can demoilsh a 10x10cm building support! Compound fractures and severe wounds are common.

(b) The cow whilst normally docile, may suddenly behave abnormally. A bite is unlikely to be too dramatic, but may transmit brucellosis, and rabies, usually acquired from bats. However, a kick may cause a serious injury. Some cows are not vaccinated, and can transmit TB *not just in the milk!*
Cows may also cause injury through their horns penetrating the abdominal cavity. This typically results in bowel evisceration and risk of strangulation because of the small size of the abdominal wall injury (55.3). Bowel laceration is uncommon because of the horn tip is relatively blunt.

(c) The horse & donkey bite may occasionally cause an arm fracture, especially if it is caught in the reins. This can transmit tetanus as well as numerous viruses; fat necrosis is not uncommon. Like the cow, a kick may cause a serious leg, chest or abdominal injury.

(d) The pig or boar does not bite, but can injure with its tusks (especially the wild pig & hog), or head-butt a person in the rear.

(e) The goat & sheep rarely may cause an arm fracture, but are notorious for passing on ticks. A goat's horns may cause an impalement like the cow's.

CARNIVORE INJURY
Whilst individual injuries by carnivores are rare, their ability to attack and propensity to eat meat, makes them doubly dangerous. Many are by nature secretive predators, and so an attack is rarely foreseen.
Carnivores include rats, cats, bears, apes, monkeys, wolves, foxes, hyenas, crocodiles & sharks.
Rats, in particular, may transmit other serious diseases, such as haemorrhagic fevers.

MONKEY BITE INJURY

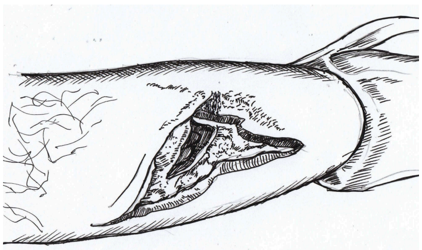


Fig. 46-29 MONKEY BITE ELBOW INJURY

To kill, carnivores usually grab the neck and drag the victim, who asphyxiates, is paralyzed or dies from blood loss. Few victims with bad injuries survive, especially as the attack often happens in the wild, far from medical help.
Unlike against dogs, to protect yourself:
(1) look large (arms & legs outstretched),
(2) *don't bend over* (*e.g.*to pick up a child),
(3) *don't turn your back*,
(4) *don't try to run away,*
(5) bare your teeth, shout loudly,
(6) use any object to defend yourself (even a camera tripod!)

Large cats have very powerful jaws and long, sharp teeth. Injuries are deep, wide and usually carry *Pasteurella*. Older animals, or those with badly injured teeth & dental abscesses, who cannot hunt animals for their food, might attack humans.
Some cats, such as tigers, are not afraid of larger animals, and so may attack a rider on a horse, or even an elephant.

LION BITE WOUND

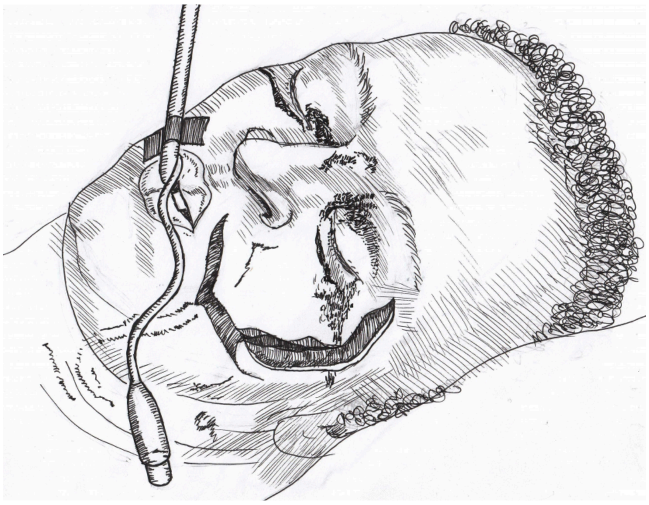


Fig. 46-30 LION BITE FACIAL WOUNDS (patient intubated)

Bears attack, usually in a standing position, with their powerful paws, claws & teeth and so usually inflict injury on the upper part of a human; mauling may result in deep soft tissue injuries & fractures, as well as crush injuries. The brown bear is more dangerous than the black, but less numerous.

Carnivores can pass on tetanus & rabies, and bears have been known to pass on hepatitis, cysticercosis, brucellosis & leptospirosis.

MONKEY & APE BITE & SCRATCH
Bites and scratches are inevitably infected. In India they are second in frequency to dog bites. They need vigorous cleansing, but may also carry harmful viruses, including Ebola.

Prophylactic vaccination may be advisable depending on location. Acyclovir probably limits transmission of some viruses.

FLYING MAMMAL BITE
Many species of bat exist; though their bite is tiny, they can transmit viral, parasitic, fungal and bacterial infection, *e.g.* rabies, histoplasmosis & encephalomyelitis.
Vampire bats, common in Central & South America, are notorious in transmission of rabies.
A rabid bat will die in 15days, but a bat feeding on cattle treated with warfarin may die of haemorrhage, but may still transmit rabies & nipah virus!

Bats bite on exposed surfaces, such as toes, fingers, nose, & ears. Proofing the lodging against their entry is important; a mosquito net is inadequate. *Don't touch these animals!*

INJURY FROM PLAINS ANIMALS

(a) The rhinoceros, and hippopotamus are enormous animals weighing several tons. The rhinoceros has poor eyesight and is guided by smell; it turns its nose into the wind when it walks. It can charge unexpectedly, and trample a person or gore with its horn.

(b) The hippopotamus is fearsome, and if a mother is separated from its young, may rapidly attack, crunching a canoe in two with its huge jaw. Its teeth are blunt but its force awesome.

(c) The buffalo is responsible for more deaths than any other wild animal in the plains. Its horn carries mud & dirt; the buffalo uses it to butt and gore, for which it flexes its neck. An injury to a human is therefore often in the chest. It hardly ever bites.

(d) The giraffe & zebra can give a fearsome kick, but rarely come close to humans.

(e) The elephant is huge and has tusks that can do great damage. Its trunk is very powerful and can uproot trees. Although it treads very carefully, it can charge through the bush at up to 40km/h. Some elephants who have lived near war zones, or where poaching is frequent, become very skittish. Most close encounters are fatal, as the chest or head is trampled, or a person is tossed after being picked up by the truck, or crushed with the knees; but a victim may sometimes survive being pushed over.
Some elephants have gone wild during pageants, and then run through crowds with disastrous effects.

INJURY FROM WATER ANIMALS

(a) The crocodile, aligator, caiman & gharial generally grab their victim using their teeth and use their enormously strong jaws to pull a victim into the water to drown them.

Obviously the huge sharp teeth may cause serious injury. You must remember, for those that escape, that the oral flora of crocodiles & alligators are faecal in origin. Suitable antibiotics must cover anaerobes.

(b) The shark attacks to kill. Therefore any such injury is likely to be very serious and quickly fatal. The rare survivor's bites may be infected with *vibrio, pseudomonas, staphylococcus, micrococcus or citrobacter*. Suitable antibiotics are: ciprofloxacin, cefuroxime, doxycycline, and co-trimoxazole.

SHARK BITE WOUNDS

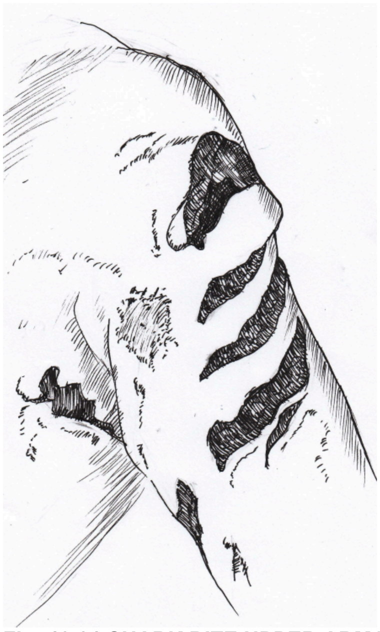


Fig. 46-31 SHARK BITE UPPER ARM WOUNDS

MANAGEMENT

There is usually much drama; you should act logically & professionally. Follow the route of care of the severely injured patient (41.2), paying particular attention to airway (especially if the neck has been attacked), breathing (if there is a penetrating or crush injury of the chest) and circulation (if there are deep wounds, crushing, or frank haemorrhage).

Attempt to staunch an overt bleeding by pressure, packing or tamponade. Try to stabilize the victim and then attend in more detail to the particular injury. This is the classic case for damage control (41.5).

Try to get as detailed a history as possible, the type of animal responsible, and first aid treatment already given (this may not have been particularly appropriate). Make sure people are protected from further attack.

Don't try to make sophisticated repair to widely damaged tissues! Your first priority, after resuscitation, must be debridement and copious lavage of the wounds. You might have to do this several times, before you can attempt any sort of repair. *Never close the wounds primarily!*

Don't forget tetanus & rabies protection, antibiotics.

Document the wounds with photographs; you may need to inform the authorities to report the incident.

(c) The garfish (which lives in the Pacific) has a very pointed beak, 2 jaws and many sharp teeth. It is attracted to light and leaps out of the water, and struggles vigorously when impaled. Like the **stingray**, its injuries are effectively deeply penetrating stab wounds : an innocent-looking wound of the chest or abdomen may prove fatal, if unattended to.

GARFISH

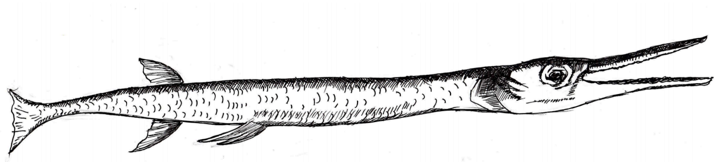


Fig. 46-32 The garfish has a very pointed beak which can cause long «stab» wounds.

(d) Fish bones & spines frequently carry *Staphlococci* & *Streptococci,* as well as anerobes. Despite antibiotic prophylaxis, these injuries usually need exploration and debridement to remove residual fragments of foreign organic material or proteins, unless they are very superficial, as necrosis otherwise supervenes.

46.11 Snake bite

Snakes are not the only species to cause venomous bites. Scorpions & spiders (46.12), & jellyfish (46.13), may cause complicated wounds.

Bites are a worldwide phenomenon, but are still a relatively neglected problem. Officially, WHO estimates between 1-5 million bites/yr, and between 420,000 & 1,800,000 envenomations with 20,000-94,000 deaths annually, though true figures may really be twice these numbers.

Snakes are quite common in tropical and subtropical zones, but exist as high as 4000m or 100m deep in the sea! They bite using fangs and inoculate venom secreted by oral glands.

SNAKE VENOMS are powerful enough to subdue preying animals much smaller than humans. They are the most complex of all natural poisons, and any one species may contain >100 different toxins, not all proteins.
Bites usually occur mainly during farming, when collecting wood, or walking bare foot (over 80% of cases), especially in the rainy seasons at night. Some 20-40% of victims are children.

There are 4 main families of snakes toxic to humans: *Atractaspis* (asp), *Colubrids* (boomslang), *Elapids* (cobra, mamba, krait & coral snake), & *Viperids* (viper, adder). Their ill effects may be dose-dependent or time-dependent.
N.B. Bite is not synonymous with envenomation, as venomous snakes inject venom in c.50% of cases only.

Though you may not have the chance to see the culprit snake, or it is brought to you mangled out of recognition, there are signs to make you suspect a venomous type of snake (46-33)

DIFFERENCES BETWEEN SNAKES

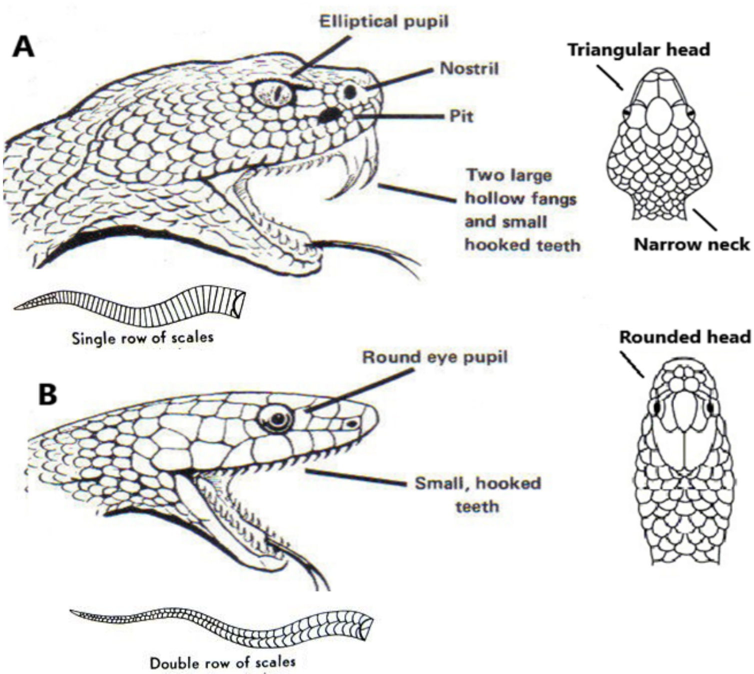


Fig. 46-33 DISTINGUISHING BETWEEN SNAKES: A, venomous snakes have an elliptical pupil, a pointed snout, a heat-sensing pit, a broad rounded head & skinny neck, 2large fangs, and single scales. B, non-venomous snakes generally have around pupil, no pit, a rounded snout, a triangular head and double tail-end scales.
N.B. The legless lizard has ear openings and a short fat tongue!

Broadly, venoms are of 3 categories: neurotoxic, haematotoxic and tissue toxic. There are also myotoxins, hypotensive agents, and cardiotoxins.
The 1st antivenoms were developed >100yrs ago, but their manufacturing process has changed little and usually uses horse serum.

N.B. Snakes' tongues are not dangerous !
N.B. There are many folkloric beliefs surrounding snake bites! Don't ignore these.
N.B. The Bibron stilletto snake has fangs on the side of the mouth, and so attacks in quite a different way to other snakes.

SNAKE BITE WOUNDS

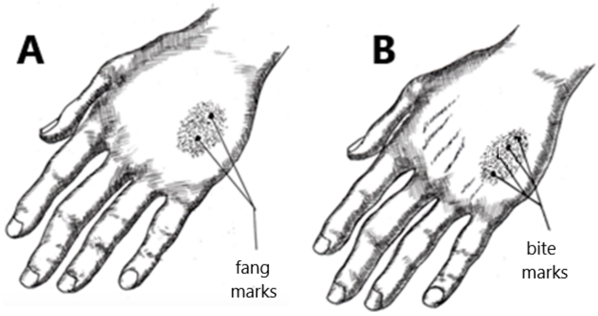


Fig. 46-34 SNAKE BITE WOUNDS. Careful examination may enable you to distinguish between A, fang marks of a venomous, and B, bite marks of a non-venomous snake.

PREVENTION

If the sight of a snake does not please you, *be sure that the opposite is also very true*! They will usually do their best to avoid you and will bite only if in danger, trapped or surprised. Preventive measures based on an adapted behaviour are key!

To reduce your snake bite risk:
(1) *Don't put your hands in unchecked, especially dark, areas* (closed shoes, cupboards, tent/bed if it was left open, WC, crackles between stones…).
(2) Make noise when walking and use a torch at night. If you stop, listen: snakes will often make a hissing or whistling noise before biting.
(3) *Never walk barefoot*, but use good, closed shoes. Light-weight boots are available for work in paddy fields for example.
(4) If you stop under a tree, have a look in its branches, as some snakes live in trees.
(5) Use a mosquito net and put it well under your mattress. Raise your bed off the floor.
(6) *Don't keep livestock in the house* (esp. chicken) and keep food in rat-proof containers.
(7) In a compound, *don't provide hiding places for snakes* (rubbish, wood, building materials, termites mounds).

(8) Keep the grass short and the ground clean around the house.
(9) *Don't collect firewood at night*.
(10) *Don't kill every single snake you see*! They are necessary in the balance of the local wildlife!
(11) Know which snakes species are prevalent in your area, be informed about their habits and try to learn how to discriminate between them.
(12) **If you cross a snake**, stay calm and back away slowly! Offer it an exit. *Don't trap it*! Remember: they can move fast and some (spitting cobras) can spit up to 2-3m usually targeting your head. So protect your eyes (spat venom is not absorbed through intact skin).
(13) *Avoid touching snakes*, even dead, as their venomous glands may still be full. *Remember: freshly beheaded snakes' heads or dead snakes might still bite by a simple reflex*.
(14) A snake, which has bitten, has not necessarily emptied its venomous glands! *So avoid it.* Even a decapitated snake can bite!

INITIAL TREATMENT
(1) Reassure and calm the patient!
(2) Secure the place and prevent any further bites.
(3) Keep the patient warm, quiet & immobile.
(4) Remove from the bite side any constrictive jewelry and clothes.
(5) Immobilise the affected area/limb.
(6) Disinfect the area of the bite with an antiseptic and cover with a dry, clean dressing.
(7) Distinguish between fang marks & a snake bite (46-34)
(8) If venom is in the eyes (spitting cobra): wash them immediately with a lot of water!
(9) Attempts to identify the snake are often futile or erroneous; *don't try to kill or touch the snake!*
(10)Take a photo.

N.B. Never apply a tourniquet and *don't lift an affected limb*.

MONITORING
Monitor for the following every 10mins for the 1st h and then every 30mins for 24h.
Measure the pulse, blood pressure, respiratory rate and GCS.

N.B. Some snakes such as boomslang can have effects after 5days.

Note any general or local symptoms such as nausea, vomiting, dizziness, headache, blurred vision, breathing troubles, muscle weakness, mental confusion.
Check for fang marks (though they may be hidden), local signs of swelling, tenderness, or bleeding, and regional lymphadenitis or lymphadenopathy.

TREATMENT
If pain is severe, administer paracetamol 1g qds, or tramadol up to 100mg (lower doses for children.

N.B. Don't use aspirin, NSAIDs, and don't use IM injections. Don't apply ice or cold water, nor potassium permanganate. Don't use a tourniquet, compression, nor aspiration devices to suck out the venom! (*e.g.*: Venon-Ex®, Aspivenin®), *suction, incision, cryo-therapy, snake stones, electric shocks nor herbal remedies.* They are not efficient and not recommended.

Establish a wide-bore venous access and administer 2l 0.9% saline (or Ringer lactate) and repeat this if the BP <90mmHg.

If there is respiratory difficulty (often presenting as mental confusion), or bulbar palsy, introduce an endotracheal tube early and assist the ventilation with oxygen.

N.B. You may have to do this manually by shifts: this can save a patient's life.

The stress of snake bite is great: administer prophylactic anti-histaminics such as cimetidine or ranitidine. Promethazine 25mg IM is useful.

NEUROTOXIC EFFECTS OF SNAKE BITE

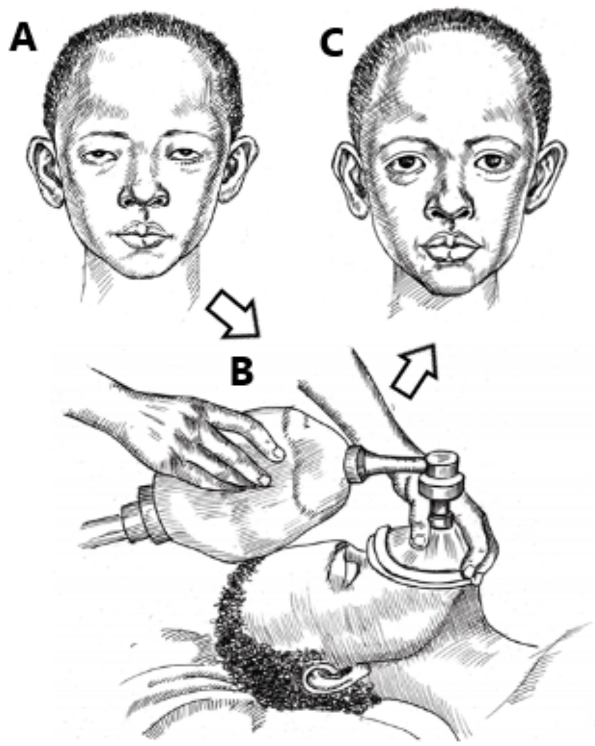


Fig. 46-35 NEUROTOXIC EFFECTS OF SNAKE BITE. A, ptosis, inability to lift the upper eyelids. B, manual ventilation. C, full recovery.

NEUROTOXICITY

Look for ptosis (usually the first sign: ask the patient to look up and observe whether the upper lids retract fully), ophthalmoplegia, mydriasis, dysarthria & bulbar palsy (secretions pooling in the pharynx).

Ask about diplopia, dysphagia, dyspnoea, paraesthesia & numbness.
Check for the use of accessory muscles of respiration ('breathing with the abdomen') & cyanosis.

N.B. Most neurotoxins do not affect the brain, but there is often a sedative effect. Don't use steroids.

The neurotoxins block neuromuscular junction with high affinity to receptors, so the effect is not reversed by antivenom. In case of severe neurotoxicity with paralysis, perform a Tensilon test if you can. Inject 0.6mg atropine IV followed by a slow IV injection of 10mg of edrophonium chloride.

If there is a positive response with improvement of the strength and recovery from paralysis, administer neostigmine 50-100µg/kg and atropine 15µg/kg every 4h or in a continuous infusion. Monitor the response.

JABULANI (10 years) was climbing a tree to get its fruits when coming down he put his foot in a crack in the tree trunk, where unfortunately a black mamba had made its home. This snake opened its jaw wide and bit him. He screamed, jumped off the tree, but very quickly became weak. He could tell villagers who came to his aid what had happened and was quickly taken to a mission hospital nearby. By then he had become paralyzed, and was having difficulty swallowing. He was intubated, but because the hospital had no mechanical ventilator, he was ventilated manually by Ambu-bag (46-35) all the way to the city hospital 200km away where he was taken by ambulance. After 48h on a ventilator, he was extubated and made a full recovery. No antivenom was available to give him.
LESSON: Ventilatory help may be all a patient needs till the snake venom wears off.

HAEMATOTOXICITY

Look for early signs of abnormal bleeding (epistaxis, bleeding gums, fang site bleeding, haemoptysis, bruising, retinal haemorrhage, or vaginal bleeding.)

Check the whole blood clotting time by drawing 5-10ml of venous blood in a clean covered glass tube. Leave it undisturbed & wait 20mins, turn it upside down.

N.B. Use ordinary glass tubes, and make sure there is no detergent left inside! If in doubt, check with a healthy person as a control.
If blood runs out (no clotting), this is an indication for the antivenom treatment.
If blood does not run out & there is clotting, repeat the test after 2h.

N.B. Haematotoxins are usually pro- not anti-coagulants and cause consumption coagulopathy. So don't use anti-fibrinolysins or heparin.

If there is unclotted bleeding and you have no antivenom, transfuse fresh fresh frozen plasma or fresh whole blood.

TISSUE TOXICITY

Check for swelling of the foot, hand or limb, and signs of tissue necrosis *(especially from cobra or viper bites).*
Look for lymphangitis.

N.B. The compartment syndrome takes time to develop *(*and usually occurs with application of a tourniquet). *Perform a fasciotomy only after checking normal haemostasis when tissue pressures are proven to be high* (49.6)*:* bruising may look like necrosis!

N.B. The main cause of permanent disability in snake bite survivors is tissue necrosis. Some toxins cause thrombosis (producing dry gangrene), some endothelial or direct tissue damage (producing wet gangrene).
Administer anti-tetanus vaccine if not vaccinated in the last 5yrs

If there is tissue necrosis, debride the wound. *Don't puncture the blisters, don't inject around the bite, don't use ice packs.*
Use penicillin G 4MU 4hrly IV or erythromycin 1g bd IV as prophylaxis and **if necrosis is already present**, add metronidazole and gentamicin or chloramphenicol.

RHABDOMYOLYSIS

Look for trismus, rigidity and myalgia. Check for dark urine (myo- or haemo-globinuria), and if no urine is passed after 4h, catheterize the bladder.
Force a high urine output (2-3ml/kg/h) with 44mEq bicarbonate in 1l 0.9% saline running at 100ml/h. Monitor the calcium.

CARDIOTOXICITY

Look for signs of acute heart failure (hypotension, dysrhythmias & bradycardia). Check an ECG, and look for T-wave inversion or peaking from hyperkalaemia..

OTHER EFFECTS

Gastro-intestinal symptoms are relatively rare, and self-limiting. Occasionally pancreatitis (15.13) may result. In pregnant women, check for fetal distress or threatened abortion.

ANTIVENOM USAGE
These may cause serious allergic reactions from urticaria to fatal anaphylaxis. However in cases of serious envenomation, their use is the only way to avoid serious complication or death. *So beware of using antivenom when it is not needed, but don't fear using it because of reactions when it is needed!*

Use antivenom preferably within 6h of a bite; if there is still severe toxicity you can still use it days later, but the dosage may need to be higher.
Check the specificity of the antivenom.
Prepare adrenaline to have it ready to hand in case of anaphylaxis; measure out 0.3-0.5mg to give IM, (*never IV*). *Make sure you get this concentration right:* use an insulin syringe. Use 0.01mg/kg for children. Observe the patient closely for at least 2h after using adrenaline.

INDICATIONS for use are:
(1) incoagulable bleeding,
(2) circulatory shock not responding to volume replacement,
(3) worsening paralysis,
(4) decreasing conscious level,
(5) cardiac failure & ECG changes,
(6) severe limb swelling beyond the wrist for a hand bite, or beyond the ankle for a foot bite within 4h,
(7) increasing the circumference of a limb by >50% (compared to the opposite side) within 48h,
(8) Metabolic acidosis or acute renal failure.

N.B. Antivenom may be specific against one snake (monovalent)*, or pooled from many* (polyvalent)*. It is not necessarily active for every case.*
N.B. Most reactions are not caused by hypersensitivity to horse or egg proteins, so don't perform skin testing before using antivenoms; sensitization may result.
N.B. Keep antivenoms in the fridge but *don't freeze them!*

If there has been a known reaction before to antivenom & the indication is correct, administer 0.25mg adrenaline SC beforehand, but still prepare the emergency adrenaline as above.

Check the dose of antivenom (this is variable), dilute it in normal saline (5ml/kg), and administer it IV over 30mins. *Don't inject it into the wound or around the fang marks!*

Use the same dosage for children as for adults (as it depends on the amount of venom injected, *not body weight*).

Repeat this after 30mins, **if cardiovascular shock persists**, or after 6h **if there is no clotting, or no improvement in neurological signs**.

N.B. Systemic envenomation may recur several days after a good initial response, so keep the patient under close monitoring for 24-48h

DIFFICULTIES WITH SNAKE BITES
If a patient arrives with a tourniquet in place for >4-6h, *don't immediately remove it.* Ensure a good diuresis by infusing large volumes of saline. make a guillotine amputation (60.3) proximal to the tourniquet. Otherwise, release the tourniquet and observe for signs of rhabdomyolysis, or toxic envenomation. If the compartment pressure is >30mmHg (49-18), perform a fasciotomy. Such high pressures are only likely to arise from intra-muscular fang bites (*e.g.* by puff adders), *not in only subcutaneous bites.* Administer relevant antivenom if available.

46.12 Scorpion & spider bite

(a) Scorpion bite
Scorpion bites may be more common in some areas than snake bites. The bite is frequently very painful. Envenomation with sympathomimetic substances may occur, but is rare as only 2% of all species carry toxins. This may be confused with substance abuse.
The types of scorpion to avoid generally have fat bulky tails, and fine pincers.

PREVENTION
As with snake bites, it is important to avoid walking barefoot, especially in long grass.

TREATMENT
(1) Reassure and calm the patient!
(2) Administer adequate analgesia; this may mean opioids.
(3) Disinfect the area of the bite with an antiseptic, and infiltrate LA around it.

SYSTEMIC TOXICITY
Check the blood pressure & blood glucose as hypertension & hyperglycaemia are frequent signs of envenomation.

Look for excessive salivation, sweating, weeping, and muscular spasms & twitching, tachypnoea, & cardiac dysrhythmias.
Priapism may occur in children.

TOXICITY OF SCORPIONS

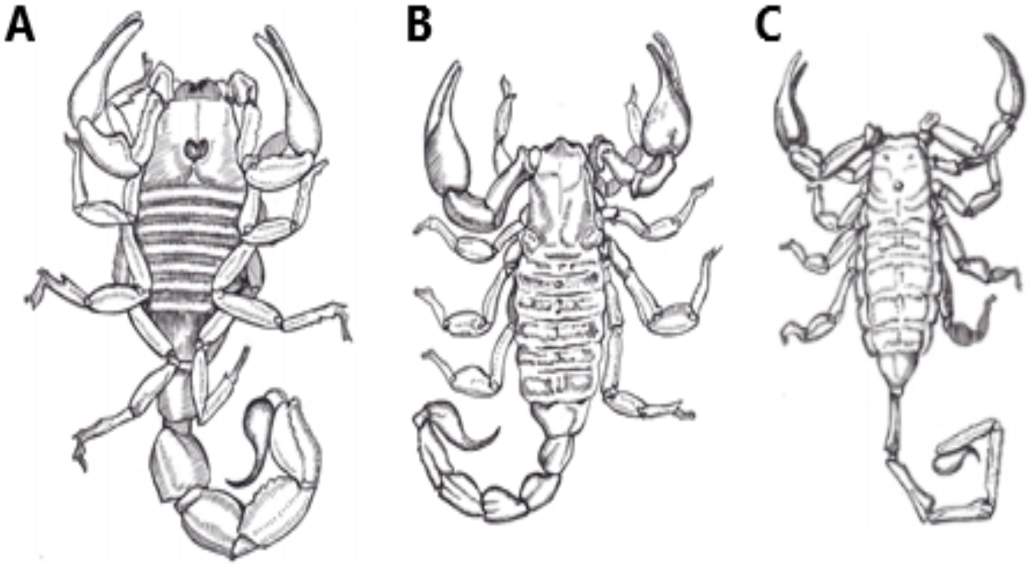


Fig. 46-36 HOW TO CHECK ON SCORPIONS. A, Thick tail & thin pincers: likely to be highly venomous. B, Medium tail & thick pincers: less so. C, Thin tail & thick pincers: not at all

Patients may vomit, complain of severe nausea and abdominal pain. Pancreatitis may ensue.

Later pulmonary oedema or respiratory failure may follow.
Use prazosin 0.5mg tds for hypertension, and diuretics for pulmonary oedema. Respiratory failure may need ventilatory support.
Antivenom is very rarely available, and is usually monovalent. Use it with as much care as snake antivenom.

(b) Spider bite
Typically these may occur when a child inadvertently crushes a spider hiding in a bed. Almost all spider bites are innocuous. The few venomous spiders, however, broadly have venoms of 2 groups: neurotoxic & tissue toxic,

In the 1st group are the Widow, Brazilian wandering, Australian funnel-web and Chinese bird spiders. In the 2nd group are the recluse and south African sand spiders.
The famous Tarantula is not very toxic to man.

Whilst their bad reputation far outstrips their actual danger, you should monitor any patient with a spider bite who complains of severe pain, or develops neurological symptoms.

PREVENTION
Keeping a house clean, removing cobwebs, and checking shoes before putting them on are simple wise preventative measures.

TREATMENT
Clean the bite wound thoroughly with antiseptic, and administer adequate pain relief. Look for signs of neurological deficit, and treat as for snake bites.
Debridement may be necessary for wounds presenting late with necrosis or secondary infection.
Antivenom may be available locally; use it with as much care as snake antivenom.

N.B. Patients may think they have been bitten by a tick or spider but actually have a primary necrotic skin infection.

Don't apply heat. Don't inject corticosteroids or antihistamines into the wound.

(c) Blister beetles
These cause painful vesicles.

46.13 Marine stings

(a) Venomous fish
Quite a number of fish can sting if they are touched or trod on. Extreme pain at the site of the sting is common, but most marine venoms are sensitive to heat.
Only a few are dangerous. If a fish spine or scale remains in the skin, it may cause necrosis & secondary infection, which may need debridement.

N.B. Don't try simply to pull out a catfish spine as it is barbed.

TREATMENT
Immerse the bitten part in hot water, taking care not to scald the victim, because sensation may be diminished around the bitten area. So check the water temperature with your own (or the patient's non-bitten hand)!
You rarely need to infiltrate LA around the bite.

SYSTEMIC TOXICITY
Vomiting, diarrhoea, sweating & bradycardia may occur, suggesting release of parasympathetic toxins. In this case, use atropine SC. You may need to repeat this.
Alternatively dysrhythmias, muscle spasm, flaccid paralysis, respiratory distress & convulsions may ensue, requiring artificial ventilation.

(b) Jellyfish
Jellyfish are found worldwide; they move rapidly pushing water behind their bell-shaped bodies. Their characteristic tentacles may be 2m long.
These have large numbers of nematocysts (stinging capsules) which fire off, injecting venom on contact, with a phosphorescent effect.
Some biochemical & mechanical stimuli, such as rubbing the tentacles off manually, cause them to discharge.
This causes intense pain, urticaria and inflammatory wheals (as in a histaminic reaction) with 'tentacle prints' but rarely systemic envenomation.

TREATMENT
Remove tentacles very gently after covering them with dry sand; deactivation of the nematocysts by bicarbonate, ammonia, vinegar boric acid, papaya, or meat tenderizer may help some species but aggravate others. Alcoholic solutions or fresh water generally fire off more nematocysts! Hot water (at 45º) may help reduce pain. Palm oil & lemon juice may be successful for box jellyfish off West Africa.

It is probably best to follow local knowledge (especially from divers). Otherwise remove each tentacle gently; using LA cream helps. Administer antihistamines.

Don't use full strength ammonia. Don't use a tourniquet.

SYSTEMIC TOXICITY
Though rare, this may be life-threatening; muscle cramps, hypertension and cardiac failure may ensue. Occasionally envenomation may occur with minor or unnoticed sting in deep waters.
Use magnesium 2g IV over 10mins to treat this.

If there are many tiny particles embedded superficially under the skin, dry the skin & apply sticky tape; then gently peel back the tape to pull out the spicules or spinules.

If you suspect retained fish spines or tentacles, radiographs or ultrasound may help locate them. Using LA, explore these wounds thoroughly and remove all foreign material, especially near tendons or joints. Use doxycycline 100mg bd prophylaxis.

N.B. Such wounds may be dangerous for immunocompromised patients, as they may contain Vibrio, Erysipelothrix *or* Mycobacterium *species.*

If an itchy rash develops inside swimwear after sea-bathing, these are caused by larvae from jellyfish and anemones ('sea lice'). Decontaminate the area with vinegar for 30mins, and apply LA cream. Administer antihistamines or prednisone if the reaction is more severe.

46.14 Missile Wounds

INTRODUCTION
Any moving body has kinetic energy. When a projectile penetrates human tissues, it releases kinetic energy causing a wound. There are 2 main types of wounding projectiles from weapons: bullets and metallic fragments, also called splinters, shards, and shrapnel.

N.B. **If the moving body does not enter the human body,** it still has kinetic energy, but causes blunt trauma: *e.g.* car crash, falling from a tree, blow from a blunt object.
All trauma, penetrating or blunt, is ultimately about how badly the transfer of energy causes damage to the tissues.
Only army doctors were familiar with weapon wounds in the past. Today, you may frequently have to deal with them, as guns are much more widely available. The standard surgical techniques will be enough to treat simple wounds (46.2).
For high-energy weapons causing high-kinetic energy wounds, it helps to understand the basic mechanisms how missiles cause injury.
This study is called wound ballistics, and will help you understand how different weapons cause different types of wounds *This will help you avoid under- or over-treating missile wounds.*

Though the study of ballistics is illuminating, when you face a victim wounded by a weapon, *you don't always know what weapon was used, and you* <u>*never*</u> *know how much kinetic energy was imparted at impact.*

The most important factor determining your successful management of a victim is close clinical assessment of the actual wound.

TREAT THE WOUND, NOT THE WEAPON.

(a) Bullet wounds

Weapons that fire off bullets include handguns (pistols and revolvers) and long guns (military assault rifles, hunting rifles, shotguns, submachine guns). Bullets are of different types and sizes and vary in their speed at the time of discharge.
They are constructed to be as aerodynamic as possible to increase their range and stability in flight. Bullet wounds in victims arriving at hospital are usually single with a small entry. An injury with multiple bullets is more likely fatal.

A bullet must be retained in the body if there is an entry but no exit wound.
If there is an exit wound, it can vary in size. The size of the wound and the amount of tissue damage depends on several factors.

N.B. According to International Law, all bullets used during armed conflict are not supposed to explode or fragment, but remain intact, so cause wounds rather than death. Such bullets have a full-metal jacket, usually copper, to prevent fragmentation on impact. However, some military bullets do break up and often the law is not obeyed.

(b) Fragment wounds

These are described in 46.15, and **Anti-personnel landmine wounds** 60.6.

BALLISTICS
Ballistics is the scientific study of the motion of a missile when fired, during its flight in the air, and in or through its target.
(1) *Interior ballistics* describes what happens inside a gun barrel when a shot is fired. This differs with the type of weapon and bullet and determines the 'muzzle' velocity of the bullet leaving the barrel.
(2) *Exterior ballistics* deals with the trajectory in the air of the bullet once it has left the barrel. Gravity, air resistance and crosswind deflection, stability of the projectile (spin and yaw), as well as any ricochet off an object all influence its flight.
(3) *Terminal ballistics* concerns what happens when the bullet hits the target, and the counter-effects (action & reaction) of the target on the bullet.
(4) *Wound ballistics* describes the effects when the target is biological.

DIFFERENT BULLETS
Different bullets have different construction, calibre (diameter) and mass.

BULLET TYPES

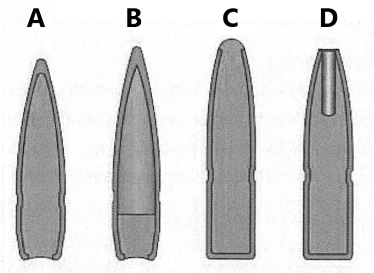


Fig. 46-37 BULLETS ACCORDING TO CONSTRUCTION. A, military bullet with a soft lead core and a full metal jacket of copper. B, hard core bullet with greater penetration : the lead is replaced by steel or tungsten. C, semi-jacketed bullet, (the point is not jacketed), should only be used in hunting animals. D, a hollow nose tip hunting bullet. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

HUNTING AMMUNITION

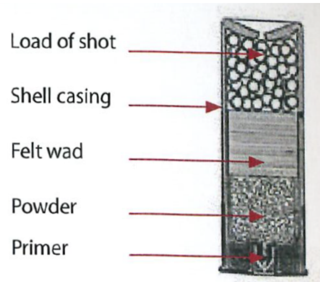


Fig. 46-38 SHOTGUN SHELL WITH BUCKSHOT. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

Although hunting ammunition should not be used in war (as its purpose is to kill, not wound), you may still see such injuries in accidents, or from banditry or terrorism.

Other, special rifles and ammunition are made for hunting: shotguns whose cartridges give off multiple lead shots (spheres).

MUZZLE VELOCITY
Low-velocity handguns fire relatively heavy bullets at speeds of 150-400m/sec when they leave the barrel. High-velocity rifles fire smaller bullets with a muzzle velocity of 700-1000 m/sec.
N.B. These velocities don't tell you anything about the speed of the bullet when it actually hits a victim.
However, high velocity bullets produce a cavity which causes much damage (46-40)

RICOCHET
During its flight a bullet may hit the branch of a tree, a concrete wall or stone, a belt buckle, or a soldier's helmet. The bullet gets a small 'push' that destabilises it (46-38). It hits its target at an angle and causes more tissue damage, like a wound made by a fragment. A 'big' push may even deform or fragment the bullet before it impacts.

RICOCHET EFFECT

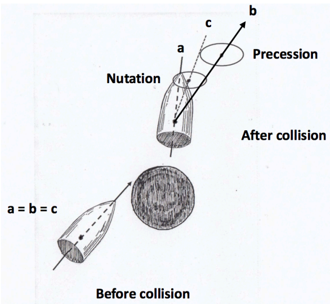


Fig. 46-39 RICOCHET: effect on a bullet after collision with an obstacle. The trajectory is changed (from b along a), but the energy impact is transferred in the arc acb. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

TISSUE CONSEQUENCES

So, several variables influence a missile before it impacts, and determine its effect on the target. The factors contributing to the severity of the wound include:

(1) the kinetic energy at moment of impact,
(2) the form and shape of the projectile,
(3) the type of weapon,
(4) the stability of the missile in flight,
(5) any disturbance in the flight or at the moment of impact.

The kinetic energy of any moving object is half its mass times its velocity squared: $E = \frac{1}{2}mv^2$

If a bullet passes through tissue, the energy transferred is $E = \frac{1}{2}m\ (v_1^2 - v_2^2)$ where v_1 is the entry and C the exit velocity.

If there is no exit wound, all the kinetic energy is transferred (v_2=0).

If a bullet breaks up into fragments, then the mass (m) also changes.

The total kinetic energy tells you the *potential* of a bullet to cause tissue damage; the transferred kinetic energy tells you the *capacity* to cause damage. The amount of tissue damage depends on how efficient the energy transfer.

Laboratory experiments to simulate what happens to human tissue use gelatine or soap blocks & give 5 types of projectile behaviour:

(a) Tumbling of the non-deforming rifle (full-metal jacket) **military bullet**, e.g. AK-47 Kalshnikov.

The bullet impacts at >600m/sec and forms a 10-15cm long straight narrow channel of diameter c.1.5x the calibre of the bullet. Then there is a a cavity formation c. 10-15x the calibre of the bullet, where it turns a full 180°, presenting its complete lateral surface to the tissues. Here resistance to its forward speed is greatest, and so transfer of energy greatest.

TUMBLING EFFECT OF A BULLET

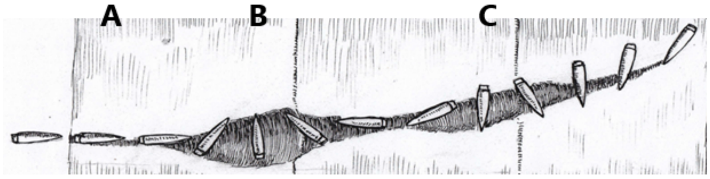


Fig. 46-40 BALLISTIC EFFECT OF A TUMBLING BULLET, *e.g.* from an AK-47 rifle travelling at >600m/sec causing A, a narrow channel. B, a short cavity. & C, an enlarged cavity of destruction in its path *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

The formation of the cavity results in forced pressure on the tissues outwards. Finally, the bullet tumbles, and having turned 270°, always ends up pointing backwards.

There are usually 3-4 pulsations of the resulting 25cm long tissue cavity, in which a vacuum is created which sucks in air, and contaminants from the outside, through the entry, and exit hole (if there is one). The elastic properties of the tissues, as well as the amount of energy transferred, determines the size of the cavity.

Different bullets from different rifles have different 'shooting profiles', but all follow the same basic pattern. How soon the bullet starts to tumble and create the temporary cavity depends on its mass, centre of gravity, shooting distance, and stability when it hits its target.

(b) Mushrooming of deforming & fragmenting ('dum-dum') rifle & handgun bullets.

If a bullet, especially if the shooting distance is short (30-100m), flattens, bends, or then fragments releasing the lead inside and giving a typical image on radiographs of a 'shower' of lead, the transfer of energy is tremendous, the cavity larger, and tissue damage severe.

Deforming bullets change their shape, or 'mushroom', when they hit an object. This increases their presenting surface area without loss of mass.

MUSHROOMING EFFECT OF A BULLET

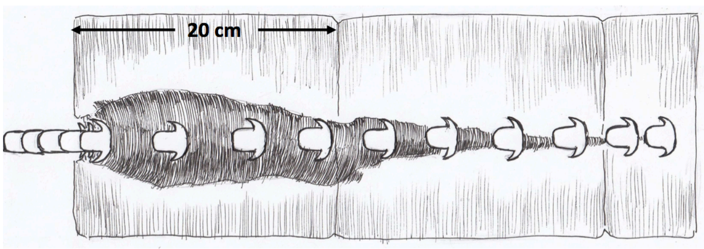


Fig. 46-41_DEFORMING SEMI-JACKETED RIFLE BULLET (SJ) mushrooms just after impact. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

There is almost no narrow channel and the temporary cavity forms almost immediately after impact, as the bullet releases all its kinetic energy (46-40)

N.B. The volume of the temporary cavities (46-36,39) is the same, meaning transfer of the same amount of kinetic energy. The difference is how deep the penetration of the bullet before maximum energy transfer, and the formation of the temporary cavity.

Hunting bullets always break up into fragments when they hit the target, creating a 'wall' of particles, which also increases their surface area; but they lose some mass.

(c) Ricochet effect of a bullet.

A rifle bullet striking an object before it hits its target is destabilised and immediately presents its largest lateral surface area to the medium. The maximum transfer of kinetic energy is immediate and resembles what happens with a deforming bullet.
This has significant clinical consequences, creating very large wounds from ordinary military rifle bullets. *They are not caused by 'illegal' dum-dum bullets*, but by people who cannot shoot straight!

(d) Straight trajectory from non-deforming handgun bullets.

Handgun bullets are usually heavier than rifle bullets, but shot at much lower velocity. There is little destabilisation of the bullet and no tumbling. The bullet tip points forward and penetrates deeply. The temporary cavity is long and narrow. (Fig. 46-42)

NARROW BULLET TRAJECTORY

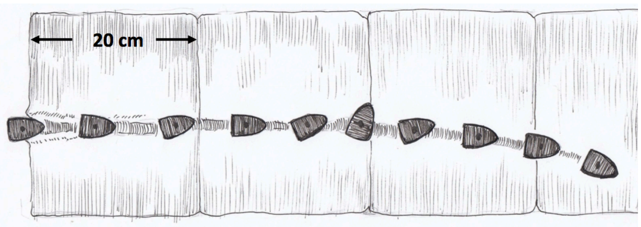


Fig. 46-42 A NON-DEFORMING BULLET at lower velocity penetrates deeply along a narrow channel. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

(e) Coning effect of fragments.

As fragments from the explosion of a bomb or grenade are irregular in shape, because of high air friction, their velocity decreases rapidly with distance and they have an irregular rotation in flight.

CONING EFFECT OF ONE FRAGMENT

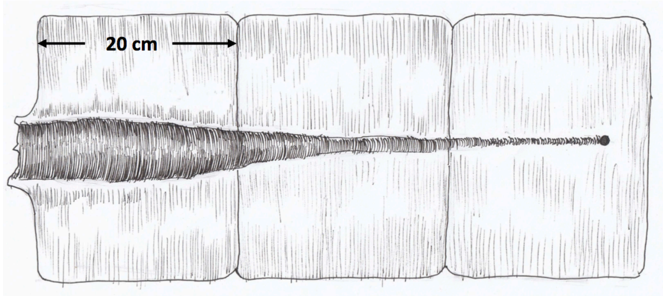


Fig. 46-43 CONING EFFECT. Profile of a metallic fragment: the widest point is at its entry. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

When such a fragment impacts, it presents its biggest cross section, and immediately transfers its energy. There is no tumbling. The cavity is largest at its entry, is 2-10x the diameter of the fragment, but becomes smaller like a cone.

Any exit wound is smaller than the entry. A heavy and slow fragment (with the same kinetic energy) has a smaller entry wound, but penetrates further.

CAVITY EFFECTS OF FRAGMENTATION

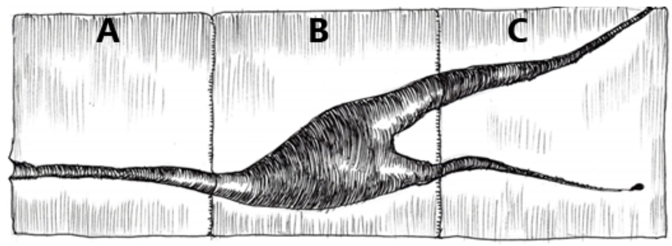


Fig. 46-44 FRAGMENTATION OF A BULLET. Typically, this deviates downwards and increases the size of the cavity, making it have two 'arms' The main part of the bullet ends up superiorly in C, but a flake of ejected lead remains in B and the rear part of the bullet inferiorly in C. Each segment is c.20cm long. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

Certain bullets deform or break up especially when fired at shorter rifle range (30-100m). The bullet flattens on its side, bends in the middle, breaks and spills out the lead inside the shell. This occurs at impact velocities ≥600m/sec.

WOUND CONSEQUENCES
The most important clinical factors you must keep in mind are the anatomic structure injured and the extent of actual tissue damage.

If the bullet path in the body is long enough, the same phases occur as in laboratory models. Permanent and temporary effects depend on the tissue types that are injured. Local energy transfer either compresses or shears tissues, causing crush or stretch.

(a) Crush injury
By compressing and crushing the tissues, direct contact of a handgun bullet or small and slow fragments cause permanent damage. With a tumbling or deforming bullet, a larger area of tissue is crushed.

(b) Stretch injury
Most tissues resist stretch to a certain point because they have an elastic tensile strength.

During cavity formation, displacement of the tissues away from the missile track stretches the tissues, The size of the cavity depends on the amount of transferred energy and the elasticity of the particular tissues.
Stretch is added onto crush of the tissues. High-energy transfer creates a bigger cavity, and the wounds are obviously more serious.

Tissue factors
Different tissues and organs have different resistance to crush and stretch. Lung parenchyma and the skin are elastic and stretch easily, but are readily crushed. Skeletal muscle and the empty bowel tolerate stretch well. Non-elastic organs, such as the brain, liver, spleen, and kidney, shatter if they are stretched. Nerves and tendons are mobile and blood vessels elastic; stretch simply pushes them out of the way.
On the other hand, cortical bone is dense and rigid and resists stretch. It is mostly damaged by crush.

But **if the cavity is formed in a large mass of muscle**, such as the thigh, and with enough energy transfer, the diaphysis of the femur can be bent enough to break, thus creating a fracture without a direct bullet wound.

Different parts of the human body are a mixture of rigid and elastic tissues. There are fascial compartments enclosing muscles, tendons and ligaments, blood vessels and nerves, bones and other soft tissues. Each tissue has its own tensile strength and the effects on the mixture of tissues can be very complicated.

In addition, some organs are dynamic or have anatomic boundaries. If you try to stretch an organ that contains incompressible fluid, such as the heart, a full bladder, a full stomach or full intestines, they may explode.

A bullet passing through an empty stomach creates a hole; cavity formation explodes a full stomach.
A bullet passing through the brain may avoid vital areas, but cavitation inside the rigid skull will destroy the brain.

CLINICAL APPLICATIONS
The near vacuum in the cavity sucks in air and contaminants (shreds of clothing, dust, bacteria etc.). The missile itself is not sterile, but does not contribute greatly to the contamination of the wound.
Clinically, it is important to understand that *all* these wounds are dirty and contaminated from the moment of injury.

You may be surprised by some strange effects. A heavy and slow bullet can damage more tissue by crush in the elastic lung parenchyma, which can accommodate stretch better, than that caused by a lighter, faster bullet with more kinetic energy.

However, the faster and lighter bullet creates more damage in less elastic tissue, such as the liver or brain, which does not deal well with stretch.

The typical 3 phases of an AK-47 bullet (46-40) are only visible if the bullet stays in the body long enough. The temporary cavity begins at c.15 cm depth and is at its maximum at c.25 cm.

If the bullet exits during the initial narrow channel formation, there may be very little tissue damage.

Exit during the formation of the cavity results in a large wound.

A small exit wound <u>after</u> the cavity formation, makes for severe damage in between.

So, don't be fooled by the appearance of the entry and exit wounds; there may be extensive soft tissue damage in between.

If a bullet hits bone, there may be only a small drill hole, or a few fragments, or severe comminution. It depends on which phase of the wound track the bone was hit.

INADVERTENT EXIT FROM THE CAVITY

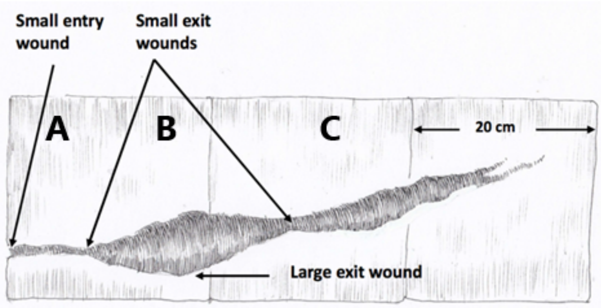


Fig. 46-45 INADVERTENT EXIT may occur before or after the cavity, depending on the length of the wound track in the body. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

In the case of a handgun bullet, the cavity is minor and the final wound almost entirely caused by crush, no matter how long the bullet track.
At very high impact velocity (>700 m/sec) and at close range (<50m), rifle bullets tend to break up. Some of the lead fragments crush the surrounding tissue, and the stretch of the cavity then acts on these damaged tissues. The damage is severe. Shotgun pellets at short range, each pellet creating its own crush track, give the same severe result.

If you see this 'shower of lead' on a radiograph, beware of the possibility of extensive soft tissue damage.

If the bullet ricochets off an object first, the resultant wound looks like one created by a dum-dum bullet, with a large entry. A bullet may pierce an old-style flak jacket and the wound be more severe than if the soldier had not been wearing it.

The outer boundary of the temporary cavity represents a 'front' of compressed tissues, creating a *pressure wave*.

This pressure wave can cause disruption and thrombosis of capillaries, rupture a full bowel or the liver, and cause even retinal detachment or bone fractures at a distance from the wound track. The formation of the temporary cavity can also squeeze the blood vessels in the tissues, emptying them, and setting up a pressure wave that is transmitted along the column of blood. You may see thrombosis or dissection of the arterial intima.

Large, slow fragments crush more; small, fast ones cause more stretch. The wounds from large and slow fragments tend to be the same whatever the tissues; the wounds of small and fast fragments differ depending on the elasticity of the damaged tissues.

In all projectile wounds, there are reversible and irreversible pathological changes and inflammatory reactions. You may find it difficult to distinguish at operation those tissues that will heal from those that are nonviable.

As with all trauma, a close clinical examination is of the utmost importance. You may see a victim with entry and exit bullet wounds in the shoulder, with no obvious haematoma nor oedema and muscles soft on palpation and with no evidence of fracture. This patient may only need debridement of the entry and exit wounds under local anaesthesia and antibiotics and analgesia for 5 days.

Don't forget: small missiles may cause small, or large & severe wounds. A small entry wound can hide serious internal damage. *Nothing replaces good clinical examination of the victim and the wound!*

46.15 Wound scores

Even experienced surgeons cannot tell the true extent of tissue damage of penetrating wounds. There is no uniform pattern, but the clinical significance of such injury depends on wound size, depth and site.

RED CROSS WOUND SCORE

E	Entry wound (cm)	1 – x (estimated)
X	Exit wound (cm)	0 = none 1 – x (estimated)
C	Cavity (>4cm = >2 finger width)	0 = <4cm 1 = >4cm
F	Fracture present	0 = none
		1 = simple, minimal comminution
		2 = major comminution
V	Vital injury	0 = none
	(penetration of dura)	N = neurological
	(penetration of pleura/larynx)	T = thoracic/trachael
	(penetration of peritoneum)	A = abdominal
	(penetration of vessels)	H = haemorrhage
M	Metallic body	0 = none
	(visible or on radiographs)	1 = single bullet or fragment 2 = two or multiple

Fig. 46-46 RED CROSS WOUND SCORE. E,X, Record the parameters: if entry & exit are impossible to distinguish, put a '?'. If there are multiple wounds, record the 2 most serious ; if one missile causes 2 wounds, join scores with a bracket. *Don't record tangential wounds.* C1 wounds are likely to produce significant tissue damage. F1 may be a comminuted fibula with an intact tibia. VH records serious haemorrhage (*not distal to the elbow or knee*). M, if radiographs are not available, put an estimate with a '?'. M2 from a fragmented bullet is more serious than from fragmented shrapnel. For a limb amputation, combine E+X, add C1 & F2 with VH if it is the upper leg or arm. *After Giannou C, Baldan M. War Surgery vol 1, ICRC Geneva 2010.*

A wound classification (46-46) helps keeping record of the injury, its management, and quickly provides information for everyone invloved.

The Red Cross score gives an easily understood and identifiable classification, which you can use to grade and type the wounds. There are obvious limitations, in particular to wounds of the head, thorax & abdomen, where the severity of a wound is rarely related to its size. The score is ideal for rapid use under extreme stress in adverse conditions, and uses no sophisticated technology.

46.16 Blast & explosion injury

DEFINITIONS
Many things can cause an explosive blast: bombs and shells, landmines, the fuel tank in a vehicle, a pressure cooker, or a gas cannister or kerosene stove used for cooking. Blasts can occur on the battlefield, in a home, or in a workshop or factory. Some are physical-mechanical (exploding pressure cooker), others involve an exothermic chemical reaction (kerosene or military-type munitions). Yet others are beyond the scope of this book: nuclear fission or fusion device. A “bomb” is a weapon that contains an explosive material whose chemical bonds, on detonation, are converted into heat: an exothermic reaction.

It gives off a powerful high-pressure energy wave that projects radially from its centre. Different names are given to explosive devices, usually describing the means of delivery: letter, pipe, car or aerial bomb; artillery or mortar shell; hand grenade and landmine.

Many military munitions are commercially available ; others are home-made and are called improvised explosive devices : they both contain manufactured munitions and their results are the same. Except during irregular guerrilla warfare, where assault rifles are the preferred weapon, explosive devices have injured and killed the most people during wars over the last century.

Explosives may be described as high- or low-order. Low-order explosives include gunpowder or a ‘Molotov cocktail’: petrol or kerosene in a bottle with a piece of tissue as a wick. High-order explosives are more powerful and are usually manufactured (TNT, dynamite, C4, Semtex).

They have civilian uses, such as quarrying or building dams, and are used in military munitions. High-order explosives can also be improvised using fertilizer and diesel fuel.

Disastrous gas explosions may occur in the home from faulty cookers, or supply pipes. Also, many electronic devices, such as laptops, mobile phones, e-cigarettes & e-bikes may overheat, and the ‘thermal runaway’ may cause the device to catch fire & explode.

Whether an explosion is due to a domestic or industrial accident, an act of war or an isolated act of terrorism, the fundamental physics involved are the same and a few basic ideas will help you to manage the victims of an explosion. The differences that you will see in the trauma suffered by the victim are due to the quantity and type of explosive material (low- or high-order), its container, and the environment in which the explosion has occurred.

AN EXPLOSIVE BLAST IN OPEN AIR

It is easiest to describe the physics of an explosion using high-order military munitions in the open air (46-47).

When a device detonates, the chemical energy in the explosive material is converted into heat.

Almost instantaneously, this enormous heat in a very small space creates gas at very high pressure, which rapidly rupture any container holding the explosive material, creating fragments flying with a velocity up to 2km/sec. The expanding gas compresses the surrounding air to produce a very high pressure wave (the shock wave), which spreads out in all directions. In addition, the explosion creates a fireball, sound, and smoke.

The positive-pressure shock wave reaches its maximum almost instantaneously, within 3msec, (46-47A) and travels outward at supersonic speed, decreasing rapidly with distance.

The very high pressure also decreases rapidly (inversely proportional to the cube of the distance, 46-47B). The edge of this wave is called the blast front and its pressure has a shattering effect.
Much damage to human tissues depends on the magnitude and duration of this overpressure: the impulse.

PEAK BLAST v. PRESSURE

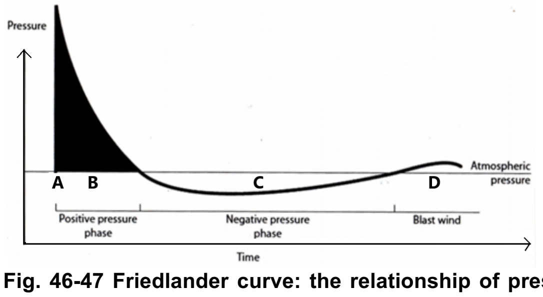


Fig. 46-47 Friedlander curve: the relationship of pressure to time of a blast wave in open air without obstacles. A, instantaneous peak pressure. B, positive pressure shock wave: pulse of overpressure (the area under the curve is the total impulse/unit area). C, negative pressure trough: a suction wave. D, blast wind: dynamic overpressure with mass movement of air. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

The positive-pressure wave is followed by a negative pressure trough (46-47C), a relative vacuum, which sucks in air and debris. The pressure is less than the positive wave, but lasts 3-10 times longer and is even more destructive to human tissues.
Finally, the rapidly expanding gas displaces an equal volume of air. The result is the 'blast wind'. This travels slower than the shock wave and is of lower pressure but lasts much longer and travels further (46-47D).

The impulse of the shock wave shatters objects, which the blast wind then knocks over or scatters. In the human body, the shock wave can fracture the tibia and the blast wind then tears away the distal fragment causing a traumatic amputation.

The shock wave travels through the surrounding medium. The example given is in air, but explosions can also take place under water or underground. The shock wave then travels at even higher speed, has higher pressures, and goes further, because the higher density of the medium transmits the pressure more efficiently.

Lower-order explosive material has less severe effects, particularly in the absence of the very high initial overpressure (shock wave) & negative trough. The blast wind, however, still occurs.

THE ROLE OF THE ENVIRONMENT

Even in air, the environment is important in determining the severity of wounds. Blast waves act like sound waves: they flow over and around obstacles, can be concentrated along streets or corridors, or have areas of wave turbulence. What this means is that a person taking shelter behind an object can still be injured, but another person may be in a 'safe area' because of the turbulence.

A person close to an explosion may not be injured at all, and another person further away may suffer severe injury. A soldier wearing modern body armour is protected against metal fragments, but not against the overpressure of the shock wave.

The effects of the blast are greater in a closed space, such as a building or a bus, or in water. Blast waves are reflected off the walls, amplifying them, adding one wave on another as the waves rebound 46-48).

Mortality and the severity of injury are increased as a result. An explosion in a building also wreaks havoc on the structure, and the building may collapse, setting off further explosion or fire.

PATHOLOGICAL TYPES OF BLAST INJURY
(a) 1° blast injury (barotrauma).

Primary injuries are due to the direct effects of the positive pressure wave and the negative pressure trough. They are usually confined to a relatively small area around the explosion in the open air, depending largely on the quantity of explosive material.

PRESSURES IN AN ENCLOSED SPACE

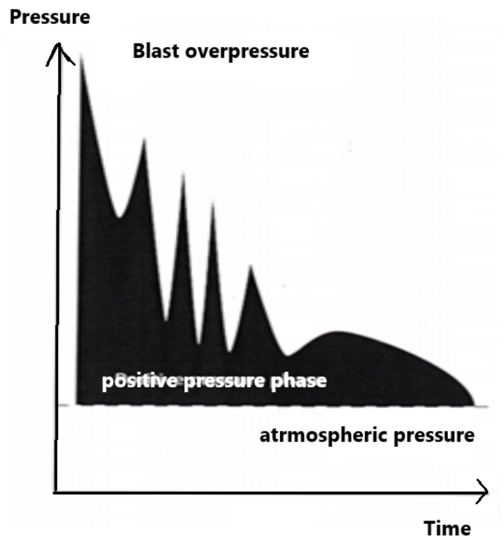


Fig. 46-48. PRESSURE-TIME RELATIONSHIP OF A BLAST in an enclosed space. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

The positive pressure wave compresses the air in hollow organs (ear, lung alveoli, bowel), which then re-expands rapidly during the negative trough causing rupture of the tissues. The same occurs as well at the fluid-solid interface of delicate blood vessels.

The positive pressure also goes through the tissues creating shear waves, with deceleration forces just as in a motor vehicle crash. Different tissues in contact with each other, with different densities, are accelerated and decelerated at different rates creating shear, which can tear and disrupt the attachments of the bowel mesentery, tracheo-bronchial tree, or placenta.

(b) 2° blast injury: fragment wounds.
The explosion can create metallic fragments from the casing or contents of the bomb (nails, nuts and bolts): primary fragments. The blast wind can pick up and propel objects from the environment: glass shards from windows, soil and stones, wood splinters: secondary fragments.

A fragment striking a person within the radius of the primary blast effect causes a more severe wound than if the victim were further away. These fragment wounds need debridement (46.2).

(c) 3º blast injury; the blast wind.
The blast wind can slam people against objects or pick up large objects which then strike people, causing blunt trauma. The blast wind can topple a building, collapsing it just as during an earthquake. After the impulse of the shock wave passes, the blast wind can produce a traumatic amputation of a limb or eventration of the abdominal contents.

(4) 4º (miscellaneous) blast injury is due to other effects of the explosion: flash burns; release of toxic gases including carbon monoxide; dispersal of dust, smoke and contaminants. Burns from a fireball may be the worst of all, carbonizing the body beyond recognition.

EPIDEMIOLOGY OF EXPLOSIVE BLASTS
Most victims in modern warfare are injured by 2º blast injury (metallic fragments). The next most common injuries are from gunshot wounds. Other blast effects come next.

In an isolated explosion, such as a single artillery shell or an act of terrorism, there can be multiple casualties suffering from multiple mechanisms of blast injury with multiple body regions being affected. There is the potential for multiple injuries in a single patient: all 4 types of blast injury.

Casualties may number a few, tens, hundreds, or even thousands, depending on the circumstances. During warfare, c.20-25% of the injured die (except for those armies whose soldiers wear sophisticated body armour).

How many people are killed or injured and what type of blast injuries you will see depends on a number of factors:
(1) The power of the explosion: high-order explosive and the bigger the bomb, the more destructive.
(2) The distance of people from the explosion site
(3) The environment: especially a confined space, the presence of obstacles or buildings, with possible collapse, the topography of the site & the presence of water, trees, snow etc.
(4) The ignition of secondary fires
(5) The numbers of people gathered,
e.g. in a crowded public space, street, or market.

The great majority of surviving patients brought to hospital suffer from fragment wounds and 50-65% affect the limbs. Injuries to the head and neck, thorax, or abdomen account for c.10-12% each.

Mortality rates of different terrorist bomb explosions in recent years vary from 5-70%. Environmental factors (especially enclosed areas and building collapse), the efficiency of prehospital triage, and the level of hospital care are the main reasons for such different results. Most of the dead have multiple injuries; brain trauma, rupture of liver or spleen, blast lung, traumatic amputation, or even total body disruption or carbonization from the primary blast and fireball, often accompanied by fragment wounds.

Building collapse from a bomb produces the same results as a major earthquake: crush of any part of the body.

Most bombings in the open air, however, produce many casualties with relatively superficial fragment wounds that *do not require hospital admission*, only first aid measures on an ambulatory basis. Most of those needing admission have injuries to the musculoskeletal system with limbs accounting for 50-70%.

The environment is important: in an enclosed space, the anatomic distribution of wounds and the mechanism of injury differ and show great variation.

N.B. Remember suicide bombers may harbour hepatitis B, *HIV or other infectious agents*; their scattered body parts may contaminate the injured.

SPECIFIC PRIMARY BLAST INJURIES

(a) Ear
The most common injury after a blast is rupture of the tympanic membrane. Less serious, but very frequent, is a temporary hearing loss due to neurapraxia of the receptor organs. More serious is degloving of the external ear cartilage. Permanent hearing loss results from disruption of the ossicular bones.
N.B. Barotrauma to the ears and sphenoid sinus, from the effects of sudden increases in pressure, can also occur in diving, sky-falling, bunjee jumping, and even the use of high flow nasal cannulae.

(b) Lung
Blast lung has the highest morbidity and mortality of 1^0 blast injuries. Positive-pressure compression and negative-pressure release both burst the alveoli. At the lung periphery, this may cause subpleural cysts and tearing of the pleura. The tracheobronchial tree may suffer shearing disruption. Haemo-, pneumothorax, pneumomediastinum or surgical emphysema may result.

Rupture of the alveoli produces intra-alveolar haemorrhage and oedema with alveolar-venous fistulae. Subsequent negative pressure can then provoke systemic air emboli. The lungs become oedematous and haemorrhagic. Just as in blunt injury to the lungs, there is ventilation-perfusion disequilibrium (intrapulmonary shunt) and decreased lung compliance creating hypoxia and dyspnoea.

The positive pressure wave can also deform the thoracic cage causing fractured ribs, lung laceration or compression between sternum & vertebral column, and direct pulmonary contusion.

(c) Head and central nervous system
Direct positive pressure can cause skull fractures, diffuse brain injury with oedema and petechial haemorrhage. There may be a coup-counter-coup effect. Shearing injuries can disrupt blood vessels resulting in subarachnoid or subdural haemorrhage.
In addition, long-term organic and psychological effects can be debilitating even after apparently mild brain trauma.

(d) Autonomic nervous system
Stimulation of vagus nerve receptors in the alveolar septa can produce the 'pulmonary defensive reflex': apnoea, bradycardia and hypotension.
The victim presents in profound shock with no tachycardia and no peripheral vasoconstriction. There may even be temporary flaccid or spastic paralysis because of a vagal-mediated loss of skeletal muscle tone.

(e) Hollow viscera
Perforation of the intestines can be immediate, owing to the pressure wave, and usually affects the ileo-caecal junction or colon. Less common is delayed perforation of the small intestines, occurring 3-5days later.

This starts with injury in the mucosa and migrates toward the serosa. Intramural haemorrhage or mesenteric ischaemia cause infarction and necrosis of the affected area. *This is important*: unlike in injury by a projectile, any serosal injury due to primary blast you see at laparotomy means *that the entire intestinal wall is involved and requires excision and repair*. In some patients a laparostomy followed by 'second look' surgery after 3-5 days may be needed.

(f) Solid organs
You may see infarction or haemorrhage of the liver, spleen or kidney. Complete rupture is rare in surviving patients.

(g) Musculoskeletal system
The shock wave can fracture bones and the following blast wind can strip away soft tissues. Traumatic amputation can occur, usually at the upper third of the tibia. Abdominal evisceration is possible and large soft tissue wounds are commonly seen.

(h) Eye and face
There may be rupture of the globe of the eye or fracture of the bony orbit. Fractures may extend into the nasal sinuses.

N.B. A special type of injury is from an exploding cell phone, or e-cigarette, which has overheated. If this is held close to the face, foreign particles including toxic alkaline battery contents, as well as flames may cause considerable damage.

CLINICAL EXAMINATION
Some patients whom you see will suffer a combination of the 4 types of blast injury. Most will have obvious fragment wounds (the most common injury) and some will suffer burns and blunt trauma. Here, we will deal only with 1^0 blast injury. For other penetrating and blunt wounds, and burns, see chapters 41,50.

Many people living through an explosive event appear dazed and disoriented and they may not respond well to your questions, even if they can still hear.

Added to the possible temporary loss of hearing is panic from the sudden flash and sonic boom.
N.B. You may have to communicate with the victim by writing

You may even see some patients develop a psycho-emotional shock or severe vagal response with bradycardia and hypotension. Most of these signs and symptoms resolve in mins to hrs if left to rest with minimal physical exertion in the great majority of victims.

You should expect some, however, to suffer long-term neurological (45.1) and psychological effects (40.5).

Use the ABCDE protocol to assess your patients and to identify life-threatening injuries (41.1). Find out if the explosion took place in the open or in an enclosed space and if there was collapse of a building. Apart from obvious injuries, look for any ear or nose discharge, dyspnoea or chest pain. Check for deafness, tinnitus, earache or vertigo. Physical examination for cyanosis, rhonchi or haemoptysis, and abdominal pain, tenderness or guarding should be thorough.

The most common injury from primary blast is a ruptured eardrum; use the algorithm in evaluating such patients (46-47). *An auroscopic examination of the eardrum is not a simple affair in the confusion of a mass arrival of frightened patients*: keep the ear clean and dry until you can make a proper assessment.

A victim with a ruptured eardrum does not necessarily have other injuries, but it is rare to have an intact eardrum with some other major trauma from a primary blast.

MOBILE PHONE EXPLOSION

Fig.46-49 MOBILE PHONE EXPLOSION. This may damage any part of the face, eye or ears as it is held close.

N.B. Your auroscopic examination on its own is not sufficient. Always look for other signs and symptoms, particularly respiratory difficulties.

If your patient is dazed but stable, and has a ruptured eardrum but no respiratory symptoms, you do not need to order a chest radiograph. Keep the patient for observation for 4-6h to see if the respiration deteriorates.

(a) Ruptured eardrum

MANAGEMENT

Treat a ruptured tympanic membrane conservatively. *Don't irrigate or pack the external auditory canal nor introduce ear drops!*

If you have an auroscope, correct instruments, & a calm quiet environment, gently swab or suck any excess debris or dirt. Cover the ear with a sterile dressing and tell the victim to lie down on the side of the injured ear. This will help drain any blood, secretions or contaminants.

If both ears are involved, the victim should lie on alternate sides intermittently.

Keep the ear dry, don't wash it, & put a wad of cotton in the ear when showering.

Tell the patient not to blow the nose. Degongestant drops may help.

Most (c.80%) have a small perforation ($<^1/_3$) of the eardrum and usually heal spontaneously. Larger injuries and failure of healing may need referral for a tympanoplasty.

Look out for any CSF in the external canal due to an underlying fracture of the base of the skull. There will usually be some CNS symptoms. Administer antibiotics systemically, *not locally into the ear.*

N.B. The cranial injury is more important than damage to the ear.

(b) Blast lung

This type of blast injury is the most difficult to deal with. It is the 2nd most common, but the leading cause of death among initial survivors.

Your diagnosis must be primarily clinical, supported by a chest radiograph, if possible. With or without mechanical ventilation, treatment of severe cases is particularly difficult.

CLINICAL PRESENTATION

Patients will present with any of 3 major clinical scenarios;

(1) Severe respiratory distress

This is immediately life-threatening with a grave prognosis whatever the treatment available. There is bloody, frothy sputum and rapid lowering of consciousness, bradycardia and hypotension, which occur very shortly after exposure to the explosion.

(2) Progressive respiratory insufficiency

This begins within a few hours of the incident and slowly develops over 24-48h. The clinical picture resembles pulmonary contusion.

At first, there may be only slight haemoptysis or a cough, which progresses to increasing dyspnoea with air hunger, cyanosis, tachycardia and hypotension. There are crepitations and wheezing on auscultation.

Monitor the oxygen saturation on pulse oximetry; a sudden decrease is an early sign. The victim's condition may deteriorate rapidly.

(3) Acute respiratory distress syndrome (ARDS) = 'shock lung', 'wet lung' or 'Da Nang lung'

This develops later and is due to a mix of various pathology: primary blast, inhalation of smoke and toxic gases, hypoxia, haemorrhage as well as resuscitation with a large volume of crystalloids.

Some patients may have added coagulopathy, sepsis or fat embolism.

Look for signs of pneumothorax, haemothorax, pneumomediastinum (retrosternal crepitus on pressure), and surgical emphysema over the chest and neck.

CHEST RADIOGRAPH

Get a chest radiograph for any patient exposed to an explosion and presenting the slightest respiratory sign or symptom. Keep the patient under monitored observation for 4-6h (46-47).

The 1st radiograph may show nothing wrong; clinical symptoms appear before any radiological signs are visible, so this is why you must monitor these victims.

If the victim with a normal initial radiograph still has respiratory symptoms after 6h, repeat the radiograph and admit for close observation.

Usually, but not always, radiographic changes are visible within 4h if a blast lung is already present: pulmonary opacities, in a 'bihilar butterfly pattern', are typical (46-47). The maximum extent arrives within 48h and resolves over 7days in survivors.

If you see progression instead of resolution after 48h, then ARDS or pneumonia is present.

MANAGEMENT

Only those with severe respiratory problems will require mechanical ventilation and, even with ventilation, treatment of blast lung is difficult.

If you have mechanical ventilation available, avoid high pressures which can cause air embolism or tension pneumothorax. The best protocol is permissive hypercapnoea with high-frequency, high-flow oxygen. You should keep the peak airway pressure and tidal volume low (5-7ml/kg).

It is wise to insert bilateral chest tubes prophylactically as pneumo- or haemothorax commonly arise or co-exist.

BLAST LUNG INJURY

Fig. 46-51 BLAST LUNG INJURY. The typical pattern is a bihilar 'butterfly' appearance of infiltration. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

ALGORITHM FOR ASSESSING VICTIMS WITH TYMPANIC RUPTURE.

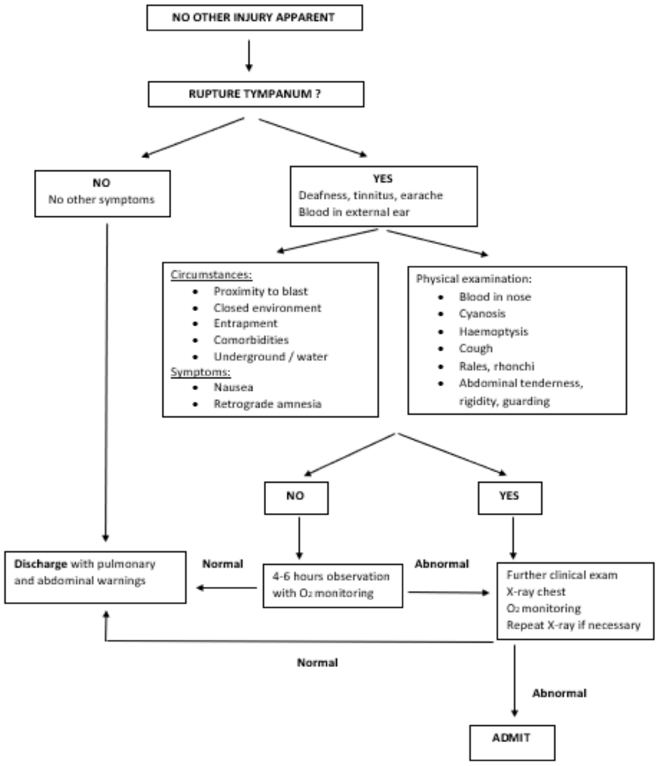


Fig. 46-50 ALGORITH FOR ASSESSING VICTIMS WITH TYMPANIC RUPTURE *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

If you do not have mechanical ventilation, you can still do much through supportive measures:

(1) Deliver high-flow oxygen through a small naso-gastric tube inserted into the trachea through a tracheostomy: this applies also for patients on mechanical ventilation.

(2) Aspirate blood and secretions regularly.

(3) Fashion a tracheostomy (29.17, 42.3): this makes suctioning easier and reduces the effort of breathing

(4) Closely observe the fluid balance: limit crystalloids to maintain good tissue perfusion but avoid overhydration & lung oedema.

(5) Control chest wall pain well with IV analgesia & intercostal nerve blocks.

(6) Regularly change the position of the patient, including use of the prone position.

(7) Insist on good, regular chest physiotherapy.

Test the patient's best position clinically: start in the lateral position with the less affected side uppermost. This allows for better ventilation with less bleeding into the good lung.

However, the blood flow into the more injured lung may increase due to gravity, thus increasing any bleeding and oedema.

If the patient's condition improves, maintain it. Otherwise, reverse the position and check the result.

N.B. Don't use corticosteroids.

A real difficulty arises if blast lung complicates other injuries causing haemorrhage and shock. Aggressive resuscitation, especially with crystalloids, aggravates any lung oedema. Practice hypotensive resuscitation (44.1), but only for 2-3h: *any longer has a very poor outcome for blast lung.*

Postpone any surgery not for life-threatening conditions for 24-48h until after you have stabilized the patient. Local, regional or spinal anaesthesia is preferred. You can use ketamine, without intubation, but bag the patient very gently.

(c) Arterial air embolism
Patients with systemic air embolism to the brain or myocardium die on the spot. *Avoid positive pressure ventilation, whether manual or mechanical, where there is only confusion !*

(d) Central nervous system injury
Many victims will be dazed and disoriented, and a few will suffer psycho-emotional shock. These effects are usually temporary: keep the victim in a quiet area with minimal physical effort.
Many will suffer from headache, fatigue, poor concentration, lethargy or amnesia: the symptoms of brain concussion. Treatment is conservative and symptomatic. Post-traumatic stress disorder is common, and the long-term effects of relatively mild traumatic brain injury is probably underestimated.
If there are focal neurological signs, surgery may well be indicated (51.2).

(e) Visceral injury
Injury to the solid organs from 1º blast injury is rare in survivors. More likely are fragment wounds (2º blast injury) or blunt and crush trauma (3º blast injury).
An acute abdomen suggests a perforation. This occurs more commonly in closed spaces and underwater; it may occur later, so if you discharge patients early, advise them to return immediately if they suffer abdominal complaints in the next few days.
Perforation from a blast causes a serosal lesion, which requires resection of small bowel, or colostomy diversion if in large bowel or rectum. Perforation from an initial serosal haematoma may occur late.

N.B. Don't perform a 1º anastomosis on bowel, as these injuries often produce 'necrosis in evolution'. Consider exteriorizing the affected bowel or fashioning a temporary proximal faecal diversion. Another option is a laparostomy followed by second look surgery after 3-5 days.

Placental abruption may occur through a shearing effect of the blast. Keep any pregnant woman under observation for 24h to monitor the foetus and check for vaginal bleeding.

(f) Eye and maxillo-facial injuries
Rarely, the globe is disrupted or the retina detached (52.8). More common is delayed cataract after a few weeks. 'Blow-out' fracture of the orbital bone, or fractures of the frontal or maxillary sinuses may be present (52.12).

(g) Limb injuries
The vast majority of limb injuries are due to fragments. Primary blast can produce a fracture, typically at the tibial tuberosity. The blast wind then avulses the distal tibia, resulting in a traumatic amputation (60.5). These injuries are most often seen when an explosion occurs in an enclosed space.
Look out for the compartment syndrome (49.6).

N.B. After an explosion, many patients are 'peppered' with multiple small fragments. Close examination will show that most are superficial. A good wash with soap and water, under analgesia, followed by povidone iodine and a dressing is often all that is required.
Deeper fragments may require a more formal debridement.
Fragment wounds from anti-personnel landmines always require debridement, as the blast of the mine pushes soil, gravel and grass up into the tissues. These wounds are particularly contaminated and need a good wound toilet in theatre. *Don't waste time fiddling with the dressings (even if soiled) before taking the patient to theatre!*

N.B. It is possible for hepatitis or HIV to be transferred through fragments from one victim to another.

46.17 Volcano injury

Whilst the location of volcanoes is well known, their eruption, even with seismological monitoring, is still often unheralded. Though rare, effects of volcano eruptions often come in high numbers of victims with severe injuries. If you happen to work in the vicinity of a volcano, or if it is in your catchment area, you should know about possible effects. It may be difficult to get this information at short notice!

The effects of an eruption classically results in people suffering from severe large area deep burns, toxic inhalation injury, and limb and body injury from falling rocks. Early mortality is high, but there are always survivors.

EXAMINATION

Make sure you strip all the clothing from victims, using protective gloves: it is wise to double-glove. You may have to splash water over a victim's simmering or burning clothing! *Remember lava can reach temperatures of 1000^{0}C* and so may take months to cool. The immediate need is to check the airway (use principles from 41.1), and breathing. Inhalation of toxic gases and volcanic ash is often fatal (as in a mine explosion).

TREATMENT

Give oxygen at high volumes by mask to any victim initially. Follow a burn protocol (50.1).

N.B. Volcanic craters have high concentrations of sulphur vapours and carbon dioxide. It is usually the latter that kills, because the former is very pungent, and so dives people away.

Volcanic ash, if fresh out of an explosion, is obviously very hot and burns, but even when cooled, contains millions of crystabolite silica particles which are deposited in the alveoli. This may then lead in later years to silicosis, and maybe also leishmaniasis, and leprosy.

Volcanic soils may also hold toxic substances leading to the development of Kaposi sarcoma, and podoconiosis (34.13), and if blown into the air by 'volcano boarding' (the sport of sliding down a cooled lava flow on a volcanic slope), may lead to histoplasmosis.

Non-accidental injury

47.1 Introduction

Much trauma to children & adults is not accidental; some is indiscriminate but much is deliberate. Violence is ever more present, organized and institutionalized. In certain areas, it is heavily influenced by drug-related crime. Although it is commoner in lower socio-economic circumstances, the rich are not exempt.

Where injury is deliberate, it may be hidden both by the perpetrator and the victim, who thus may present late. Help may also not be immediately available, resulting in severe complications.

In cases of assault, look for deliberate signs of torture. Sexual violence is a type of torture.

Don't forget 'suicide attempts' may actually be cases of assault. The classical gunshot injury on the left by a right-handed person is a case in point!

Self-inflicted harm is a specific form of psychological disturbance, often represented by multiple relatively superficial cuts on arms & legs.

Specific types of injuries are described:
Rectal enema: 26.11
Circumcision: 27.29
Oil aspiration: 42.1
Strangling: 42.5
Uvulectomy: 42.6
Caustic ingestion: 43.6
Drowning: 42.7
Hypothermia: 45.2
Hyperthermia: 45.3
Gunshot wounds: 46.14
Explosions: 46.15
Volcano eruptions: 46.16
Burns (fire, hot liquids & chemical): 50.9

(a) Patterns of torture
Torture is either inflicted deliberately on political prisoners, or to extract information or confession. Maltreatment in custody is similar, with less defined aims. As such, much injury is deliberately calculated to cause maximal pain with minimal signs.

Thus you need to look carefully to assess such injuries, and document everything precisely, especially with photographs.

You should try to distinguish between maltreatment which is not life-threatening, that which is, and that which intended to kill.

Typically these are:
(1) multiple bruises, or patterned skin injuries,
(2) internal trauma to thorax & abdomen,
(3) electrical & thermal injuries,
(4) suspension by the limbs for long periods, causing rhabdomyolysis (49.9), as can multiple beatings, which may result in renal failure; or suspension by the thumb or fingers, causing their gradual necrosis,
(5) isolated ulnar fracture (63.6) (from warding off blows to the face)
(6) periosteal tibial swellings (from repeated beating of the legs),
(7) gunshot destruction ('capping') of the patella (68-10),
(8) suffocation producing either lung aspiration or cerebral hypoxia,
(9) being kept in forced positions for long, resulting in joint contractures (32.1),
(10) electrocution causing muscle contracture, fractures (especially high T1-T5 vertebral), broken teeth & jaw,
(11) burn wounds, lacerations, and remnants of foreign bodies used to inflict harm,
(12) multiple rib fractures sustained at different times,
(13) avulsion of fingernails & toenails,
(14) compression of digits by screws, stamping on them, or squeezing them together,
(15) amputation of fingers, toes & hands.

Rope marks on the limbs are tell-tale signs of forcible restraint, as CT signs of brain injury.

Falanga, the repeated beatings of bare soles of the feet or palms of the hand, is one of the most commonly used methods of torture. On the feet, it can produce: (1) plantar fasciitis, (2) rupture of the plantar aponeurosis, (3) a crushed heel, or (4) a compartment syndrome (49.6). Radiographs of hands & feet may be helpful, showing old fractures & calcifications.

Psychological torture is more frequently used, as evidence of its use is harder to prove. Mock executions, near drowning ('water boarding'). Unfortunately many governments hide their culpability by describing torture as 'allegations', implying victims invent or exaggerate their maltreatment. This does occur, though rarely: a prisoner might fear to be denied an early release that has been promised.

(b) Surgical trauma

N.B. Don't forget that operative complications are a special sort of non-accidental injury!

So, remember always to explain and discuss any surgical intervention with your patient & relaives, and obtain unforced consent.

Be very careful to persuade a patient against their better judgement, unless it is a matter of survival!

(c) Sexualized violence

INTRODUCTION

Several projects have been started in LMICs which address the challenging topic of *sexualized violence*. This term is primarily used to emphasize violence and more specifically where sexual means or targeting sexuality is used.

N.B. We should like to use the term of 'survivor' as opposed to 'victim' to emphasize resilience on the part of the patient, but the sense of many a sentence is obscured thereby.

One famous example is the famous Panzi hospital in Congo; its founder Dr. Mukwege was awarded the Nobel Peace prize for his efforts to establish a hospital dedicated to the survivors of sexualized violence in conflict.

This hospital exhibits a most vital aspect of care for survivors of sexualized violence: to provide care in a 'one-stop shop approach'. This requires that all services are available in one place, so that the patient is not discouraged having to run from one place to the other, re-tell the situation, and be re-examined all over again. Similar efforts have been made in Rwanda at the Isange one-stop shop centres where medical care is given, forensic evidence is gathered, social workers and legal advice is available and access to a safe house is granted. Such multi-disciplinary centres are difficult to establish even in rich countries, but if you are willing to tackle this challenge and if you are in charge of rolling out a strategy, this is the gold standard of care which has successfully been implemented.

Keep in mind several pitfalls when faced with this complex topic!

Sexualized violence has long been used to motivate society to wage war, either by using rape as a trophy, or, on the other hand, to use the threat of rape by the enemy as an efficient way to recruit combatants and mobilize battle strength.

These factors have an impact on numbers reported, and not only increases the complexity of the problem but may exert adverse political influence on your work.

Another aspect is that sexualized violence against men has been widely under-estimated; in fact, c.25% of men living in war-afflicted households in Congo were affected. So, if you are caring for survivors of sexual violence, don't think of this as a female problem only, and be careful of your wording, and creating implied barriers to accessing care.

Using the term, 'victim' may not always be helpful; be mindful of creating stereotypes! In Sierra Leone, for example, the UN Disarmament Demobilization and Reintegration programme offered opportunities for education, apprenticeship and public job placements for former combatants who put down their weapons. Here, as many as 75% of girl soldiers or abducted women had been raped, but they identified themselves as soldiers with rank and military roles and many, if not all, carried a weapon. However, when it came to accessing re-integration benefits, only a limited set of choices were offered to women to allow them to be financially independent. In some cases, NGOs focused on re-instating social and marital 'normality' which obliged women to 'blend in' and marry their sexual assailant.

Don't forget so-called 'troop behaviour' by regular army personnel, which has been recorded from former Yugoslavia to West Africa and Vietnam. Such behaviour may be casually passed off as 'boys will be boys', even by high ranking UN officials, although these attitudes are slowly changing, on account of more stringent consequences, and close media scrutiny.

Remember that it is difficult, often impossible, to *prove* rape in war time, although forensic evidence and DNA sampling make this much easier now. Remember though that where society perceives pre-marital sexual contact as taboo, it may be difficult to discern whether an alleged rape might be an exit strategy to mask consensual sexual activity. However, it is all too easy to accept alleged consent on the part of the woman, if claimed by the man. There is all too often a 'culture of silence' on the part of both the victims & the aggressors.

Note that sometimes rape is facilitated by adding hypnotics to drinks ; then the victim often has absolutely no recollection of the event, except for bizarre neurological or hallucinatory effects of the drugs.

A maybe unexpected knock-on effect, is that patients seeking treatment at a specialized hospital like the Panzi may claim rape in order to receive treatment for an obstetric VVF.

Remember that prevention is always better than cure! For example, lighting on paths leading to the toilets are essential, the architecture of facilities must ensure proper privacy.
Remember also that survivors are not all young!

Despite the complexity of this subject, *don't hesitate to get involved and offer as adequate care as possible* to survivors of sexualized violence no matter which gender or age group.

47.2 Traditional rituals

Surprisingly, many harmful rituals still persist, despite educational efforts. We describe a few, but would be interested to learn of others not mentioned.

(1) Umbilical sepsis & bacteraemia:
Applying cow dung or other substances to a child's umbilicus.
(2) Burns to feet (50.14f):
Fire as treatment for epilepsy.
(3) Rectal injury (57.3):
Enemas as treatment of intestinal ailments.
(4) Penile & urethral injury (57.2):
Circumcision for religious reasons.
(5) Uvula injury (42.6):
Uvulectomy for stammer or epilepsy.
(6) Head injury (51.3):
Trepanation, or thrusting a nail into the cranium for supposed witchcraft.
(7) Amputations : (as forms of punishment).

The introduction of ornaments to stretch facial skin is well-known (and has been adapted in plastic surgery flaps, 34.16) but rarely harmful.

Tattooing may, however, be not so benign, as some inks are truly permanent and may be oncogenic. Piercing various parts of the body has become widespread: obvious possible complications are bleeding & infection.

In a significant number of countries, **albinism, mental illness or congenital deformity** are associated with possession by evil spirits. Such children are often ostracized, but also distressingly penalized in various extreme ways, even including human sacrifice. The burning or use of human body parts is also widespread in some parts. Little of such practice reaches the hospitals or doctors, alas.

47.3 Child abuse

This exists unfortunately throughout the world and is much commoner than anyone really wants to believe. Out of 1 million cases reported in the USA per year, 5,000 die.

Child abuse is more common in lower socio-economic groups, but also exists in rich homes. The most vulnerable age is that of the infant between 6 & 12 months of age. Most children abused are <4yrs old, and over 50% <2yrs.

A specific sibling may be singled out for abuse; this may be physical (battered child syndrome), emotional, sexual or through wilful neglect. This may be because the care giver is underaged or minimally interactive.

A deliberately deprived child may be malnourished, dehydrated, anaemic and have growth retardation. There is often other violence or alcohol abuse at home, and a family history of abuse.
N.B. Overfeeding a child is also a form of abuse!

Child labour and child soldiers are other more extreme forms of abuse which still exist in several parts of the world, particularly, Afghanistan, Chad, Congo, Myanmar, Somalia, Sudan & Yemen. The misuse of children is not limited as fighters; they are also used as human shields, spies, sex slaves & suicide bombers.

RED FLAGS
Beware of:
(1) Inconsistent injury history, discord between history & findings, delay before presentaion, inappropriate agitation by carers, visits to different health centres,
(2) Buttock, trunk, scalp & neck bruising,
(3) Burns, especially by cigarette ends, & scalds from hot water.
(4) Solitary head, chest or abdominal injury (especially in children <3yrs: 50% fatal),
(5) Repeated fractures,
(6) Multiple fractures sustained at different times,
(7) Marks (cuts, abrasions, ecchymoses) in unusual sites, especially bites, half-hidden.
(8) Poisoning (deliberate, or by overdose, or leaving noxious substances within reach),
(9) Electrocution marks.
(10) An apathetic child.

Have a high index of suspicion, if something doesn't feel or look right. *Don't be beguiled by a sweet-talking parent or health carer.* Get advice & share findings with a colleague!

CLASSICAL INJURIES are:
(1) Fractures of the sternum, acromion, posterior rib, long bone metaphysis (47-2), both limbs simultaneously, scapula, & unsuspected fractures on radiographs.
(2) Epiphyseal separation & subperiosteal bone formation (47-3): (late coxa vara of femurs)
(3) Carpal dislocation (64.5),
(4) Anoxic head injury (from strangling),
(5) Spinal injury without radiographic changes
(6) Subdural & subarachnoid haemorrhage (from shaking) : *N.B. this may cause hypovolaemic shock in young children!*
(7) Lip & oral lacerations, torn frenulum (53.8),
(8) Dental injuries (53.2), maxillary (53.3) & mandibular fractures (53.6)
(9) Retinal haemorrhage, & hyphaema (52.9),
(10) Perineal injuries (57.1).
(11) Hot water burns, especially soles of feet, sparing popliteal fossae & medial surfaces.
(12) Multiple fractures of varying age (47-1)

DIFFERENTIAL DIAGNOSES to exclude are:
(1) Osteogenesis imperfecta
(2) Scurvy (rare <5 months)
(3) Rickets
(4) Congenital syphilis
(5) Cortical hyperostosis (Caffey's disease)
(6) Birth delivery injury (47.4)

MULTIPLE OLD OR NEW RIB FRACTURES

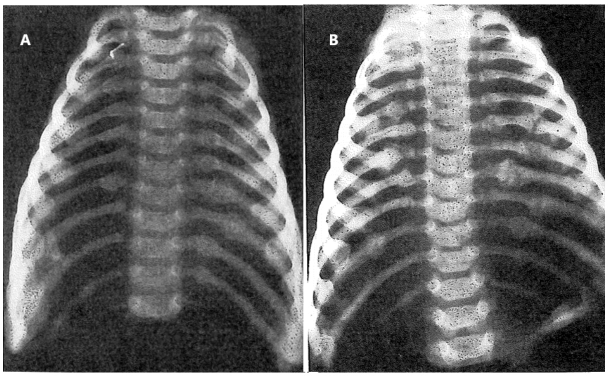


Fig. 47-1 Multiple rib fractures of varying age is a classical sign of child abuse. A, multiple fractures at posterior costochondral junctions 2-4 wks old. B, mostly 3wks old. *After Cameron JM, Rae LJ Atlas of the Battered Child Syndrome. Churchill Livingstone Edinburgh 1975.*

MULTIPLE METAPHYSEAL FRACTURES

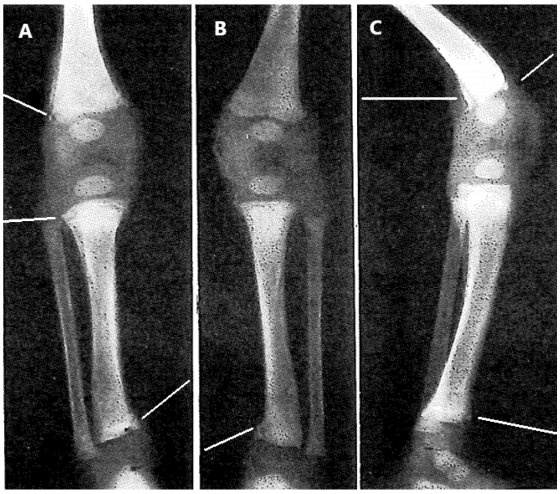


Fig. 47-2 Metaphyseal fractures of different ages in an infant of 4months. A, fragment fractures of the right distal femur, proximal & distal tibia 7-10days old. B, similar fractures on the left >10days old. C, lateral view showing more extensive damage. *After Cameron JM, Rae LJ Atlas of the Battered Child Syndrome. Churchill Livingstone Edinburgh 1975.*

SUBPERIOSTEAL HAEMATOMA

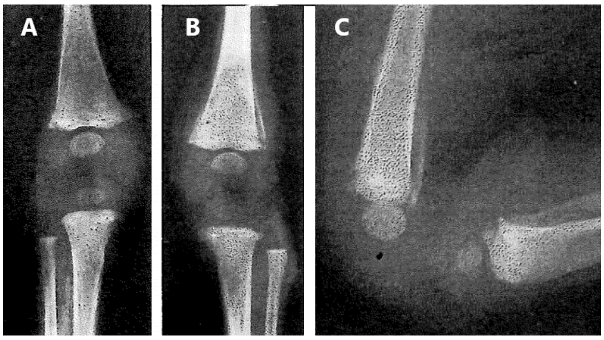


Fig. 47-3 A, Metaphyseal injuries of the distal right femur. B, periosteal calcification of the distal left knee. C, Lateral view showing this clearly. *After Cameron JM, Rae LJ Atlas of the Battered Child Syndrome. Churchill Livingstone Edinburgh 1975.*

You need to get institutional help where available, and often need to involve the police; these are difficult cases. Careful documentation is mandatory: get photographs. Pictures taken under UV light may show up bite marks well.

In case of death, an autopsy is essential (37.6), together with an examination of clothing & its state of disrepair, cleanliness & nutrition.
Check for a disparity between stasis & the position of the body, is temperature & details of whether the history & physical findings match.

47.4 Neonatal injury

Neonates are usually well protected. In utero, fetal injury may occur when a pregnant woman is hurt. The fetus is also at risk in amniocentesis, and with amniotic infection, whose adhesions may produce limb amputations or constriction bands.

The fetus is particularly at risk in delivery, from dysproportion or malpresentation, and delay in the 2nd stage of labour.

Typical injuries seen are:
(1) Petechiae, bruising & purpura on the head, or buttocks & perineum in breech delivery.
(2) Cephalhaematoma (a subpericranial haemorrhage, which is limited at suture lines): this may ossify to produce a 'volcano cone'.
(3) Intra-orbital haemorrhage leading to ptosis.
(4) Cerebral haemorrhage, especially with long labour, use of forceps or vacuum.
(5) Lacerations at Caesarean section.
(6) Scalp degloving (with use of vacuum).
(7) Clavicular fracture & brachial plexus injury (in manipulative delivery).
(8) Hepatic rupture & adrenal haemorrhage (rarely in manipulative delivery).

Minor injuries from poor nursing care include:
(1) Burns from towels too warm,
(2) Tissue necrosis from IM injections,
(3) Bruising from venepuncture,
(4) Transfixion from a nappy safety pin.

A baby may injure itself by lacerating its skin with long fingernails, bruising the head or limbs when restless, or burning is skin from acid vomitus.

Accidental injury may occur by a fall, or being dropped, or from other children; *but beware of the possibility of abuse* (47.3).

Over-enthusiastic massaging of limbs by oil may produce a femoral fracture (73.11)

47.5 Sexual violence

DEFINITIONS
The WHO defines sexual violence as: 'Any sexual act, attempt to engage in a sexual act, unwanted sexual comments or advances, act of trafficking for sexual purpose, act directed against a person's sexuality using coercion, by any person in any setting, regardless of their relationship to the victim, in any place'.

In armed conflicts, the breakdown of social infrastructures, the disintegration of families and communities and the disruption of responses leave women and girls vulnerable to sexual and other forms of gender-based violence, including rape by combatants and intimate partners or acquaintances and, at times, sexual exploitation by humanitarian carers.

Reports of the dimension of the problem are being documented more and more.

BACKGROUND
Sexual violence is no new problem in both peacetime & war. Women and girls bear the burden of insecurity and loss of access to health care in ways that have both immediate and potentially long-lasting implications. Men & children have been victims as well. Although it is difficult to obtain reliable representative figures, many societies still tolerate violence against women.

Sexual violence against women in war has existed since humans started fighting, although almost unbelievable atrocities are still being perpetrated. Many think of sexual violence in general, and rape in particular, as unfortunate but inevitable collateral damage in an armed conflicts. This can take on enormous dimensions, as armies increasingly employ traumatization of the civil population as military strategy.

"Rape is not a aggressive form of sexuality but a sexualized form of aggression."

Rape in the presence of the husband, children, or neighbours, is used to demoralize a whole community and terrorize people into leaving their land, or humiliate men by showing they cannot protect their families. Rape is also used as a tool of ethnic cleansing.

Forced pregnancies to 'dilute' the ethnic identity of the enemy or gang rapes by HIV infected men to infect their victims are part of explicit extermination strategies.

In 2001, the International Criminal Tribunal in The Hague has recognized rape as a crime against humanity. Sexual violence affects millions of people across the world. It destroys people, families, and communities. The statistics on violence against women are daunting. Rape is the world's most underreported crime.

WHO statistics suggest 20% of women globally are victims of sexual violence in their lifetime (this includes 'honour' crime, domestic violence, rape, forced prostitution). In some countries, this figure is as high as 80%. In peacetime situations, perpetrators are often known to the victims. Most episodes of rape remain unreported because victims are unable, too scared or too ashamed, to seek assistance and be counted.

A state of shock, and shame, as well as fear of reprisal and stigmatization, are just some of the factors that contribute to victims' reluctance to speak out. Approximately, only 3% officially report sexual aggression to the police and >50% are unable to access healthcare either due to lack of means or unwillingness on the part of health providers to assist.

PREVENTION OF SEXUAL VIOLENCE; REDUCING THE RISK FACTORS

Analyzing where, how and by whom sexual violence is committed in a community is the first step at prevention. The perpetrator in peacetime is often a family member, or a tenant. Recognition of unsafe places (usually related to the location of water and sanitation) is important. Children must also learn the signs of potential sexual abuse. Many women are abused when they are in a state of inebriation or under the influence of drugs. Other women are abused in the context of marriage, where protracted violence is usually hidden.

CONSEQUENCES OF SEXUAL VIOLENCE:

Sexual violence, particularly rape, has serious negative somatic, psychological and socio-economic effects on the survivors. These include gynaecological as well as other physical injuries, sexually-transmitted infections and unwanted pregnancy.

Mental health impairment can result in long-term anxiety, post-traumatic stress disorders, depression and even suicide.

Social effects may mean expulsion from the community.

ACCESSIBILITY OF CARE FACILITIES; POPULAR ACCEPTANCE
As rape is an acute medical emergency, it requires an immediate response. Any health care provider should ensure facilities are in place so that victims are guaranteed confidentiality, privacy, and sympathy (from cleaners to doctors).
Most times, a female victim prefers to be seen (and especially examined) by a female healthcare worker.

Consultation should be easily accessible, whatever the hour of day or night, and cost-free.

Often professional counselling is limited, but everyone can be sympathetic. Many victims fear not being believed about the incident, and lack trust in unprepared professional help.

It is therefore crucial to set up a comprehensive system for provision of care and, if necessary, referral. You should write out guidelines for staff to follow and train your staff accordingly.

N.B. If you have safe housing available, or legal help, this may be of great comfort for the victim.
N.B. There is a decisive difference if a victim presents <72h after the incident or later (57-5).

Train your health care providers how to recognize victims of rape.

N.B. Although the vast majority of sexual violence is meted out to women, it may also occur to men! The victim in the text is assumed to be female.

SIGNS

Signs may vary depending on the context of the assault and the pre-exising condition & activity of the survivor.

Physical injuries may be visible but may often be internal, and so invisible. There may sometimes be no physical injuries at all, even after an incident of violence or abuse.

Signs may range in severity: bruising, bleeding vaginal or anal lacerations, fractures and dislocations. There may also be signs of incidental thoracic or abdominal injury. Walking may be impaired,

There are often hidden, psychological, mental or behavioural effects such as depression, anxiety, apathy and withdrawal, with later manifestations such as self-harming behaviour or suicidal attempts, or inappropriate use of drug and alcohol.

Many victims may not initially report what happened. Look out for vulnerable people: unaccompanied women, adolescents, children, disabled or mentally handicapped people.

Explain everything that will happen during the examination and reassure the victim that she can refuse anything she does not feel comfortable with or stop the examination at any time. It is crucial to emphasize that the guilty party is not the victim of violence but the aggressor, and such assault is a very serious crime.

PROVIDING CARE TO RAPE SURVIVORS

If there are many victims presenting simultaneously, beware of burnout amongst staff working with survivors, because the emotional stress is enormous.

You must show empathy from the very start. Don't ever make light of the event!

N.B. You may need one or more 'safe houses' for the survivors.

MEDICAL INTERVIEW & DOCUMENTATION

Make sure the victim is not feeling unprotected. Help her to realize everything said remains confidential; this applies equally to any interpreter present. Explain that a detailed medical history and a careful but thorough examination is needed. Involve the patient throughout the process.

1ST CONTACT WITH THE RAPE SURVIVOR

Where a victim is bleeding, hypotensive or has obvious serious injuries, you need to apply ABC criteria to the treatment (41.1), but *don't omit the psychological support!* Particularly in armed conflicts, rape is very often accompanied by physical torture and intended mutilation; serious injuries in addition, outside of the genital area, are not at all unusual.

Get written consent *(without coercion)* for your examination, and obtaining laboratory samples A victim's emotional reaction may vary depending on individual factors such as personality, age, previous experiences, and external circumstances, *e.g.* culture, level of support, and the extent & chronicity of suffered violence.

HISTORY

Take your time, and show empathy. *Don't rush your patient to get facts.* Be prepared that the survivor will have difficulty describing what happened, and may not relate a logical sequence of events.
You should concentrate on listening rather than just wanting to document the incident report form (47-3). Be very mindful that certain questions may be extraordinarily embarrassing, even hurtful. Allow the survivor space also to cry and grieve. *Don't ignore physical injuries when concentrating on the sexual assault !* Remember that there may be repeated episodes of abuse & trauma.

Explain that many questions may be difficult to answer, and that you can go back to these if the survivor is too distressed to answer. Make it your mission to show that you are on the victim's side!

Get a detailed history:
(1) date, time,
(2) number of assailants (if known),
(3) where and on what surface the attack took place,
(4) clothing removed (if any, by whom),
(5) position of both parties in the attack,
(6) resistance put up,
(7) injuries to the assailant,
(8) verbal & physical threats (*e.g.* weapons),
(9) type of sexual assault, ejaculation,
(10) use of instruments,
(11) use of a condom,
(12) loss of consciousness of the survivor.

Find out if, afterwards, the survivor has passed urine, stools, bathed or washed. Find out if there is discharge, bleeding or deep pain, and if the survivor has changed clothing.

A gynaecological history is important: parity, last menstruation, menstrual cycle irregularity, contraceptive use, and previous interventions.

EXAMINATION & DOCUMENTATION

Start with a general physical examination (heart rate, blood pressure, temperature, inspection of the skin etc). Have a previously prepared standardized specific 'rape kit' box available.

As the examination may have forensic importance, *meticulous documentation with diagrams & photographs is vital*. Adequate analgesia is of great benefit; sedation is only required in special cases.

N.B. Violence to a pregnant woman is just as much an assault to the unborn child as to the mother. Its consequences may include abortion, sepsis, haemorrhage or all three (20.2)

MEDICAL CERTIFICATE

Sample Incident Report Form

NOTE: Staff filling this form must be properly trained in interviewing survivors and in how to complete this form correctly. This form is NOT an interview or examination guide. Separate guides and forms are available that should be used for counselling and health exam/ treatment.

INCIDENT TYPE		Secondary incident type	
Case Number	Camp Name/Area of Town	Date and Time of Interview	
Previous Incident Numbers for This Client (if any)			
VICTIM/SURVIVOR INFORMATION			
Name: (optional)	Age:	Yr of Birth:	Sex
Address:	Tribe/Ethnic back-ground:	Marital Status:	Occup:
No. of Children:	Ages:	Head of family (self OR name, relationship to survivor)	
If victim/survivor is a child>>Name of Caregiver:			Relation:
THE INCIDENT			
Location:	Date:	Time of Day:	
Description of Incident (summarize circumstances, what exactly occurred, what happened afterward):			

Sample Incident Report Form - page 2 (can be copied 2-sided for easy use in the field)

PERPETRATOR INFORMATION		
Name:	No. of Perpetrators:	Sex:
Address:	Nationality: Age:	Tribe/Ethnic background:
Relationship to Victim/Survivor:	Marital Status:	Occup.:
If perpetrator unknown, describe him/her, including any identifying marks:		
Current location of perpetrator, if known: Is perpetrator a continuing threat?		
If perpetrator is a child: Name of Caregiver: Relation:		
WITNESSES		
Describe presence of any witnesses (including children):		
Names and Addresses:		
ACTION TAKEN – Any action already taken as of the date this form is completed		
Reported to	Date Reported	Action Taken
POLICE Name		
SECURITY Name		
UNHCR Name		
LOCAL LEADERS Name		
HEALTH CARE Name/nfo.		
OTHER Name		
MORE ACTION NEEDED AND PLANNED ACTION – as of the date this form is completed		
Physical Security Needs Assessment and Immediate Safety Plan:		
Has the victim/survivor received any kind of counselling – if yes, which kind?		
Is victim/survivor going to report the incident to the police? □ Yes □ No Is she/he seeking action by traditional court? □ Yes □ No		
What follow-up will be done by community development/SGBV workers?		
What further action is needed ?		
Form completed by (Print Name):		**Signature:**

Fig. 47-4 SAMPLE INCIDENT REPORT FORM. *(example from IASC Guidelines for Gender-based violence Interventions in Humanitarian Settings, Geneva, September 2005 [58]).*

Collect samples carefully and package them *without contaminating them!* (Change your gloves frequently!) Take care to label them properly!

N.B. A 'rape kit' should have Dacron swabs, sterile water, catch paper, self-adhesive seals & blood collection equipment.

You need to persuade the victim that it is important to send as much material as possible for medical analysis. *Stress that these items don't go to the police.*

Obtain:
(1) Oral swabs (in case of oro-genital contact) under the tongue, along the gums, from cheeks & palate.
(2) Sanitary towels, tampon & underwear,
(3) Finger swabs from under the nails & Dacron swabs elsewhere where saliva or semen has been deposited.
(4) Hair samples from combing the head & pubis, pulling (x5 hairs with consent!), & cutting away any matted hair.
(5) Foreign débris such as soil, leaves, sand, fibres,
(6) Wet anal swabs (collect these before genital swabs) by gently puling the buttocks apart,
(7) Wet swabs of external & internal *labia majora* & *minora*, clitoris, peri-urethral area & *fossa naviculais*, with a little gentle pressure,
(8) Vaginal swabs (before you perform an internal examination) of anterior & posterior fornix & cervical os.
(9) Blood samples depending on your facilities for DNA, HIV, Hepatitis, Syphilis etc.
(10) Urine sample for a pregnancy test.

Look for and describe carefully as abrasion, laceration, contusion, incision, or penetrating injury, noting size, shape,& age, especially:
(1) Petechial haemorrhage in the eyes (signs of strangulation), on lips & mouth,
(2) Finger nail damage and finger imprint contusions,
(3) Abrasions, especially on the neck, breasts & inner thighs (so-called 'love bites')
(4) Defence wounds in the hands,
(5) The surface the body was forced against,
(6) Peri-anal and perineal lacerations & bruising: *N.B. the abscence or presence of tears of the hymen can be misleading!*
(7) Vaginal contusions (darker red than the normal mucosa), especially anteriorly on the lower $^1/_3$ & posteriorly on the upper $^1/_3$, and lacerations which may extend deeply or into the perineum.

N.B. You may need to re-examine wounds 24-48h later, as bruising may only become visible later!

N.B. Keep copies of your documentation; make sure everything is legible!

PREGNANCY MANAGEMENT

Determine whether the victim is already pregnant. History and the pregnancy test will help: if the test is +ve within 2wks of the rape assault, the pregnancy is *not the result of the rape*.

If you cannot perform a pregnancy test, consider offering emergency contraception, as this will not harm a pre-existing pregnancy: use 1.5mg Levonorgestrel once, or x2 0.1mg Ethinyloestradiol with 0.5mg of Levonorgestrel 12h apart.

Therapeutic abortion may be indicated but you must abide by the wishes of the victim and her family, and the relevant laws of the country in place.

STI PREVENTION & TREATMENT

Prophylaxis against chlamydia, gonorrhoea, syphilis & chancroid as well as trichomoniasis depending on its prevalence is recommended. Administer 400 mg cefixime plus 1g azithromycin & 2g metronidazole as single doses. Adjust these doses for children, and divide doses in pregnant or lactating women. You may need to add an anti-emetic, and proton-pump inhibitor, because these large doses of antibiotics often cause nausea. Repeat the dose of antibiotic if vomiting occurs within 2h of taking the treatment.

Post-exposure prophylaxis to HIV is advised in most situations where the culprit is unknown (and even if he is), and it is <72h after the incident. Check the HIV status of the victim as well, in case treatment is needed. Repeat this test after 3-6months. Preferred regimes are: Zidovudine 300 mg + Lamivudine 150 mg bd, for 4wks. An alternative regime is: Tenofovir + Lamivudine or Stavudine + Lamivudin.
This will be the most common treatment; triple PEP is indicated only in situations when drug resistance of the source person is known or expected (when the background prevalence of resistance to ART in the community exceeds 15%).

If drug resistance is suspected and a 3rd drug is considered necessary, it should be a boosted-protease inhibitor, *not* a non-nucleoside reverse-transcriptase inhibitor.

Recommended 3-drug combination therapy including a boosted protease inhibitor for HIV post-exposure prophylaxis is: Zidovudine 300mg + Lamivudine 150mg (combined) bd plus Lopinavir/Ritonavir 200mg/50mg bd for 4wks.
Modification of the regimen or adapting the dosage may be necessary for children, pregnant and breastfeeding women or in settings where some of the mentioned drugs are not accessible.

Administer hepatitis B vaccine series into the *deltoid* or anterolateral thigh (in children) if the victim has not been previously immunised; if the immunisation is incomplete or long ago, administer a booster dose. The vaccine is safe for pregnant and breastfeeding women. Symptomatic or asymptomatic HIV infection is *not* a contra-indication. You can administer it at the same time as tetanus vaccine.

N.B. Administer anti-tetanus toxoid according, if there are dirty or contaminated wounds, to unprotected victims.

Medical certification

This document (47-4) contains details of the physical (and psychological) examination. Objective findings, illustrative drawings and, if possible, photographs should describe the victim's condition. Although you cannot verify rape, you can provide evidence of injuries sustained. The document is highly confidential, but you should offer one original dated and signed copy to every victim of sexual violence. In case of child victims, you might offer the document to the parents (provided of course they are not the perpetrators). It may be used in court as legal evidence to achieve justice or for other purposes (i.e. seeking political asylum or accessing other support programmes). Keep one copy of the document in a secure place.

47.6 Female genital mutilation

INTRODUCTION

The impact on the lives of women & girls from female genital mutilation (FGM) is enormous. This traditional practice, sometimes known as female circumcision, or female genital cutting, has its aim centred around female chastity and purity. However, it is usually carried out in non-sterile conditions with primitive instruments, frequently without anaesthesia. There are often terrible, serious lifelong consequences. You must challenge its *raison d'être*: *it is not helpful, not necessary, not a religious requirement, and does not fulfil its supposed purpose*. Furthermore, the girls on whom it is inflicted receive neither a full explanation how it is done nor what complications might ensue, and they are rarely given an informed choice in the matter.

Many believe that FGM is a Muslim requirement, but it is not. It was carried out 5000yrs ago, and is still practiced in several countries in West, Central & East Africa & Arabia. Some 24 countries where FGM is most performed have legislation concerning its practice.

CLASSIFICATION OF FGM

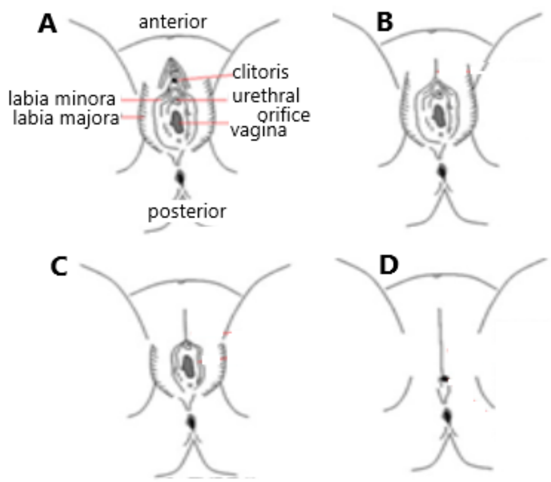


Fig. 47-5 TYPES OF FGM. A, normal. B, Type I a, removal of prepuce only, b, with part or whole of clitoris. C, Type II Clitoridectomy + excision of *labia minora* in part or whole. D, Type III Infibulation (removal of all vulval structures, leaving only a small opening for urine & menstrual flow)
.*https://www.flickr.com/photos/blatantworld/5052042821*

Many reasons for FGM are given: tradition, social acceptance, religious cleanliness, prevention of promiscuity & adultery, preservation of virginity. Tradition far outweighs other reasons, and FGM is often seen as necessary to improve a woman's chances in marriage.
The role of religion in FGM is, however, important, and it is practiced by Russian Coptic Christians, Israeli Bedouins, Ethiopian Jewish Fallasha, as well as by several Islamic groups. The Bible nor the Qu'ran condone its practice, however.

CLASSIFICATION
The WHO has defined 4 categories:
(1) Preputial removal with or without part or the entire clitoris.
(2) Clitoridectomy + partial or total excision of the *labia minora.*
(3) Infibulation with removal of part or all of the external genitalia with closure of the the vaginal opening, leaving a small passage for urine & menstrual blood.
(4) Other procedures including piercing, tattooing and cosmetic labiaplasty.

RESULTS
The operation may be carried out from birth to adulthood; in some cases the legs are kept apart by paste, and in others bandaged together.

The outcome depends on the age of the child, the type of intervention, the conditions under which it is performed, the general health of the girl, and the skill of the operator. However some 80-90% of victims need medical, surgical, or psychological help. Because of social taboos, they often never get any such assistance.

Although most severe consequences are from infibulation, all other interventions may cause long-lasting problems.

COMPLICATIONS
The most common acute complications are bleeding, infection (often leading to abscess formation or septicaemia), and pain so severe that long-term psychological *sequelae* ensue. Death may result from any of these, including from tetanus, but the mortality is unknown.

The commonest long-term problems are recurrent & persistent urinary tract infection, or chronic PID, both of which impact on menstruation & fertility.

Trauma to adjacent structures, such as the urethra, vagina, perineum & anus, is also common. Results may be: (1) permanent incontinence, (2) chronic urinary retention, (3) swelling & deformity of vagina & vulva.

Where wounds do not heal properly, they may result in fistula formation, keloid, or contracture.

Urethral stenosis will cause incomplete bladder emptying, recurrent urinary infection and stone formation.

Vaginal closure may result in haematocolpos or vaginal stricture (23.17).

The major problem for most young women begins with marriage. In many cases, the vaginal orifice is so small that sexual intercourse is impossible. This may result in attempts by the new husband to 'open up' the wife. This often entails the use of razor blades or other sharp instruments, again without sterile precautions or anaesthesia.

Severe haemorrhage, further uro-genital damage (including VVF, 21.18), & chronic pelvic pain may result.

If anal intercourse takes place as an alternative, this may lead to anal fissure, sphincter incontinence or recto-vaginal fistula.

Dyspareunia is a major issue in up to 65% of cases.

If pregnancy is achieved, prolonged labour, perineal tears, vaginal haemorrhage, and other causes for difficult delivery are commonplace.

Psychological consequences are often severe, diverse and long-standing, leading to post-traumatic stress & depression.

EXAMINATION

In areas where FGM is frequent, women may be extremely reluctant or outright refuse to be examined by a man. They may even not wish to discuss any problem related to FGM, and may present with symptoms that appear unrelated.

Therefore (unless you are female!), you may need to instruct a female assistant how to examine the perineal area and what to look for. A good idea is to produce pre-printed diagrams to draw on.

RECONSTRUCTION

Whilst physiotherapy may restore pelvic floor function and reduces pain, psychotherapy and counselling are essential to treat a woman's suffering, as she rarely can lightly accept FGM even though her society does.

The anatomy may be so distorted that identifying normal structures is difficult. Various restorative measures can be relatively simple to perform; however, *don't perform these under LA* as this will only serve to remind the victim of their first experience.

DE-INFIBULATION (GRADE 2.4)

Divide the skin or scar tissue closing the vaginal orifice, working from the free lower edge to the apex just above the root of the clitoris. Then freshen the edges of the 2 flaps you have made, and suture these to re-create the *labia minora.* Sometimes you may need to suture the skin back onto itself to achieve a good anatomical result. *It is important for the patient to wash, clean & dry the area scrupulously post-operatively if there is any urinary leakage.*

N.B. In severe cases, reconstructive pelvic floor surgery may be necessary.

The aim is to make a functional accessible vagina & to visualize the urethral opening. Most women wish to look normal, feel comfortable, pass urine without obstruction, and have sexual intercourse without fear.

If you perform this procedure at delivery, carry out an anterior episiotomy.

N.B. Don't let inexperienced personnel do this as urethral damage might otherwise easily occur.

N.B. Without an episiotomy, obstructed labour may result in major lacerations, urethral avulsion and fistulae.

DE-INFIBULATION

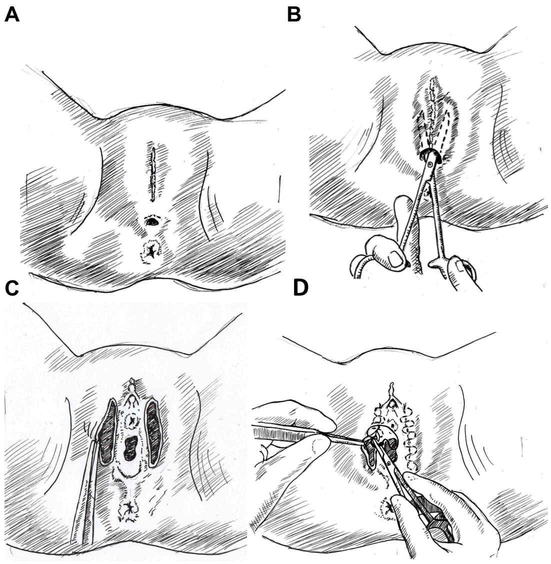


Fig. 47-6 DE-INFIBULATION. A, Insert LA around the perineum, B, divide the scar tissue from below to above the root of the clitoris. C, freshen the edges. D, suture the 2 flaps to re-create the *labia minora* & *majora.*

48 Nerve & tendon injury

48.1 Examining peripheral nerves

In any limb injury, especially where there is a penetrating wound, test the function of the nerves and tendons before you anaesthetize the patient or refer him elsewhere. Test the most distal point supplied by each nerve. The following tests are so easy that you can do them all in a few seconds.
Always record your results as this is important not only for patients' management but also has medico-legal implications. It will then be certain if paralysis did or did not exist initially.
Record both power and sensation

QUICK TESTS FOR PERIPHERAL NERVES

MAJOR NERVE TESTING AT A GLANCE

Nerve	Motor testing	Sensory testing
Axillary	Upper arm abduction	Outer part of the shoulder, over the *deltoid* insertion
Musculo-cutaneous	Elbow flexion	Outer side of the forearm
Radial	Elbow & wrist extension	Dorsum of hand & thumb
Median	Thumb abduction & opposition	Palmar surface of the index finger
Ulnar	Little finger abduction	Palmar surface of the little finger
Femoral	Hip flexion & knee extension	Medial side of the thigh, leg & foot
Sciatic	Hip extension	Sole of the foot
Post. tibial	Ankle plantarflexion & standing on tiptoe	Sole of the foot
Common peroneal	Walking on the heels with the forefoot raised (Ankle dorsiflexion)	Posterior calf (superficial branch) Web between hallux & 2nd toe (deep branch)

Table. 48-1 TESTING MAJOR NERVES AT A GLANCE. Try to memorize these tests, so that you can make an accurate neurological summary quickly.

N.B. Testing the hand nerves, see 65-3.

(a) Axillary (circumflex) nerve
This arises from the posterior cord of the brachial plexus, and winds round the neck of the humerus to supply the *deltoid* and the skin over the lower part of this muscle. It is typically injured in shoulder dislocation.

N.B. When testing arm abduction. Put your palm over the *deltoid* (48-1): even a flicker of contraction proves some function is present.

(b) Musculocutaneous nerve
Injury occurs rarely, usually as part of a brachial plexus injury.
Elbow flexion is almost impossible if this nerve is injured.

(c) Radial nerve
This curves round the humerus, and is readily injured in fractures of the distal humerus, or improper use of crutches.

(d) Median nerve
Injury may occur in distal humeral or wrist fractures, and deep lacerations of the anterior wrist.

(e) Ulnar nerve
This is injured typically at the elbow, where the nerve passes in a tunnel behind the medial epicondyle, or in midshaft forearm fractures.

(f) Femoral nerve
Injury may occur in an inferior pubic ramus fracture.

(g) Sciatic nerve
Common injury occurs with injections in the lower medial (instead of upper outer) quadrant of the buttock, or in sacral fractures or hip dislocation.
The nerve gives rise to the posterior tibial & common peroneal nerves.

(h) Posterior tibial nerve
This is in danger with upper tibial fractures.

(i) Common peroneal nerve
Often injured by pressure on the lateral upper fibula, *e.g.* from a cast, skin traction or bedsore, or in knee dislocation.

Combine this examination routine; all motor testing except for hip extension can easily be tested on a supine patient with a quick sequence: (1) upper arm abduction, (2) elbow & wrist flexion, (3) thumb abduction & opposition, (4) finger abduction, then (5) hip flexion & knee extension, (6) ankle plantar & dorsi-flexion.

Follow this by testing sensation on the *deltoid,* outer forearm, dorsum of hand & thumb, palmar surfaces of index & little fingers; medial thigh, leg & foot, posterior calf, sole of the foot, and between the hallux & 2nd toe.

TESTS FOR SOME PERIPHERAL NERVES

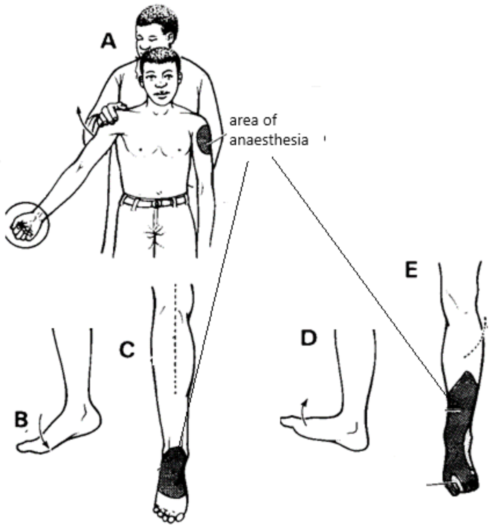


Fig. 48-1 ROUTINE TESTS FOR PERIPHERAL NERVES. A, shoulder abduction & sensation over the lateral upper arm (axillary). B, elbow flexion (musculo-cutaneous & radial). C wrist flexion (radial). D, thumb abduction & opposition (median nerve). E, little finger abduction (ulnar nerve). F, hip extension & knee flexion (femoral nerve), G, hip flexion (sciatic nerve). H, ankle plantarflexion (posterior tibial nerve). I, ankle dorsi-flexion (common peroneal nerve).
Check sensation over the *deltoid;* outer forearm, dorsum of hand & thumb; palmar surfaces of index & little fingers; medial thigh, leg & foot; sole of the foot; posterior calf and between hallux & 2nd toe.

48.2 Primary nerve repair

The digital nerves, median and ulnar nerves commonly need repairing, but almost any nerve may need repair. Whenever you clean a wound, inspect any nerves that might be injured, *but don't try to repair them*, unless they have been cut completely. Closed injuries usually only bruise nerves, so that they are able to recover in a few weeks.

One of your first problems is to distinguish a nerve from a tendon deep in a wound. Even supposedly expert surgeons have sutured a nerve to a tendon, *e.g.* the median nerve to *palmaris longus* at the wrist.

A NERVE is yellowish and flexible. You can make it lie in various positions, and if you press it, it will flatten fairly easily from side to side and from back to front. Its cut edge bulges slightly. Look at it carefully, if possible with a lens, and you will see its fibres lying in bundles, like fine spaghetti.

If it has been cut, you can easily see these bundles surrounded by connective tissue.
A nerve often has a small tortuous vessel running along its surface. This is a rare on a tendon.

A TENDON is bluish white and glistening, straighter and firmer and more difficult to deform by compression than a nerve. It has a flat smooth cut surface like wood cut across the grain, and its bundles are more difficult to see.

Try to refer nerve injuries immediately to an expert.

DISTINGUISH A NERVE FROM A TENDON

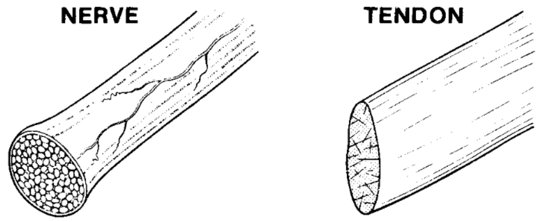


Fig. 48-2 DIFFERENTIATING BETWEEN NERVE & TENDON. A, the nerve is yellowish, softer and more flexible, its cut end bulges slightly, and has many nerve fibres in bundles, a vessel on the surface. B, the tendon is bluish white, glistening, straighter, firmer, its cut surface resembles wood. *Kindly contributed by Peter Bewes.*

The ideal is a nerve stimulator: you can make this yourself with a simple battery of 4V making an impulse of 0.1-5mA. Using a blunt needle on a motor nerve a minimum stimulus should cause muscle twitching distally; *if the stimulus is too great, the current will pass through other tissues, though!*

If nerve repair is not possible, mark the nerve ends with a non-absorbable monofilament suture. Clean the wound, and close the skin loosely. Make this quite clear to the patient and record it in his notes; also write it on a PoP if applied.

Arrange secondary repair between 3wks & 3months under controlled conditions.

PRIMARY NERVE REPAIR (GRADE 2.4)

If the wound is clean, and you have the equipment, attempt nerve repair immediately. *Don't do this if the wound is contaminated,* debride it first.

Use your finest monofilament sutures, needles, and needle holder. Ideal is a 8/0 suture on 3mm atraumatic needle.

Any suture larger than 6/0 is too big. Ophthalmic forceps and needle holders, and magnifying loupes are ideal.

REPAIRING A CUT NERVE

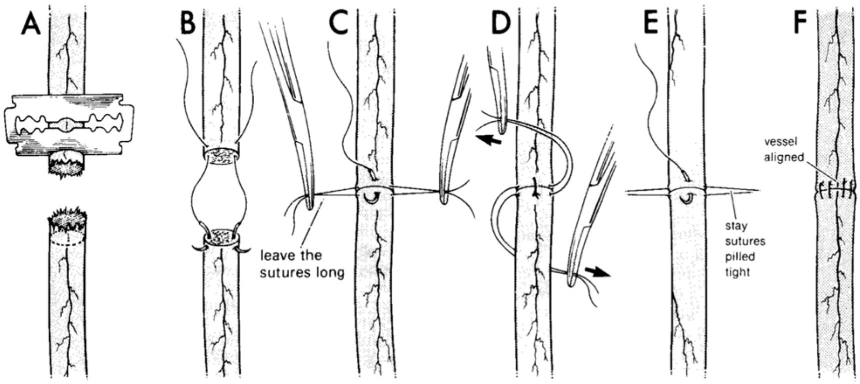


Fig. 48-3 REPAIRING A NERVE. A, freshen the ends. B, insert stay sutures. C, with the stay sutures pulled together, insert an anterior epineural suture. D, reverse the stay sutures to visualize the other side. E, insert a suture on the back side. F, complete the anastomosis by 2-6 more sutures. *Kindly contributed by Peter Bewes*

While waiting for the nerve to recover its function, splint the limb to prevent contractures, and advise the patient about avoiding harm to numb areas. Start passive physiotherapy to avoid muscle & joint stiffness.

Don't use silk, catgut, human hair, or glycolic acid sutures because these are irritants.

N.B. Coarse or braided sutures may cause so much fibrosis that the nerve will never function again.

METHOD
First explore the wound (46.2). Find the cut ends of the nerve. Put the limb in a position which will help to bring the nerve ends together.

Trim back both the cut ends of the nerve by 2mm with a new sterile blade (48-3A) to obtain a flat fresh surface.

Match the cut ends in their correct anatomical position, without rotation. There are usually very fine blood vessels on one side of a nerve which will enable you to distinguish its two sides. Study the cross section of its fasciculi carefully, and get the two cut ends to match.
Try to put all sutures only into the outer sheath (epineurium) *of the nerve*, as sutures deep inside will interfere with its function seriously.

Follow the technique of 48-3.
CAUTION! Don't put >8 sutures into the epineurium; Don't let any nerve fibres stick out of the suture line.
Make sure you cover the nerve after its repair. You may need an advancement flap (46.5) to do this; a split skin graft is less satisfactory. Splint the limb in the position which best relieves tension on the nerve. If it is under tension, release the splint slowly over several weeks. *If you fail to do this, the sutures may cut out.*

48.3 Secondary nerve repair

If a patient presents with an injured nerve late, or you decided not to repair it at the time of the injury, this will be a 'secondary' repair.

Try to refer such cases to an expert. If this is impossible, you need to prepare the surgical field carefully before you even reach the nerve!

By 3wks, a rounded neuroma forms (48-4B). You need to cut this back in small slices until you reach healthy nerve (48-4E-I). Sometimes a nerve is incompletely divided and although its ends join together, it is deformed by bulbous neuromas (48-4D). You need to cut these back until you reach a healthy nerve structure.

The best time for secondary repair is as soon as possible after the initial injury.
You may find the cut nerve ends are deep in scar tissue, and you need to look for them both proximally & distally. *Be careful to cut longitudinally* not transversely so as to avoid inadvertently dividing the nerve!

Also be careful not to divide branches, *e.g.* of the ulnar nerve to *flexor carpi ulnaris,* and the medial half of the *flexor digitorum profundus*.

You may then find that, when you have found & excised the swollen ends of the nerve, quite a gap is left. Nerves are not very elastic, so bridging this gap can be difficult.

An expert may be able to bridge the gap with a graft. You may be able to mobilize enough nerve to enable it to reach.

SECONDARY NERVE REPAIR (GRADE 2.5)

N.B. Don't consider exploring a closed wound for several months. The nerve is probably only contused, and will recover.

SECONDARY NERVE REPAIR

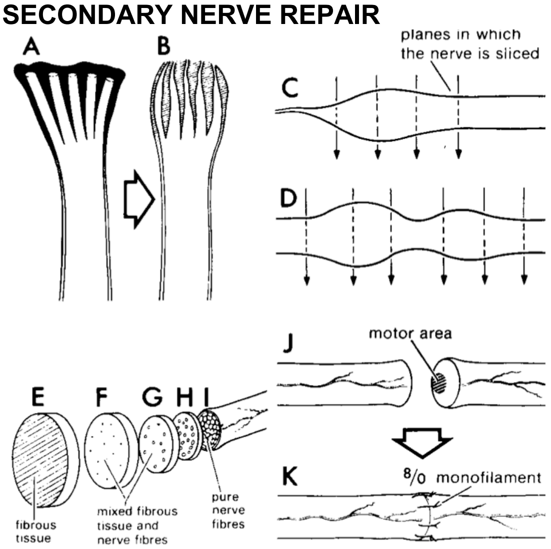


Fig. 48-4: SECONDARY NERVE REPAIR
A, a ragged recently injured nerve surrounded by blood clot. B, later, when the clot has organized and become fibrous tissue. C, taking successive sections of the thickened end of a cut nerve. D, an incompletely divided nerve with two thickened swellings. E-I, trial sections along a thickened nerve ending. J, the motor area is situated centrally in the nerve. K, try to get a tidy accurate approximation of the ends. *Kindly contributed by Peter Bewes.*

Explore the healed wound and mobilize the injured nerve, with the precautions described.
Feel carefully for the parts of it that are hard and fibrosed. Use a sharp scalpel to cut thin slices across its thickest part at both ends. The 1st slice you cut from the neuroma (48-4E) may show a uniform slab of fibrous tissue. In the 2nd slice (48-4F), a few little dots of nervous tissue start to appear. In the 3rd slice (48-4G) there are more little dots. The 4th slice is mostly nerve tissue (48-4H). The final slice (48-4I) has normal fibrillary structure. You need to reach this point at both ends to perform a satisfactory repair.

Special points to note for specific nerves:
(a) Ulnar nerve
Move the nerve anteriorly from behind the medial epicondyle. This will give you the extra length you need to make a repair without due tension. Keep elbow and wrist flexed postop.

(b) Median nerve
At the wrist, you can release the nerve by incising the flexor retinaculum.

SIGNS OF SUCCESSFUL REPAIR
Tap the course of the nerve, if the patient feels tingling over its distribution, it is regenerating. (At the wrist, this is known as Tinel's sign.)

Examine and record the power of all the muscles that the injured nerve supplies. The most proximally innervated ones will recover first.

After repair, the average axonal regeneration rate is c. 1mm/day. Regenerating axons have to grow down the full course of the damaged nerve tube to the neuromuscular end-plate. After this period, nerve maturation and initial muscle recovery may take a few more months.

48.4 Tendon injury

Rupture of the belly of a muscle usually causes little disability, but rupture of its tendon or the junction of tendon with muscle is usually serious. The result depends greatly on whether or not the tendon is surrounded by a sheath. The wrist flexor tendons when cut, retract, become rounded, lie loose inside their sheath and fail to heal.

Repair is easier when a tendon has no sheath, as with the wrist extensors. Tendon injuries often involve the hand (65.15,16), or the Achilles (71.8).

SUTURING A TENDON

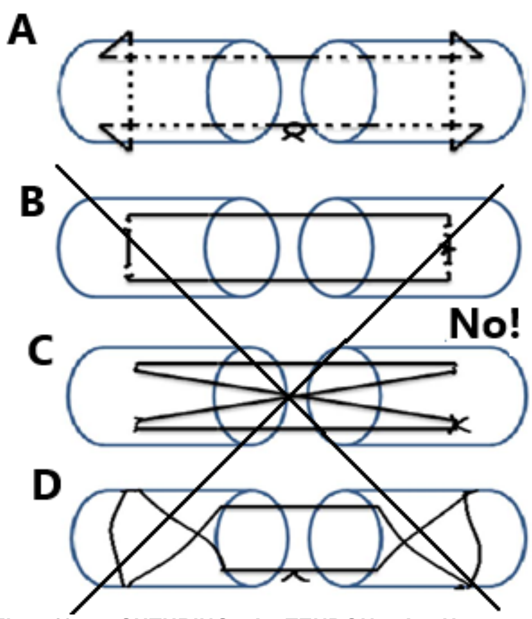


Fig. 48-5: SUTURING A TENDON. A, Use non-absorbable sutures; anchor the tendon with a transverse suture. Introduce a suture at one side of the tendon and pass it along the tendon, and out at c.2cm. Then pass it through the cut end of tendon on the opposite side, and along it 2cm along, before coming out on the same side, and then transversely through the tendon, coming back in the same way and joining the suture ends at the join. (Modified Kessler method)
N.B. Methods B,C,D are no longer recommended.

Follow general principles in all cases. The main one is the method for inserting sutures.

TENDON REPAIR (GRADE 2.3)
Do this primarily unless there is:
(1) rupture with scarred ends >1cm,
(2) segmental loss of flexor tendons,
(3) disruption of the pulley system
(4) loss of overlying soft tissues
(5) delayed presentation
You will need to open the sheaths of those tendons ruptured within a sheath. Cut off the rounded scarred ends, so you are left with plain straight cut ends.

Preferably use 3/0 monofilament nylon, fishing wire or stainless steel. *Don't use absorbable suture*. A straight needle is the easier to use. Hold the cut ends of the tendon by stay sutures Follow 48-5.

CAUTION! Take care to identify the cut ends correctly. *Don't join a profundus to a sublimis tendon, or a nerve to a tendon!*

POSTOPERATIVE CARE
Immobilize the limb for 3-4wks in a close to functional position which will cause least tension on the cut tendon. Encourage early mobilization with dynamic splints.

Don´t force a normal range of motion, but move the tendon just as much as possible without strength. Pain is a good control to stop moving. The critical period for rupture of the repair is after 8-10days, when you remove the splint and start motion with force. So, start movements gradually, and with ascending strength over a period of another 3wks before the patient reaches a full range of motion and strength.

49 Vascular injury

49.1 Immediate treatment for severe external bleeding

Stopping a patient losing blood from the circulation is one of *the* most urgent of surgical tasks.
A litre or more can easily be lost internally into the peritoneal or pleural cavities, or around broken bones (44.3). External bleeding is much easier to diagnose and stop. The most useful methods are elevation, pressure (digital, bandage or by packing/balloon tamponade), suturing or tourniquet (44.2).

(a) Elevation:
Useful for controlling venous bleeding in a limb.

(b) Direct pressure
Use a digit or hand, or proper compressive bandage. *Don't do anything more until you have waited for at least 5mins by the clock*, unless a torrent of blood pours from the dressing. If bleeding stops, be thankful and *don't meddle with the dressing*.
Occasionally occluding a vessel compromises the distal circulation if there is no collateral flow. Check this if there is a delay in getting help. Releasing the pressure slightly, in this case, may get some flow distally but at the great risk of more bleeding, so remember: 'life comes before limb'

CONTROLLING EXTERNAL BLEEDING

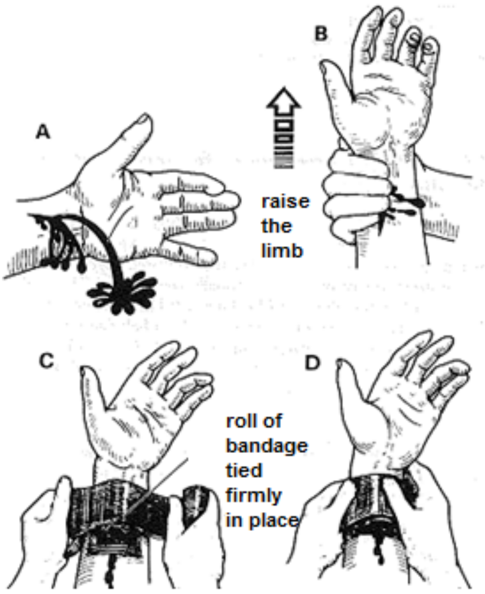


Fig. 49-1 IMMEDIATE TREATMENT FOR A BLEEDING LIMB WOUND. A, a typical bleeding laceration. B, raise the limb and press on the wound firmly with gloved hands for 5mins. C, apply a dressing & a compressive bandage. D, *do not use a huge wodge of dressing:* this will simply soak up the blood but not produce enough pressure. *Kindly contributed by Peter J Safár.*

SPECIFIC PRESSURE

This is only effective if you can localize a specific bleeding vessel. Press always on a pressure point proximal to the wound, such as (49-4) the:
(1) carotid artery against the transverse process of the 6th cervical vertebra.
(2) temporal artery against the skull just in front of the ear.
(3) subclavian artery against the 1st rib.
(4) brachial artery against the middle of the humerus.
(5) femoral artery over the mid–inguinal point.

(c) Packing
Use this to control deep inaccessible bleeding (55-14). Sometimes inflating a balloon (or condom) inside a wound cavity (49-2), is more effective.

BALLOOON TAMPONADE

Fig. 49-2 BALLOON TAMPONADE. A simple Foley catheter inserted into a cavity and inflated can arrest exsanguinating bleeding and buy you time. *Kindly contributed by Jan Swinnen.*

(d) Tourniquet (3.4, 44.2):
This is an example of proximal control; *use this in specific indications:*
(1) life-threatening or multiple bleeding wounds in a limb,
(2) the wound itself is not accessible (*e.g.* patient is trapped in a vehicle),
(3) lack of time because of other severe problems,
(4) failure of simpler measures.
Apply a pneumatic tourniquet (or the cuff normally used for taking blood pressure) at least one hand's breadth proximal to the wound, avoiding regions where nerves are at risk (e.g. directly below the knee) and joints.
A proper arterial tourniquet must have a windlass (which may be a stick) to obtain sufficiently high pressure. *Don't turn this >5 times!* (Each turn may deliver 100mm Hg pressure).

Apply the tourniquet with some padding (*e.g.* cotton) to protect the skin, but *not over clothes* which may slip. *Tighten it till the bleeding stops!*

TOURNIQUET POSITION

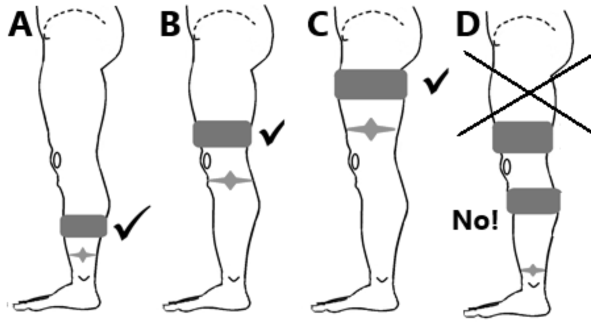


Fig.49-3 TOURNIQUET POSITION is important. A,B.C, show correct placing of the tourniquet. D, it is too far proximal to the wound *and will cause unnecessary ischaemia. You don't need 2 tourniquets on the same leg!*

If you have a cuff, pump it to c. 20-40 (not >80) mm Hg than the patient's systolic blood pressure. Bleeding will stop if you have applied the tourniquet properly. *If it only impedes venous backflow (not enough pressure!) bleeding will increase*.
Don't forget analgesics: a correctly applied tourniquet is always painful!

ALWAYS NOTE THE TIME WHEN YOU HAVE APPLIED THE TOURNIQUET!

Do not leave it >1½h on the arm & >2h on the leg; 60% less for thin adults & children.
In the unlikely case that bleeding does not stop after you have applied the tourniquet properly, apply another tourniquet proximal to the first one.

HAEMOSTATIC AGENTS:
Haemostatic gauze, bone wax, hydrogen peroxide, may all help the clotting process, especially where tourniquet use is not feasible.

HAEMOSTATS (3-2,3-3):
If bleeding continues in spite of applying all above mentioned measures, a large vessel may be injured, probably an artery, more likely from a tear rather than a complete transection.
N.B. When an artery is completely divided, bleeding usually stops spontaneously owing to thrombus formation & muscular contraction at the injury site.

CAUTION!
(1) Get proximal control by pressing on a pressure point first.
(2) The vessel must be clearly visible.
(3) Secure the bleeding vessel with a haemostat (arterial clamp).
Don't jab a haemostat blindly into a pool of blood! Be careful that you do not crush a nerve running next to an artery!
(4) When the haemostat is in place, incorporate it in the dressings.
N.B. Don't then remove it and try to tie the vessel until your patient is in theatre.

SURGICAL ANATOMY OF LIMB ARTERIES

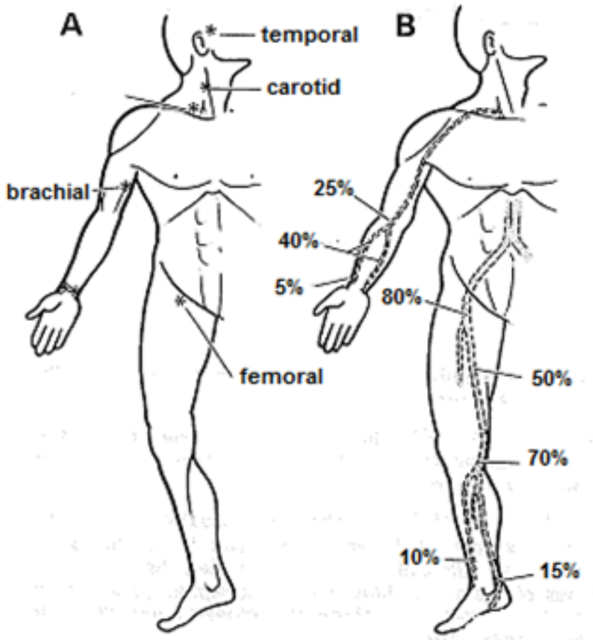


Fig. 49-4 SURGICAL ANATOMY OF LIMB ARTERIES. A, the pressure points, where you can stop the flow in an artery with a finger or two. B, the chance of ischaemia developing if you ligate the artery. *Modified from 'Techniques élémentaires pour médecins isolés,Institut de Médecine Tropicale Du Service de Santé des Armées le Pharo, Marseille, DGL 1981 ' with kind permission.*

TEMPORARY SUTURES:
In some situations, such as the scalp & face, a continuous suture is useful. You can remove this later, if necessary, to perform more aesthetic repair, especially on the face.
Never try to use diathermy in the trauma situation.

49.2 Immediate diagnosis & treatment of hidden bleeding

INTERNAL BLEEDING
A person may easily exsanguinate because of hidden bleeding into the chest or abdomen (44.3). Fractures of the pelvis or the legs may also cause profuse internal bleeding. A pelvic sling will help to decrease blood loss at the trauma site. Use tranexamic acid 1g IV slowly over 8-12mins and then 1g over 24h or 25mg/kg tds.

In any case of an injured limb, remember the possibility of vascular trauma – *especially if there is no visible bleeding*. Check if peripheral pulses are palpable with the same force in both limbs.
Use an ultrasound Doppler device (35.2), if you can. Look for the signs of ischemia (49.5).
You must actively rule out a vascular injury!

There are critical sites, where major arteries are at risk in trauma:
(1) distal femoral fracture (66.6),
(2) complex knee injuries (67.12-14),
(3) posterior knee dislocation (67.15),
(4) complex elbow fracture (61.1),
(5) anterior elbow dislocation (61.3),
(6) subcapital humeral fracture (60.2).
N.B. The most frequently involved arteries are the brachial, and popliteal including its branches.

SYMPTOMS & SIGNS OF ARTERY INJURY:
Remember the 6 P's :
(1) **p**ain,
(2) **p**araesthesia,
(3) **p**allor,
(4) **p**aralysis,
(5) **p**oikilothermia (feels cold to touch),
(6) **p**ulse missing or weak.

In addition, these are sure (hard) signs:
(1) active arterial haemorrhage,
(2) a rapidly expanding (pulsatile) hematoma,
(3) absent peripheral pulse
(4) a palpable thrill or audible bruit over the wound,

These are soft (suspicious) signs:
(1) history of significant/unexplained blood loss
(2) decreased distal pulse
(3) penetrating or related bone injury,
(4) concomitant neurological deficit,
(5) ankle-brachial pressure index (ABI) <0.9 (with a difference between the affected and the unaffected limb),

If there is a penetrating Injury, (in other words the direction of trauma is from outside inwards), the results depend on how the artery is damaged:
(1) if only the outer layer (adventitia):
late rupture or late aneurysm,
(2) if the lumen is partly opened:
bleeding, peripheral ischaemia possible,
(3) if the vessel is completely cut:
temporary bleeding & no blood flow distally.

If there is a blunt Injury, in other words the direction of trauma is from inside outwards, the results depend whether the intimal or medial layer is damaged: distal blood flow may then be occluded.

If only the adventitia is undamaged, a thrombus may form blocking distal flow, or an aneurysm develops later.

If you find signs of ischaemia in an injured limb, you must look for an arterial injury, but remember: *life before limb. Don't waste time trying to tie or repair a vessel if there are life-threatening problems elsewhere!*

If you are not sure whether there is an arterial injury or you can't find its exact location, perform an intra-arterial angiogram (49.3). *Remember the compartment syndrome* (49.6).
N.B. Reduce any fracture or dislocation before exploring the artery!
N.B. There is no need for an arteriogram if there are hard signs of injury.

49.3 Principles of vascular repair

Once you have controlled bleeding as described (49.1), you need to explore the wound and tie or repair the injured vessel, depending upon its collateral circulation. You can normally safely ligate (3.2; 3-4) these arteries, *(but don't use catgut, silk or linen):*

(1) external carotid,
(2) internal & common carotid (*N.B:* though there may be 25% risk of stroke, *ligation of the internal or common carotid arteries are usually safer than repair in an emergency)*,
(3) subclavian *(N.B: this may rupture on ligation!)*,
(4) profunda femoris,
(5) radial & ulnar,
(6) posterior tibial, & anterior tibial.
N.B. If the patient is old, or a smoker, he may rely entirely on these arteries if the natural collateral circulation is ineffective.

These arteries almost always need repair or reconstruction:
(1) brachial,
(2) external iliac,
(3) common or superficial femoral,
(4) popliteal.

In the abdomen (55.4), you can tie:
(1) the coeliac trunk,
(2) the inferior mesenteric &
(3) internal iliac arteries,
but you need to repair:
(1) the superior mesenteric,
(2) the renal,
(3) the common iliac arteries.

You may have great difficulty finding an injured artery, because the wound may be so badly mangled. The artery may be contracted and look very thin.
To find it you may have to release the tourniquet or the proximal clamp, and look for bleeding, or feel for pulsation.

IMMEDIATE TREATMENT
Take the patient to theatre, and make sure you have good lighting available. Place a pneumatic tourniquet (if it is not already there) (3.8) loosely round the injured limb high above a leg wound so that you can inflate it in a hurry later if you need to. Disinfect the wound site and at least 20cm on either side of it. Disinfect and drape any site from where you may need to take a graft (*e.g.* the opposite leg for harvesting the greater saphenous vein). Drape the limbs in such a way that they are moveable.

If the wound is so high up the limb that you cannot apply a tourniquet or a clamp, be prepared to expose and temporarily clamp the subclavian (49-7) or external iliac artery (49-8).
Use a prophylactic antibiotic and infuse 5000 IU heparin before clamping any vessel.
Gently remove the dressings, and explore the wound. Ligate larger vessels with non-absorbable sutures. To be absolutely sure, especially for larger vessels, place a transfixion-suture or doubly ligate the vessel, the 2nd time 2-5mm proximally.
N.B. Oversewing a vessel may include a nerve, so if the patient complains afterwards of pain or has a neurological deficit, it is worthwhile re-exploring the wound when the situation is calm.

If most bleeding has stopped, explore the wound without further trouble.

If the wound bleeds profusely, inflate the tourniquet before you try to explore it. Try to find the torn artery. Expose it nicely by increasing the incision, if necessary.
Obtain proximal and distal control by placing a rubber band (best made from a sterile surgical glove) or non-crushing 'bulldog' clamp on the vessel above and below where it is torn. Once you have control, you can release the tourniquet to check if there is serious bleeding elsewhere. (You can temporarily release the clamp on the artery if you are not sure that it is on the right place, but be ready to pump up the tourniquet again immediately!)

If you cannot find the damaged vessel (unusual), complete the wound toilet and any other repair, then deflate the tourniquet and look again for bleeding.

If you find massive bleeding from a major artery and you can't clamp it quickly, insert a Fogarty catheter into the lumen of the vessel and inflate it, until the bleeding stops. In very large vessels you can use a Foley catheter for the same purpose.

If you still cannot find the find the damaged artery or you are unsure, try to perform an angiogram.

Don't diagnose arterial spasm before you have opened the artery concerned (to exclude intimal damage).

INTRA-OPERATIVE ANGIOGRAM *(check that there is no known allergy to iodine or contrast)*:
N.B. You need an operating table with a space for an X-ray cassette, or for a limb, to have the cassette underneath it.
Expose the required proximal artery (the external carotid for severe maxillofacial injury, the subclavian artery for an axillary injury, the external iliac or common femoral artery for a thigh injury). Use a small butterfly needle to puncture the artery. Alternatively, especially if you have ultrasound, and you have a long enough needle (38.1g, 38-4), you can cannulate the required artery without exposing it.
Just before and during hand injection of full-strength contrast, manually compress the proximal inflow.
Use boluses of 10ml half-strength contrast for each phase sequence, and try to visualize the whole extremity. Normally 2-3 boluses are enough.
N.B. Full dose contrast may cause vasospasm and give a false impression of arterial injury.
Afterwards, press firmly over the puncture site for 2mins (without compressing the artery completely), or oversew the puncture site with 6/0 non-absorbable suture.

LIGATION, REPAIR OR SHUNT?
Once you have controlled the bleeding and debrided wound, decide whether to tie off the injured artery, try to repair it, or put in a shunt. Check with the list above on those arteries it is safe to ligate.

Always doubly ligate arteries! Use an atraumatic needle if available. *Don't try to ligate where the vessel is not looking healthy!*

If you find you can't repair the artery, **either because of lack of time or difficulty**, restore the circulation with a shunt. You can use any sterile tubing available, such as an IV line, NG tube, suction catheter or paediatric chest drain. Make sure you have proximal & distal vascular control.

If there is poor flow from either end, insert a Fogarty embolectomy catheter into both proximal and distal ends of the vessel, and irrigate diluted heparin-saline (1000 IU) both distally and proximally.

Insert a clamped shunt into the distal end of the vessel and allow back bleeding into the shunt, then insert the shunt into the proximal end of the vessel and release the clamp on the shunt. Secure it in place with sutures or vessel loops (49-5). *Be careful while inserting the shunt that you make as little damage as possible to the intimal layer of the artery*. *Make sure the shunt cannot dislodge*. Close the wound loosely.

Note the time when the shunt was inserted!

REMEMBER LIFE OVER LIMB!

You can leave the shunt in place up to 24h or even longer (but maintain IV heparin), giving you time to plan what to do next. Unless you can insert a vein graft (49.3), refer the patient.

A VASCULAR SHUNT INSERTED

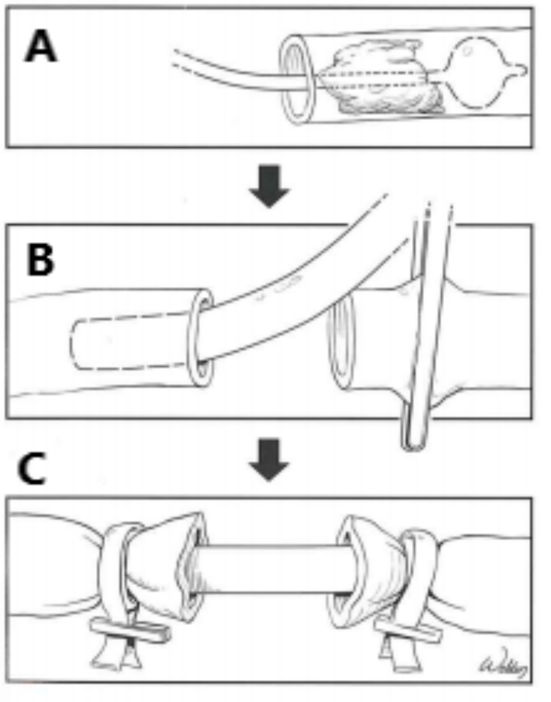


Fig. 49-5 A VASCULAR SHUNT INSERTED. A, pass an embolectomy catheter down both ends of the vessel. B, control the distal end, release the clamp and insert the shunt. Fix this with a Rummel tourniquet (*a ligature damages the artery*). C, insert the shunt into the proximal end and fix it likewise. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission*

49.4 Exposure of arteries

EXPOSING MAJOR ARTERIES
These are the classical methods of surgery. Though you may not need this information, no surgical textbook is really complete without these, and they may be life-saving.

(a) The external carotid artery (GRADE 3.3)
After a severe maxillofacial injury, you may have to expose the external carotid artery. This arises from the common carotid at the upper edge of the thyroid cartilage. It runs upwards behind the neck of the mandible, and ends by dividing into the maxillary and superficial temporal arteries. It lies under the posterior belly of the *digastric* muscle, and its upper part lies deep to the parotid gland.

PROCEDURE
Tilt the table 10º head up to minimize venous bleeding; but not more, because this increases the risk of air embolism. Turn the patient's head to the opposite side, and extend it slightly.
Make an oblique incision from just below and in front of the mastoid process, almost to the thyroid cartilage. Divide the *platsyma* and deep fascia in the line of the incision, and dissect flaps upwards and downwards.

EXPOSING THE CAROTID ARTERY

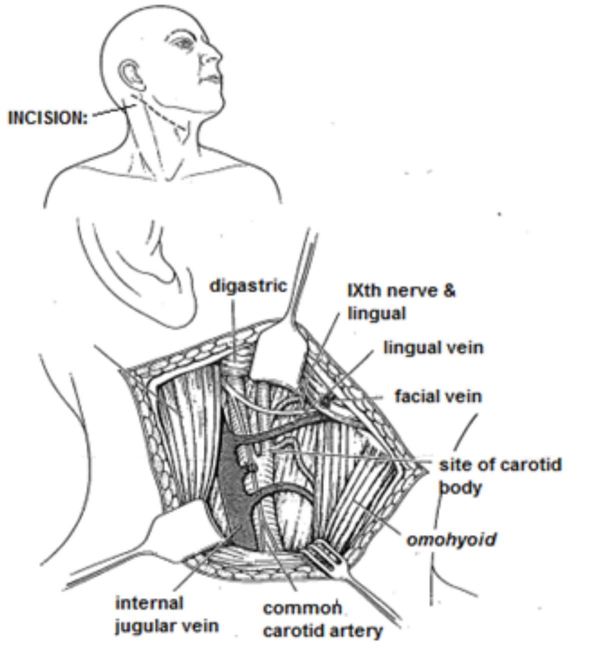


Fig. 49-6 EXPOSING THE RIGHT EXTERNAL CAROTID ARTERY. This controls bleeding in a severe maxillofacial injury. *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone, 7th ed 1976 with kind permission.*

Free the anterior border of the *sternomastoid* and retract it posteriorly. You will then see the common facial vein. Divide this between ligatures.

Carefully retract the internal jugular vein backwards, to visualize the common carotid artery bifurcating to form the internal and external carotid arteries.

If you have difficulty in deciding which artery is which, find some branches of the external carotid and follow them backwards to the main stem; *the internal carotid artery has no branches in the neck*.

CAUTION! (1) **If you tie the external carotid**, do so just proximal to the origin of the lingual artery. (2) *Avoid the IXth nerve* which crosses the external and internal carotid vessels and then runs anteriorly to lie on the *hyoglossus* in company with the lingual vein. (3) *Avoid irritating the carotid sinus and body* in the bifurcation of the internal and external carotid vessels, as this may cause alarming fluctuations in blood pressure!

(b) The subclavian artery (GRADE 3.4)

When a humeral neck fracture tears the axillary artery, it may cause a huge arterial haematoma which you can only control at the site of the subclavian artery.

The subclavian artery crosses the cervical pleura in the root of the neck. It passes over the 1st rib behind *scalenus anterior* which divides it into three parts. The 1st part is medial to this muscle, the 2nd is behind it. The 3rd part, lateral to the *scalenus anterior*, is the most accessible part.

The subclavian vein lies in front of the artery and slightly inferior to it. The phrenic nerve runs down the front of *scalenus anterior*.

Very occasionally, you may have to remove the middle part of the clavicle and split the fibres of *pectoralis major*, to reach the artery in the axilla.

PROCEDURE

Tilt the table 10º head up to minimize venous bleeding. Put the patient's arm by his side, and draw it downwards to depress his shoulder. Turn the head to the opposite side.

Make an incision 2cm above the clavicle from the sternal head of the *sternomastoid* to the anterior border of the *trapezius*. Incise the superficial fascia, the *platysma*, and the deep fascia in the line of the incision. If you see the external jugular vein crossing the operative field, divide this between ligatures. Retract the *omohyoid* upwards and you will see the 3rd part of the subclavian artery, with *scalenus anterior* medially, and the trunks of the brachial plexus laterally. The subclavian vein lies in front of the artery and below it.

EXPOSING THE SUBCLAVIAN ARTERY

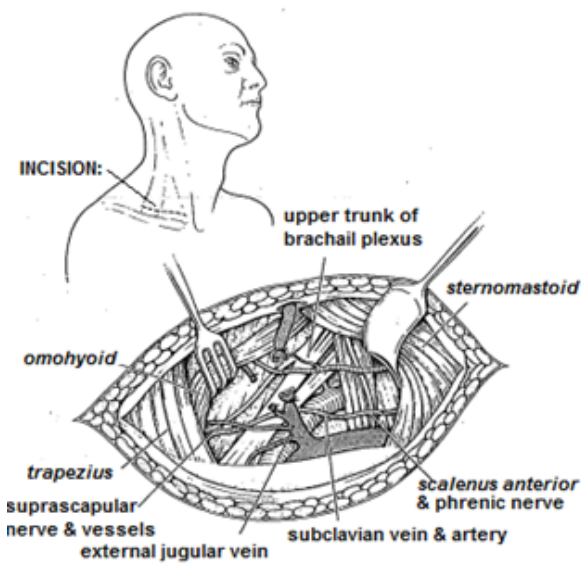


Fig. 49-7 EXPOSING THE 3rd PART OF THE SUBCLAVIAN ARTERY. If a humeral neck fracture tears the axillary artery (rare), it may cause an arterial haematoma which you can only control at the subclavian artery. *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone 7th ed. 1976 with kind permission.*

Ligate the subclavian artery with sutures around the clavicle. *Don't try to dissect it out as it has no adventitia and will crumble to pieces!*

N.B. Don't cut the transverse cervical artery under the omohyoid muscle, or the suprascapular artery crossing the subclavian artery, because they help maintain the collateral circulation to the arm.

N.B. Related damage to the brachial plexus is common.

(c) The axillary artery (GRADE 3.4)

PROCEDURE

Make a lazy-S incision (49-8A) from the mid-point of the clavicle to the anterior border of the *deltoid* with the *biceps.* Retract the cephalic vein with the *deltoid* upwards, and the *pectoralis major* medially and incise the clavi-pectoral fascia (49-8B) to get proximal & distal control of the axillary artery.

You may have to divide the humeral insertion of *pectoralis major* and the insertion of *pectoralis minor* (which covers the brachial plexus branches, *i.e.* origins of the musculocutaneous, median and ulnar nerves, lying on top of the artery, 49-8C) to get adequate access. You also may need to divide branches of the thoraco-acromial vessels obscuring the axillary vein, and retract the superi-lateral branch of the brachial plexus gently upward to obtain access to the axillary artery.

EXPOSING THE AXILLARY ARTERY

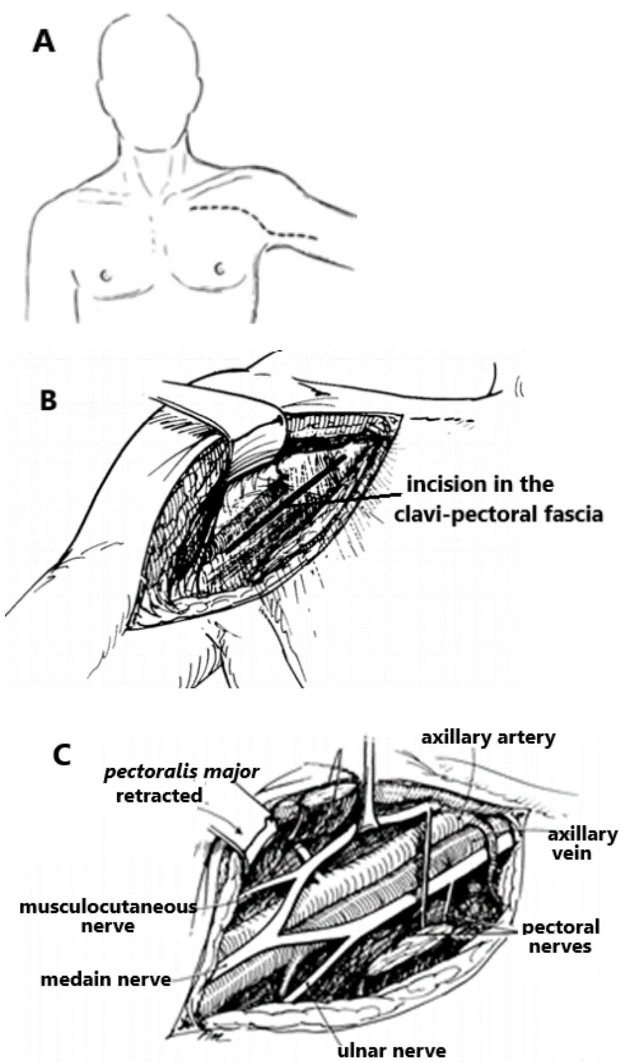
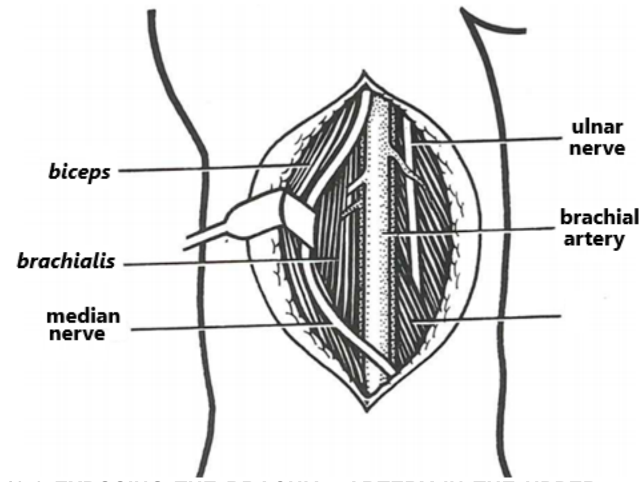


Fig. 49-8 EXPOSING THE AXILLARY ARTERY. A, a lazy-S incision. B, incising the clavipectoral fascia. C, the axillary artery exposed. *Adapted from Dudley H, Carter DC, Russell CG eds. Rob & Smith's Operative Surgery Butterworths 4th ed. 1989*

(d) The brachial artery (GRADE 3.3)
In the proximal upper arm, the brachial artery emerges behind the *teres major* tendon, and runs along the arm beneath the median border of *biceps* deep to the aponeurosis.

PROCEDURE
Put the arm at right angles on a table, with the hand supinated. Make an incision between *biceps* & *triceps*, hugging the former. Divide the deep fascia, and retract both *biceps* and median nerve, which crosses the artery superficially, laterally. The ulnar nerve lies deeper medially, and the musculocutaneous nerve is more superficial, retracted with the *biceps* (49-9).

EXPOSING THE BRACHIAL ARTERY



49-9 EXPOSING THE BRACHIAL ARTERY IN THE UPPER ARM. Make an incision along the medial border of *biceps,* and retract this with the musculocutaneous and median nerves laterally. *Adapted from Dudley HAF ed. Emergency Surgery. Wright Bristol 11th ed. 1986*

(e) The external iliac artery (GRADE 3.3)
If a wound in the groin, or too high up in the thigh to control with a tourniquet, is bleeding, get control of the external iliac artery if you can, although this may take longer than direct control of the femoral artery. *Be careful not to injure the external iliac vein and femoral nerve* as you do so.

The external iliac artery arises at the brim of the pelvis from the common iliac artery and runs to the mid inguinal point, where it becomes the femoral artery. The external iliac vein lies medial to it, and the *psoas* muscle behind it. The femoral nerve lies about 1cm lateral to it, with the genitofemoral nerve in between. The peritoneum lies in front of the artery, until the point at which it turns upwards onto the anterior abdominal wall.

Below this point, and immediately above the inguinal ligament, the external iliac artery lies on
(1) the *transversalis*, (2) *internal oblique*, & (3) *external oblique* muscles.
There are 2 branches of the external iliac artery: (1) the inferior epigastric artery, which runs upwards into the rectus sheath, (2) the deep circumflex iliac artery, which runs laterally along the back of the inguinal ligament.

PROCEDURE
Put the patient into a moderate Trendelenburg position. Make a 6cm incision 2cm above and parallel to the middle of the inguinal ligament (49-8). Incise the aponeurosis of *external* & *internal oblique* and open the transversalis fascia to expose the external iliac artery.

EXPOSING THE EXTERNAL ILIAC ARTERY

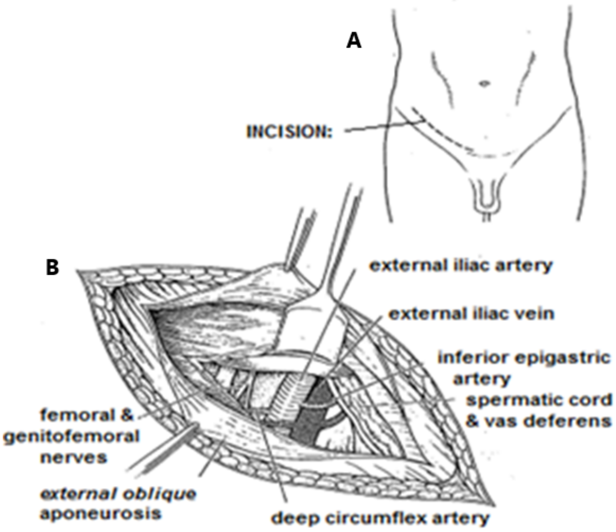


Fig. 49-10 EXPOSING THE EXTERNAL ILIAC ARTERY. A, groin incision. B, Exposing the external iliac artery. *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone 7th ed. 1976 with kind permission.*

Incise the *transversalis* fascia, and retract the spermatic cord upwards and medially. Gently push the peritoneum cranially and you will see the external iliac artery and vein. *Be careful not to cut the inferior epigastric artery and its vein*.

Separate the external iliac artery carefully from the vein, pass an aneurysm needle round it, and control it with a rubber band sling.

(f) The femoral artery (GRADE 3.3)

PROCEDURE
Make a vertical incision halfway between the pubic tubercle & the anterior superior iliac spine. Cut the *fascia lata* longitudinally and enter the fatty femoral triangle. Keep the wound open with a self-retaining retractor. Identify the inguinal ligament. Palpate for the femoral artery (*it might be pulseless!);* if you find muscle, you are too lateral! Open the femoral sheath above the artery and re-position the retractor. *Don't stray medially and hit the femoral vein or stray laterally and cut the femoral nerve!*

If there is a large groin haematoma, and you can't get access to the femoral vessels, find the inguinal ligament (49-11) and divide it. This will lead you straight to the external iliac artery, which you can put a loop round and control as above.

A LARGE GROIN HAEMATOMA

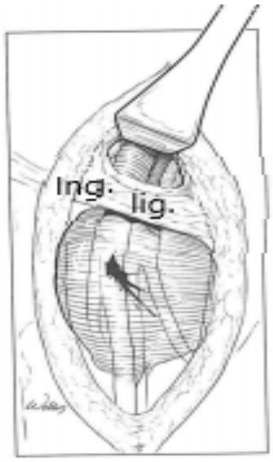


Fig. 49-11 DEALING WITH A LARGE GROIN HAEMATOMA. Find & incise the inguinal ligament so you can get access to the proximal external iliac artery. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission*

N.B. You will also need distal control!

The femoral artery will continue to bleed from its distal end. It is control of the deep femoral *(profunda femoris)* artery that is difficult: *don't try to dissect it out!*

You will find the junction of the long saphenous and femoral veins at the mid-point of the transverse inguinal crease.

Pass a tape from the lateral side under the common femoral artery proximally and out on the medial side; pass this again under the superficial femoral distally artery after its bifurcation to the lateral side.

ISOLATING THE DEEP FEMORAL ARTERY

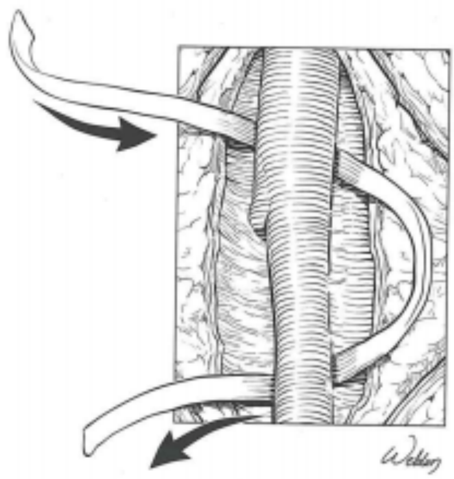


Fig. 49-12 ISOLATING THE DEEP FEMORAL ARTERY. Pass a tape under the common & superficial femoral arteries to hook the deep femoral branch. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission*

Pull on this and you will hook the deep femoral branch and isolate it (49-12); if you take the tape once more round the common femoral artery, you can control both together.

(g) The superficial femoral artery (GRADE 3.3)
The femoral artery starts at the mid inguinal point as a continuation of the external iliac artery. It runs down the thigh obliquely, first across the femoral triangle, and then underneath the *sartorius* muscle. It ends at the junction of the middle and lower thirds of the thigh, by going through a hole in the *adductor magnus*, and becoming the popliteal artery.

As the femoral artery crosses the femoral triangle, the femoral vein lies medial to it, becoming posterior distally; the femoral nerve lies c.1cm laterally.

Further on, when the femoral artery is in the canal below *sartorius, adductor longus* & *adductor magnus* lie behind it; *vastus medialis* lies antero-laterally.
The femoral vein now lies postero-laterally, the nerve to *vastus medialis* laterally and the saphenous nerve anteromedially.

PROCEDURE
Flex the patient's thigh slightly, support it on a pillow, and rotate it externally. Draw a line from the mid-inguinal point to the adductor tubercle. The femoral artery lies under the upper ⅔ of this line. Make an adequate incision here (49-13A).
The long saphenous vein lies in the superficial fascia. *Don't divide it,* as if the femoral vein is damaged or thrombosed, it provides the main venous collateral.

Incise the deep fascia, mobilize the *sartorius* muscle, and reflect this anteriorly to expose the upper part of the femoral and profunda arteries (49-16B). Use self-retaining retractors.

Gently separate the artery from the vein and *make sure you don't damage the overlying saphenous nerve*.

To expose the lower part of the femoral artery, reflect the *sartorius* posteriorly, and divide the bridge of fibrous tissue which makes the roof of the subsartorial (Hunter's) canal.

EXPLORING THE FEMORAL ARTERY IN THE THIGH

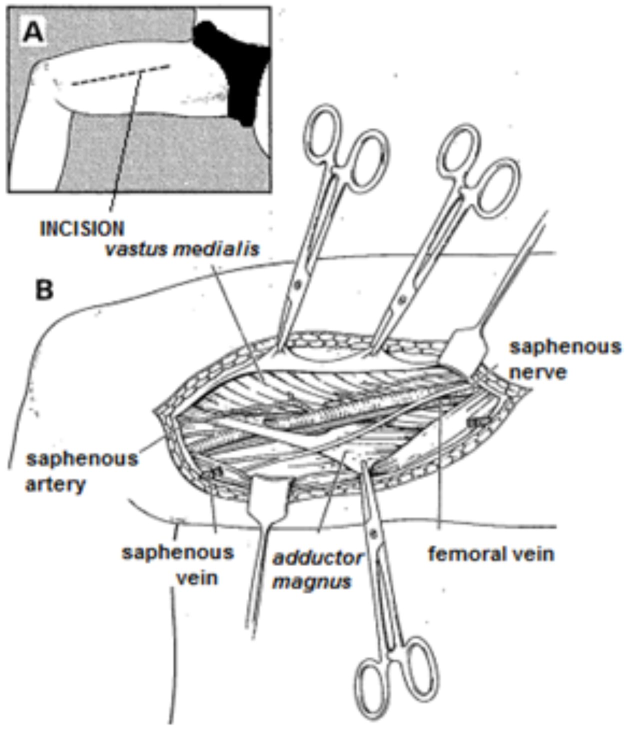


Fig. 49-13 EXPOSING THE ROUTE OF THE FEMORAL ARTERY. A, make an incision as shown. B, divide the fascia and expose the vessels carefully. *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone 7th ed. 1976 with kind permission.*

(h) The popliteal artery (GRADE 3.4)
Although the popliteal fossa looks easy in diagrams, in reality all its contents are cramped together. Nerves, arteries, and veins all look much the same until you dissect them out carefully.

The popliteal artery begins as the continuation of the femoral artery, at the opening in *adductor magnus*. It then runs downwards in the popliteal fossa until it reaches the lower border of the *popliteus*, where it divides to form the anterior and posterior tibial arteries, and the peroneal artery.

The popliteal vein lies medial to the lower end of the artery and crosses it posteriorly to lie posterolateral to its upper part.

The medial popliteal nerve crosses the popliteal artery and vein posteriorly from the lateral side above, to the medial side below. The lateral popliteal nerve lies more superficially in the lateral part of the fossa.

EXPOSING THE POLITEAL ARTERY

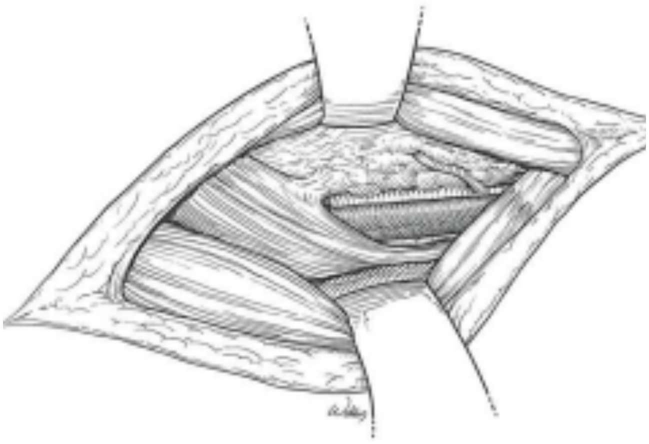


Fig. 49-14 EXPOSING THE PROXIMAL POPLITEAL ARTERY. Always begin with a lower leg fasciotomy. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

PROCEDURE
Begin with a lower leg fasciotomy, because you will need one later. Make a 10cm incision in the groove between *vastus medialis* & *sartorius,* somewhat distal to the distal femoral incision (49-14). Palpate the lower border of the femur. Incise the fascia behind it and try to feel for the popliteal artery. *Beware: the popliteal vein lies just next to it as well as the saphenous nerve!* Put a sling round the proximal popliteal artery.

Since exposure of the popliteal region is complex, it is better to create a tunnel between the femoral condyles with a finger big enough to enable you to pass a reversed saphenous vein graft through it later. Expose the distal popliteal artery through a separate incision 1cm behind the tibial border. *Make sure you don't damage the saphenous vein just posterior to your incision!* Divide the deep fascia behind the tibia, and carefully dissect the popliteal vein adjacent to the artery.

49.5 Vessel repair

OPTIONS FOR ARTERIAL REPAIR
Your choice in arterial injury is:
(1) Direct repair, if the defect is <25% of the circumference,
(2) Using a patch, if the defect is <50% of the circumference,
(3) Primary end to end anastomosis, if the defect is <2cm long,
(4) Inserting a graft, if the defect is >2cm long.
(5) Inserting a shunt, especially if there is an open fracture associated.
These last 2 may be quite long, *e.g.* in the adductor canal of the thigh, or in the popliteal fossa.

EQUIPMENT YOU NEED:
(1) Non-crushing arterial clamps.
(2) A very fine needle holder.
(3) Fine dissecting forceps (*e.g.* Adson's or ophthalmic forceps.
(4) Vessel loops made from strips 5mm wide, 10cm long cut from sterile surgical gloves.
(5) Half circle round–bodied atraumatic (or better, micropoint) needles on 6/0 mono-filament sutures. (Double-ended sutures are ideal.)
(6) Magnifying spectacles (*e.g.* Bishop Harman loupe): *very* useful.
(7) Heparin (or citrate solution from a blood transfusion bottle or bag).
(8) A fine blunt-ended hollow probe (for flushing).
(9) A good suction device.
(10) *Cross-matched blood!*
(11) Good lighting.
(12) Bipolar cautery (if possible)

Vascular surgery is normally considered to be strictly the work of a specialist. But the patient must reach such expertise within 4h of the injury; if this is impossible, you will have to do as best as you can yourself, *e.g.* by using a shunt. If you operate carefully, and handle the injured artery gently, you may succeed in repairing it, or at least ligating it. In so doing, you may save a patient's life, even if you cannot save the limb. *Don't try heroics which take hours of fine surgical craftsmanship*, if circumstances are against you. *The penalty for failure may be worse than accepting limb loss.*

A VASCULAR REPAIR MUST NEVER BE UNDER TENSION!

Other than the tools described, you do not need any special equipment, but this sort of surgery will take you a rather long time. Use the finest instruments you have; eye instruments are suitable if you treat them carefully, and so are eye sutures. But successful repairs have been done with coarser ones. You will need good aseptic technique, a strong light, adequate anesthesia, good eyesight, or magnifying spectacles, and maybe a blood transfusion.

You must perform wound toilet carefully, removing all dead or non-viable tissue. *Make sure adjacent bone fractures are well-aligned and fixed beforehand. Do not hesitate to enlarge the wound to improve visibility. If orthopaedic repair will take long, insert a temporary shunt.*

You have to stop the proximal flow in arteries before you can repair them; for this you can use tape, a rubber band or a non-crushing arterial clamp.

NEVER PUT A CRUSHING CLAMP ON AN ARTERY YOU WISH TO REPAIR!

Even rubber protection over the jaws of a haemostat will not prevent arterial injury. Instead

use special arterial ‘bulldog’ clamps, or the Rummel vascular tourniquet (49-17A).
This is simply a length of stout linen, cotton tape, or vessel loop passed round the artery and then threaded through a rubber or plastic tube.
By pulling the tape and pushing the tube down onto the artery you will occlude it. In order to stop blood clotting in an occluded artery, inject diluted heparin into both proximal and distal ends.

TORN ARTERIES
Arteries are elastic, so mobilize enough of the artery above and below the wound to let you work on it. However, if they go into spasm & retract, then you may have to search for their ends. Occlude the flow above and below the arterial injury.
In an emergency, ask your assistant to hold the artery between first finger and thumb.
Irrigate heparin-saline into the vessel on each side of the injury. Try to preserve any reasonably sized branches, because these will help to maintain the collateral circulation if the repair fails.

If the artery is only partly divided or cut longitudinally, you may be able to close it primarily – the injury must not involve >25% of its circumference: *you must not narrow the lumen* and produce a stenosis – better in this case to use a patch.

If the artery has been nearly cut across, re-unite its cut ends.
If a length of the artery is bruised or torn, **or its cut ends are ragged**, trim the damaged piece (49-16A,C) and bring clean ends together for anastomosis (49-16D,E).
You may be able to excise ≤2cm and still bring the ends together after mobilizing the artery properly.
Make sure that there is no tension on the anastomosis!
If the ends of the injured artery will not come together easily, insert a reversed saphenous vein graft.

PRIMARY ARTERIAL SUTURE (GRADE 3.2)
This is usually only feasible for knife injuries.
For successful results, remember:
(1) primary suture may create a stenosis,
(2) use 5/0 or 6/0 sutures, or 4/0 for larger vessel,
(3) always make an everting suture (from inside outwards, from proximal to distal) on the arterial wall,
(4) keep 1mm distance between sutures,
(5) keep the knots on the outside of the artery.
Before completing the closure, flush and rinse both arms of the reconstructed vessel with heparin-saline, inspect the lumen, and restore the blood flow. Only then finish applying & tying your suture.

DON’T TRY PRIMARY ARTERIAL REPAIR IF THERE IS CONTAMINATION OR CONTUSION OF THE VESSEL WALL.

PATCH ANGIOPLASTY (GRADE 3.3)
Harvest a piece of saphenous vein (35.8), open it out, make sure the *intima* faces inwards, and discard any segment with a valve in place.
Trim a template of glove material to size to match the arterial defect you wish to close, and use this to cut out the vein patch carefully.

Start at the distal end of the patch, or at the end which is more difficult to reach. Place a continuous everting suture (49-13B), sewing the patch onto the defect. Continue till you reach the middle of the circumference of the patch, taking care to place the points of the suture slightly further apart on the vessel than on the patch. Then start again where you began and go round the other way on the patch to reach where you had stopped before.
Before completing the suture, release the clamps to flush the distal and proximal ends and rinse both with heparin-saline in both directions, as with the primary repair.

ARTERIAL END-TO-END ANASTOMOSIS (GRADE 3.3)
There should never be any tension on the anastomosis! If the ends of the injured artery do not come together easily, insert a vein graft!

It is best to make oblique cuts across an artery (49-16E), rather than perpendicular cuts. Place a cut piece of glove behind the artery to make it easier to see where to put your sutures.
Before you start the anastomosis, allow the artery to bleed from both ends to flush out any thrombus that may have formed within its lumen. Squeeze any more thrombus out of the cut ends of the artery and irrigate heparin-saline into both ends of the artery.

THROMBECTOMY

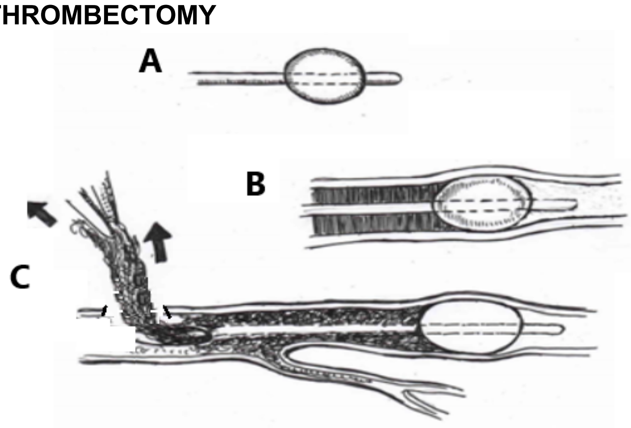


Fig. 49-15 EXTRACTING A THROMBUS. A, The balloon of the Fogarty catheter passed beyond the thrombus (or embolus) & inflated. B, Extracting the thrombus from an artery, through the arteriotomy. *After Fogarty TJ, Krause RJ,*

Hafner CD, A method of extraction of arterial emboli and thrombi. Surg Gyn Obs 1963; 116:241-4.

ARTERIAL THROMBECTOMY (GRADE 3.2)
If there is no backflow or no inflow perform a Fogarty manoeuvre if possible. Introduce the catheter gently into the blocked lumen of the artery for 10cm or so, and then inflate the balloon; pull the catheter gently back (49-14). You may have to repeat this till you get a good flow.

Bring the cut ends of the artery together with two stay sutures at opposite sides. Two more intervening stays may help steady the artery and rotate it, where necessary. *Make your sutures from proximal to distal, tacking the distal intima down to prevent it lifting like a valve.*

If the artery is >5mm in diameter, starting at the back of the artery, place a continuous everting suture with points 1mm apart (49-17B).

If the artery is <5mm in diameter, use an interrupted suture. When the suture is nearly complete, release the clamps first, flush and rinse the artery in both directions with heparin-saline, as before. Then complete the suture and release the distal clamp first. This low pressure retrograde flow will show up any leaks. If there is a significant leak, close it with 1 or 2 sutures.

REPAIRING INJURED ARTERIES

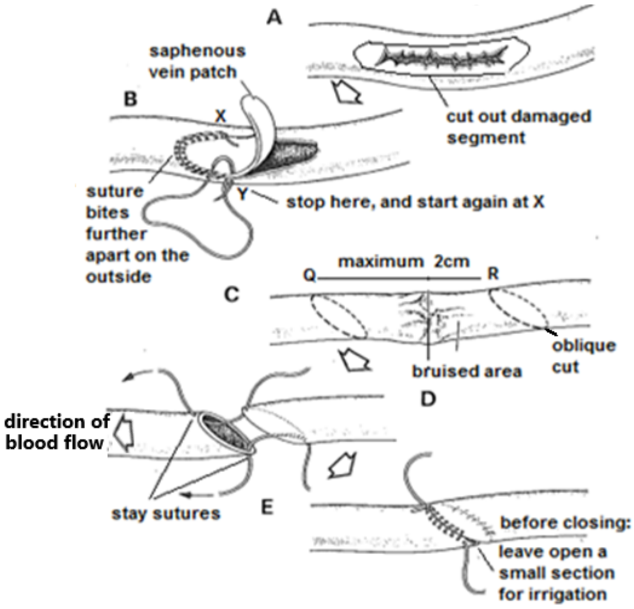


Fig. 49-16 REPAIR OF INJURED ARTERIES. A, a ragged laceration needing part of the wall excised. B, suturing on a patch: start at X, with suture bites further apart on the outside than on the inside of the curve. C, a bruised section of artery needing total excision; cut the artery *obliquely*. D, as long as the excised portion (QR) is <2cm long, start the anastomosis with stay sutures opposite each other, suturing from proximal to distal. E, before completing the anastomosis, flush the vessel with heparin-saline. *After Blackburn G, Field Surgery Pocket Book, Min Defence, HM Stationery Office, London. with kind permission.*

Then press lightly on the anastomosis with gauze and gradually release the proximal clamp. The repair will bleed, but this will usually stop spontaneously in 5mins. If it does not, and there is an obvious leaking site, put in more sutures. *Be patient: do not put in more and more sutures in panic!*

Finally, remove the piece of glove you put behind the anastomosed artery.

END-TO-END ARTERIAL ANASTOMOSIS

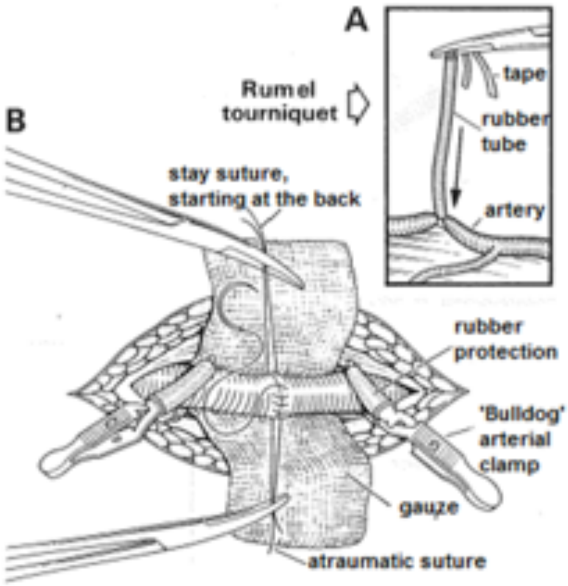


Fig. 49-17 END-TO-END ARTERIAL ANASTOMOSIS. A, insert a tape into a tube, and sling it round the artery to obstruct it, and hold it with a clamp. B, use protected arterial clamps. Start the anastomosis at the back. *Adapted from Dudley H, Hamilton Bailey's Emergency Surgery, Butterworth 9th ed. 1976 with kind permission.*

REVERSED SAPHENOUS VEIN GRAFT (GRADE 3.4)
If a large section of an artery is injured so that you cannot bring its ends together, use a piece of saphenous vein to bridge the gap. Although you are only using a vein, it will withstand arterial blood pressure adequately, and will resist infection better than an artificial graft. This is a procedure for the careful operator where referral is not an option (35.8).

Expose the saphenous vein (*don't take it from the injured leg, unless you have to*) through an adequate incision along its length, starting at the groin. Remove a suitable length of vein, and doubly ligate with 4/0 monofilament all its side branches and cut them off.

N.B. The cephalic vein in the arm is another choice.

Proximally (for larger branches) it is better to transfix them. Remove the isolated segment of vein, turn it round so that the foot end becomes the proximal end.

Clamp the distal end with a haemostat, and irrigate the vein with heparin-saline under mild pressure. This will show up leaks from any ligated side branches (35-25) you may have missed. It will also distend the vein most usefully, but *take care not to distend it too much*. Leave it distended with heparin-saline and lying in some heparin-saline or blood while you prepare the artery to receive it.
Trim both ends of the vein obliquely to the correct length and anastomose the ends to the artery, as above.
Make sure you have reversed the vein and any valves do not block the blood flow.

Remove the distal arterial clamp just before the last sutures, as before, so that any air caught inside the vein can escape through the remaining gap between your last sutures. Rinse proximal and distal arms as before with heparin-saline.

Leave the repair under a warm saline pack while you wait 10mins. Then inspect it, and if it is pulsating, cover it with adjacent tissue and close the wound. *Make sure near-by fractures are well aligned before you attempt any vascular repair!*

ARTERIAL BYPASS (GRADE 3.4)
Where greater arterial damage exists, or you have had to tie off one of the critical arteries listed earlier, you can insert a bypass using a long segment of reversed saphenous vein.

Harvest the saphenous vein as before, but *make sure you have enough length.* Start with the distal anastomosis; remember to turn the vein round so the valves do not block the blood flow.
Make a longitudinal arteriotomy of at least 15mm (or at least 3 times the diameter of the artery) at a suitable site where the artery is undamaged. Start at the heel of the graft and suture as for a patch graft. The flatter the angle, the better the haemodynamics of the subsequent blood flow.

If you are performing an above-knee bypass, place the vein underneath *sartorius*, along the adductor canal.

If you are performing a below-knee bypass, place the vein through the popliteal region in between the femoral condyles (where the popliteal artery normally lies).

Once you have exposed the artery, controlled haemorrhage, and excised the damaged segment, you are ready to start. Fill the graft with heparin-saline before pulling it through its preformed channel: in that way, it is less likely to twist.
Use a long straight artery clamp to pull the bypass vein graft along the channel you have made.
Finally perform the proximal end-to-side anastomosis in the same way. Similarly, before completing the sutures, flush and rinse as before; then release the distal clamp. *Make sure there is adequate backflow.* Then release the proximal clamp. There should now be a good pulse visible or palpable on the graft.
Make sure you can also feel the pulse on the distal artery. The peripheral part of the limb should now warm up: check the peripheral pulses!

WOUND TOILET
Do this carefully. Remove all dead or non-viable tissue from the wound (46.2). If there is a fracture combined with the arterial injury, first realign the bone before inserting a shunt. If you don't do this, you will not be able to judge the length of the graft needed.

Cover the arterial repair with living muscle or subcutaneous tissue. *Don't leave it exposed while waiting for delayed primary closure*. You can rotate a tissue flap over it, or partially close the wound. If the wound was a very contaminated, use a vacuum dressing, *but never put the sponge directly on the vessel*! Some healthy tissue should always cover your reconstruction.

TORN VEINS
You can safely tie most lacerated veins without causing any disability, but those bigger than the common femoral vein you should repair, if possible.
Repairing a large vein is usually more difficult than suturing an artery, because blood wells up into the wound, instead of spurting out, and obscures the view. However, a simple continuous suture usually suffices.

Veins you should repair are the:
(1) internal jugular vein,
(2) external iliac vein,
(3) common femoral vein.
Try always to repair combined arteriovenous injuries: deal with the vein first, before repairing the artery. Always harvest the saphenous vein from the uninjured leg, if possible.

Sponge holding forceps are useful in pressing onto a torn vein because they flatten it. If possible, use lateral occluding clamps which will let you see the edges of the tear and insert a layer of fine continuous sutures.

If bleeding continues, press firmly on the vein above and below the tear. This will empty it and show you its hole outlined against the posterior wall.

Venous walls are very delicate and easily torn: use only 6/0 sutures and only attempt to repair big veins. Sutures readily tear a small vein wall and enlarge a hole in it.

If all else fails, occlude the vein above and below the tear, and ligate it. Fortunately, you can tie nearly all veins in case of emergency.

POSTOPERATIVE CARE
After a vascular repair, monitor the patient carefully, looking for signs of haemorrhage, distal ischaemia infection or compartment syndrome.

Elevate a limb slightly and begin isometric muscle exercises on the 1st day postop. (Bed rest may still be necessary for wounds.)

N.B. Treating a patient with 7500 IU heparin IV continuously over 24h, or otherwise 2500 IU tid, needs very careful monitoring for haemorrhage, and *may not be wise in your situation.*

DIFFICULTIES WITH ARTERIAL REPAIR

If the wound becomes infected, the arterial repair may break down & bleed, or thrombose. *Don't try to make another repair until all the infection has settled.* You will have to remove the infected arterial segment, and put in a shunt or resort to a distal amputation.

If the arterial repair thromboses, this is due to inadequate debridement, residual distal thrombus, severe anastomotic stenosis, or flow interruption of a vein graft from kinking, twisting, external compression or failure to reverse its flow orientation. Unfortunately, you will have to repeat the operation.

Other dreaded complications are compartment syndrome (49.8), false aneurysm or arteriovenous fistula (49.9).

49.6 Stab wound close to a major artery

The common danger site for this emergency is the groin. Open and explore the wound early, so as to examine the artery and repair it if necessary. This will be easier than trying to deal with the arterial hematoma or false aneurysm that may result from leaving it.
Explore the wound under GA (ketamine is usually ideal). Try to get proximal control of the vessel (if necessary expose a proximal artery, through a separate incision, 49.3). Repair the damage by direct suture, patch or graft, as needed (49.3)

If the artery and vein are both injured, use suction to find out where to press to gain control. Separate the two vessels to prevent an arterio-venous fistula.

ALWAYS EXPLORE STAB WOUNDS CLOSE TO ARTERIES!

49.7 Pulsating arterial haematoma

Several things may occur if bleeding from an injured artery cannot escape to the surface:
(1) Blood may track widely in the tissues.
(2) A tense arterial haematoma may form locally, which may press on the collateral vessels and obstruct them.
(3) The outer layers of the haematoma may become organized and form a traumatic (false) arterial aneurysm (35.8).
(4) A false aneurysm may rupture into a vein, forming an arteriovenous fistula.

Initially, an arterial haematoma may be difficult to diagnose. Suspect that this is likely whenever an artery is injured by a penetrating wound (especially in the groin), a fracture or even needle puncture.

If it is rapidly expanding, explore it before it becomes an aneurysm or an arteriovenous fistula, both of which are even more difficult to treat.

If there are no signs of distal ischaemia, apply a bandage and wait for the fistula to 'mature'.

EXPLORING A PULSATING HEMATOMA (GRADE 3.2):
Apply a tourniquet proximally to control bleeding. If this is not possible, control the external iliac artery (49.3).

Make an adequate incision to explore the wound. Expose the artery first proximal to the injury, and control its flow with an arterial clamp, or tape. Try to get distal control in the same way.
Remove the clots. Use suction to define the anatomy carefully; you may find you have to improve proximal control. When there is no more bleeding, repair the injured artery (49.3) and ligate injured veins. Finally, release the clamp or tourniquet cautiously to see if your repair leaks. If so, press on it for 5mins and look again.

If the haematoma is below the elbow or knee, you may tie the injured artery.

If the haematoma is above the elbow or knee, try to repair the injured artery. If you feel you cannot do this, or you don't have the necessary equipment, insert a shunt (49-5).

49.8 Limb compartment syndrome

The circulation in a limb is probably impaired and there is danger of ischaemic damage (Volkmann's ischemic contracture (44.8) or even gangrene)
if a patient with a limb injury:
(1) has severe pain (*always believe him!)*,
(2) has loss of sensation in the fingers or toes,
(3) has peripheral pallor or cyanosis,
(4) has cold fingers or toes,
(5) cannot move the fingers or toes,
(6) has absent distal pulses,
- the 6 P's (49.1) – even if the pulse is still palpable, and capillary return is still normal, suspect the compartment syndrome.

Pain is often out of proportion to the visible signs.

Don't rely entirely on the figures, though!
The commonest causes of these disasters are:

(1) An unsplit cast on a forearm or lower leg fracture (58.2).
(2) A child's supracondylar humeral or forearm fracture (72.6,7) .
(3) A fractured tibia (68.2).
(4) Any complicated fracture or crush injury, especially if delayed >4h.
(5) An elbow (61.3) or knee dislocation (67.15).
(6) Gallows or extension traction for a femoral fracture (72.4).
(7) A bullet wound & combined arterio-venous injury.
(8) Re-perfusion injury after arterial ligation or repair, *especially the popliteal.*
(9) Burn contracture (34.2).
(10) Tourniquets left *in situ* too long.
(11) Snake bites (46.11).
(12) Acute venous thrombosis.
(13) Chronic muscle exertion.
You may be better off performing a fasciotomy pre-emptively, especially in a popliteal artery repair.

ASLAM (43) struck his forearm while water-skiing but did not fracture it. Eight hours later it became acutely painful and he could not extend his wrist or fingers. He consulted his neighbour, an orthopaedic surgeon, who decompressed his forearm within the hour, from wrist to elbow, leaving his skin and fascia open. Dark swollen muscle bulged out of the wound. He was discharged the following morning, and his incision was closed 5 days later. He recovered completely.
LESSONS (1) Remember the compartment syndrome. A happy outcome followed what might have been a major tragedy after a minor injury. (2) *Don't delay!* Immediate decompression is imperative.

When a patient's fracture is reduced the pain should lessen. *Severe postoperative pain is thus a critical early sign.*

After a fracture, or even after bruising of the lower leg, blood and oedema fluid may collect in all, or any, of these compartments. As the volume of fluid increases, the intra-compartmental pressure rises so that the circulation to the foot is obstructed.

The cure is simple: FASCIOTOMY!

MEASURING TISSUE COMPARTMENT PRESSURE

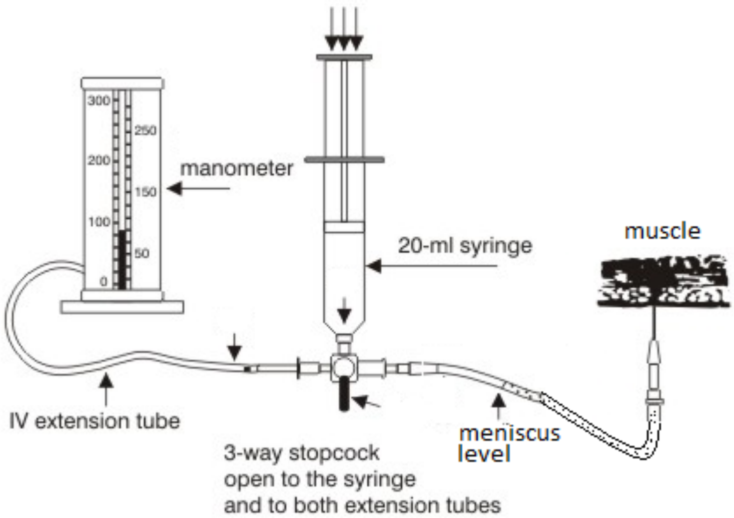


Fig. 49-18 TISSUE COMPARTMENT MEASUREMENT. ***Do this only in dubious cases!*** **A, connect a syringe with the plunger at the 15ml mark to IV tube connected to an 18G needle and another IV tube to a manometer via a 3-way stopcock. B, aspirate saline into the tubes and syringe so that a meniscus rests c. ¾ the length of the injection tube. C, close the stopcock, and insert the needle into the muscle compartment without spilling fluid. D, now open the 3-way stopcock so that the syringe is open to both manometer & muscle compartment. E, depress the plunger of the syringe gently and watch the meniscus. Measure the manometric pressure just when the fluid level begins to move.** *After Whitesides TE Jr, Haney TC, Morimoto K, Harada H. Tissue pressure measurements as a determinant for the need of fasciotomy. Clin Orthop Relat Res. 1975; 113:43-51*

You can measure the tissue pressure in the compartment easily (49-18). *Make sure the manometer and the limb are at the same level*. If the pressure is >30mm Hg, or the difference between diastolic BP and tissue pressure is <30mm Hg, the limb is in danger.
N.B. 30mm Hg = 40cm H_2O.

You must diagnose the compartment syndrome in time. Unless you perform a fasciotomy within 4h of symptoms starting & open up each compartment in turn through a generous longitudinal incision, the soft tissues will die. So **if you cannot perform the**

measurements (49-18) in time, go straight ahead with fasciotomy!

If the muscles feel tense, swollen, and almost woody hard, decompression is urgent. However operation is still worthwhile even if a patient presents late. Perform a fasciotomy liberally or even prophylactically in patients with arterial injuries or the suspicion of ischaemia. Open up all the muscle compartments using long scissors, *not a knife*. *N.B. Beware rhabdomyolysis* (49.9) !

THE AFTER-EFFECTS OF A FASCIOTOMY ARE MINIMAL, BUT ISCHAEMIC MUSCLE NEVER RECOVERS.

Arterial spasm from local blunt injury may produce the same effects, and also needs rapid treatment.

There are 2 compartments in the forearm, where muscles are enclosed and separated from each other by strong fascia:
(1) The anterior compartment with the flexors.
(2) The posterior compartment containing the extensors.

There are 4 compartments in the lower leg,
(1) The lateral compartment with the *peroneal* muscles.
(2) The anterior compartment with the *extensor* muscles of the ankle and toes.
(3) The superficial posterior compartment with the *gastrocnemius* and *soleus* muscles.
(4) The deep posterior compartment with the deep *flexors*.

TREATMENT

If the symptoms persist, proceed urgently with fasciotomy.

If the limb is in a cast, split, open, and elevate it.

If this does not rapidly relieve the symptoms, remove the cast entirely.
Unfortunately, in removing the cast you will lose immobilization of a fracture. So, as soon as the circulation returns, apply skeletal traction. Later, reposition the fracture if necessary, and reapply the cast.

WHICH COMPARTMENT?
Function relates to the compartment affected, but stretching an ischaemic muscle causes pain, so:

If extending the fingers is weak, the anterior compartment is ischaemic.
If flexing the fingers is weak (rare)**,** the posterior compartment is ischaemic.

If flexing the foot and toes causes pain, the anterior compartment is ischaemic.
If extending the foot and toes causes pain, the anterior compartment is ischaemic.
ANTERIOR FOREARM FASCIOTOMY

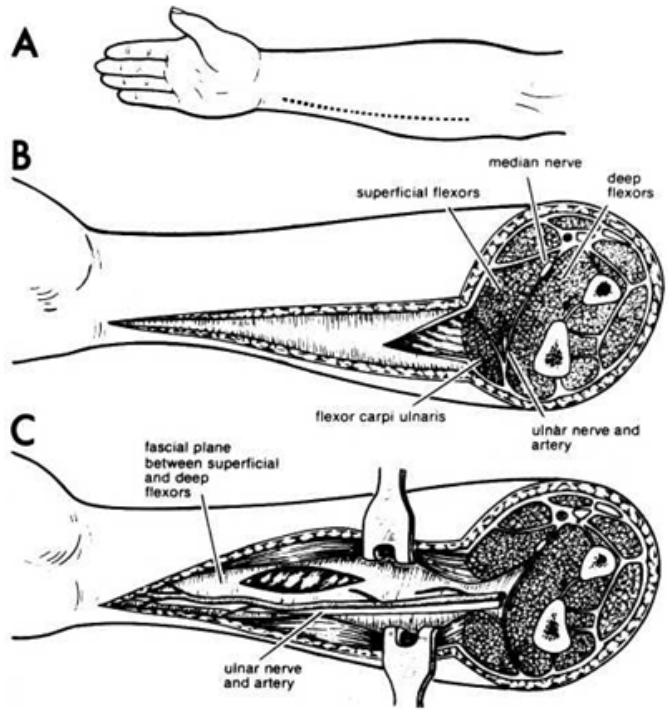


Fig. 49-19 ANTERIOR FASCIOTOMY IN THE FOREARM A, the incision. B, cutting the fascia over *flexor carpi ulnaris.* C, cross-section showing the positions of the ulnar nerve and artery. *After Sheridan GW, Matsen 3rd FA, Fasciotomy in the treatment of the acute compartment syndrome J Bone Joint Surg Am 1976;58(1):112-5 with kind permission*

ANTERIOR FOREARM FASCIOTOMY
(GRADE 1.4)

Make an incision from the medial epicondyle to the ulnar end of the flexor crease on the wrist (49-19A). Incise the fascia over the *flexor carpi ulnaris* (49-19B), and retract this muscle medially. mRetract the *superficial flexor* muscles laterally, and incise the fascia over the *deep flexors*.

Decompress each muscle by making a longitudinal incision through its sheath, carefully avoiding its nerve. The pale compressed muscle tissue will bulge up gratefully, as you release the pressure in its sheath. If you have acted in time, a conspicuous hyperaemia will follow. If you are too late, the deep flexor muscles will be mauve, yellow or necrotic.

The nerve lies close to the artery under the *flexor carpi ulnaris*, and between it and the *deep flexors* (49-19C).

CAUTION! Don't cut the ulnar nerve or ulnar artery. Put K-wires through the 2nd, 3rd, & 4th metacarpals (64.29), suspend the arm vertically, and leave the wound open, unsutured, under a gauze or hypochlorite dressing. Continue to apply traction. This usually reduces the fracture.

CAUTION!
Don't re-apply a cast till the swelling has subsided. Don't close the compartments!

Leave the wound wide open, covered with gauze, and a suction dressing if possible. The gap will usually close as the swelling subsides. If necessary, close the wound with a skin graft, or delayed primary suture.

DECOMPRESSING THE FOREARM IS AN ACUTE EMERGENCY

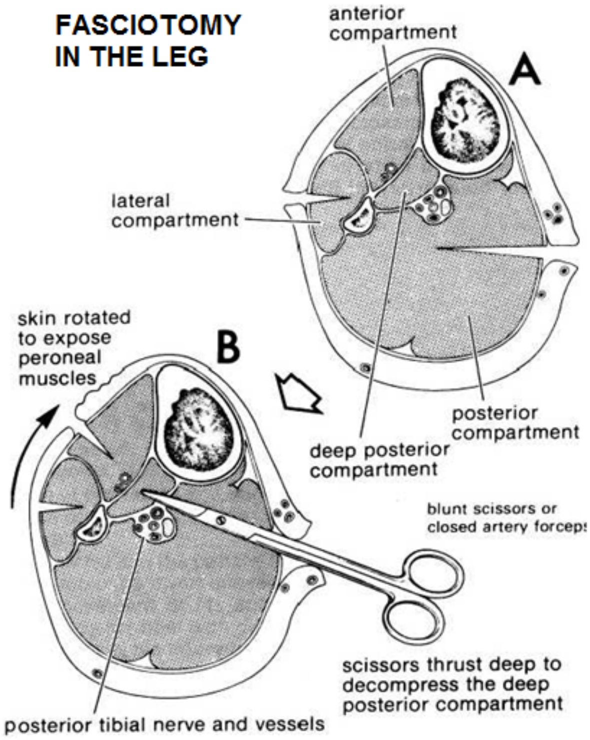


Fig. 49-20 FASCIOTOMY IN THE LEG. A, incisions for the lateral and posterior compartments. B, opening up the deep posterior compartment, showing how you can slide the skin incision you have used to open the lateral compartment forwards, so that you can also open the anterior compartment through it. *Kindly contributed by Peter Bewes.*

LEG FASCIOTOMY (GRADE 1.4)
Make at least 2 incisions in opposite compartments because you may otherwise miss dangerous muscle necrosis in an unopened compartment.
Make sure you always open both compartments in the forearm and all 4 in the lower leg.

DIFFICULTIES WITH COMPARTMENT SYNDROME

If you have no K-wire, decompress the forearm, splint it with a plaster backslab, and refer the patient as soon as you can.

If the ischaemia is advanced when you decompress the forearm, maintain a high alkaline urine output, to assist the excretion of the myoglobin released from the necrotic muscle, and watch for renal failure (44.10).

If a contracture develops, apply splints to minimize the deformity as much as possible.

(a) Medial incision: make a 15cm longitudinal incision on the medial side of the leg. Cut through deep fascia from the knee to the ankle. Incise the turgid, dark, reddish blue, ischaemic muscle of the posterior compartment.
Slide the skin incision anteriorly over the subcutaneous tissue (49-20), and incise the muscle under it so as to decompress the anterior tibial compartment. This will enable you to decompress both compartments through the same incision.

Don't miss out cutting the retinaculum which keeps the tendons of the anterior muscles in place at the ankle).

DIFFICULTIES WITH FASCIOTOMY
If the circulation returns to the foot, no further incisions are necessary.

(b) Lateral incision: make a similar 15cm longitudinal incision on the lateral side of the leg. Incise the fascia and the muscle directly underneath it, and decompress the peroneal compartment

.
If the circulation does not return to the foot in a few minutes, deepen the medial incision to open up the deep posterior compartment. Push scissors deeply into it and open the blades, as if you were exploring an abscess by Hilton's method (6-3).
Don't use a knife in the depths, or you may cut the posterior tibial artery, or tibial nerve.

If circulation still does not return, expose the artery: a tightly contracted artery may look like a piece of solid cord. The distal part of the brachial artery, the femoral, the popliteal, and the tibial arteries can all contract like this.
Expose the injured vessel through an adequate incision. This alone may be enough to make it start pulsating again.

If the artery does not start pulsating after exposing it and part of it looks like a piece of whipcord, expose the healthy artery above and below the cord-like section. Expose it on all sides, so that there is no tissue surrounding it.

If the artery fails to dilate, open an ampoule of 2% papaverine, or less satisfactorily, pethidine, or 2% lidocaine (without adrenaline), and spray this onto the contracted segment.
Then lay a warm moist pack on it, and wait 10mins, after which the artery will usually have increased in size and will have started to pulsate.

If the artery is still not pulsating, apply an arterial clamp above the constriction, and inject 2ml 2% lidocaine with a little heparin, between the clamp and the constriction. This may distend it enough to make it start pulsating. Wait another 10mins while the heparin acts.
Then release the clamp. **If the artery is torn or the spasm does not recover**, repair or graft it (49.3).

If there is a fracture, apply calcaneal traction until definitive treatment is possible later.

If the muscle does not recover rapidly, contractures are likely. Splint the extremity in the position of function.

If the patient presents >6h*, it is still worthwhile performing a delayed decompression,* because any improvement will result in some functional gain and gangrene is much less likely.

If the compartment syndrome is several days old*, don't perform a fasciotomy.* Splint the limb in the position of function (neutral and slightly everted). If it survives, it will still be useful for some activities. *Fasciotomy at this late stage will not help* and may lead to infection and an otherwise unnecessary amputation.

49.9 Rhabdomyolysis

Decompression of a compartment may result in rhabdomyolysis (the re-perfusion injury). The urine becomes dark or 'bloody' looking; the dipstick is positive but there are no red cells on microscopic examination. Look for myoglobin in the urine, if you can.

Rhabdomyolysis occurs when muscles remain immobile, during seizures, in long-standing splinting, in patients collapsed for longer periods on the ground, in crush injury (58.16), excessive exercise and being suspended in torture (47.1).

This is more likely to occur in sickle cell disease, in drowning (43.7), hypothermia (45.2), hyperthermia (45.3), and drug & alcohol abuse, even without compartment syndrome, as well as in certain snake bites (46.11).

Maintain a high urine output to excrete the myoglobin (which blocks the kidneys). Aim for a urine output of 2–3ml/kg/h). You may need to infuse 6l/day; (children may require 2-3x maintenance dose). Try to monitor the CVP if possible.

For moderate and severe rhabdomyolysis and in patients with acidosis, dehydration, or underlying renal disease, add 44mEq of sodium bicarbonate to 1L 0.9% saline, and infuse this at 100 mL/h as part of the total IV fluid administered.
Try to adjust the IV bicarbonate concentration or rate to achieve a urine dipstick pH>6.5-7.0.
CAUTION! Don't alkalinize the urine in children. *Using sodium bicarbonate* may potentiate hypocalcaemia.

To increase urine output if it is inadequate, use mannitol (in adults) and furosemide. You will need to be aggressive with IV fluid input to be sure of a good urine output until all the myoglobin is excreted.

50 Burns

50.1 Introduction

Burns are common and can vary from minor superficial injuries that you can treat as out-patients to severe life-threatening trauma with extensive deep tissue damage.

The skin is the largest organ in the body. It isolates the inside of the body from the outside, chemically, thermally, mechanically, and biologically. It presents a huge surface protecting against body loss of water, electrolytes, proteins, and heat, and ingress of bacteria and toxins.

There is a very real risk of death in extensive burn injuries, so don't raise expectations beyond what is possible. Full thickness burns covering >50% of the body surface are usually fatal outside specialist burn centres with the necessary resources. However, with the majority of burns, appropriate treatment can significantly improve outcomes and reduce complications.

Most burn injuries are of mixed depth and it is not always easy to assess the depth and surface area involved accurately, especially in the acute situation.

A thorough history and examination is critical and should include details of any comorbidity. Burns accompanying other trauma, such as from a blast or explosion, have a higher mortality; as do burns associated with inhalation injury, especially if there is also chronic airway disease or in old age.

However, with the majority of burns, appropriate treatment can significantly improve outcomes and reduce complications.

Children, because they are still growing are at increased risk of developing contractures (32.1); so, be careful especially to treat children with small deep burns, especially over joints.

Effective management of burns requires a team approach and good nursing care, physiotherapy and psychological support. You can make an enormous difference by getting involved, supervising the management and carefully selecting patients who are most likely to benefit from surgery.

Be ready for surgery in the acute stage: escharotomy & fasciotomy may be needed or early excision and skin grafting (staged if a large surface area involved, but very appropriate for small areas on the hands, feet, neck or face); and then later for release of contractures if they have occurred.

Burn patients often arrive late with contaminated and infected wounds which require intensive treatment. When you see such a patient arrive with little hope in a desperate state, malnourished and with soiled dressings and smelly wounds, *don't just throw up your hands in horror*, but rapidly evaluate their needs, start urgent treatment, and follow the principles we outline.

If you follow these basic rules, and use a safe and simple approach, you will successfully treat many burn patients, so that they are able to continue to contribute to society. Inevitably some will have psycho-social problems which will need further support and long-term follow up. They deserve all the help they can get. Compassionate treatment and a caring team will do much to alleviate the suffering of these young patients and support their journey to recovery.

WHAT SHOULD NOT HAPPEN IN BURNS

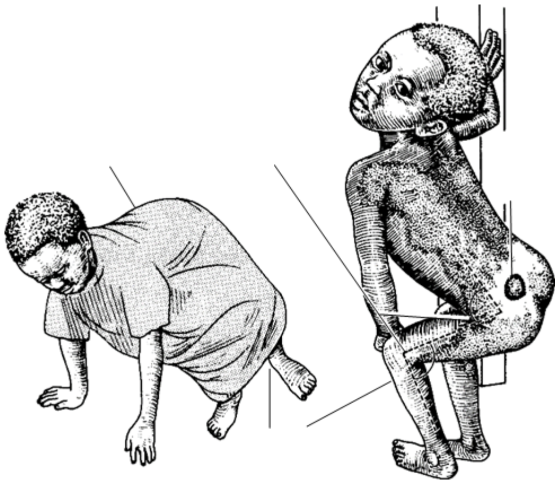


Fig. 50-1 Pepita (7yrs) was accidentally pushed into a fire by another child two years previously and received an 8% TBSA burn of her lower back, which was at first thought to be superficial, but is still open and has never been skin-grafted. She cannot stand upright (A) because of flexion contractures of both hips and one knee. Instead, she has to crawl (B). Her groins were not burnt, and the burn on her knee was only a minor one. Her contractures are the result of failing to make sure that she used her unburnt and minimally burnt limbs during the acute stage of her injury. She has now been abandoned by her family. Early grafting and elementary physiotherapy would have prevented this tragedy.

The focus of this chapter is on the appropriate treatment of less severe burns like this one, so you avoid preventable complications as shown.

50.2 Initial treatment of burns

FIRST AID

The first step is to remove the subject from all potential burning sources including heat flame, electricity or chemicals. The first thing to do is to attend to the personal safety of anyone in the vicinity, especially if a fire can spread or there is risk of explosion.

For flame burns, adopt the rule: *"Stop, Drop and Roll"*. Prevent the victim from running, which only fans the flames and makes them burn faster. As flames always burn upwards, lying flat not only prevents them involving the face, head and scalp hair, but also prevents the fire from going around the body.

Do your utmost to put out the fire by dousing with water; if water is not available, any nonflammable liquid such as milk or canned juice can be used.

N.B. Throwing a blanket over the victim traps the heat and worsens the burn, though may be necessary if he is on fire, to roll him!!

Once the fire is extinguished, remove all the burned clothes (including belts, socks and shoes) from the victim's body.

N.B. Especially with scalds on infants, remove the nappy!

Leave fabric that has melted and is stuck to the burn wound in place. Remove ornaments as they retain heat and continue tissue damage for a prolonged period. Remove rings on fingers and toes before they swell up.

Don't put ointments, creams and lotions over the burn wound before they have been evaluated, as otherwise assessing the depth and extent of the burn wound is difficult, and removal of creams is painful to the patient.

Aspirate or puncture the burn blisters, but leave the epithelium intact as a dressing.

Cool a heat or flame injury with clean running water, the temperature adjusted to the victim's preference for 15–20min. After cooling, keep him warm till medical attention arrives. The 1st 6h following injury are critical; transport the patient with severe burns to a hospital as soon as possible.

If the victim arrives at your health facility without any first aid, drench the burn thoroughly with cool water to prevent further damage and remove all burned clothing.

If the burn area is small and there is no running water, immerse the site in cool water for 20 minutes. This reduces pain, oedema and minimize tissue damage.

If the burn area is large, after it has been doused with cool water, apply clean non-stick wraps around the burned area (or the whole patient) to prevent heat loss and hypothermia. This is a particular risk in children, so remember to keep them warm (even in hot climates!).
If such wraps are not available, use clean cotton sheets.

If the availability of water is limited, soak clean sheets or towels in cool water and keep replacing them on the burn wound to keep it cool.

After you have washed the burn, r*emember to keep the victim warm!*

HISTORY & EXAMINATION

Get a full history as in any case, but concentrate on the events surrounding ithe burn injury. This will help with predicting the burn depth, the risk of inhalation injury and the likely need for admission.

Key factors in the history are:
(1) How was the victim burnt? (what was the mechanism)
(2) When did it occur?
(3) Where did it occur? (*e.g.* indoors, outdoors, at home, work etc)
(4) Was any first aid or other treatment given?
(5) Are there any associated injuries?
(6) Is there any evidence of inhalation injury? (lots of smoke at the scene, coughing, difficulty breathing, burns to face)

Diagnosing a 'serious' or 'major' burn injury is not that simple as it depends on a number of factors. Clearly if someone has a large deep burn, then it is obviously serious, but even fairly small burns, especially if they involve critical areas such as hands, face or perineum are also serious, because they need special care.

Chart the severity of a burn injury (best by a drawing), noting:
(1)Total Burn Surface Area (TBSA)
(2) Depth of burn
(3) Site of burn
(4) Presence of inhalation injury
(5) Associated injury
(6) Co-morbidity

N.B. The degree of injury depends on the heat imparted, the duration of exposure or contact.

Fire or hot metal, plastic, or oil, will generally cause deeper burns than hot water.

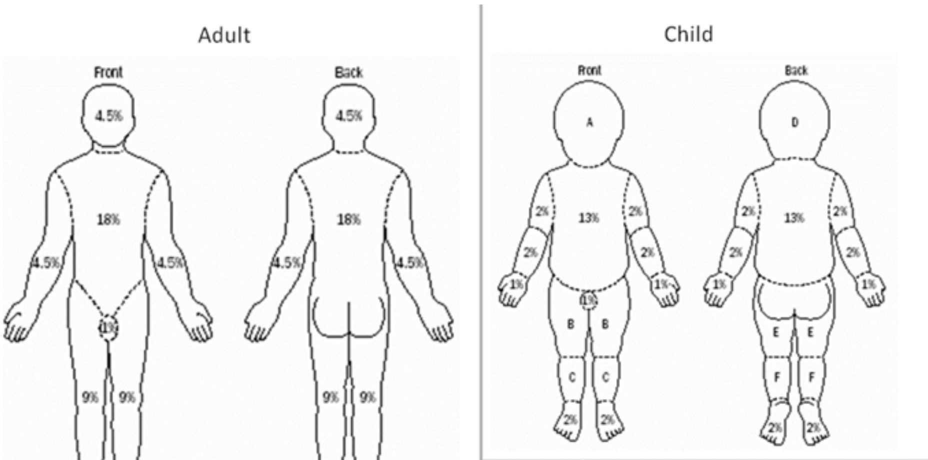
EVALUATING THE SIZE OF A BURN

Measure the size of a burn as a percentage of total body surface area (TBSA). There are several ways of doing this, but it is not always easy. Take care to be as accurate as possible. Describe very small burns in terms of actual size such as 3x5 cm.
For larger burns, a common and simple method is the 'rule of 9's' in adults or '7's' in children.

This is a good way of making a rough estimate of TBSA. Remember 9% is equivalent to the whole arm (back & front), but half a leg (either back or front, or thigh or lower leg). The whole front of the body makes up 2x9% =18%.

The proportions in children vary with age. You can get a more accurate estimate using the Lund & Bowdler chart (50-2). Draw the area of burrn involved onto the chart and then use the chart to predict the TBSA.

ESTIMATING TBSA OF A BURN



Area	Age (Years)			
	0	1	5	10
Head (A/D)	10%	9%	7%	6%
Thigh (B/E)	3%	3%	4%	5%
Leg (C/F)	2%	3%	3%	3%

Fig. 50-2 Calculating TBSA; A, in adults 9% is equivalent to the head, 1 whole arm & hand, the front or back of 1 leg, the chest front, the abdomen, & half the bac, leaving 1% for the perineum. B, in children the head is much bigger compared to the rest of the body. Proportions change with age. *N.B.* the palm & palmar side of the fingers make up 1%. A child's hand is c. 1/2 the size of an adult hand.

As it is rare for the whole of a limb to be affected, especially when multiple areas are involved, it is then easier to use the patient's hand (including fingers adducted) as 1%.

This also works in children; but remember a child's hand is c.50% the size of an adult hand, which is usually a little less than 10x20cm. To simplify estimations, a computerized graphic is useful (50-3); you simply colour in the affected parts, and count the squares & divide by 4.

MODIFIED LUND-BROWDER CHART

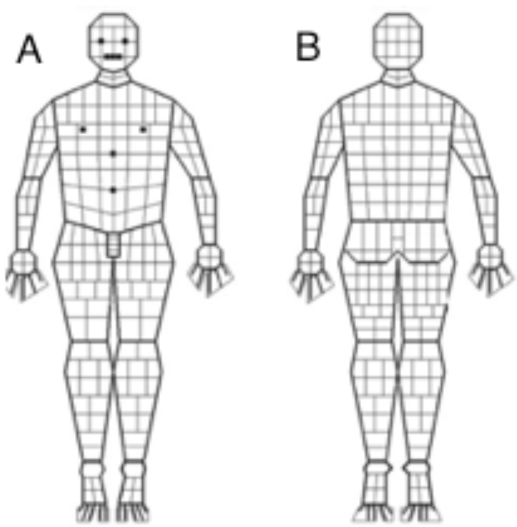


Fig. 50-3 MODIFIED LUND-BROWDER CHART for adults. Colour in affected are as: each square represents 1/4 %, so add up the squares and divide by 4 to get the TBSA. *After Murari A, Indian J Past Surg 2017: 50(2):220-1.*

It is very common to get different TBSA calculations for the same patient. There is no 100% accurate method, but if the estimations differ wildly, re-evaluate the patient, especially in relation to response to fluid therapy.

EVALUATING THE DEPTH OF A BURN

A severe burn is a 3-dimensional rather than a 2-D lesion
Burns are usually classified:

(1) 1st degree (superficial),
(2) 2nd degree (superficial partial thickness),
(3) 2nd degree (mid-partial thickness),
(4) 3rd degree (deep partial thickness),
(5) 4th degree (full thickness dermis).

The depth of burn equates to the liklehood of healing within a certain time frame and therefore the risk of significant scar and contracture formation.

Characteristics Thickness	1st degree	2nd degree superficial partial	2nd degree mid-partial	3rd degree deep partial	4th degree full
Cause	Sun burn	Scalds, flash	Flame contact	Flame contact	Prolonged contact
Depth	Epidermis	Epidermis and part of dermis	Epidermis and dermis	Up to fat & fascia	Charring of muscles, bone or joints
Colour	Erythema only	Pink	Wet, greyish white	Dry, brown, black leathery thrombosed veins present	Dry, brown, black leathery
Blisters	Absent	Present	Absent	Absent	Absent
Capillary return	Present	Present	Absent	Absent	Absent
Pain	Present	Present	Absent	Absent	Absent
Healing	In days without scarring	2wks without scarring	>3wks with hypertrophic scars & contractures	In months with hypertrophic scars & contractures	Will not heal without intervention

1st degree burns have erythema but no blistering; they heal rapidly and represent a minimal injury to the epidermis which rapidly regenerates.

CROSS-SECTION OF SKIN LAYERS

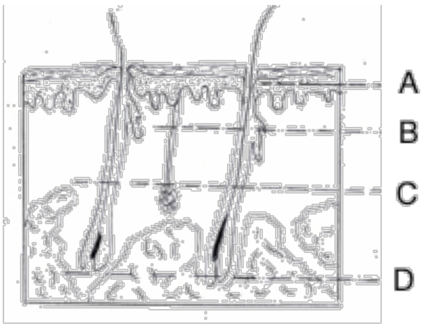


Fig. 50-4 Epidermis & dermis. A, superficial layer. B, superficial partial thickness. C, deep partial thickness. D, full thickness.

Superficial 2nd degree burns form blisters within 24h which rupture to leave a wet pink surface. Most of the deep epidermal structures are still alive, so they heal in<3wks. The pain fibres in the skin are also still intact, so the wounds are very painful and sensitive to the of prick of a needle. Blanching on pressure occurs because capillary return remains intact.
Most flash burns and a lot of scalds are of this type, although scalds often involve all the epidermis and upper dermis. However, there are enough dermal remnants, sweat glands and hair follicles to enable re-epithelialisation with a maximum of 2-3wks and so, the risk of extensive scarring is low.

Deep 2nd degree burns appear greyish white and have all of the epidermis and most of the dermis except for the bottom of the sweat glands destroyed. Therefore re-epithelialisation often takes >6wks (unless the burn is only very small) because the epithelial cells at the bottom of the sweat glands take this long to grow out and cover the dermis. When this re-epithelialization happens, the quality of the skin produced is poor, and prone to recurrent breakdown, hypertrophic scarring & contracture.

Many of the nerves in the dermis are destroyed so they are likely to be insensitive to pin prick, though pressure is still felt. Many of these burns will benefit from skin grafting, to prevent significant scarring and risk of contractures.

3rd degree burns involve the full skin thickness. The dead skin looks greyish brown, and is completely insensitive to pin prick. Thrombosed veins are visible through translucent subcutaneous fat, and hairs are easily pulled out.

The wound can only re-epithelialise from its edges; healing will take weeks to months and definitely result in severe scarring and contracture formation, unless this is prevented by skin-grafting & splinting.

4th degree burns are profoundly deep with fat & muscles charred, and sometimes even the bones & joints.

Burns are dynamic injuries and can worsen because of:
(1) infection,
(2) poor blood supply (*e.g.* as a result of inadequate fluid replacement, cold, septic shock or use of vasoconstrictor drugs, such as adrenaline.
(3) poor nutrition (mainly hypoproteinaemia)

Don't count 1st degree burns (purely erythema) *as part of the TBSA.*
CAUTION! Wounds may deteriorate with time, because of poor perfusion, and so a 1st degree burn may develop into a 2nd degree in a few hrs of injury .

2nd degree burns are relatively easy to diagnose as they are exquisitely painful and moist with blistering. You can treat these with cleaning & dressings. Likewise 4th degree burns are relatively easy to diagnose as they are firm, insensate, and leathery, or even charred. They need excision and skin-gratfing.

The most difficult for diagnosis are the deep 2nd degree burns which may have some sensation and be moist or dry.
These will often require grafting, but not always. If resources are limted, they can be observed and treated with dressings over a few weeks to see if they progress to healing.

You may get an idea of the likely depth of a burn from factors in the history. The hotter and longer the agent, the deeper the burn. Thin skin, such as on the dorsum of the hand, or of a child or elderly person, is likely to suffer greater damage than thick skin.

If someone is drunk, drugged, paralysed, feeble, very old, burnt during an epileptic fit, or unconscious from smoke fumes, he may not have been able to escape from the flames, and so suffers with more extensive burns.

PIN PRICK TEST

This is a test of pin prick (pain, *not pressure*). The patient must be conscious and cooperative, and understand the difference between pain and pressure.

Take a sterile hypodermic needle and practise first on normal skin by asking if he can feel both its sharp or blunt ends. Then test the burn. If he mostly says "sharp", the burn is most likely 2nd degree. If he mostly says "blunt", the test is of less significance, as it might be 3rd or 4th degree

This test is not approapriate in young children. If the area of burn is relatively small, stretch the skin on either side of the burn area to see if there is blanching of the burnt skin; this indicates a 2nd degree burn.

THE BURN SITE

The site of the burn is important in terms of both the severity, but also the risk of long term disability and functional & aesthetic outcome. Hand burns are critical and if not treated appropriately can lead to significant deformities and impact a person's ability to perform even simple tasks (50-22).

Likewise the face is a critical site; fortunately the blood supply is very good, so 2nd degree burns tend to heal rapidly without any sequelaue; however full thickness burns can be devastating and produce major deformities to the eyelids, mouth and nose particularly.

The dermis on the back is thicker and even deeper burns may heal on the back without significant deformity.

Admit all burns to hands, feet, perineum and face unless small and 2nd degree, as with good care excellent results can be achieved for the majority.

50.3 Inhalation injury

Inhalation injury refers to damage to the respiratory system; this can significantly affect outcome.

There are 3 types of inhalation injury:
(1) Thermal: injury to the upper airway,
(2) Chemical irritation from particles in smoke causing an inflammatory response (bronchopneumonitis),
(3) Hypoxic poisoning from reduction in air FiO_2, Carbon monoxide, or Cyanide.

Recognize inhalation injury by the symptoms and signs, at the primary survey (42.1) Typical are: cough, dyspnoea, hoarse voice, headache, anxiety & confusion.

Signs are facial burns & oedema, singed nasal hairs, blackened sputum, stridor, wheezing & hypoxia.

The history may be helpful; inhalation injury is more common with burns in enclosed spaces and with explosions.

Ask if there was a lot of smoke at the scene, if the victim had to cough or gasp for air, look for singeing around the nose & mouth, and note decreased consciousness or agitation.

If you suspect airway injury, observe the patient over 24h as this is the period when airway problems are likely to develop:

TREATMENT

(1) Sit the patient up – it's easier then to breathe
(2) Administer oxygen, preferably 15l/min, humidified.
(3) Add nebulised salbutamol 2.5-5mg/h for stridor or wheezing.
(4) Encourage deep breathing and coughing to clear sputum, and arrange chest physiotherapy.
(5) Administer rehydration fluids at 1ml/kg/h in adults and 1-2 ml/kg/h in children; but beware: *excess fluid is never helpful.*

If there is a risk of airway obstruction, from swelling: lift the chin & pull out the jaw (42.1) & pass a Guedel or nasal airway if tolerated & available. Administer nebulised adrenaline 5mg as required; *this will not cause cardiac effects.*

If hypoxia persists, intubate and ventilate the victim if you have the facilities; use as big an endotracheal tube as possible to allow efficient suctioning.

Administer 100% O_2 initially until COHb is <5%; humidified. Pressure controlled ventilation is best, and aim for a tidal volume of 6-8ml/kg body weight. Start antibiotics (erythromycin or co-amoxyclav)

N.B. Corticosteroids don't act quickly enough, but are useful if you cannot control wheezing with salbutamol alone.

Start feeding as soon as possible; this reduces the movement of bacteria across the gut wall which provokes pneumonia and sepsis.

50.4 Associated injury

Burns don't always happen in isolation and can be associated with other trauma such as fractures, head injury and other soft tissue injuries. This is particualry true in explosions or a road traffic accident.

Don't focus immediately on the burn wounds, but follow the ABC system (41.2). Shock in early stages is from injury elsewhere.

50.5 Emergency management

INDICATIONS FOR ADMISSION

There are no hard & fast rules who needs admission for burns, but this list will guide you:-
(1) Burns of eyes, perineum or hands
(2) Burns of TBSA >20% in adults
>10% in children
>5% in babies
(3) Deep burns needing debridement
(4) Full thickness burns >5% TBSA
(5) Acid or corrosive substance burns
(6) Smoke inhalation
(7) Burns with other serious injuries
(8) Orther uncontrolled illness (*e.g.* epilepsy)
(9) Unclear history or suspected abuse
(10) Poor support at home
(11) Long distance from hospital to home
(12) Likelihood of poor return for review or poor treatment compliance.

NEED FOR TETANUS PROPHYLAXIS
Any burn patient who has not had a booster within the previous 10yrs should receive tetanus toxoid & tetanus immune globulin (TIG). If this is unavailable, use IV immune globulin.

PROTECTION AGAINST STRESS ULCER & ILEUS
Use a PPI, or cimetidine, or *Gaviscon.* Pass a NG tube for burns >30% TBSA, or when there is a depressed conscious level.

ESCHAROTOMY (GRADE 1.3)

Where there are deep burns, especially if circumferential, they can restrict chest or abdominal movement and lead to respiratory distress, or restrict venous return and lead to a limb compartment syndrome, or neck vein obstruction.

Deeply burnt skin has lost its sensation, and its blood supply, so you can cut it without danger of pain or bleeding. However, it is good to sedate your patient, and when you reach living tissue, there will be pain!

Cut through the escar down to unburnt live tissue, and spread open the wound to release the scar in 2 parallel vertical lines on chest & abdomen, or longitudinal liness on limb surfaces. *Don't hesitate to cross joints, if necessary.*

ESCHAROTOMY

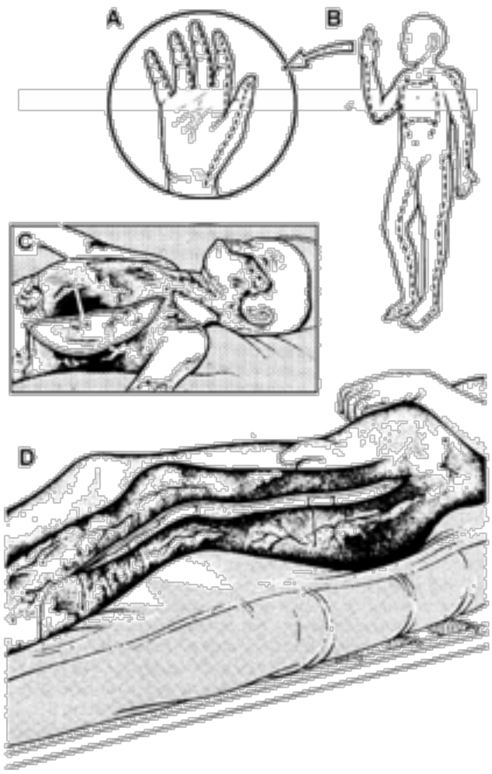


Fig. 50-5 ESCHAROTOMY. A, cut on the dorsum of the hand. B, on the mid-axial lines, lateral & medial, of the limbs (& dorsum of feet); vertical laterally on the chest, with added transverse incisions suprasternally & in the epigastrium. C,D, detail of escharotomies on the chest & thigh. Make multiple cuts if burns are circumferential. ***Note visible veins in scarred skin.*** *Kindly contributed by Peter Bewes.*

If the patient feels pain when you cut, the burn is not deep, or you are cutting in the wrong place! Escharotomy is the incision of the eschar, and may occasionally need to include the fascia, particularly with electrical burns.

Don't hesitate to perform an escharotomy when there are circumferential or near circumferential deep burns.

Extend your incision (70-5) to normal skin beyond the eschar, or at least from joint above to joint below. *Avoid & spare the veins:* ligate these to ensure haemostasis.

As with all surgical procedures, maintain a clean, if not sterile, operative field. The most frequent complication is bleeding from the subdermal plexus and superficial veins, while the most serious is incomplete release.

N.B. **If you divide eschars late**, there may be extensive septic sloughy tissue below, which may require repeat debridement on several occasions.

Avoid injury to deep structures by staying within the upper subcutaneous fat layer without including the superficial fascia.

An escharotomy is of great value; it might save a life and/or a limb. Always go ahead you are in doubt, particularly in full thickness circumferential burns. Clear important indications are, in a limb:
(1) Painful swelling
(2) Paraesthesia distally
(3) Poor capillary refill distally
(4) Pale cool peripheries
(5) Absent distal pulses *(a late sign)*
(6) Paralysis distally
& in the chest:
(7) Limited chest expansion
(8) Laboured breathing
(9) Hypoxia.

N.B. The presence of distal pulses does not rule out early compartment syndrome, because the pressure required to reduce arteriolar or capillary filling is much less than to occlude blood flow in the larger arteries.

The earliest sign is excruciating pain on passive extension of fingers or toes.

Simple pulse oximetry will help in decision making. A value <90% indicates the need for escharotomy. Likewise compartment pressure (49.8) >40 mmHg is an absolute indication.

However, the decision is usually clinical. Mistakes are usually from:
(1) not performing an escharotomy when needed,
(2) performing escharotomy with inadequate length and/or depth,
(3) extending the incision too deep and damaging underlying nerves or tendons;
(4) performing unnecessary escharotomy in burn skin which will eventually heal without grafting.
(5) overinfusing fluid when burns are limited.
(6) not protecting the kidneys when performing >2 escharotomies.

Structures particularly in danger are the:
(1) Posterior tibial vessels behind the medial malleolus,
(2) Long saphenous vein anterior to it,
(3) Common peroneal nerve winding round the fibular head at the knee,
(4) Ulnar nerve behind the medial epicondyle at the elbow,
(5) Median nerve in the antecubital fossa.

FASCIOTOMY (GRADE 1.3)

Fasciotomy (49.8) is usually indicated for compartment syndrome when this persists following escharotomy. Apart from in high-voltage electrical injuries, fasciotomy is rarely indicated as a primary procedure in burns. When muscular necrosis is evident, fasciotomy has the advantage of direct inspection of muscles to enable early excision of necrotic tissue, thus preventing acute renal failure, infection, and further limb loss.

Complications of fasciotomy occur much more commonly, particularly the injury to neurovascular bundles and deeper structures, than in escharotomy. Fasciotomy, in contrast to escharotomy, is a more technically challenging procedure, and requires GA.

Perform a fasciotomy only when you have firm evidence. First, make an escharotomy alone; if this fails to relieve compartment pressure, *don't hesitate to perform a fasciotomy*.

EMERGENCY DEBRIDEMENT (GRADE 1.3)

If a patient presents late & is toxic and septic from infected burns, with fever, tachycardia & signs of shock (44.5), resuscitate him with large volumes of IV Ringers lactate, start IV antibiotics, and surgically debride the infected wound (50.12). Remove all dead tissue, controlling bleeding either by applying a tourniquet, or using hydrogen peroxide soaks.
Don't attempt to graft the wound at this stage!

N.B. A temperature on its own of <38^0C is not significant but hypothermia is!

CRICOIDOTOMY & TRACHEOSTOMY IN BURNS (GRADE 2.2)

Cricoidotomy or tracheostomy is not often required in the acute situation An overwhelming full thickness burn involving th face, head, or neck, associated with inhalation injury is extremely unlikely to survive. If the airway is compromised due to swelling, and intubation not possible, a tracheostomy can be life saving.

Observe your patient carefully and anticipate the need, before massive swelling of the neck makes a tracheostomy through oedematous tissues a difficult & bloody operation. This procedure is usually only indicated to secure the airway for transfer.

Don't attempt this outside the theatre!
Make a transverse incision. Divide the scarred tissue, carefully securing haemostasis as you proceed, and expose the trachea, then open it (42.3).

50.6 Fluid replacement

Circulatory disturbance in the 1st hour will not be due to the burn, but likely due to haemorrahge (including gastric stress ulceration) or other trauma, or cardiac events. Specifically examine for this (41.1).

If the patient presents many hours, or even days after a major burn, dehydration and shock are usual owing to fluid loss into the tissues and from the burn surface.

Patients with burns >20% TBSA have an increased capillary permeability resulting in massive 'fluid creep' into the interstitial tissues, and decreased intravascular volume, particularly in the 1st 8h after injury. They lose more fluid this way than by evaporation from the surface of the burn wounds or into blisters. However, their total loss of fluid can be immense and can readily cause shock.

Early after a severe burn, patients may look suprisingly well, but without early fluid replacement they risk rapidly becoming shocked. Prevent this and resuscitate them *before they become shocked.*

Burns of >15% TBSA in an adult, or >10% in a child need IV fluid replacement.

Put in as big a cannula as you can *through unburnt skin*, and fix it firmly and start an infusion with Ringer's lactate (or if not available, 0.9% saline).
Avoid using the saphenous vein. An intra-osseous route (44.3) is ideal in children.
N.B. Never use 5% dextrose. There is no advantage in using colloids early on.
As you put the cannula in, take blood sample for a haematocrit (or Hb), random blood glucose, serum electrolyte, urea and creatinine (if possible) and for grouping and cross matching for burns >30% TBSA in adults or 20% TBSA in children.

The amount of fluid needed is proportional to the size of the burn and the size of the patient. This amount tails off after 36h. There are several formulae to help you but each is only a guide; you must adjust the volumes to obtain a urine output of 0.3–0.5 ml/kg/h in adults and 1ml/kg/h in children.
N.B. This is the replacement fluid needed. A patient (especially a child) needs maintenance fluids, including a source of glucose.

If you replace fluid loss by mouth, use saline or oral rehydration fluid, or milk *but not plain water or tea.* This is especially important with young children. To make a suitable solution, add a teaspoonful of salt, and another one of sodium bicarbonate, to 1L water. If you add fruit juice, and serve the mixture cold from the fridge, no child will refuse it.

INFUSE 3ml/kg/%TBSA IN THE 1st 24h
FROM THE TIME OF INJURY
(NOT THE TIME OF ARRIVAL IN HOSPITAL)
WITH $^1/_2$ OF THIS IN THE 1st 8h.

Calculating the amounts needed, especially if you are stressed, have many patients to see, or it's the middle of the night, is not simple!
N.B. You must avoid the dangers of over- & under-infusion!

It is in children, that calculations are difficult & the risks greatest. Unfortunately, burns affect children mostly! Those critically ill are children with large area burns who arrive late; this is unfortunately often the norm.

As a fluid infusion rate >10ml/kg/h is not advisable in children, this means that a child with 20% burns who arrives 6h after the injury, cannot catch up fluid losses till at least 4h after admission. Thus it is wisest to start at the maximum rate, and slow it down later when you can carefully calculate the requirements.

Overloading children and inhalation burn victims occurs all too easily. In these patients, albumin or FFP infusions are useful, but this needs specialist advice.

If a burn patient presents > 24h after injury, the immediate resuscitation period has passed. He will have a significant fluid deficit. Administer 10ml/kg/h and assess the response by the urine output, which should be >0.5ml/kg/h.

You can normally stop an IV infusion after 48h.

ORAL FLUIDS

Except if a patient is sedated, or has gastritis or ileus, allow as much fluid as tolerated, *but include salt!* Check with the nomogram (41-2) to see how much you should give. In a mass casualty, the ICRC recommendation is to rehydrate patients with up to 40% TBSA with oral fluids at a flat rate of 100ml/kg/24h.

50.7 Monitoring

URINE OUTPUT

Charting urine is the most reliable method to ensure adequate fluid input, but *it needs to be done accurately!*

Don't forget to check for thirst, to insepct the mucous membranes, skin turgor, *pulse, blood pressure, jugular venous pressure, capillary refill and peripheral temperature* as these will all help to evaluate the fluid status.

Remember that you can readily collect a child's urine in a bedpan or urine bottle and measure it 4hrly. This may be more accurate than using a catheter, and measuring the volume every hour.

To do this, use a specially designed urine bag or urine will accumulate and make measurements inaccurate.

N.B. Catheters can become kinked or blocked and give false hourly readings!

Start a fluid balance chart & record *all the input & output.* Keep early urine specimens to compare with later ones. If he develops haemoglobinuria, you will know if this is getting worse or not.

If the urine output drops <0.5 ml/kg/h after the 1st 12h, check if the catheter is blocked.

N.B. Even in acute renal failure, the kidneys can usually manage to produce some drops of urine.

This is a serious sign of kidney failure: if this persists for 2h, challenge an adult with 1l of normal saline in 30mins after checking there are no signs of pulmonary oedema. If this increases the urine output, increase the previous infusion.

If an IV challenge fails to increase urine output, administer 15% mannitol (1 g/kg) or 40mg frusemide IV. If this has no effect, renal dialysis may be required.

If a burnt child becomes irritable, vomits, twitches, has fits, becomes apathetic or comatose, suspect that he is hyponatraemic.

Although all these signs are unlikely to occur together, when several are present, cerebral oedema from water intoxication is likely. This may be fatal. Use IV diazepam to control twitching. Correct hyponatraemia by adding:
Na^+ deficit (140–serum [Na^+]) x weight (kg) x0.6.

If you cannot estimate the serum [sodium], assume it is 125 mmol/l, so administer 4.5 x wt (kg) mmol, and repeat this. 3% hypertonic NaCl has 513mmol/l, so use 660ml of this.

FLUID & SODIUM REQUIREMENTS

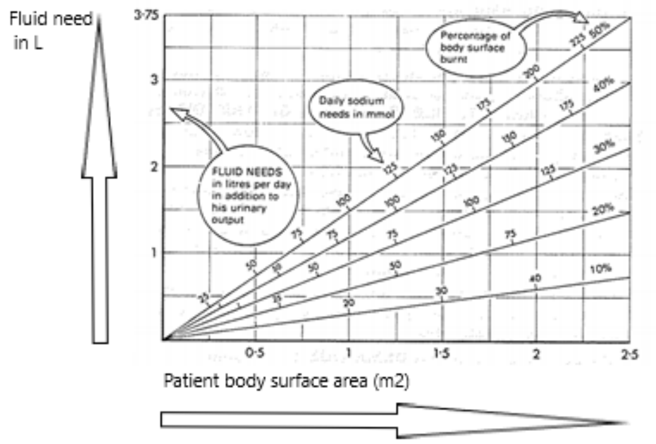


Fig. 50-6 SODIUM NEEDS. Calculate the surface area from 41-2 & read off the daily Na^+ losses (urine loss *not* included) according to % TBSA burnt. Y axis: Fluid need (l) in addition to urine output. X: axis BSA 3% hypertonic NaCl has 513 mmol/l. *Data from Cason.*

BLOOD TRANSFUSION

There is destruction of red cells at the time of burn. A deep burn >10% TBSA in a child, or >20% in an adult, needs some blood, especially if 4th degree. Transfuse after the fluid resuscitation period is over, and repeat it as necessary. A rough guide is to transfuse 1% of his blood volume for each 1% TBSA deep burn. (Check blood volumes from 41-2).

The need for transfusion may increase if there is haematemesis or melaena from gastric ulceration, or other trauma. Further need for blood may arise from depression of the bone marrow as a result of sepsis, and blood loss from desloughing or debriding the wound.

In a malaria endemic area, administer anti-malarial prophylaxis best for that area. Consider prohylaxis for other endemic diseases, such as Leishmaniasis, Leptospirosis, Brucellosis & Filariasis (46.8).

TEMPERATURE
Burn patients readily get cold, as their skin protection is lost, especially if the burn is exposed! Nurse them at 40°C with ideally 40% relative humidity. Monitor the temperature carefully. Feel the extremities.

If necessary, close the windows & put a heater beside the bed. Electric fan heaters are best, but make sure they are kept clean. *Don't put your patient in the sun*, except for short periods, because pink raw skin sun-burns easily.

WEIGHT
Burn patients quickly lose weight unless they have a high protein, high calorie diet.

50.8. Pain relief for burns

There are numerous factors that contribute towards pain and how each individual experiences and reacts to it. Suffering includes what is discomforting or unpleasant for the patient, not just physical pain.

Suffering encompasses anxiety, fear, helplessness, sorrow & guilt.

It is not always possible to prevent all pain, because all burn injuries cause immense physical discomfort. Although a superficial partial thickness burn is much more painful to the touch than a full thickness burn, an extensive full thickness burn gives rise to severe distress.

You must anticipate anything that might contribute to or precipitate pain, such as dressing changes or any operation, or physiotherapy exercises.

Don't think if you don't have potent analgesics such as morphine, there is nothing you can do! By using varied medications, different modes of administration, and combining drugs, you can achieve much (37.1)

Look at what you do have and see if you can use any of these medications. Changing the route of administration, the dosage or the frequency may all be useful.

50.9 Burn wound care

WOUND CLEANSING

Gentle washing is the most important component of burn wound cleansing. Do this with water that is safe to drink; *it does not need to be sterile*. This is the first step in infection prevention and cure, and essential for sound healing, and patient satisfaction.

The main objectives are to remove:
(1) contaminants at the wound base,
(2) debris,
(3) foreign bodies,
(4) microorganisms in infected wounds,
(5) superficial slough,
(6) dressing materials,
(7) excess exudate & crusts
(8) hyperkeratotic skin from wound edges & surrounding skin.

However, most importantly, by this you aid the patient with personal hygiene and comfort.

Irrigation is significantly more satisfactory than swabbing to patients.

During the first 3-4h after a burn, wounds are generally sterile or are at the stage of superficial bacterial colonization. By the 4th or 5th day, extensive bacterial involvement of the wound itself appears. By 7days, the damaged skin is thoroughly permeated by a large number of organisms and those more virulent begin active invasion of the unburned tissue. Because blood vessels in the burnt skin are damaged, antibodies & antibiotics cannot reach them.

Gently clean early wounds to avoid injury to the lower layers of the epidermis, responsible for regeneration and healing.

However, for heavily contaminated or infected wounds, aggressive, thorough, and frequent cleansing is necessary to eliminate the biofilm.

If the biofilm is not responding to irrigation, debridement (surgical cleansing) is needed to break the vicious cycle of biofilm-induced infection. Only remove dead tissue and tight debris.

Then re-start irrigation for another few days and reassess the situation for possible further debridement.
In heavily infected wounds with an evident biofilm, use topical antimicrobials after irrigation to combat the exposed bacteria and organisms that became accessible after cleansing. Similarly, use these after debridement, as they block virulent organisms getting into the spaces opened up by surgical intervention

BLISTERS

Blistering occurs in 2nd degree burns; there are no hard and fast rules about leaving them or puncturing them. It's best to leave small blisters. De-roof large blisters as they are uncomfortable and prohibit mobilisation (especially on the hands); alternatively aspiratie them using a sterile technique. However, de-roofing eases wound inspection and management.
N.B. Remember the de-roofed surface is very sensitive!

2nd DEGREE BURNS
These will heal within 2-3wks and the key to succesful management is avoiding wound infection and preventing the wound drying out.
You can acheive this best by closed dressings whenever possible.

CLOSED BURN WOUND CARE

Make sure your patient gets adequate analgesia (GA may be needed); take a pus swab, and then clean the wound thoroughly with an antibacterial wash such as aqueous *(not alcoholic)* betadine or chlorhexidine, using a sterile 'no touch' technique.

Apply a liberal layer of a topical antimicrobial ointment such as silver sulphadiazine followed by 2 layers of paraffin gauze (to prevent the dressing sticking to the wound, making it painful to remove), extending 10cm beyond the burn wound. Follow this with a layer of gauze, & a firm (*but not tight*) crepe bandage to prevent oedema. Cover this with a loose layer of wool to act as an absorbent layer, followed by a further layer of crepe. The whole dressing should be at least 2cm thick.

If the wound soaks through the dressing, remove this outer layer of wool and crepe, leaving the inner layer intact for up to 5 days depending on the state of the wound.

Advise the patient not to get the dressing wet or dirty and review the patient regularly until complete healing.

If the wound is small (<5%TBSA) and there is no soiling of the dressing, leave it for 5days on the hands, 7days on the arms, 10days on the legs.

However larger areas often produce quite a lot of exudate in the first few days and may need daily or alternate day dressings initially.

Advise the patient to look out for signs of infection such as a foul discharge, increasing pain, tachycardia and a temperature and come for review straight away.

Closed methods enable early mobilisation. This is beneficial form a psychological point of view, but only if you change the dressings regularly, inspect the wounds. *Never condemn a patient to days with soiled and smelly dressings gradually unravelling*!

So, the primary goals are preventing viable tissue from drying up and controlling the bacteria. If the wound dries out, a scab forms and delays epithelialisation.

DRESSING A BURN WOUND

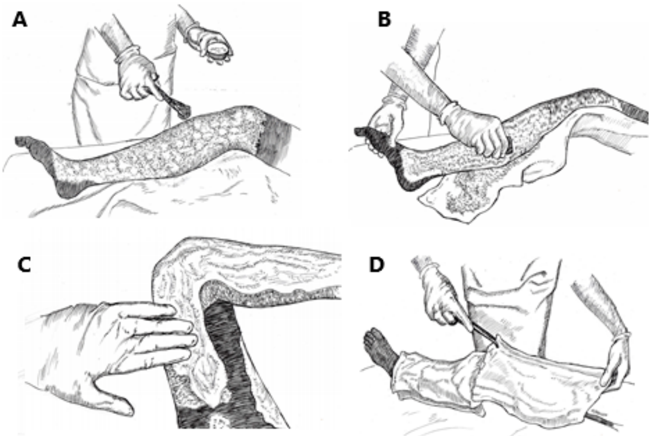


Fig. 50-7 DRESSING A BURN WOUND. A, use a 'no touch technique'. Use sterile forceps & sterile gloves so that no human hand or unsterile instrument touches the burn or the dressings, and no sterile glove touches anything else in the room. Clean the wound and the skin around it with chlorhexidine solution. *There is no need to puncture any blisters.* B, remove any necrotic tissues C, using a sterile spatula, spread an antiseptic agent (such as silver sulphadiazine) onto the wound. D, cover the cream with sterile gauze & then by firm bandage.

The closed method: (1) Demands more and better nursing care than the exposure method. (2) Needs abundant dressings. (3) Is more dependant on a local antiseptic agent than the exposure method. (5) Can cause hyperpyrexia in large burns in hot environments.

Done *well,* the closed method can be wonderfully successful. When you remove a dressing from a partial thickness burn which you have left undisturbed for 10days, you may find perfect new skin underneath.
But this method can be very dangerous if you forget that dressing a burn is a surgical procedure, which must be done aseptically, and the aim of the dressings is to contain exudates, and prevent organisms reaching the burn.

This means that you must change them on the indications given below.

Done badly, this method is a disaster, and too easily converts a partial thickness burn into a full thickness one.

Common errors are: (1) Not applying enough dressings (sometimes only a thin layer of gauze). (2) Letting exudates soak through without changing the dressings. (3) Not bringing the dressing well beyond the edges of the wound. Then this technique is painful, messy, expensive, and hinders healing.

There should be no compromise; either a burn should be left open with nothing on it at all, or it requires 2cm of dressings. *If therefore you use the closed method, you must do it properly!*

Under most circumstances, it is only suitable for parts of the body where the necessary dressings will stay in place. In effect, this means the limbs. In practice, because of the cost of the dressings and the labour involved, you will find the closed method suitable for burns on the limbs. It becomes increasingly difficult with larger burns, and on the trunk.

THE MERE APPLICATION OF A FEW 'DRESSINGS' IS *NOT* THE CLOSED METHOD

EXPOSURE METHOD

This is useful for for parts of the body which cannot easily be dressed, such as the face, hands, trunk, buttocks, and perineum. The patient should be under a mosquito net.

In this method nothing touches the burn wound except air, and an antibacterial agent, such as silver sulphadiazine. Air keeps the wound cool and encourages a dry eschar to form, both of which minimize the growth of bacteria.
You can examine the wounds easily and it avoids expensive dressings; but outside of special units, the risk of infection is great, and the likelihood of neglect increases.

In 2nd degree burns, the crust eventually separates like the skin of a snake to leave new, pink, well healed skin underneath; however, if the wound dries out too much, the wound will deepen and delay healing..

In deeper burns, the dead tissue forms a tough eschar (sometimes with pools of pus underneath it), or less often forms a moist slough. It is best to cover these then with saline soaks, or continuous irrigation, till you can remove them easily & skin-graft the surface.

If the exposed burns itch & are scratched, try to prevent the patient from doing so, because scratching can easily infect or convert a superficial burn into a deep one. Immobilize both the elbows in padded plaster cylinders to keep them extended. Add sedation. *Don't tie the hands to the sides of the cot*, because this is cruel and dangerous.

CONTINUOUS IRRIGATION

Use $^1/_2$ strength saline (0.9% saline is painful.) Either place the burnt part in a basin or bath, or pour or drip it over the wound, and catch excess in a bucket .

If you see green discharge staining the dressings, use vinegar (0.5% acetic acid) instead of saline for a few days, as it is *very* effective against pseudomonas.

ALTERNATIVE DRESSINGS

Amniotic membrane; whether iused fresh, lyophilized or irradiated, is useful on heavily infected or exudating wounds.

Its main risk, if fresh, is the transmission of HIV, hepatitis and other serious diseases, so despite it being readily available in large amounts, you must have a proper set up in place to use it, rather than just once off.

SLOUGHS AND ESCHARS

Dead tissue from a burn wound separates off with time. If the burn is superficial, it peels off as pieces of a dry membrane. If it is deep, it forms either a slough, which is moist, soft, grey, and stinking, or an eschar which is dry, hard, and dark, which may be so brittle that it cracks.

There is no sharp distinction between slough & eschar; at the wet end is a slough, at the dry end an eschar. So irrigation tends to produce a sloughy wound, and exposure an eschar.

Occasionally, an eschar may protect underlying tissues from infection for several weeks (particularly if only skin is burnt), but a thick, tough, dry eschar can act like a tourniquet, and constrict the neck, chest, limbs or fingers.

The underlying oedematous tissue swells, but as the eschar around it is rigid and cannot expand, the circulation becomes impaired. Escharotomy (50-5) may therefore be needed as an emergency.

Underneath slough & eschar is a wet surface needing skin grafting. Maggots can deslough dead tissue effectively, although their use is not, naturally, very popular!

TOPICAL ANTIBIOTICS HAVE *NO PLACE* IN BURNS DRESSINGS

If muscle is dead, infection occurs much more readily, and a rise in temperature about the 10th day is usually the sign. You cannot often see Infection under an eschar, but pain is a significant symptom. When infection is advanced, you may be able to feel a dry eschar floating on a pool of pus.

If there is much dead muscle, beware of anaerobic infection, particularly gas gangrene and tetanus, and proceed to early surgical desloughing.

DESLOUGHING

Manipulating any infected tissue may cause bacteraemia, and removing an extensive slough or eschar may shower so many bacteria into the circulation that it causes septic shock (53.4). So, if you deslough a severely infected burn, administer broad spectrum antibiotics beforehand.

Slough not badly infected does not need antibiotic treatment; that is why regular pus swabs are useful.

Sloughs and particularly eschars may bleed massively when you try to remove them, especially if they are large. So, do so a little at a time in stages, separated by a day or two. Remove them gently, and watch out for heavy bleeding and stop.

Hydrogen peroxide is useful to control bleeding, as well as firm pressure for 5mins by the clock. *Never deslough >10% BSA at one time!*

The ideal is to skin-graft the raw area after you have removed a slough, but the granulations on the surface should be smooth with small undulations (50.13).

Continuous suction (negative pressure) dressings (11-20) are particularly useful if wounds are infected, boggy and wet.

A nurse may carry out a minor sloughectomy in a dressing change, but anything more major is best done in theatre.

Desloughing can vary from a minor procedure, if a burn is small, to an extensive 'sloughectomy' in the theatre, particularly if large and deep.

One of the commonest mistakes is not to deslough a burn; as long as any slough or dead tendon or bone remains, a graft will fail.

DESLOUGHING

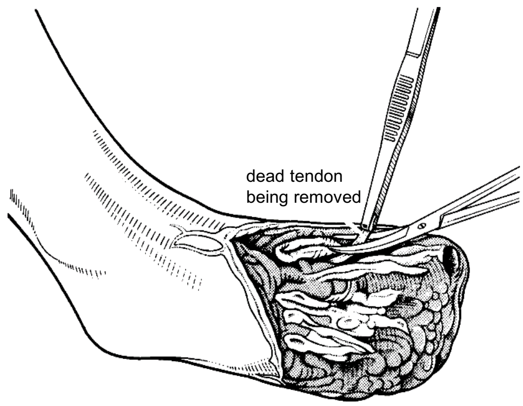


Fig. 50-8 DESLOUGHING Eda's tendons and some of the metatarsals have sloughed, which are being removed. She went home walking.

IF YOU TRANSPORT A BURN PATIENT, KEEP HIS WOUNDS MOIST

50.10. Nutrition in burns

All burn victims have an increased requirement for calories, owing to the healing response. Children are growing and therefore require relatively more energy than adults.

In burns, there is a marked inflammatory response. This leads to a high basal metabolic rate, protein breakdown, muscle wasting, & deficiencies in vitamins and minerals.

Early feeding (starting when the patient is admitted) can prevent gut ulceration, which can lead to bleeding, & bacterial translocation, where gut bacteria pass across the gut mucosa into the blood stream, causing septicaemia.

Adequate nutrition allows optimal healing, & a satisfactory result for the care team and patient. Convalescence is reduced and the victim can resume normal activities, and get back to work or school much quicker.

Inadequate nutrition results in significant complications and increased mortality from;
(1) Weight loss
(2) Muscle breakdown
(3) Generalised weakness & anaemia
(4) Apathy
(5) Delayed wound healing & chronic wounds

Protein loss leads to oedema (which can lead to joint stiffness), muscle weakness & Immune suppression, so increases the risk of infection.

If a victim loses 10% from his pre-morbid weight, he is likely to develop complications. *A 40% weight loss is generally fatal.*

A severely burnt patient may develop gastritis or paralytic ileus. This may result in nausea, vomiting, haematemesis, gastric ulceration, or abdominal distension & intestinal stasis.

Avoid these problems by administering antacid, H_2-blocker or PPI, & pass a nasogastric tube, aspirating on this hrly. You need to replace these extra fluid, sodium & potassium losses.

N.B. Exclude other causes of GI upset such as septicaemia, malaria & simple constipation.

Anaemia may result from:
(1) red cell destruction at the time of burn,
(2) bone marrow depression from sepsis,
(3) a lower lifespan of red blood cells,
(4) blood loss from over-zealous debridement.

Many patients are anaemic even before their burn; a child may easily drop his Hb level to <50g/l 7days after burn injury. As transfused red cells are relatievely inefficient, *don't hesitate to transfuse early*.

HIGH PROTEIN HIGH CALORIE DIETS

You may not be abe to calculate the amount of calories and protein a patient is getting. The principle remains to give locally available high calorie high protein foods frequently.

Requirements are:

	Energy (kcal)	**Protein**
Children	60/kg+35/%TBSA	3g/kg+1g/%TBSA
Adults	20/kg+70/%TBSA	1g/kg+3g/%TBSA

N.B. 1 kcal ≅ 4kJ.

Poor patients often need oral supplementation of vitamins.
Keep to an approximate ratio of carbohydrate: protein: fat at 50:30:20% in the daily requirement.

Monitoring the weight of the patient on a regular basis is very important; remember to try to find out a child's weight before the burn injury; check the weight on arrival, and then *daily for 2wks.* Also measure children's mid-upper arm circumference

N.B. Danger alert is a loss ≥10% of the pre-morbid body weight.

N.B. Fluids administered & oedema may give you a falsely high weight reading.
Generally stick to these rules:
(1) Give extra food high in calories and protein
(2) Use locally available foods
(3) Be sensitive regarding vegetarian or meat diets.
(4) Choose an oral or nasogastric route (or both): 8Ch for children, 14Ch for adults
(5) Give small frequent feeds rather than infrequent large ones
(6) Start feeding straight away
(7) Give extra feeds between standard "meal times"
(8) Encourage the patient's family to help
(9) Supplement with vitamins A, B,& D, 600 mg ascorbic acid, + 600 mg ferrous sulphate daily.
(10) Weigh patients every 2nd day.
(11) Supplement feeds *(& fluids)* in case of diarrhoea

Approximate protein/energy contents of simple foods are:

100g	**Protein (g)**	**kcal (=Calorie)**
Milk powder	150	500
Cow's milk	8	60
Soya beans	50	350
Beans	15	260
Peas	5	90
Groundnuts	25	560
Beef	25	150
Liver	20	190
Maize meal	7	370
Eggs	12	160
Margarine	0	700
Oil	0	900

A butter milk diet is good option; it consists of 4 eggs, 4 bananas, teaspoons sugar, 1l curd & 600ml water; you can add 50g ghee (clarified butter): this gives 1 kcal/mL.

NASOGASTRIC FEEDING

CAUTION! **If you use a NG tube for feeding**, make sure that the tube is in the stomach, *and not in the trachea,* (4.9). *Always aspirate the stomach before giving a feed*, to make sure that it is emptying properly. *In an unconscious patient, overdistension may cause regurgitation and aspiration of feed.*

If the patient has previously not been eating, start with $^1/_2$ or $^1/_4$ strength feeds initially, until you are sure that he has adapted adequately to this new method of feeding.

Use small blenderized feeds to start with, well spaced throughout the day and night. Filter them through gauze and make sure you give water at the end of every feed to prevent them clogging the tube .

ALWAYS LABEL THE FEEDING LINE &
NEVER CONNECT IT TO AN IV CANNULA !

If the feed blocks the tubing, administer it intermittently with a large syringe, but *beware of pushing large quantities into the stomach!* If you aspirate 100ml, wait before re-introducing another 100ml.

Work up to the required intake over several days. 3,5kcal and 180g of protein are about as much as an adult can take.

Always add enough water (about 30 ml/kg) in addition to the non-renal losses to help digest the food.

Make sure you provide at least 10% of the energy needs as fat.

Urinary potassium losses may be large. As a rough guide, administer 100mmol/day by mouth.

DIFFICULTIES WITH TUBE FEEDING

If you don't have a blender, mix milk, eggs, sugar, vegetable oil, and gruel of various kinds.

If diarrhea ensues, the feed may be hypertonic. Try diluting it.

If the feed regurgitates you have probably failed to check that the stomach was emptying poroperly before adding more feed. So, check the gastric residue, and raise the head end of the bed.

CAUTION! A blenderized feed is readily infected, so boil it and keep it refrigerated. *Don't add salt or you will overload your patient with sodium.*

Nursing Care

Use this nurses‘ wound care checklist:

1.Inform the patient about today's wound care
2. Assess the patient's general condition
3. Record the patient’s vital signs
4. Decide where & when you will change the dressings
5. Make sure of adequate analgesia
6. Prepare all the materials for dressing change
7. Assess the condition of the old dressings
8. Assess the wound (depth, size, infection)
9. Note any changes from the previous dressing change
10. If infected, take a wound swab
11. Decide if you need to change the treatment
12. Assess the range of joint movement around the burns
13. Decide if you need to inform the doctor
14. Check if there are any pressure sores
15. Check if there are any new wounds
16. Reapply the splints
17. Check if the new dressings allow sufficient movement
18. Document 1-16
19. Inform the family of progress
20. Ask if the patient has any questions or concerns

50.11 Physiotherapy in burns

The majority of the care for burns patients is delivered by nurses including dressing changes, general hygiene, infection prevention and control, nutritional support and psycho-social support. Physiotherapy is often not available and if this is the case, correct positionoing and encouraging mobilization must be carried out also by the nursing staff.

There are many things which make it difficult for burn victims to move. These include fear, pain from wounds, bandages, scarring, being systemically unwell and lack of education. However, if they do not mobilise, they will become stiff, develop contractures, have a longer in-patient stay and find it harder to regain their place in society.

Anti-contracture positioning must start from the 1st day (and should continue for many months after injury). It applies to all patients before or after skin-grafting. Scarring reduces tissue length, and range of movement (ROM).

Patients will naturally rest in a position of comfort, which is usually the position of flexion; this leads to contractures which can severely restrict movement. The results are catastrophic, with disfigurement and muscle loss.

Correct positioning, splinting and exercising results in less scarring, better function, decreased pain, increased muscle power, and makes management easier for patients and relatives. This leads to earlier discharge, earlier return to work and an improved economic and social future.

Patients need to adhere to a positioning regimen in the early stages of healing and this takes teamwork and dedication. They require ongoing advice and help with positioning, from all members of the healthcare team and their family. Encourage them to maintain anti-contracture positions all the time (except for when carrying out exercise programmes and functional activities), not just whilst a therapist is on hand. Early compliance is essential to ensure the best possible long term outcome and also to ease pain and assist with exercise regimens. Educating the patient and family so they have a good understanding as to the benefits of participating in therapy is essential; getting the family on board at this early stage also helps them to be more prepared to assist the patient on his return home.

You can achieve correct positioning in a number of ways; this sometimes involves the use of splints.

It is crucial not to overlook patients who have relatively small burns as they may also develop serious and debilitating contractures which could be easily avoided. These patients comprise the largest proportion of patient numbers and may be only attending hospital as out-patients. Look at positions to avoid contractures (50-9A-J).

SPLINTING

Splints hold a joint (or body part) in a rigid position: *you must make this the 'anti-deformity' position*.

Splints are particularly needed when a patient is not exercising, and whilst adopting a position of comfort, *e.g.* at night when asleep. So, get patients mobilising at every opportunity but use splints whilst at rest.

Splints may have to be continued for 6months after the burn injury, in order to prevent late contractures. *You can always find and provide some form of splint.* Splint materials are everywhere around; it is just a matter of looking!

The principles of rehabilitation programmes are:

(1) Minimise swelling & oedema
(2) Prevent Deformity
(3) Mobilise
(4) Maintain function
(5) Treat long term scarring problems

PREVENTING CONTRACTURES

The great danger of a scar is that as it contracts it will pull a joint into an abnormal position. Also, as a child grows, the scar does not. Most contractures result on the flexor surfaces but also on the extensor surfaces of the wrist, hand, & fingers.

You can minimize all contractures and prevent many of them completely by using quite simple methods. *Failure to apply these methods is one of the commonest mistakes in treating burns.*

These are your priorities:

(1) Correct positioning, maintained by splinting as necessary
(2) Early activity to prevent stiffness (full active & passive ranges of movement)
(3) Elevation to prevent oedema
(4) Good analgesia to enable mobilization
(5) Good nutrition to support wound healing
(6) Preventing infection converting partial to full thickness skin loss
(7) Get early skin cover, especially over joints
(8) Use sheets, rather than patch grafts or mesh over joints if possible, but make sure you 'fenetstrate' them (make small holes with a scalpel to allow fluid and blood to drain out.

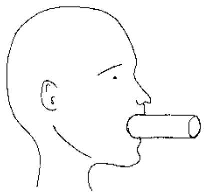
N.B. Stiffness is seldom serious until you immobilize a joint for 3wks in an adult or 6wks in a child.

So splint a joint continously ≤3wks in an adult & ≤6wks in a child, while the skin over it heals.

After this, you must mobilize the joint; only splint it then at night. You are battling against time to get the skin to heal: that is why grafting early is so important!

Contractures may continue to form for >12months, so continue the appropriate night splinting as an out-patient, and review regularly. Contractures form less quickly later, but early on, they can form in a few days.

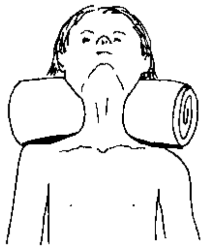
(a) Face
AVOID MOUTH & EYE CLOSURE
(1) Facial stretching exercises
(2) Well-padded splint in the mouth
(3) Tarsorrhaphy (28-13)



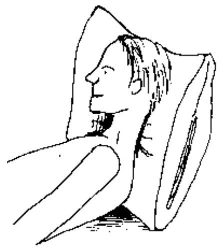
A

(b) Anterior neck. **(c) Posterior neck**
AVOID NECK FLEXION & NECK EXTENSION
(1) Roll behind the neck (1) Pillow behind head
(2) Neck collar with chin lift

B



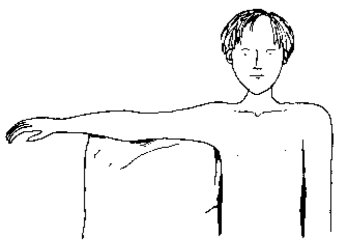
C



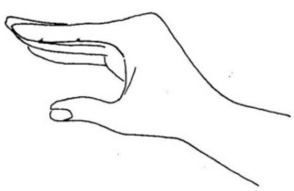
(d) Axilla
AVOID SHOULDER ADDUCTION
(1) Lying and sitting with arms abducted to 90° supported by pillows or angled splint between the chest & arms. Figure of 8 bandaging or strapping.

(e) Elbow
AVOID ELBOW FLEXION
(1) Splinting elbow in extension

D,E

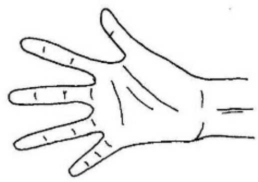


(f) Wrist & back of hand
AVOID WRIST FLEXION;
MCP HYPEREXTENSION;
IP FLEXION; & THUMB ADDUCTION
(1) Extend wrist 30-40^0
(2) Extend mcp joints 60-70^0
(3) Extend ip joints
(4) Abduct radius in mid-palmar position



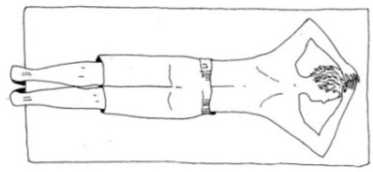
F

(g) Palm
AVOID FINGER FLEXION & ADDUCTION;
& CUPPING OF PALM
(1) Hyper-extend wrist
(2) Minimally flex MCP joints
(3) Extend & abduct fingers



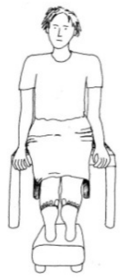
G

(h) Groin
AVOID HIP FLEXION & ADDUCTION
(1) Lying with leg extended
(2) Limit sitting and lying on the side
(3) Traction on lower leg



H

(i) Knee
AVOID KNEE FLEXION
(1) Leg extended when lying & sitting



I

(j) Ankle
AVOID DEFORMITY
(1) Keep ankles at 90^0 using pillow or splint
(2) Sitting with feet flat on the floor
(if no oedema)
N.B. You may need to keep a serious dorsal ankle burn plantigrade initially (71-10)

J

Fig. 50-9 POSITIONS TO AVOID CONTRACTURES. A, mouth. B, anterior neck. C, posterior neck. D,E axilla & elbow. F, wrist & hand. G, palm. H, groin. I, knee. J, ankle.

Therefore, try hard to educate a mother of a child what a night splint is for, and why she *must* apply it. It is very sad to see a contracture recur, which you have carefully released, because the night splint was not used!
Train a physiotherapist, and also the family to be home physiotherapists!
You can reduce the risk of hypertrophic scars by applying a specially made pressure garment. A child should then wear this for several years.

N.B. Remember that if a patient lies continually in the same position because of a burn elsewhere, contractures will form in the unburnt limbs!
.
RULES FOR MANAGEMENT

(a) Reduce oedema
(1) Sit up the patient
(2) Elevate limbs (feet above heart level)
(3) Elevate the head (raise the head end 20º)
(4) Firm dressings, mobile at joints (50.9)
(5) Active mobilization
(6) Good nutrition (50.10)

(b) Prevent deformity
(1) Correct positioning
(2) Splinting at rest & night
(3) Exercises (passive & active) early on
(4) Encourage stretching
(5) Encourage activity

(c) Mobilize
(1) Exercise (Improve exercise tolerance and muscle strength); possibly 5days after skin grafting.
(2) Play therapy for children

(d) Maintain function
(1) Educate patients and family
(2) Encourage functional tasks
(3) Encourage independence; adapting to the environment where necessary
(4) Control pain and suffering
(5) Encourage social interaction & re-integration into the community

(e) Reduce long term scarring
(1) Compression therapy
(2) Splinting
(3) Moisturise wound with cream or oil
(4) Massage
(5) Stretching
(6) Muscle exercises
(7) Avoid secondary trauma to the scar

50.12 Surgical care of burns

Surgery is critical if you want to get the best results for burn patients and avoid many of the long term complications that happen when wounds are left to heal spontaneously.
Debridement and skin-grafting are essential for the optimal treatment of patients with a significant %TBSA of deep burns.

EARLY EXCISION & GRAFTING
Done between 3-5days after the burn, this reduces the incidence and severity of contractures, improves long-term outcome, reduces hospital stay and is cost effective.

Nonetheless, you need a properly set up dedicated team to manage this properly. Apart from a real sterile theatre environment, skin grafting equipment (Watson or Humby knife, dermatomes, electrocautery, tourniquets, skin graft mesher), you need good microbiology & blood transfusion.

If you don't have these, your efforts may endanger patients and give poor results, which will harm your burn service because of damage to morale and reputation.

So, don't try this for:
(1) partial thickness (2nd degree) burns
(2) >20% TBSA burns

The main indications are small deep burns, especially of the hands (back & palm). Remember though, that excision on the fingers must be delicate and takes time.

Don't excise >10%TBSA at any one time! You can anyway not cover >30-40% TBSA with skin from the same patient. Waiting for skin donor sites to heal, so you can harvest skin from the same site as before, takes at least 10-15 days. Also, debriding >20% TBSA will cause much haemorrhage which will require blood transfusion.

The face has a very good blood supply, *so don't excise facial burns unless very obviously full thickness and small.*

After early surgical excision of the burn, the surface is likely to be optimal in cleanliness, so you must cover all excised burn wounds with a skin graft.

If there is a very obvious purulent infection, clean the wound thoroughly, use dressings and antibiotics, and try grafting after 48h.

DELAYED SKIN GRAFTING
on granulation tissue after delayed primary burn excision, spontaneous sloughing or active desloughing of the burn wound, happens after 10-21days.

So decide whether to excise burn wounds early or late, and whether this excision is tangential or fascial.

In the tangential method you take repeated thin slices of necrotic tissue (burn eschar) till you reach viable tissue). In the fascial method, you remove the burn wound and subcutaneous tissue to a pre-determined deep level, typically down to deep fascia.

The routine practice of early excision and grafting of full thickness burns can reduce both direct & indirect medical costs. This is particularly true of smaller burns, on functionally important areas such as the face, hands and feet. So, reduction of scarring and subsequent immobility, by early excision and grafting will have an enormous impact on reduction of disability.

You will see the economic benefit not only for your patients, but also your hospital!

If, however, in your set-up, you have:
(1) concerns regarding infection,
(2) patients presenting late,
(3) large burn wounds which will bleed,
(4) limited experience,
(5) very basic equipment,
you will probably prefer the conservative management of deep burns by desloughing. By waiting until sloughing of the eschar has occurred, surgery is kept to a minimal scale, with harvest of the skin grafts being the main surgical intervention.

If you use this conservative approach, it is crucial for your burn team to emphasize a rigorous approach to dressings and wound care, develop pain management protocols, optimize patients' nutritional intake, and work assiduously to prevent contractures by means of physiotherapy and splinting.

If you leave a deep burn wound, it is at high risk of becoming infected, which can lead to generalised sepsis and death.

So, remove as much full thickness burnt skin as possible, as early as possible.

DEBRIDEMENT (GRADE 1.3)
Remove any dead or infected tissue using scissors if there are large sloughs that normally seperate well.

If there is no obvious slough, use a Humby or Watson knife (50-10) to shave the dead tissue away until healthy tissue is reached underneath. Take quite thin tangential layers even if this means repeating cuts 5-6 times till you get to healthy tissue. When you are more experienced, you can use fewer, deeper shaves.

N.B. Non-viable tissue is usually thick and leathery with no bleeding and thrombosed vessels. It can also appear white or dark red depending on how old the burn is.
Viable tissue has punctate bleeding, bright yellow fat and no thrombosed vessels.
This tissue will take a skin graft.

Although a tourniquet will prevent the area being covered by a constant ooze of blood, you need to be careful to make sure you don't cut too deeply. Use tangential shaves till you get to punctate bleeding. When you have excised all the dead tissue, wrap the limb in adrenaline soaked gauze and apply a further layer of dry gauze then a tight elastic banfdage.

Elevate the limb and then let the tourniquet down and maintain elevation for 3-5 minutes. The slowly unwrap the elastic dressing and soak the gauze off starting distally whislt still maintaing the limb elevated. Do not rub the excised area as this will just restart the bleeding. Any obvious bleeding can be stopped with cautery.

If there are extensive deep burns, remove all the subcutaneous layer right down to fascia. It is easier to control the bleeding, but takes longer and does not give a good aesthetic result, but can be life saving. You can apply a skin graft directly to the fascia.

50.13 Skin grafting

DIFFERENT KINDS OF WOUND COVER

If the whole skin thickness of the skin is lost, natural healing will cause the epidermis to grow slowly inwards from its edges. If the wound is <2cm across, this works well.

But if the wound is larger, healing will take a long time with contracture, or disability if nerves & tendons are exposed. Tropical ulcers (34.9) also often need cover.

So, if you cannot bring the skin edges of a wound together by direct suture, or advancement flap (34-12, 46.5), you have 3 choices:

(1) You can slice the superficial layer of skin (a split skin graft) from another part of the body (the donor area) and lay this on his wound (the recipient site). It can survive, because the whole epidermis can regenerate from the deeper parts of the skin layers.

(2) You can take the whole thickness of some skin from another part of the body (a full thickness graft) and suture this into the wound. It may survive but can only be small (<$2cm^2$) & needs a good blood supply. If you use many small full thickness 'pinch' grafts, you can cover quite a large area.

Both split & full thickness skin grafts are completely deprived of their former blood supply. They initially survive from nutrients in inflammatory exudate, and then on tiny vessels that grow from the wound surface into the new skin.

(3) You can move the whole thickness complete with its blood supply, and suture it in place over the wound (a flaps or pedicle grafts). This requires some experience (46.5) and depends on how long and wide the flap can reach.

SPLIT SKIN GRAFTS
are the most useful kind of graft because they:
(1) can cover large areas of the body.
(2) take (*i.e.* survive) well.
(3) are easy to cut.
(4) resist infection moderately well, so you can put them on granulations which are not completely sterile.

Disadvantages are that they:
(1) are fragile
(2) *don't match undamaged skin well*
(3) *don't resist trauma well.*
(4) shrink.

However, it is a major surgical disgrace that not enough skin grafting is done, because it can do much to reduce suffering and disability.

FULL THICKNESS GRAFTS
give a much better colour and texture match shrink less, but *are very sensitive to infection & are more difficult to apply. They are really useful only on the hands and face.*

EQUIPMENT
WATSON KNIFE
N.B. (The Humby knife has a sliding roller which is less easy to use, and has no advantage)
SET of 50 spare blades
N.B. Autoclaving the blades make them blunt.
SKIN HOOKS HOOKS, single point, Gilles, stainless steel, 200mm, 4 only. With these, you least damage the skin when handling it. You can use fine dissecting forceps instead, but they may tear the graft.
SKIN GRAFT BOARDS, hardwood or plastic, with bevelled edges, 6x100x200mm, 2 only. These are rectangular boards with rounded edges to hold the skin taut as you cut the skin (50-xxA). However, you can use any conveniently shaped board, or even a wooden spatula.
N.B. You can (with practice) take a good skin graft with a well-sharpened carbon steel carving knife.
N.B. There is a miniature knife, developed by HLSilver of Toronto, which uses ordinary safety razor blades. Its disadvantage is that it can only cut a narrow strip of skin. Otherwise you can use a modified standard razor.
N.B. The electric dermatome can be set accurately, and gives a more reliable regular cut, but it is quite heavy, and you need practice, just like the Humby knife, to use it.

SKIN GRAFTING EQUIPMENT

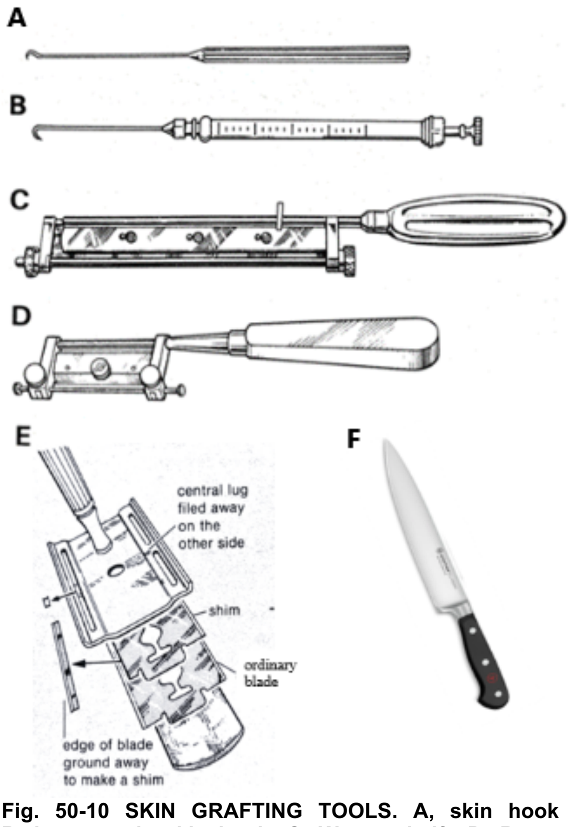


Fig. 50-10 SKIN GRAFTING TOOLS. A, skin hook B, home-made skin hook, C, Watson knife D, Razor blade holder. E, modified razor. F, carbon steel carving knife *With the kind permission of James Smith; kindly contributed by Peter Bewes.*

TECHNIQUE

You can vary split skin graft thickness by altering the setting of the knife. There are theoretical advantages of thinner & thicker grafts, but in practice, use a standard thickness (4-5mm).

Place the blade in place on the Humby knife & lock it in place. Check that the screw fittings gve an equal width at both ends of the blade, and that the blade does not wobble in its place.

Adjust the screws so that the gap between blade and roller is exactly how you want it, and then tighten the screws & locking nut to fix the position. You should see a thin sliver of light between blade & roller.
You should be able to slide the rod easily back & forth in front of the blade.

Don't use a faulty knife: it will disappoint you! Practice first on a bar of soap or an orange. and then on an animal limb from the butcher!

If you handle the blades carefully, you can use them several times. *But you cannot cut a graft with a blunt blade.*

Try to cover the wound with as few sections of skin graft as possible. The result is always better if you can use one 'sheet' to cover the wound completely.
You can expand the cover of a sheet by making a mesh. Do this by making cuts into the graft with an osteotome (50-15) or simple blade.

ADJUSTING A WATSON KNIFE

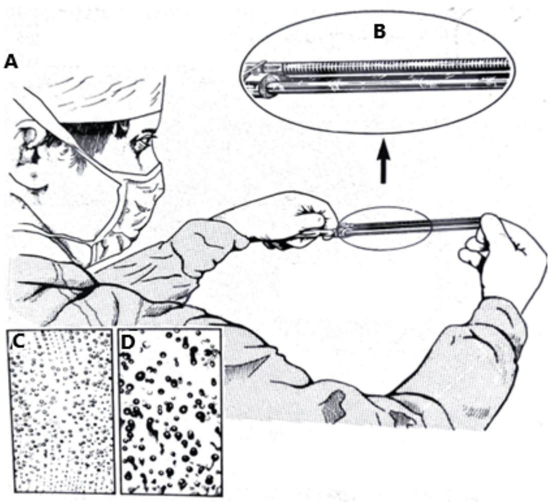


Fig. 50-11 **ADJUSTING A WATSON KNIFE. A, Hold the knife up to the light. B, adjust the screws to check the gap between the roller & the blade. This should be 3-5mm (enough just to allow a razor blade through), and equal the length of the blade. C, undersurface of a thin split skin graft with small punctate bleeding. D, undersurface of a thicker graft.** *Kindly contributed by Ian McGregor & Peter Bewes.*

This will enable you to increase the surface cover up to 6 times, depending on the number and closeness of the cuts. You can get a plastic template on which you place the graft, and pass this through a roller which looks like a miniature towel wringer.
However, at x6 expansion, the skin graft tends to curl up and then becomes difficult to manage and place nicely on a wound surface, so this is really only practical for x2 or x4 expansion.

IF POSSIBLE, USE SHEET GRAFTS

Remember that where there are gaps in the graft, the epidermis will need to grow across to heal. This will leave marks, and *so this technique is not useful for the face.*

PREPARATION OF THE WOUND SURFACE

You vastly increase your chances of a skin graft succeeding if the granulations on the wound are satisfactory. This is the purpose of desloughing (50.9).

Ideally, these granulations should:
(1) be firm, flat, rough, & bright red,
(2) bleeding on touch,
(3) have no significant discharge,
(4) have no sign of infection,
(5) show active epithelialization at their edges,
(6) have gently sloping wound edges.

Unsuitable granulations are:
(1) pale, avascular, & heaped up,
(2) slimy, soggy, oedematous, & friable,
(3) wet with a purulent or smelly discharge,
(4) accompanied by lymphangitis or adenitis.

Therefore, always scrape away most of the granulations from the base of a wound, unless they are very thin and have a very good colour. This reduces the fibrous tissue which will form under the graft & give a better cosmetic result with less likelihood of contracture formation.

If granulations are very unfavorable, excise and curette them, together with the fibrous base of the wound (50.9). Accompany this with frequent soaks using either (1) half-strength saline, (2) hypochlorite, (3) chlorinated lime & boric acid solution, (4) 0.5% acetic acid, (5) diluted hydrogen peroxide, (6) sugar, (7) honey, (8) yoghurt, (9) mashed fresh papaya, or (10) fresh placenta or amniotic membrane.
What you use is probably of less importance than how often you change the dressings.

DON'T GRAFT GRANULATIONS WHICH ARE HEAPED ABOVE SKIN LEVEL

SITES SUITABLE FOR GRAFTING

Split skin grafts readily take on:
(1) favourable granulation tissue (57.3).
(2) healthy red tissue in a fresh wound.
(3) dermis.
(4) muscle.
(5) any vascular tissue or organ normally covered by aeolar tissue. This includes paratenon, nerves, fascia, and blood vessels.
(6) periosteum.
(7) cancellous bone.
(8) pleura.
(9) peritoneum.
(10) meninges.
(11) gut.
(12) penile shaft.

Grafts take less readily on:
(1) fat.
(2) joint capsule.
(3) ligaments.

Grafts will fail to take (so a flap is needed) on:
(1) bare dry tendon, except in young children.
(2) bare cortical bone.
(3) hyaline cartilage.
(4) open syovial joints.

N.B. Split skin grafts look ugly on the face, and will rub off where there is constant pressure, such as the heel.

CAUTION! (1) *Don't try to graft a badly anaemic patient*. (2) *Don't try to graft too large an area at once:* 10% of the surface area is the absolute maximum at any one time.

METHOD FOR SKIN GRAFTING (GRADE 2.1)

(a) Preparation of the patient
Make sure your patient is well nourished, not anaemic & not febrile. The Hb level should be >80g/L. A recent pus swab should be negative. Use prophylaxis against *Streptococcus*: penicillin is simplest, with erythromycin asan alternative.

Once you are satisfied that the granulations in the wound are suitable, decide on where the donor sites should be. You can use depilatory creams, *but not immediately before surgery*. Make sure your patient gets a good bath pre-operatively, and scrubs the donor areas on the morning of surgery.

N.B. Don't attempt to take >10% TBSA skin graft at one attempt: this is equivalent to front & back of the thigh, or both thighs.

(b) Choice of donor site
You can take skin most easily from any convex surface of the body. The most convenient is the anterior thigh, which amounts to c. 5% TBSA.

The posterior, medial & lateral sides of the thigh, calf, medial & lateral upper arm, and medial forearm are also sites easy to use. Where large areas are burnt, you can also use the buttocks, calves, chest, back, head or even the abdomen.

(c) Preparation of the donor site
Scrub the donor site with cetrimide and a scrubbing brush, and then swab it with a mild antiseptic, such as hexachlorophane soap. *Don't use iodine or spirit,* because they may kill the graft. Drape round the donor site with drapes.

Raise a layer of diluted LA in a rectangle where you intend to obtain the skin graft.
The key is to get into a comfortable position, and get your assistant to hold the skin where you want to cut absolutely taut, and not to release the tension till you have finished the cut. Keeping the skin taut is more difficult in obese & elderly patients.

DONOR SITES FOR SKIN GRAFTS

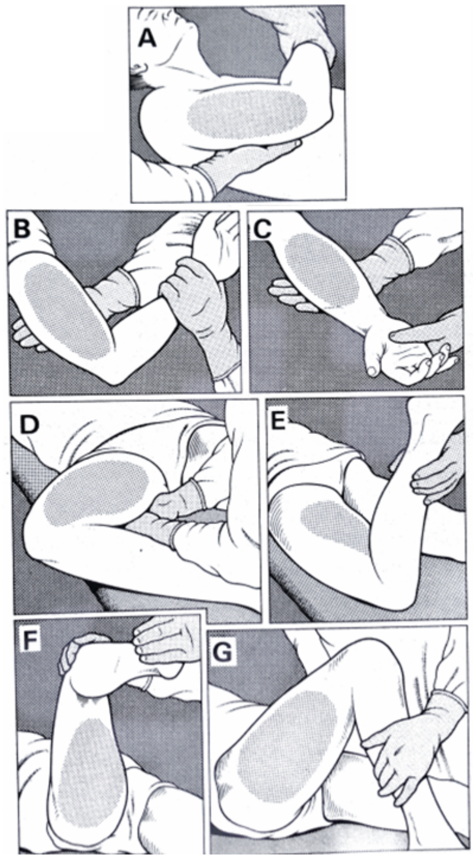


Fig. 50-12: COMMON SITES FOR SKIN GRAFTS. A, outer side of the arm. B, inner side of the arm. C, forearm, D, inner side of the thigh (usually the best place). E, back of the thigh (patient prone). F, back of the thigh (patient supine). G, outer side ot the thigh. *With the kind permission of Ian McGregor***.**

Use plenty of a very dilute LA, such as 0.4% lignocaine with adrenaline, to raise the skin all over the donor site. By raising it like a plateau, it will be easier to cut (50-13).

For the thigh, you can use a regional femoral and lateral cutaneous nerve block.

CAUTION! The skin of the upper arm is thin, so *don't cut a full thickness graft by mistake*.

For the head, *be careful to not go beyond the hairline*. Shave the hair & infiltrate the subgaleal layer. Because you leave the hair follicles, the hair will regrow on the head, but not where you apply the skin graft.

For the chest, fill out the skin from between the ribs (especially in a thin patient) by injecting the subcutaneous tissues with saline or diluted LA, so as to make a flat surface.

DONOR SITE PREPARATION

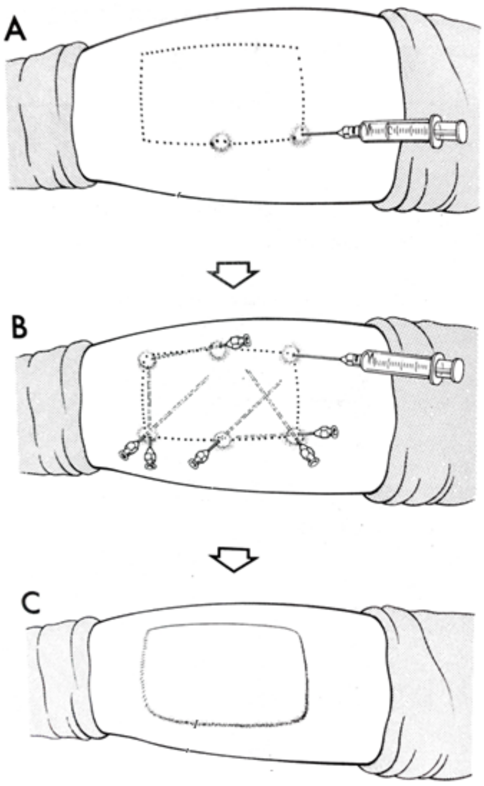


Fig. 50-13: LA FOR DONOR SITE PREPARATION. A, use plenty of a very dilute LA, such as 0.4% lignocaine with 1ml of 1;1,000,000 adrenaline. B, raise the skin all over the donor site. C, by raising the skin like a plateau, it will be easier to cut, and bleed less. *After London PS, A practical guide to the care of the injured, E&S Livingstone, Edinburgh 1967 with kind permission.*

For multiple sites, use ketamine.

(d) Harvesting the split skin graft Make sure your Humby knife (or dermatome) is correctly adjusted, the skin kept taut by your assistant, and the donor surface well lubricated with liquid paraffin (50-14A).
Press the Humby knife flat gently against the skin, keeping the board pressing firmly at 45^0 ahead of the rod, and, using a zigzag sawing motion, advance the knife from right to left, moving the board ahead at the same speed.
Make sure your assistant keeps the skin taut at all times.
The graft usually collects in folds on the knife. If it does not, ask the scrub nurse to pick up the ends of the graft with skin hooks.

When you have cut the skin you need, lift the blade slightly upwards, and left the skin ride past the rod. Then divide it with scissors, or do this beforehand.

SPLIT SKIN GRAFTING

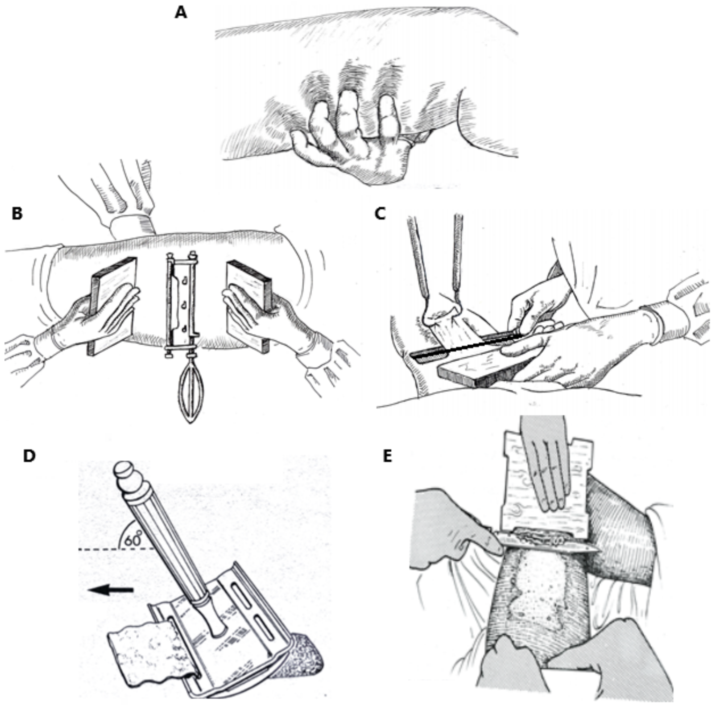


Fig. 50-14: HARVESTING A SPLIT SKIN GRAFT. A, One assistant is holding a board behind your knife, & the other hand keeping the skin taut. B, An assistant holding the skin with hooks. C, gripping the thigh taut. D, using a modified razor. E, using a carbon steel carving knife. *Kindly contributed by Peter Bewes.*

CAUTION!
(1) *Don't force the knife down the limb:* you will make too deep a cut.
(2) *Don't stop or pull the knife backwards*.
(3) Take a little more graft than you think you may need.
(4) Place hot moist dilute adrenaline packs over the donor site to reduce bleeding, and elevate the limb.

If after cutting c. 1cm of graft, you think the graft is too thick (or, rarely, too thin), *stop!* Assess the graft thickness by its tranlucency. If it is like tissue paper, it is too thin. If has large bleeding points, and curls up, it is too thick.

If you have cut into fat, *stop,* close the wound with fine sutures, decrease the blade-roller distance, and start again.

It is a good idea to lay the graft upside down onto a solid surface, preferably plastic, prior to placing it onto the wound site. Though pigmented skin looks bluish & shiny on its underside, white skin looks very similar whichever way up!

If you place the graft upside down on granulation tissue, it won't take!

Alternatively, place the graft onto paraffin gauze, and flatten it out as it tends to curl up.

It is useful to pierce some holes in the graft, so that exudate can drain through it, without lifting it off the granulation tissue surface.

MESHING A SPLIT SKIN GRAFT

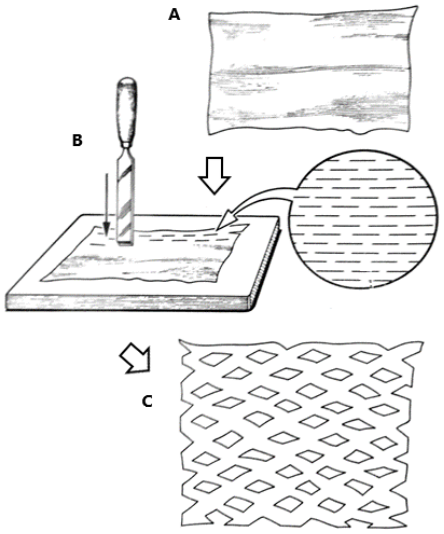


Fig. 50-15: MESHING A GRAFT. A, the sheet of split skin. B, cutting holes into the split skin. C, spread the graft, so increasing its cover; use mesh grafts for extensive areas. *Kindly contributed by Peter Bewes.*

Then carefully place the graft onto the wound surface. Trim it to shape. If you have to use several pieces of graft, lay them edge to edge, and let them overlap the edges of the wound a little. Make sure that they fit snugly to the bottom of any irregular areas, and *don't bridge any concavities*.

If sheets of graft cross a joint, *try not to make a join in the joint*; if you cannot avoid this, make sure that the join (where a scar may form), lies transversely across the joint, *not along it*.

It is best to suture a single sheet graft in place to stop it moving about, though this is not essential, but advisable at sites with much movement such as the eyelids, the palmar surface of the fingers, the axilla, and the popliteal fossa. Use small curved needles and fine non-absorbable sutures. Insert the needle from within outwards.

If you need to cut more skin grafts, cut the graft thin so that you can take another crop of skin from the same donor area 15 days later.

If the graft is over a joint, put a plaster cylinder over the dressings.

If the graft is over a flexure, the position in which the limb rests is critical (50.11), to prevent contractures.

(e) Dressing the grafted wound
APPLYING A DRESSING

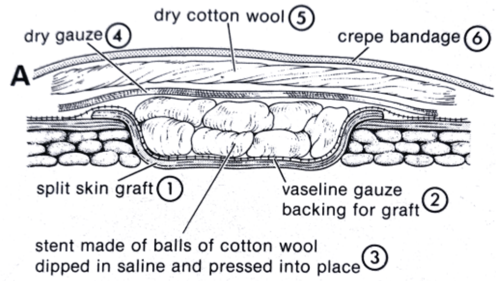


Fig. 50-16: APPLYING A DRESSING. A, The 1st layer is the graft itself, sticking to its backing of paraffin gauze (B). The gauze, but not the graft itself , should extend well beyond the edges of the wound. C, the next layer acts to mould the graft onto the concavity of the wound. Make it by fluffing out some balls of cotton wool, dipped into a bowl of saline, and while they are still dripping wet press them gently into place over the graft. They will mould themselves to any of its concavities. Alternatively use enough layers of gauze. Make sure that the bandages applied subsequently exert even pressure. D, next apply a final layer of dry gauze, and let it overlap the edges of the wound. E. then apply some dry cotton wool. F, hold it in place with a crepe bandage.
In children you often need plaster bandage to prevent movement. *With the kind permission of Peter London*

THE TIE-OVER METHOD

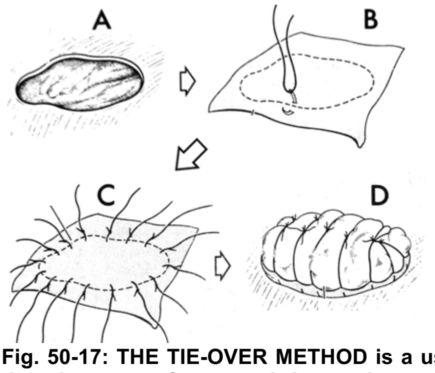


Fig. 50-17: THE TIE-OVER METHOD is a useful way of dressing a graft sutured in a place awkward for dressings. Use it for eyelids, the axilla, and for small intricate grafts, such as those over the tips of fingers. A, the wound. B, the graft placed over it. C, sutures all around, put from inside out. D, sutures tied over a thick dressing. *Kindly contributed by Peter Bewes.*

CAUTION! The graft must not move over its bed. In a child, this may be difficult to prevent, so you may have to use a frame, or apply a cast.

If the graft site is oozing, apply a negative pressure suction dressing.

(f) Dressing the donor site
The donor site always bleeds, and if it is large, much blood may be lost. When you have applied the graft and dressed it, remove the pack on the donor site and replace it by paraffin gauze, plain gauze, and a pressure bandage.
Leave this for 7-10 days and then remove the dressings.

THE DRESSINGS ARE CRITICAL:
DON'T ALLOW A GRAFT TO MOVE DURING BANDAGING OR AFTERWARDS

If the donor areas itch and the patient scratches it, sedate him, re-dress the wound, and consider applying a cast.

If the dressings have stuck to the donor site, leave them in place till they fall off. If you tear them off, *the wound will be very slow to heal.*

If the donor site becomes infected, treat it as any other superficial wound with frequent cleaning and changes of dressings.

(g) Removing the dressings
REMOVING THE DRESSINGS GENTLY

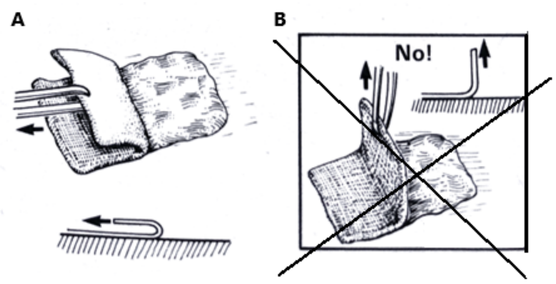


Fig 50-18, REMOVING THE DRESSINGS A, the right way, so as not to pull newly adherent graft away from the surface. B, the wrong way, *From Yang CC, Hsu WS, ShihTS (eds.) Treatment of Burns, Springer 1982, with kind permission*.

Leave the dressing on *unless there is a smelly exudate*. In this case remove the dressing very gently. You may still save the graft if you can keep it on the wound site.

At the 10th day*, change the dressing yourself, so that you can inspect your handiwork. Don't let your nurses do this, however competent, because you will not know, if your graft has failed, what the problem was.*

At first carefully remove only the superficial layers, using plentiful soaks. Leave the layer of paraffin gauze which was used to spread the split skin. Remove this only if the graft is firmly adherent.

If you see any blood clots under the graft, remove them. Wash them away from under it with saline, a syringe and a blunt needle. If some clots still remain, pull them out with non–toothed dissecting forceps. Immediately apply pressure to control further bleeding. Leave the graft in place for 3 more days.

Use paraffin gauze for the first dressing only on a successful graft. If you use it repeatedly, granulomas may form.

If there are any granulating areas, clean them gently with saline. If they cover a significant area, regraft this when granulations are suitable, if possible, with stored skin.

If blisters appear, incise them, or aspirate them with a syringe.

Start active joint movements 1 week after grafting. After 2 weeks you can usually remove all dressings.

N.B. It is possible to treat skin grafts without dressings, by simple exposure. This is economical, and well suited to warm countries, but beware flies & mosquitoes! You can also observe a graft and express fluid from underneath it more easily. The graft surface needs to be clean with good granulations & the grift secured with sutures. The patient needs to co-operate, not scratch the graft, and be very attentive not to damage the graft. You need to swab away excess fluid every 2h. Nurses need to understand this still needs *active* care!
It is useful for large areas on the back, the face & perineum where dressings are difficult.

(h) Graft failure
Grafts should take on any wound you have made surgically, such as one at excision of a contracture. For burns and other potentially infected wounds, there the most important reason why grafts don't take is lack of preparation. However, even if you have optimized the granulations as best you can, a graft will not succeed if:

(1) The wound is infected, particularly with *Strep. Pyogenes*, which secretes an enzyme that destroys the fibrin that sticks the graft to the wound.

Suspect it is present if the growing epithelium at the side of the wound has a sharp edge, instead of a normal gently shelving one. Routine prophylaxis should prevent this.
Pseudomonas, which give a greenish tinge to the wound and have a smell like rotten bananas, can also cause a graft to fail. Gentamicin is the antibiotic of choice, though *Pseudomonas* is notorious for developing resistance.

(2) The graft is lifted off the wound surface by exudate or bleeding. If you see this happening when you are applying the graft, make sure you have fenestrated the graft with stab wounds. Wait till the oozing stops. If necessary, store the graft for re-application after 2-3days.

(3) The graft is moved from the wound. Even a slight motion in the first 2-3days can shear tiny blood vessels growing from the graft bed to vascularize the graft. So suture the graft at its edges & make sure the dressing is firm, and if near a joint, immobilized with asplint or plaster.

(4) The patient is malnourished, anaemic, or in renal failure.

(5) There is a very poor vascular supply at the site of the graft, *e.g.* in diabetics.

(6) You have put the graft on upside down!

(7) The graft comes from another patient! However, in the very rare case when your patient has an identical twin, you could use the sibling's skin if there is a dire need!

(i) Storing grafts
You can store a graft in the ice compartment of an ordinary refrigerator. Stick its upper surface to paraffin gauze. Roll it in gauze moistened with saline, with its raw moist surfaces together. Keep paraffin away from the undersurface, or it will prevent the graft taking. Put the roll in a sterile screw capped bottle labelled with the patient's name.

You won't need any anaesthetic to apply the stored graft, and you can do this, with sterile precautions, in the ward. Unroll the bundle, cut the paraffin gauze to the required size, and lay the graft on the wound. The sooner you apply it the better.

We suggest you discard grafts after 8days, although they may keep for 2-3 weeks.

If you have taken more graft than you need, put it back on the donor site. You will still be able to use it within 4 days by lifting it off gently.

(j) Pinch grafts
These are effectively a a combination of a full thickness and a split skin graft. You pull up the skin, and cut off little pieces off; the centre is full thickness skin, but the circumference is epidermis only.

Pinch grafts are easy to cut, they resist infection well, and because they contain some full thickness skin, they resist pressure better than a split skin graft; this makes them useful on the heel, or over the Achilles tendon.

Pinch grafts leave an ugly donor site, unless you make a decorative patern of cuts (which you should discuss with your patient!)

Pinch grafts are so easy to take, and need no special equipment, they are particularly useful in peripheral health centres.

THE MOST FREQUENT FAILURE OF BURN CARE IS NOT DOING ENOUGH SKIN GRAFTING!

50.14 Special burn scenarios

(a) Deep burns to the face
If the diagnosis of a deep burn is reasonably certain, excise and skin graft this. Where the depth is clear-cut at the outset, graft the face after 3-4days (50.12). Always use sheet grafts and apply them in aesthetic units if possible. Use sutures for tie-over dressings (50-17) or simple fixation. *Don't mesh the graft.*

Clean regularly around the nose and mouth afterwards.

(b) Burns around the eyes
Burnt eyelids are much more common than burnt eyes. If someone is awake, shutting the eyes is a natural reflex. So, the cornea are spared unless consciousness is lost.

However, sight is still in danger from the burns of the eyelids, or from late effects of scarring. Burnt swollen eyelids will cover the eyes for a few days, but if they are seriously burnt, they will contract, particularly the lower ones, and expose the cornea, forming an ectropion (28.10).

This may result in conjunctivitis, exposure keratitis, corneal ulceration, perforation, and finally infection of the globe.

AVOIDING EYELID CONTRACTURES

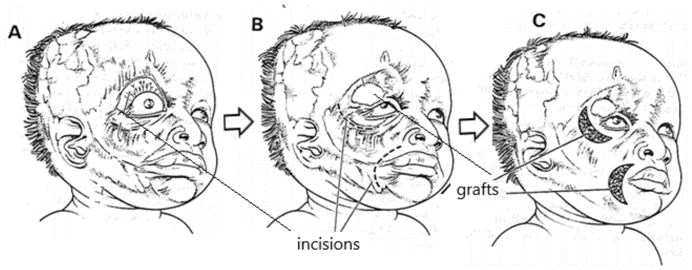


Fig. 50-19 AVOIDING EYELID CONTACTURES. A, excise the everted upper eyelid. B, after grafting, but leaving a lateral contacture. C, further release, also at the lips. *Kindly contributed by Randolph Whitfield II.*

Prevent this tragic sequence of events by making sure that the cornea is always covered and moist. The easiest way to do this is to use an antibiotic eye ointment every 6h. The most radical way is, temporarily, to sew the eyelids together (tarsorrhaphy, 28-13). Keep sutures in the eyelids, so you can retract them by pulling on the threads.

Don't worry too much about what the patient's eye looks like at this stage. What matters is not to leave the cornea exposed.

If there is a 3rd degree burn of the eyelids, excise it & put a full thickness skin graft (28-14). Grafts take well on eyelids, so that grafting them is not as difficult as you might think.

Often contractures continue to form, so that a release is only partially successful, and needs repeating (50-19), maybe 2-3 times.

CAUTION! Stretch the lid first so that there will be some slack tissue when it contracts later. The thinner the graft, the more the shrinkage.

Treat chemical burns in the same way. As with all chemical insults, use vast quantities of water to wash them at the earliest possible moment.

Examine the eyes fully early, preferably before eyelid swelling starts. If the eyelids are very swollen, you'll need gauze and sterile gloves, and maybe eyelid retractors. A bright shiny cornea is a good sign. Stain it with fluorescein and look for ulceration.
There are 4 grades of corneal injury; in I & II, the prognosis is good.
I. Epithelial injury only.
II. Cornea hazy but iris clear.
III. Total epithelial loss, and stromal haze.
IV. Cornea opaque completely obscuring the iris & pupil.

If the cornea is hazy, apply chloramphenicol ointment, and atropine or homatropine eye drops.

If there are foreign particles in the eyes, irrigate them away with water or saline.

If the punctae or canaliculae are damaged, pass a style or indwelling suture through them to keep them open, as they heal.

If the palpebral and ocular conjunctivae begin to stick together, separate them with a smooth glass rod.

If all or most of an eyelid is destroyed, dissect the conjunctiva of the lid free of the *orbicularis* muscle and tarsal plate, and cover the globe by suturing the remains of the lids together. Graft their exposed surfaces.
Refer to an expert later. If an eye is hopelessly damaged, it will have to be removed at some stage.

If the cornea is exposed, **and above efforts fail, & the eyelids are charred and tight**, make relaxation incisions, if necessary combined with traction sutures from the cheeks.

Try especially to prevent retraction of the upper eyelids, because these protect the cornea during sleep.

CAUTION! (1) *Don't use steroids.* (2) *Never apply an eye pad directly to the cornea*, because it may rub and ulcerate through. *Even paraffin gauze can cause ulceration.*
If you are unable to cover the cornea by the eyelids, just make sure you keep the open eye covered with an antibiotic gel.

(c) Massive facial burn
Warn a patient's family that massive oedema may greatly distort the facial appearance, but that this will disappear. Raise the head to 30º and administer oxygen.

The most significant acute risk is loss of airway patency, so have intubation and tracheostomy equipment ready (42.1). If a cricoido-thyroidotomy is necessary, *don't try this outside the theatre*. Try intubating first if possible. Get everything ready! Find the person with most experience, as often there is only one chance and then the larynx goes into spasm, the swelling then increases with each failed intubation attempt.

Oedema will be at its maximum 12-24h after the burn, so monitor the patient carefully, because respiratory obstruction may be sudden.

Full thickness burns of the beard area are rare, because the hair follicles extend so deep.

The most common cause of graft failure is movement of the graft.

(d) Burns of the ears

Inflammation of the ear cartilage can occur 2-5wks after a severe facial burn, when the skin over the ear may have healed. The burnt ear becomes acutely, painful, red, and tender, because its cartilage has become necrotic. Unless you excise the dead cartilage, it becomes infected and sloughs. Once this has happened, an ear needs reconstruction.

Dress a burnt ear carefully, putting a pad of gauze behind it to prevent it bending. If a fluid collection gathers on the ear, incise and drain it urgently, if necessary, more than once, *otherwise the cartilage under it may necrose*.

If the ear cartilage does become necrotic, incise the outer border of the ear, so as to separate its anterior and posterior surfaces.

Remove any soft yellow cartilage which lacks the normal resilience of healthy hyaline cartilage. Pack the ear with fine gauze, being careful not to bend it (50-20).
Keep it moist with saline. Examine it 24h later, under LA. If necessary, remove more necrotic cartilage. If there is sepsis and abscess formation, drain it with a wide incision, and remove all necrotic tissue.

EAR CARTILAGE DEBRIDEMENT

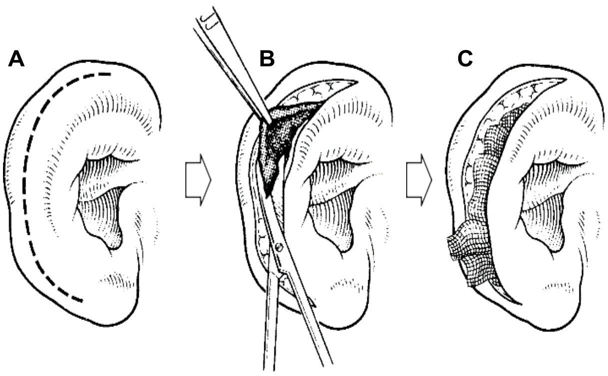


Fig.50-20 DEBRIDEMENT OF NECROTIC EAR CARTILAGE. A, incise the helix. B, dissect out the necrotic cartilage from under the skin. C. pack the cavity with paraffin gauze.

(e) 3rd degree hand burns

For deep partial thickness burns, use the plastic bag method,

N.B. To practice tangential excision you need skill, so do this if only 1-2 fingers are affected, and graft within 3-5days.

If burns have exposed tendon, bone, cartilage, or joints, the patient is usually in so much pain that you cannot find out if his nerves and tendons have been injured or not. The hand requires skin flaps, which is a highly skilled task, so try to refer him.

If a burn is very severe, you may have to amputate, but don't do this unless it is absolutely necessary. The same indications for amputation (60.2) apply in burns as in other hand injuries. Early excision & grafting will be the only way you can hope for reasonable function in the fingers.

Dressing fingers will almost always make them stiff. The expose method is probably the simplest initially. However, or messy wounds, you can use the plastic bag method (50-21). This keeps the fingers moist and allows movement, which is reasonably comfortable and almost completely painless. It is critical that the all the joints move through their full range on an hourly basis. *If not, they will end up with stiff swollen fingers which will lead to contractures.*
Stiffness appears very rapidly, but takes wks or months of therapy to overcome, once established.

PLASTIC BAG METHOD FOR HAND BURNS

Fig. 50-21 PLASTIC BAG METHOD FOR 3rd DEGREE HAND BURNS. Use big sterile bags: this keeps hands moist & mobile.

You can use the plastic bag method for up to 5days. Use any big sterile plastic bag of a suitable size.There must be plenty of room for the hand to move about inside. *Don't use a plastic glove.* Smear the hand in either silver sulphadiazine 0.5%, or povidone iodne with a little more of the same antiseptic, and place it inside the plastic.

Wrap a piece of gauze round the wrist and hold it in place with a piece of strapping and gauze to form a watertight seal.

Remember a burnt hand swells alarmingly, so elevate & suspend it. *Ensure the patient moves and uses the hand inside the bag right from the start.*

Large volumes of murky fluid will collect in the bag: this is normal. Change the bag twice a day; take the hand out of the bag, wash it with soap and running water. Apply more antiseptic, and put it back in a new sterile bag.

Full thickness burns of the digits inside a plastic bag may still need an escharotomy, so observe the circulation in the fingers carefully.

N.B. Sloughs will usually fall off in pieces into the bag by themselves, so that desloughing with scissors is usually unnecessary.

It's not easy to see inside the bag when a hand may be ready to graft: *never make this decision without looking at the hand outsuide the bag!* Once some granulations have appeared, it's usually time to remove the remaining slough by rubbing or excision and apply grafts. You should do this before 2wks.

A hand which stays uncovered longer than this is more likely to develop severe contractures. Once you have grafted hands, *don't put them in a plastic bag!!* Splint and dress the fingers & then mobilize the hand when the grafts have taken.

Splinting in the correct position helps prevent contracture formation; however, if splinted for too long without exercise, stiffness can still develop.

Splint hands at night and mobilise them as much as possible during the day. After grafting, it is important to keep the splints on continually for at least 5 days or until the graft is well adhered.

A plaster cock–up wrist splint is generally the best with the wrist slightly extended, the mc joints at 90° and the ip joints in full extension (65-8). Place the splint outside the dressing or the plastic bag and then bandage it in place. Keep a pad or splint in the space between the thumb and index to prevent an adduction deformity.

If you decide to dress a hand burn, put paraffin gauze between the fingers to prevent them sticking together and forming bridging webs. Cover each finger separately, and change the dressings daily. Dress the hand and splint in the position of safety (65-8) .

DISASTERS: STIFF HANDS

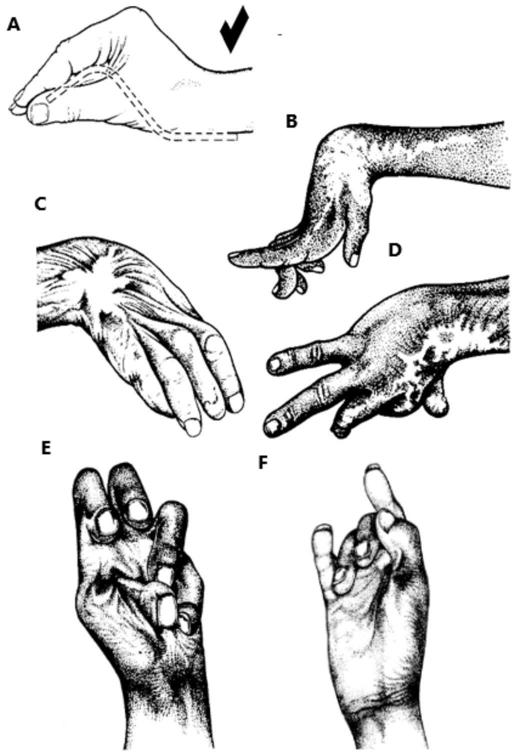


Fig. 50-22 DISASTERS WITH BURNT HANDS. If the methods described here had been applied, almost none of these disabilities and deformities would have occurred. A, the correct position for splinting. B-F results of not splinting the hand.

If there are exposed joints, aim for an arthrodesis in the position of function (usually 30° of flexion at the ip & mp joints). Remove any dead cartilage and fix the position with crossed K-wires, left in place for 3wks.

If a single finger is fixed in significant flexion, try to release the contracture & place a tissue graft; however, depending on the function of the hand and the wishes of the patient, it is often advisable to amputate it, *if it is interfering with function of the rest of the hand*.

(f) 3rd Degree foot burns

Feet are often burnt in children walking barefoot on ashes. Whilst the foot is not as complex a structure as the hand, contractures of the toes will prevent walking. Also, the skin of the sole is special and hard-wearing, so a simple skin-graft from elsewhere will not replace its function.

So, splint the toes straight (you need K-wires to do this effectively) and do your utmost to prevent infection, which worsens the burn wound.

High voltage electric burns often involve the foot which then requires extensive debridenent. *You may get a better result finally with an amputation & prosthesis.*

(g) Perineal burns
The perineum is an area where it is almost impossible to keep dressings clean, so use the exposure method (50.9). Avoid urine and stools soiling the wound by catheterization, and the creation of a diversion colostomy (11.5). Avoid excision and grafting before this is done.

The testes may be involved in young boys, and the labia in girls. You may have to bury exposed testes in a pouch under viable skin. For labial burns, you may have to use techniques as in de-infubulation for FGM (47-6).

N.B. Up to 50% of perineal scalding in children is from abuse!
N.B. Sepsis in the perineal area may rapidly lead to Fournier's gangrene (6-16).
N.B. Drinking white spirit may give rise to an 'alcoholic' watery diarrhoea which can produce a nasty perineal burn.

(h) Child scalding:
Scalding in children, usually by hot water, most often produces mixed depth burns with the majoirity being 2nd degree with areas of 3rd & 4th degree. It is often difficult to determine the depth initially and the appearance will tend to change over the first few days.

However, the aim of management is to achieve complete wound healing within 3wks as this minimises the risk of hypertrophic scarring.

A reasonable approach is therfore to treat the burn conservatively with dressings and topical antimicrobials for 10-14days. If there are significant areas that have not healed by this stage then excise and graft these areas. Use meshed sheet grafts when possible.

(i) Burns of the trunk
Follow up a child with severe burns of the trunk carefully. As growth occurs, scarring may prevent normal breast development or chest wall movement. At puberty, you may need to release more scar tissue.

Make a semilunar incision just below her contracted breast. Continue it into her intermammary cleft. Cut down to the deep fascia, lift the breast upwards, and correct its position by gauze and scalpel dissection.

Apply split skin grafts, and hold them in place with tieover sutures over wet wool. Cover them with dry wool and crepe bandages. Unless you can supply a firm elastic chest covering, make sure she lies flat until the grafts have taken.

If the nipples have been totally destroyed, you may need to suppress lactation in case of childbirth.

Likewise, an abdominal scar may need releasing to allow for pregnancy.

(j) Exposed (not necessarily burnt) bones
The tibia, the ulna, and the skull are often burnt when an epileptic falls into the fire. If the tissues over the periosteum are burnt, the latter dies, and with it the bone underneath, even if it had escaped previous injury. As you debride the slough or it falls away, you may see greyish yellow bone protruding from among pink granulations round the edge of the burn.

Granulations don't form on dead bone, although they sometimes form under it as it separates, so speed up this process by chiseling away dead bone, until you see some bleeding which shows that you have reached living bone. Wait for granulations to form, usually in 5 to 10 days. Then apply split skin grafts.

N.B. For treatment of contractures, which are not always caused by burns, see 34.2.

50.15 Electrical burns

Electrical burn injuries are a significant cause of morbidity and mortality, arising as a result of domestic, occupational accidents & lighting strike. They are frequently associated with being thrown, falling from a height, and combined with violent muscular contractions. This may directly affect the heart, causing an arrest in systole, or respiratory muscles, producing apnoea.

Unlike other burn injuries, the visible area of burn may only represent a fraction of the total amount of internal tissue damaged. In an electric shock, the current passes in and out of the body at two points, which are indistinguishable and small, often white or grey and insensitive.

Current, i = $^{V}/_{R}$, where V is voltage and R resistance. Direct currect causes muscle contractions, and can throw a victim (*e.g. in a lightning strike, or from a car battery)*, or cause unrelenting grasp on a cable, whilst high frequency alternating current does not.

Very high voltage may arc across a gap and jump 2-3m per 10,000V, so an adolescent climbing to the top of a railway carriage can easily be electrocuted from overhead high tension wires, even without standing up.

A lightning strike fans along the ground, so if it hits a tree and you are near that tree, you are in danger! You are best off standing than lying down, and better off inside a house or car.

Damage to the body depends on the route taken by the current: if this traverses the heart, dysrhythmia is likely, along with other tissue damage.

The heat generated (causing most damage) is proportional to the resistance, which is greatest in the skin (even when wet), and then bone, fat, muscle & body fluids. Thrombosis in veins and arteries of limbs is a frequent consequence. *The later use of anticoagulants does nothing to reverse this!*

Voltage over 500V can cause deep burns, but low frequency alternate current of only 60mA may cause ventricular fibrillation. (A pacemaker supplies <1mA.) Household voltage is usually <250V, but higher to an electric stove. Industrial voltage may be much higher.

The striking feature in a survivor may be the absence of any alarming signs.

The 1st action must be to remove the electrical supply from the victim, either by switching off the current, pulling a cable away, or removing the victim from something metallic with a non-conducting implement. *Take care not to electrocute yourself!*

You may need to initiate CPR (44.9), and continue this for along time. *Remember that most people with electrical injury don't have underlying heart problems!*

Next, make sure you administer good amounts of Ringer's lactate, as the major problem will be fat & muscle damage (resulting in rhabdomyolysis & myoglobinuria, staining urine red) which will damage the kidneys.

Maintain a urine output >2ml/kg/h, & administer mannitol 25g 6hrly in adults with a continuous infusion of 5% sodium bicarbonate to alkalinise the urine.

Significant swelling of the limb is likely to cause a compartment syndrome (49.6), so prepare for fasciotomies. Where there is significant tissue necrosis, you may need to amputate. At any rate a second-look & serial debridement are. usually necessary in high voltage injuries.

Assess the contact points (which may need debridement), and any other chest, abdominal or sleletal trauma from falls.

Monitor with an ECG trace if possible: in about 30% there are dysrhythmias. Carefully follow the urine output – *this is important!*

N.B. A shock which may not affect a pregnant woman much may be lethal to the fetus!

You will be able to treat minor, low voltage, partial thickness burns conservatively.
High tension injuries will almost always require early fasciotomy, exploration and extensive debridement.

Any 3rd & 4th degree burns need excision; explore deep muscle compartments, carrying out extensive fasciotomies. Remove all devitalised muscle, but preserve tendons and nerves, if possible, especially if they show anatomical continuity.

A child who takes an electrical cable into the mouth may sustain deep damage to the lip, which results in a secondary labial artery haemorrhage 7days later.

N.B. Severe electrical injuries often need expert care; local flaps from the zone of trauma are not advisable, especially in high voltage injuries. Secondary procedures, such as nerve & tendon grafting or tendon transfers may be needed to rehabilitate these patients.

50.16 Chemical burns

A huge number of chemicals can produce burn injury, including acids, alkalis and organic solutions, as well as powders in weapons such as phosphorous bombs.

The amount of tissue damage is related not only to the substance involved and its concentration but also on the length of time the body is exposed to the toxic chemical.

Chemicals act in different ways: some by coagulation (direct necrosis of tissues), saponification (an alkali converting fat to soap), or heat on contact with water in the skin.

The severity of a chemical burn and its area of contact may often be difficult to assess initially. In addition, systemic toxicity is not uncommon and can result from apparently minimal contact.

Eye injuries are frequent and often result in blindness.

The 1st action must be to prevent further spillage of the chemical agent and to decontaminate anyone who has been in contact by:
(1) brushing off any chemical powder
(*N.B. you must wear gloves & protect eyes*)
(2) cutting away clothing
(3) removing any constricting articles (such as belts and rings)
(4) removing contact lenses if worn.

THE SOLUTION TO THE POLLUTION IS DILUTION!

Irrigate the affected areas with huge amounts of water! Remember that acid concentrations are measured in logarithmic scales, so you need 10 times the volume to change the pH by 1.

Wash the victim early for a prolonged period of time (at least 2h). A continuous flow of clean water will dissipate the heat as well as diluting the chemical. (In cold climates, you may have to use warm water to avoid inducing hypothermia.

Burns of >10–15% TBSA require formal fluid resuscitation and monitoring.

A simple two-layered paraffin &h dry gauze dressing followed by wool and crepe will usually suffice in the initial stage.

(a) Acids

Acids cause injury, firstly by protein breakdown and hydrolysis and secondly, by heat. Dessication, coagulative necrosis and direct thermal damage result. The result is usually a hard yellow-brown leathery eschar which then prevents further penetration of the acid.

N.B. Salicylic acid used as a skin paste for acne can cause a burn if used in excess!

N.B. Hydrochloric acid (used in making fertilizer, dyes, textiles, rubber & electro-plating) *gives off chlorine, which is noxious & can cause oral burns, laryngeal oedema and pneumonitis.* Observe then for airway burns and later stenosis.

N.B. Hydroflouric Acid (used in glass & metalwork & electronics) *gives off fluorine, which is even more toxic, and combines with calcium and magnesium to form insoluble salts.* This leads to hypocalcaemia and also release of intracellular potassium, causing severe pain, and greyish discolouration, turning black later. Monitor for ECG changes, airway burns and stenosis later.
This is where an antidote of copious application of 2.5% calcium gluconate gel & sub-eschar injection of 10% calcium gluconate may be life-saving . Add 20ml 10% calcium gluconate to the first litre of resuscitation fluid. *Death may occur with as little as 5% TBSA hydrofluoric acid burn owing to severe hypocalcaemia!*

N.B. White phosphorus converts to phosphoric acid when wet. It burns terribly because it sticks to the skin. Copper sulphate will inactivate it.

(b) Alkalis

Alkalis (in detergents, ammonia & bleach, and from Lithium battery explosions, 46.15) cause massive extraction of water from cells, reaction with tissue proteins and saponification of fats (forming soap). Such burns often initially appear less dramatic than acid burns but cause deeper injury. A slow penetrating deep burn results with a soft friable eschar. The injury may progress many hours after exposure, and so needs prolonged washing.

N.B. Calcium Oxide (Cement) is an alkali, and prolonged contact can give very deep burns. (It is also used in paper making, insecticides & the steel industry)
Mineral oil may be more effective than water in metal alkali burns.

(c) Organic Solvents

Organic solvents (*e.g.* in hair dye, nail varnish remover, as well as **petrol**) dissolve fat, have an anaesethetic action and are highly toxic to the lungs. The skin protects, but inhalation can lead to renal, hepatic,cardiac, respiratory and CNS failure.

N.B. Hot tar is petroleum-based but sticky, so adheres to the skin. Don't try to pull it off or soak it off with solvents as you will pull off the skin as well. Cool it down with cold water and then use butter or sunflower oil to rub off the tar, and then apply burns dressings.

N.B. Large body surface area chemical burns are often fatal owing to systemic effects of absorption as well as severe tissue damage.

(d) Chemical eye Injuries
Whilst the eyes close spontaneously to fire, heat & light, a splash to the face may easily involve the eyes also, and cause either direct corneal damage, or later, exposure keratitis.

Always irrigate the eyes with copious quantities of warm clean water for over 2h; apply an antibiotic eye ointment. Prevent expose keratitis by a tarsorrhaphy (28-13) if the eyelids are badly damaged.

Special treatments such as amniotic membrane transplantation may save corneas, so try to refer such a victim to a special eye centre.

50.17 Cold injury

It might appear that cold injury should not occur in hot climates, but nights are still often cold, and at high altitudes, snow persists even at the Equator.

Frostbite describes 'cold burns' affecting usually the fingers and toes, but may affect the ears, nose & lips. The depth of injury parallels other burns:
1st degree: numbness & erythema only,
2nd degree: superficial blisters, erythema & oedema,
3rd degree: deeper haemorrhagic blisters, & damage into reticular dermis,
4th degree: necrosis extending to deep tissues,
Simple injury is easily reversible, *though a loss of sensation and so absence of pain may give a false sense of security!*
More severe injury is characterized by ice crystals forming within the tissues.
Rewarming, where there has been ice formation results in swelling of the tissues, which may give rise to a compartment syndrome (50.5).

In most cases, especially if the injury is <24h old, rapidly rewarm the frostbitten parts in a water at 40^0C over 30mins, making sure the injured skin does not touch the sides of the bath or pot. As the water cools, you will need to replace it with newly warmed water.
N.B. Prevent the parts from re-freezing! Do not rub frostbitten fingers! Do not puncture the blisters!

Then elevate the limb affected. Use NSAIDs or opiates for pain control.

Where tissues do not respond to rewarming, you will need to carry out an amputation, but this is not urgent.

50.18 Friction burns

Large abrasions disrupt the skin to varying depth, and act exactly like burns of equivalent depth. These abrasions may be relatively clean, if incurred indoors, *e.g.* from a treadmill belt or vacuum cleaner, but are more often contaminated especially if the result of being dragged along a road.

They are often overlooked when associated with other (usually more severe) injuries. However, they may contribute significantly to fluid and blood loss.

If not debrided (as a septic burn should be), they can give rise to necrotizing infection and severe sepsis. This is more likely when there is an underlying internal degloving injury, where the subcutaneous tissues are ripped off the fascia, creating a significant haematoma.

This is known as a Morel-Lavalle lesion, and is rare, but easily diagnosed by ultrasound. *You must drain the fluid collection* oterwise sepsis will inevitably ensue.

MOREL-LAVALLÉE LESION

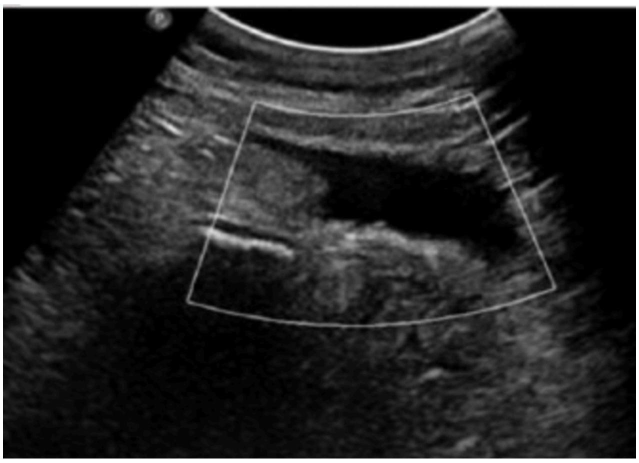


Fig. 50-23 Morel-Lavallée lesion: a large subcutaneous fluid collection seen on ultrasound. *After Nair Av, Nazar PK, Sekhar R, Ramachandran PV, Moorthy S. A closed degloving injury that needs real attention. Indian J Radiol Imaging 2014; 324(3): 288-90.*

Friction burns in children are common on the hand, but may occur on the buttocks, back and legs from water slides.

In younger adults, they are common in motorcycle riders not properly protected by a thick leather jacket. In such victims, >50% of friction burns are 3rd degree depth.

They may also occur in sports, falls (particularly from cliffs, or in mountains) or any road crash event.

Most friction burns can be treated by skin-grafting, but some require flaps.

50.19 Reconstruction

SIMPLE TECHNIQUES

You can excisie the scar tissue and replace it with either a skin graft or a local flap. The former is particularly useful for relatively wide scars or if there is scar tissue is over a whole limb with joint contractures.

Make incisions away from the joint itself otherwise you will end up exposing the joint itself and its tendons. For a flexion deformity, make one incision above the joint and another below. Incise down though all the scar tissue, which often includes the underlying fascia.

Remember postop to splint the joint in extension until the graft is fully healed and then encourage movement but advise wearing the splint at night for at least 6months.

You may be able to release and perform a Z- plasty; this is a useful way of releasing a contracture, if it is narrow enough. It is not an easy method, but if your result is not perfect, you can always graft any bare areas that remain.

Unfortunately, most burns usually cause scarring in all directions, so that there is no lax tissue at either side, and a Z–plasty is unsuitable. But in those burns where it is suitable, it is very effective.

Place the long limb of the Z in line with the contracture and then make two further incisions at c. 60^0 angle to the main limbs of the Z. This creates 2 triangular flaps which you can raise and transpose to create lengthening.

Details are in volume 1: 34.2

51 Head injury

51.1 Introduction

"No head injury is so severe as to be despaired of, nor so trivial as to be lightly ignored", wrote Hippocrates (460-370 BC).
This is by and large still true.

Unfortunately, seemingly trivial injuries are often ignored, and every such patient who dies is an indictment of the hospital which failed to treat him properly.

Although an injured scalp can bleed severely, and the skull bones break, it is brain concussion, contusion, or compression that usually affects consciousness.

Think always of non-accidental injury, especially in children.

(a) Concussion prevents reacting to stimuli for a few minutes after a head injury, but has no after effects.

(b) Cerebral contusion is a bruise of brain tissue, with laceration of small blood vessels and resulting bleeding into the brain tissue. The symptoms depend on the severity of the injury and the site of the contusion, and may produce coma or spastic hemiparesis, or just minor symptoms.

(c) Cerebral compression is due to raised intracranial pressure caused by increasing cerebral oedema or an expanding haematoma.

In practice, coma due to brain compression brain is rarely treatable surgically outside specialized centres.

So, try to keep a patient with brain contusion alive until natural healing processes allow recovery. You will be surprised how much a person, especially a young person, can recover from deep unconsciousness.

This means *excellent* nursing care and especially care of the airway to prevent inhalation of blood, vomit, or secretions.

A patient is more likely to die from these complications, than from any other cause, except irreversible brain injury.

N.B. Vomiting is particularly a sign of cerebral irritation in children.

Pay attention to vulnerable pressure points, urine output, and the need for a high protein/calorie diet and physical & mental stimulation.

Death is either due to the initial severe brain injury, or because you operated too late, or because you allowed complications (especially those producing hypoxia) to cause further cerebral oedema. As cerebral deterioration is so dependent on the airway, *you must always apply the ABC rules of resuscitation!* (41.2)

N.B. A head injury patient very often has other injuries also, so make sure you always examine him systematically.

Head injuries from a fall from >1m or a high speed impact are always suspicious.

Consequences of a minor head injury are greater in those with cranial malformation, bleeding disorder, previous skull injury (including surgery), osteogenesis imperfecta, or acromegaly.

CLASSICAL PATTERNS OF HEAD INJURY

Although cerebral compression from an expanding haematoma is much less common, timely intervention to evacuate such a haematoma, or just allow it to expand without pressing on the brain, may dramatically save a patient's life.

Making a burr hole in the skull is so comparatively simple that any doctor should be able to do it. Even If you fail to find a haematoma, you will have done no harm. The very fact of relieving some of the pressure may enable the brain to recover! *You will certainly not have time to refer such a patient:* the commonest mistake is to do nothing!
Cerebral compression can be the result of bleeding in 3 places within the skull.

(a) Extradural haemorrhage
Bleeding outside the dura only occurs in c.2% of all head injuries. Some of these patients have a lucid interval (51-2D) which usually lasts only 2-4h, but may be longer. Others have steadily deepening coma from time of injury (51-2F). Their important 1st symptom is increasing headache, *so take such a complaint very seriously in any patient with a recent head injury*. There may also be giddiness, mental confusion, or drowsiness; as this gets worse, unconsciousness deepens, and pyramidal signs (spasticity, weakness, slowing of rapid alternating movements, hyperreflexia, and a +ve Babinski sign) develop on the contra-lateral side.

INTRACRANIAL HAEMORRHAGE

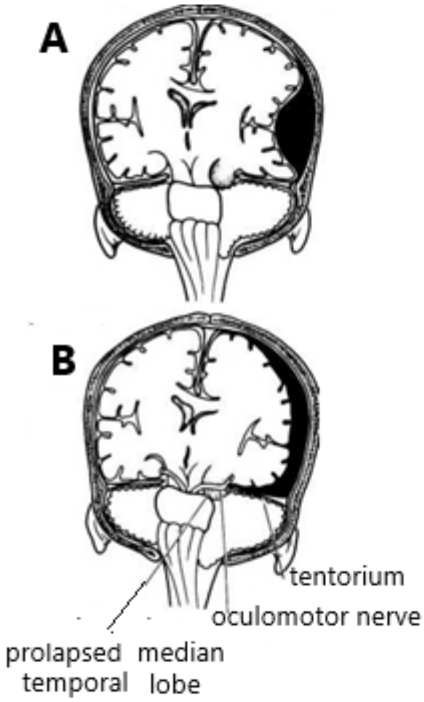


Fig. 51-1 INTRACRANIAL HAEMORRHAGE. A, extradural, usually rapid, making a concave indentation on the brain. B, subdural, usually slower, making a crescent-shaped filling defect. *After Martin G, A Manual of Head Injuries in General Surgery. Heinemann, London 1974..*

(b) Subdural haemorrhage
Bleeding under the dura occurs in c.8% of head injuries, and can follow any of the patterns (51-2D,E,F).
Unconsciousness may develop very quickly (at the scene of the injury), after some hours, or even days or months if there is a very slow bleed. Such a patient, who is usually elderly, suffers from repeated or increasingly severe headaches, drowsiness, apathy, or mental changes. The typical picture is that of a slowly developing cerebral crisis some time after a complete or partial recovery from a head injury, perhaps even a very minor one, which the patient may not even remember.

(c) Intracerebral haemorrhage
Diffuse oedema follows severe injury, where there is usually bleeding in many separate places of the brain.

(d) Cerebral oedema
Occasionally, oedema may develop after a seemingly minor injury, especially a 2nd head injury after the 1st only a short while before.

(e) Mixed picture
Sometimes, a patient may become unconscious (from a stroke, alcohol, or other cause) and then fall and hit the head. The 2nd injury may be superimposed on the 1st!

As cerebral compression increases, the blood pressure rises in line with increasing intracranial pressure, and the pulse becomes slow, full, and bounding. *These are late signs; death is imminent!* Now only strenuous efforts to reduce the brain compression will save the patient's life.

51.2 Management of head injury

MANAGEMENT OF AN UNCONSCIOUS HEAD INJURY PATIENT
N.B. This applies to all patients who have lost consciousness after an injury, even if their most obvious injury is a fractured femur.

FOLLOW ABC PRINCIPLES

TRENDS IN CONSCIOUSNESS AFTER HEAD INJURY

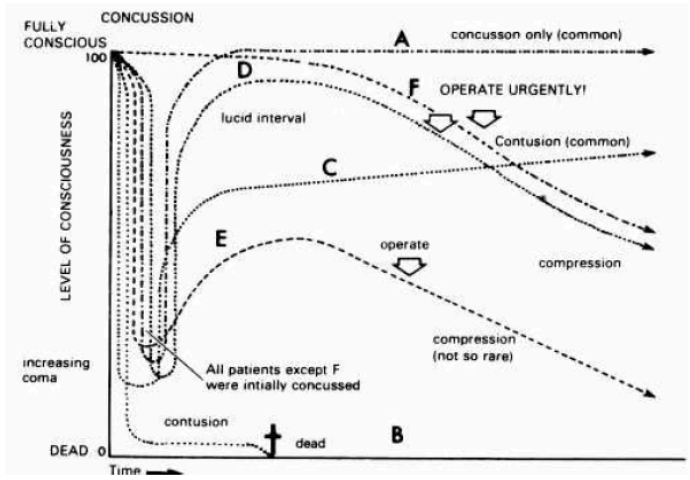


Fig. 51-2. LOSS OF CONSCIOUSNESS AFTER A HEAD INJURY. All patients, except F, were concussed to begin with. A was concussed, lost consciousness momentarily, and then recovered (common). B's brain was seriously contused; he stayed deeply unconscious and remained so (common). C was concussed & contused, and became deeply unconscious, after which he steadily improved (common). *None of these patients (A-C) deteriorated, so would not benefit from surgery.* D was concussed, then had a lucid interval before becoming unconscious again (rare but important). E was concussed, his consciousness improved but then deteriorated (not so rare). F did not lose consciousness at the time of the injury, but progressively lost it afterwards (rare). *These patients (D-F) all had cerebral compression and needed decompression to prevent further deterioration.* *Kindly contributed by Peter Bewes.*

AIRWAY *is critically important.*
(1) Place the patient in the recovery position (42-1).
(2) Clear the mouth and pharynx.
(3) Perform the jaw thrust manoeuvre (42-2C)
(4) Insert a Guedel oral (42-4), nasopharyngeal (42-5) or laryngeal mask airway (42-6), as tolerated.
N.B. The airway may be compromised by a cervical collar!

BREATHING
(1) Check the tracheal position.
(2) Assess pulmonary air entry.
(3) Insert an intercostal drain, if necessary.

A TRACHEOSTOMY MAY SAVE A LIFE

CIRCULATION
Insert an IV line and replace lost fluids with saline, to keep the systolic BP >90 mmHg.

N.B. An adult with a pure head injury and no other injury does not need IV fluids! They may worsen the intracranial pressure by increasing cerebral oedema.

ESTIMATE THE CONSCIOUS LEVEL (45.1) according either to the Glasgow Coma scale (45-1); write, *e.g.*, as E3,V4,M4:

Eye opening (E)	Spontaneous To speech To pain None	**4** **3** **2** **1**
Best verbal response (V)	Oriented Confused (disoriented) Inappropriate words Sounds only (Grunts) None	**5** **4** **3** **2** **1**
Best motor response (M)	Obeying commands Localizing pain Withdrawal to pain Flexing arms, extending legs to pain Extending 4 limbs to pain None	**6** **5** **4** **3** **2** **1**

N.B. M3 is the decorticate response; M2 the decerebrate. M1 the limbs are flaccid, as in a spinal injury.

N.B. V4: A child who has not yet learned to talk may grimace instead.

N.B. A mentally disabled or alcoholic person may have a normal baseline GCS <15.

Alternatively, use the AVPU method (which is useful in a case of polytrauma, or if there are many casualties to assess:

A	**Alert**	(not necessarily oriented, usually with spontaneously open eyes, responding to voice & able to move some part of the body).
V	**Verbal**	(some kind of response to speech)
P	**Pain**	(some response to severe pain, such as sternal pressure or pressing the fingernails)
U	**Unresponsive**	

DECORTICATE & DECEREBRATE SIGNS

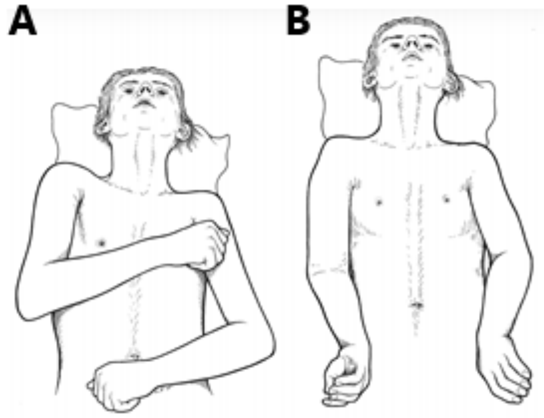


Fig. 51-3 SEVERE HEAD INJURY may result in A, decorticate or B, decerebrate positions. *After Hamilton Bailey's Emergency Surgery, ed. Dudley HAF Wright Bristol 11th ed. 1986.*

If there is no cough reflex, (GCS usually <5), intubate the trachea *before you pass a stomach or nasogastric tube.*

If intubation is impossible, and the airway is inadequate, perform a tracheostomy (42.3). This may be necessary later anyway, especially if coma is prolonged.

If unconsciousness is profound but the head injury relatively minor, *think of consumption of drugs, particularly alcohol!*

N.B. Remember: patients on anticoagulant therapy are at high risk of bleeding.

Don't however assume that because someone is drunk & unconscious, he has not also had a severe head injury! A state of confusion or agitation may be a sign of increasing intracranial pressure.

EMPTY THE STOMACH
Many patients vomit and aspirate their stomach contents after admission to hospital. *If the stomach was full at the time of injury, it will still be full!*
Pass an oro- or naso-gastric tube after endo-tracheal intubation, or you may stimulate a vomiting reflex, resulting in massive aspiration of gastric contents. If intubation is not possible, pass the tube *only while the patient is in the recovery position*.

HISTORY
What exactly happened? Try to gauge the violence of impact to the head. Try to assess the level of consciousness immediately after the injury. *A patient cannot know by himself how long he was unconscious!* Try to find this out from reliable witnesses.

If a patient is stable enough for you to consider an invasive diagnostic intervention, then you certainly have enough time to interview the next of kin thoroughly!

Did the patient take alcohol or drugs? Did anyone witness a seizure? If so, was it generalized, or affecting which side only? Is there full recovery from the seizure or not?
Find out if the patient had a lucid interval (a period of consciousness before becoming comatose) following the injury. This is a classic feature of an extradural haematoma.

Enquire how much loss of memory there is for events following the injury. The duration of pre– and post–traumatic amnesia are good indicators of the severity of a past head injury.

EXAMINATION
Look at the patient in a good light, examine the body and limbs first, and then the head and neck. Smell the breath for alcohol and acetone, and *don't forget the other causes of coma*, including epilepsy, diabetes, liver failure, meningitis, drugs, malaria, & trypanosomiasis.
Check the pupil sizes & their reaction to light: *N.B. size is more important than reaction! Never use atropine!*

PUPIL REACTIONS AFTER HEAD INJURY

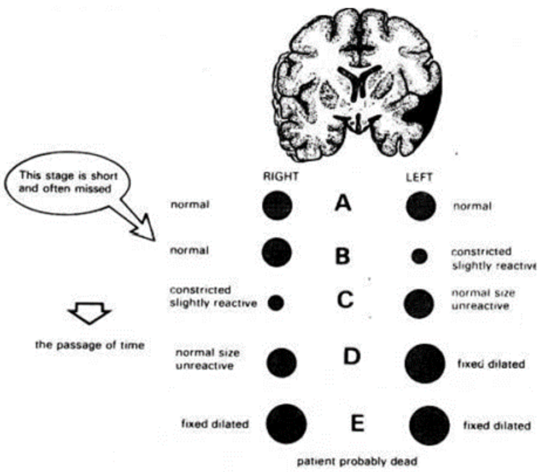


Fig. 51-4 PUPIL CHANGES AFTER A HEAD INJURY. Testing reaction to light stimulus: A, normal. B, the ipsilateral pupil constricts first and then dilates. The ipsilateral constriction usually lasts only a short time and is often missed. C, later the ipsilateral pupil returns to normal size, but is unreactive. D, then a fixed dilated ipsilateral pupil is accompanied by an unreactive normal-sized contralateral pupil. E, both pupils are dilated & fixed. Surgical intervention at this stage is futile. *Kindly contributed by Peter Bewes & Gerishom Sande.*

THE PUPIL ON THE SIDE OF THE LESION DILATES FIRST

NEUROLOGICAL EXAMINATION
If the patient is sufficiently conscious, test the motor power of all 4 limbs. Look especially for lateralization signs (weakness on one side of the body, relative to the other).
This is not easy to determine in a patient who is not fully cooperative.

If the patient is restless, observe the frequency & periodicity how each side of the body moves.
Look at the eyes & eye movement to check spontaneity of movement & the reactions of a 'curiously conscious' patient

If the patient is unconscious, see if there is any difference one side versus the other & the response to (strong) sternal pressure. *The signs may only be minimal.* Examine the knee, ankle, abdominal & especially, the plantar reflexes.

If peripheral reflexes are absent, assume a spinal injury (54.2)

CAUTION! Don't perform a diagnostic lumbar puncture! Sudden drop in intracranial pressure may be fatal. However, if you suspect meningitis or subarachnoid haemorrhage, it is indicated.

OCULAR EXAMINATION
Examination of the pupils is fundamental. Even if the eyelids are swollen, you can usually gently pull the lids apart to look at the pupils.
Get an assistant to help you to shine a torch into the eye. A 'black eye' is the result of bleeding into the eyelids and is of little significance by itself.

Conjunctival haemorrhage is, likewise, in most cases merely local bruising. This only indicates an orbital fracture (usually of the orbital plate of the frontal bone) if:
(1) The conjunctiva is oedematous.
(2) The posterior edge of the haemorrhage is not visible.
(3) Eye movement is restricted.

SCALP EXAMINATION
Look for cuts and bruises. This is especially important if the patient is drunk, and you are not sure there is also a head injury. Palpate such a laceration with a sterile gloved hand to feel for the edges of a depressed fracture.

Most often, a pad and bandage will control scalp bleeding, but if it does not, close it, even if only temporarily, with a continuous suture, or if the hair is long and strong, approximate the skin edges by tying the hair together firmly. *Don't attempt to explore a wound outside the theatre!*

EARS AND NOSE EXAMINATION
Blood from the nose is usually a sign of a nasal fracture (53.4), rather than something more serious (which will be quite obvious).

However, CSF leak from the nose or ear signifies a skull fracture (51.3). If there is only a trace of blood from the ear, it is worth examining the auditory canal with an auroscope to see if there are signs of damage. Blood behind the eardrum confirms a fractured skull base, as does bruising behind the mastoid appearing a few days after the injury.

N.B. You can reliably check for CSF by using glucose uristix (provided the blood glucose level is >6mM): CSF [glucose] is usually $^2/_3$ blood [glucose]. CSF makes a gauze dry & stiff.

NECK EXAMINATION (54.1)
Look especially for injuries of the neck and back that may indicate spine fractures, especially the cervical spine (41.3). Carefully log roll the patient onto the side while maintaining gentle head traction (54-4). Palpate every spinous process. Look for even a small *kyphus* or an abrupt misalignment.

If you suspect a fracture of the cervical spine, fit a *firm* cervical collar. If there are signs of limb paralysis (54.3), protect the pressure areas, and make sure no movement is allowed in the neck, which may make the deficit worse.
N.B. Beware of the dangers to the neck at endo-tracheal intubation!
Get AP & lateral cervical spine radiographs.

CAUTION! **If the patient is shocked**, look for severe injuries at other sites, especially in the thorax and abdomen. *Cerebral injuries do not cause hypovolaemic shock in adults,* though they may do so in small children. Serious abdominal or thoracic injuries must anyway take precedence over the head injury (44.1).

RECORDS
Always record the state of consciousness on a coma chart (51-5). Careful notes are most important. Note the exact times at which all observations are made: *this is important for medico-legal reasons*!

Completion of a chart (51-2) is vital; every head injury patient admitted *must* have one.

The purpose is to *monitor* changes, so regular completion of the chart is imperative. If your nursing staff are not familiar with such charts, it is worthwhile spending time teaching how to complete them properly. Encourage them to have faith in their own observations!

You should always re-examine a serious head injury patient 1h after your first examination fully; remember that the *trend* is more important than the *status.*
A fully conscious patient may deteriorate & die! Never use subjective evaluations such as 'partially conscious'.

INVESTIGATIONS
Plain radiographs are of little help. They may be difficult to interpret, may fail to show the seriousness of the situation and *anyway not all serious head injuries have fractures!*
However, if you have palpated an open or suspect a closed depressed skull fracture, a radiograph is useful.

CAROTID ARTERIOGRAM (38.1)
Any X-ray machine that can take a skull radiograph can take a carotid arteriogram. You need a long fine needle, and IV contrast.
Particular indications are when GCS <8 with:
(1) Basilar skull fracture
(2) Le Fort I or II maxillary fracture (53.2)
(3) Near-hanging or strangling (54.7)

OPTIC NERVE SHEATH ULTRASOUND (45.1)
Place the probe over the closed eye. At a distance of 3mm from the posterior border of the globe, a measure >5.2mm is a significant indicator of raised intracranial pressure >20mmHg. You can carry out this examination repeatedly as it is non-invasive. *Don't press hard or take a long time* or else you may damage the eye.
You may also detect papilloedema with a simple ophthalmoscope.

NURSING A HEAD INJURY

POSITION
Provided there are no other injuries which might prevent it, nurse the patient in the recovery position (42-1) & turn him 2hrly. If agitated, it may be best to place the patient on a mattress on the floor.

PAIN AND SEDATION
Pain is obviously only described by a patient whose conscious level is near normal. However, it may be manifested by confusion or violence. Use haloperidol (1mg adult, 0.5mg child) to calm someone who becomes a danger to himself and other people. Avoid stronger sedatives, especially morphine, because they depress respiration & interfere with the assessment of consciousness.
N.B. Monitor a restless child very carefully, as deterioration may be dramatically rapid.

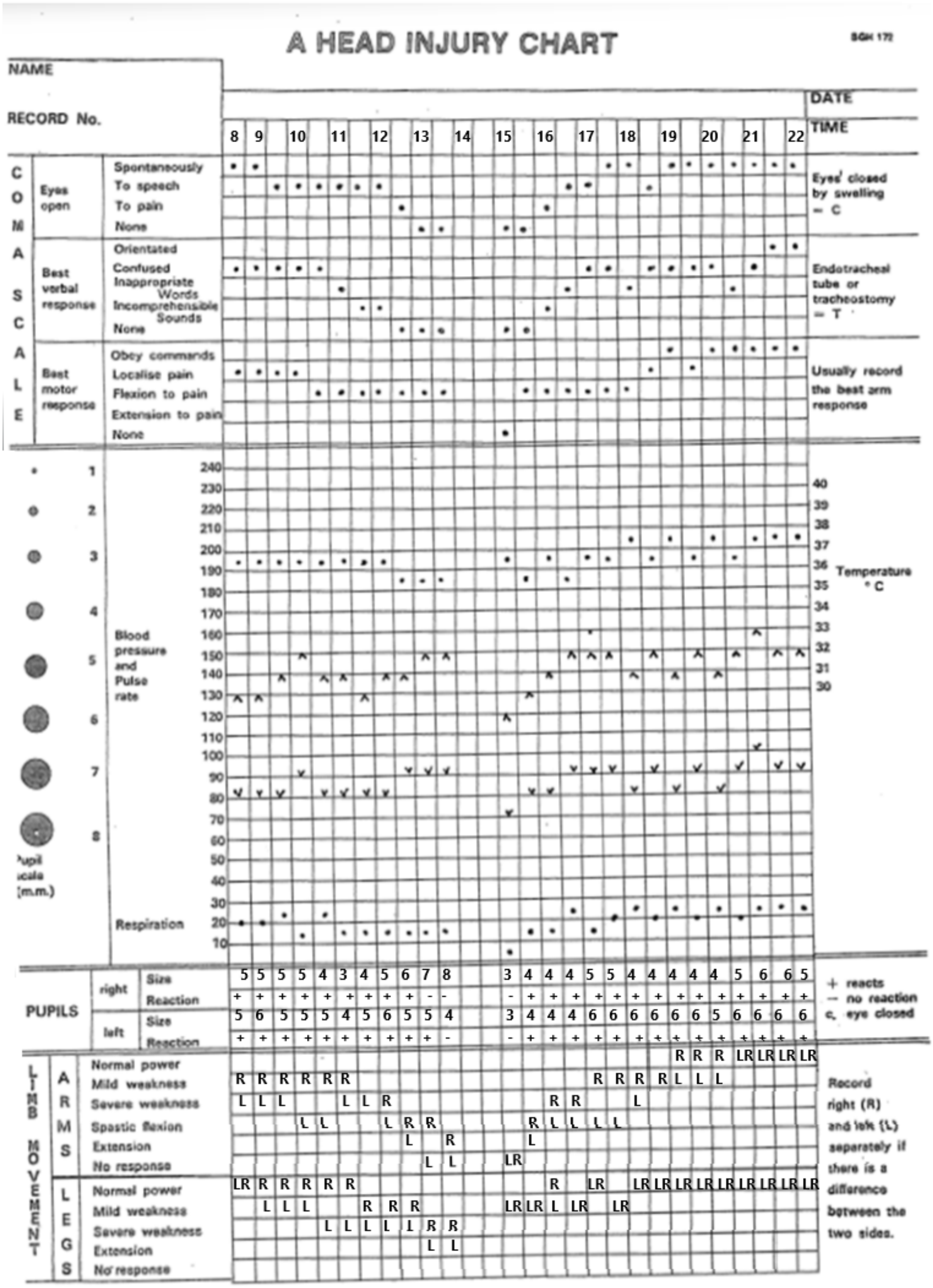


Fig. 51-5 COMA CHART. Make sure you complete this diligently ½hrly. Note the progressive neurological decline (an extradural haemorrhage often produces more rapid deterioration than a subdural); as central function fails, so does peripheral; eye signs are key. The pupil dilation occurs first on the affected side, with contralateral limb signs. Here, the patient should have gone to theatre 1h earlier (at least!) Note the *trend is more important than the actual readings!* *Kindly contributed by Gerishom Sande.*

Moderate restlessness may be useful as it provides good lung limb exercise and prevents pressure sores. Make sure overactivity is not caused by a full bladder, constipation or a missed injury.

MONITORING
Apart from the coma chart, record the temperature, if possible, rectally bd.
Watch for hyperthermia (45.3); start cooling at 39°C.

Complete both coma & fluid balance charts.
N.B. Consider other causes of drop in conscious level:
(1) Haemorrhage elsewhere
(2) Seizure (especially in a child)
(3) Fat embolism
(4) Sepsis (particularly, meningitis)
(5) Pulmonary embolism
(6) Hypothermia & hyperthermia

INTRACRANIAL PRESSURE (ICP)
Monitoring ICP may be helpful in difficult cases, especially where there is considerable brain swelling. To do this, you need to make a small burr hole, and perforate the dura, & advance a cannula into the lateral ventricle *with all aseptic precautions*. This is not as difficult as it sounds (33.12). Make sure you tunnel the cannula under the scalp, and connect it to a pressure monitor.

FEEDING
If a patient is likely to be in hospital for a while, IV fluids alone will not supply the calories. Obviously initially maintenance fluids are needed *(though even this does not provide sufficient glucose)* but at least by 72h, pass a nasogastric feeding tube.

N.B. Both hypoglycaemia & hyperglcaemia are bad for the brain!

An adult needs up to 4x as much energy as a normal conscious adult, and especially protein; 4KJ (9cal)/kg in 3L fluid, with 1.5g/kg protein, and 4g/kg glucose daily. If the input gives less energy than needed, try to increase the protein content, *e.g.* with peanut butter.
(Note 1 egg = c. 6g protein.)
Try to keep the glucose level between 3-8mM.
A patient may be unconscious for many days but eventually recover fully, *so allow starvation meanwhile*.

CUSHING'S ULCERATION
Prevent this with 40mg omeprazole or double if there is upper GI bleeding (half in children).

If you see the muscles wasting, *it is due to lack of protein and lack of exercise!* (In-bed physiotherapy is important not only in maintaining muscle tone but preventing DVT)

SPECIAL NURSING FEATURES
(1) Cornea
If the blinking or corneal reflexes are absent, and the eyes remain open, put adhesive strapping across the closed eyelids to protect the corneas from drying out.

(2) Bladder
Examine this to make sure it does not distend; most males can manage with a condom catheter, but females need catheterization.
Releasing the stopcock 4hrly is better than letting it drain continuously, and allows bladder tone to survive.

(3) Bed sores
Care for the skin from the start, as for paraplegics (54.3).

(4) Stimulation
Apart from physiotherapy, mental stimulation is vital. Play music through earphones, show pictures (of family & friends, and scenes familiar), talk or sing, and don't forget to touch the patient. Allow the patient also to touch, hear & smell you!

51.3 Complications of head injury

HYPERTHERMIA (45.6)
This may occur especially during the 1st 12h after an injury, even rising alarmingly rapidly to 42°C. When this is not due to infection *(remember endemic disease such as malaria, dengue, scrub typhus)*, it is known as neurogenic fever. It is associated, especially in children, with seizures. This puts a severe demand for increased metabolism on the brain, and leads to worse outcomes. So, it is worthwhile cooling a patient with a head injury.
N.B. Don't use NSAIDs or antipyretics!

Expose such a patient, apply cool sponging, use a fan to cool the air, and if this fails to lower the temperature <38°C, infuse IV saline at 4°C.

CONVULSIONS
These can occur at any time, and may be focal or general. They are usually associated with sudden deterioration of consciousness.

Use prophylactic anticonvulsants for:
(1) children with severe head injuries
(2) known epileptics
(3) depressed fractures (especially compound)

(4) gunshot injuries
Adjust a dose of 2.5mg/kg bd phenytoin for children or 3-4mg/kg od for adults to 4-8mg/kg od according to the response.

N.B. Status epilepticus may be fatal.

When a convulsion does occur, make sure the airway is patent. **If the convulsion continues despite correcting the hypoxia,** administer 0.3-0.4mg/kg (max 10mg) diazepam IV, and repeat this slowly after 10mins if convulsions continue.

If there is no IV line, administer the same dose rectally.

Such patients need anticonvulsant therapy on discharge.

CSF LEAKAGE
This is the result of a fracture of the skull base Where there is communication with the nose & ears. *Don't plug them*.
Advise against blowing the nose, as this may push bacteria into the meninges.

Start a 3rd generation cephalosporin as prophylaxis. Nurse the patient in a sitting position, if possible.

Make a lumbar puncture and repeat this 48h later if necessary. If the leak continues, the dura needs repair.

If the patient starts to sneeze, there may be a pneumatocoele, an air sac within the meninges, which connect with a sinus, usually the frontal. This requires neurosurgical attention.

CRANIAL NERVE PALSIES
These are usually the result of skull base fractures. No specific treatment helps.

LIMB PARALYSIS
During deep unconsciousness, you may observe no movements in all 4 limbs, and only realize this is permanent when the patient wakes up, or when you try to wean off the ventilator! If this is the case, you have missed a catastrophic cervical spine injury! By this time it will be far too late to remedy the situation*, so always remember to check the neck!*

AIR EMBOLISM (44.5)
If air is sucked into large veins (such as the venous sinuses), the risk of air embolism is high. A 200mL bolus may be fatal. There is a sudden hypotension & tachycardia, which may make you think of sudden bleeding. Pre-cordial US Doppler may pick up air in the right side of the heart.

Administer 100% oxygen at 10L or more, and noradrenaline if necessary.

FEW HEAD INJURIES ARE SO SEVERE AS TO BE HOPELESS

NO HEAD INJURY IS SO TRIVIAL AS TO BE TAKEN LIGHTLY

OTHER INJURIES
If a patient with a head injury has fractures elsewhere, at least splint them temporarily in the reduced position, even if you cannot treat them definitively.

LOOK FOR ANOTHER INJURY IF A HEAD INJURY PATIENT IS IN SHOCK
ALL HEAD INJURY PATIENTS MUST HAVE A COMA CHART

MANJI 40yrs
One Christmas Day a missionary doctor was called 40km to see a patient who had been beaten over the head with an axe, only to find him with such a severe degree of cerebral compression that he appeared lifeless apart from his pulse. It seemed that each breath he took would be his last. Unfortunately, the primitive operating theatre had collapsed, but the doctor decided to use a little laboratory barely $4m^2$ in size. Light was provided by an electric torch and some hurricane lamps. No anaesthesia was required, as the patient was so limp, but after the removal of some bone and a large haematoma, blood clot, he had to be held down for skin suturing. LESSON: While there is life there is hope

51.4 The need for imaging

Try to become proficient in checking optic nerve sheath diameter by ultrasound (45.1) as this is relatively easy and non-invasive indicator of raised intracranial pressure. You can repeat it as many times and as frequently as you like.

Remember that a head injury is a dynamic event; no patient's status remains static initially. *So, if you wait till signs of deterioration are obvious, it might be too late; conversely any scan images taken too soon after an injury may not show the development of complications!*

Therefore, make a great effort to examine your patients extensively, carefully & repeatedly! Where there is a deterioration, there is almost always some sign!

Look out for such deterioration especially in these patients with this history:
(1) Fall over 1m onto the head
(2) High speed impact (especially cyclist-car)
(3) Penetrating head injury
(4) Non-accidental injury
(5) Skull deformity or previous injury or surgery
(5) Patients using anticoagulants
or these symptoms:

(1) Vomiting more than once (esp. in children)
(2) >30 mins retrograde amnesia
(3) seizure without full neurological recovery

or these signs:-
(1) Depressed skull fracture
(2) CSF leak/bleeding ear/raccoon eyes
(3) Focal neurological deficit
(especially of the pupils & limbs)
(4) Persisting coma
(5) Hypertension with bradycardia

Where the signs are present on arrival in hospital, you have to presume they developed since the injury, and *you should not necessarily wait for further deterioration to act!*

Deterioration may be quite subtle and you will only pick this up if the coma chart is diligently filled in!
Occasionally, deterioration may be so rapid that you need to act without wasting time getting an image. *Don't insist on this, even if you have some doubt about your diagnosis.* The penalty of delay is death or serious neurological disability to the patient! *Time lost is brain lost.*
A skull radiograph will not guide you (except in rare instances) for surgery.
The carotid arteriogram will give just as much information as a CT scan, so it is worthwhile to become good at the former if you can't do the latter!

51.5 Open head injury

What may look like a simple scalp wound may conceal a dural laceration. The dura protects the brain from infection, so any dural tear may lead to meningitis, or a brain abscess.

RADIOGRAPHS are useful in open wounds of the skull vault (much more than in fractures of the base), especially in:
(1) An open fracture under a penetrating wound.
(2) A depressed fracture
(3) A retained foreign body.

The main problems with head wounds are:
(1) they may be deeper than you think,
(2) they may bleed profusely.

ARE YOU ABSOLUTELY SURE THERE IS NO PENETRATING SKULL WOUND?

OPEN HEAD WOUNDS
N.B. **If the patient has more serious wounds elsewhere**, the head wound can usually wait 12-18h, unless it is bleeding. Get control of the bleeding as a 1st priority (51.7).

You can easily confuse unconsciousness or severity of injury with instability where attention to ABC is paramount. It is wiser to proceed with any intervention in the OT.

Explore a deep small head wound with a sterile glove under LA. Feel for a gap in the skull bone. *Otherwise explore it in theatre*, because it may be deeper than it looks. Torrential bleeding may occur, so you may need theatre facilities in a hurry.
N.B. You can use a LA ring block of the scalp.

WOUND TOILET
Shave the scalp around the wound, and clean it with detergent. Be prepared to use several razor blades, because any grit in the scalp will blunt them. Protect the wound meanwhile with a sterile swab or towel.

If the wound is clean, and its edges are healthy and bleeding, *don't excise them*.

SURGICAL ANATOMY OF THE SCALP

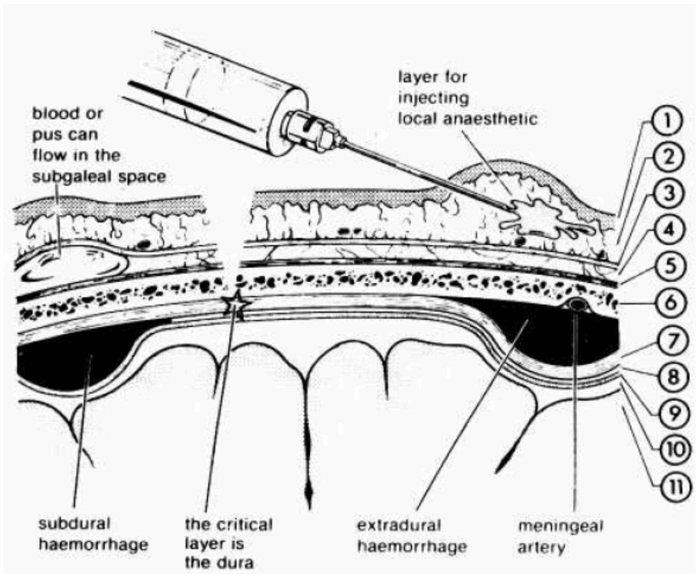


Fig. 51-6 THE ANATOMY OF THE SCALP AND SOME IMPORTANT LESIONS. The epidermis (1) is separated by a fibro–fatty layer of dermis (2), from the strong fibrous *galea* (3). These three layers are firmly united to one another to form the scalp. Under the *galea* there is a potential space, the subgaleal space (4), which enables the scalp to slide over the pericranium (5). Under the pericranium lies the skull (6), the dura (7), the subdural space (8), the arachnoid (9) the subarachnoid space (10), and the brain (11).
***N.B. LA injection should go into the fibro-fatty layer, not under the galea*. Blood or pus sometimes collects in the subgaleal space and may perforate superficially or spread into the bone. An extradural haematoma lies between the skull & dura, and a subdural haematoma between the dura & brain.**

If the wound is dirty and ragged (63-19C), excise the skin edges all round it as little as necessary in one clean sweep right down to the pericranium. *Take care not to cut away excess scalp*, or then the wound will be difficult to close.

Insert a self-retaining retractor, and explore the wound cautiously with your gloved finger.
This is safer and provides more information than a metal probe. Palpate & look for a depressed skull fracture.

Remove all debris and dead tissue, and flush it out with sterile water.

If you feel any sharp bony edges, expose the surface of the skull widely (63.7)

CLOSURE
A wound which only cuts through skin does not gape, but one which cuts the *galea* gapes widely. Close this, if possible, with a large square vertical mattress suture of stout monofilament (51-7), taken through *galea* & skin. *Avoid inverting sutures.*

CLOSING A DEEP SCALP WOUND

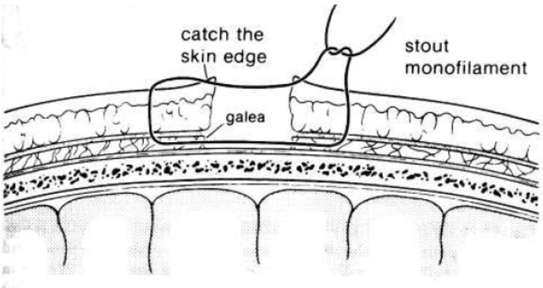


Fig. 51-7 CLOSING A DEEP SCALP WOUND. Make sure you pick up the *galea* with a large curved needle. *Kindly contributed by Peter Bewes*

Bleeding scalp vessels are difficult to pick up in haemostats, because they are held by the fibro–fatty tissue. Use LA with adrenaline, and swab the wound with hydrogen peroxide *(provided the dura is not torn).* A continuous locked deep suture (51-7) will control the bleeding: get an assistant to press on the wound edges.
Apply a series of artery clips to the *galea,* pushing them inwards to get good traction. (Special right-angled clips are very useful here.) Try to get proper haemostasis; leaving blood below the *galea* is inviting infection.
N.B. Don't use diathermy!

SCALP LOSS
Try to bring the skin edges together without tension, or the scalp may necrose. *Don't leave bare bone exposed*, or it will slough.

If there is comparatively little loss of scalp, you may be able to free it from the pericranium round the wound, so as to mobilize it over the subgaleal space. Mobilize the scalp in the layer between the *galea* and the pericranium (51-7).

If the defect is larger, use a flap (46.5). A long curved 'S' is a typical advancement flap (51-8B-D). The flaps need to be big, because the skin is quite tight on the skull.
If possible, design the flap to be based on one of the arteries supplying the scalp (46-16).
These are:
(1) The temporal arteries ascending in front of the ears.
(2) The supraorbital arteries which ascend over the forehead from the medial ends of the eyebrows.
(3) The occipital arteries behind the mastoid processes.

If the scalp hangs loose from the head, trim it, wash it with an antiseptic, such as hydrogen peroxide, and suture it back. Its excellent blood supply will probably allow it to survive, even if it has a narrow base.
N.B. Beware: such a patient has usually lost much blood and may well need a transfusion.

JABIT, 25yrs, was brought from 2h away having been attacked by a machete several times on the head. He was brought in comatose with a weak pulse. On primary examination there were no fractures but the scalp had been chopped off in multiple slices. He had lost a lot of blood and died within minutes of arrival, even before an IV line could be set up. There were no other injuries at all: the victim exsanguinated from his scalp alone. LESSON: Don't underestimate surface bleeding from the head!

FLAPS TO CLOSE SCALP DEFECTS

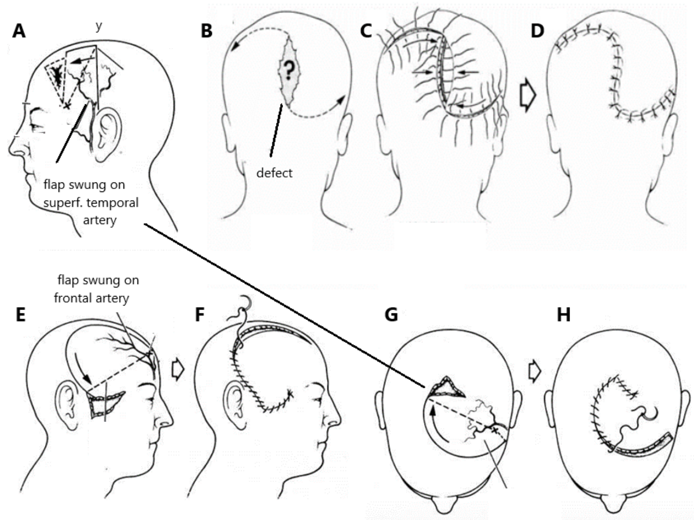


Fig. 51-8 FLAPS TO COVER SCALP DEFECTS. Because the scalp skin is tight, you need a large rotation flap to cover a relatively small area without tension. A, the pivot point is in front of the ear, based on the superficial temporal artery, and rotates on the axis xy. BCD, the flaps needs to be large. EF, here the pivot is frontal, based on the frontal artery. GH, based once more on the superficial temporal artery. *With the kind permission of Hugh Dudley & A Rowbotham.*

If the exposed skull is covered by epicranium, skin graft it immediately (46.2).

DON'T HESITATE TO EXPLORE A HEAD WOUND

DIFFICULTIES WITH OPEN HEAD WOUNDS
If blood collects under the *galea*, *don't drain the swelling*, as you may infect it, or cause it to bleed again. The haematoma will subside spontaneously, just as a cephalhaematoma does in a newborn child. Use 3rd generation cephalosporin prophylaxis.

N.B. **If a patient has more serious injuries elsewhere**, you may have to deal with vital bleeding first (or arrange 2 surgeons to operate simultaneously).

51.6 Skull vault fracture

When you discover a patient has a skull vault fracture, determine if:

(1) the fracture is not depressed, the chances are that the dura is not torn, so you can ignore the fracture, sand concentrate on the brain.

(2) there is an overlying skin wound, debride in theatre.

(3) the fracture is depressed, the dura is likely to have been torn, and needs repair.

(4) there is a foreign body in the wound or in the brain, remove it if superficial & readily accessible. *Don't try to extract a bullet or other object deep in the cerebral tissue! Never explore where you cannot see!*

Try to repair the torn dura. This might need pericranial tissue or *fascia lata* graft (51-11) Replacing pieces of skull is rather simpler.

FRACTURES OF THE VAULT
Be sure you are familiar with the methods of controlling bleeding.

INDICATIONS FOR RAISING DEPRESSED FRACTURES IN ADULTS
(1) Coma, or other signs of cerebral compression.
(2) Local neurological signs such as hemiplegia or aphasia, if most likely caused by the fracture.
(3) Fragments of bone or foreign body in the brain.
(5) Penetration of the dura.
(6) Leaking CSF (51.3).
(7) A compound (open) fracture.

CONTRAINDICATIONS
(1) Depressed fractures over a sinus (63.9).
(2) Very large closed depressed fractures.

RADIOGRAPHS
Examine these carefully to check if the sagittal or lateral sinuses are near the fracture. *These can bleed torrentially.*

PREPARATION
Shave the scalp hair generously from around the fracture, and preferably the whole head. Use a 3rd generation cephalosporin prophylaxis. Mark the side to be operated upon.

ANAESTHESIA
GA is preferable, although using LA in a comatose patient is acceptable. The skull, most of the dura, and the brain are insensitive to pain, so you need only anaesthetize the skin.
Before injecting LA with adrenaline deep to the *galea*, test the mobility of the scalp to plan any flaps.
Arrange to minimize venous bleeding by adjusting the slope of the table, and carefully positioning the head and neck (51-9).

PREPARING THE THIGH
Always prepare and towel the lateral aspect of the thigh, so that you can quickly raise a *fascia lata* flap if necessary (51-11). Be sure to take it from the lateral aspect: there is little fascia anteriorly.

METHOD
Paint the whole head with betadine, and get an assistant with sterile gloves to hold it up. Position the head so that the plane of your craniotomy will be as horizontal as possible. If your operating table does not angulate at the head, place a double-folded towel under the head to flex the neck accordingly.

Turn the head to one side and place it on a head ring (so it doesn't move about, 51-9A), and the surface you wish to operate on is uppermost. Close the eyes, pad them and seal them with strapping. Cover the nose and eyes but not the ears with a sterile towel, and clip this to the first sterile towel. *Make sure the whole scalp & ears are visible.* Put a sterile towel *under the head* after you have shaved and sterilized the scalp (51-9B). Make sure the eyes (strapped closed with ophthalmic ointment) are covered with a gauze, taped onto the nose.

Get a gowned assistant wearing two pairs of sterile gloves to raise the patient's head, using 2 fingers at the occiput and 2 at the bridge of the nose.

Now sterilze the head from frontal to occipital, from beyond the sagittal plane down to the neck, suprasternal notch and shoulders.

Draping: three small square towels and one long towel. If an extra long drape with a hole in it is available, so much the better.

POSITIONING & DRAPING THE SKULL

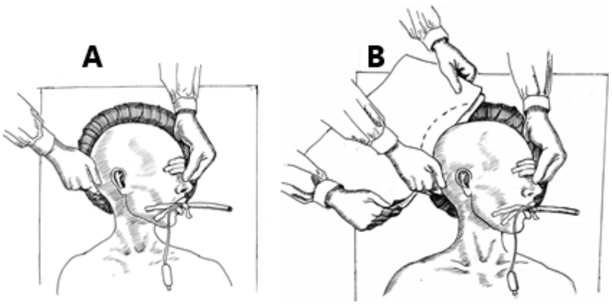


Fig. 51-9 POSITIONING & DRAPING THE SKULL. Make sure the face & ears are covered*, and the part you want to operate upon is uppermost.* A, turn the head to one side on a head ring. B, place a double sterile towel under the head, so you can fold the upper towel to cover the face.

ELEVATING A SKULL FRACTURE

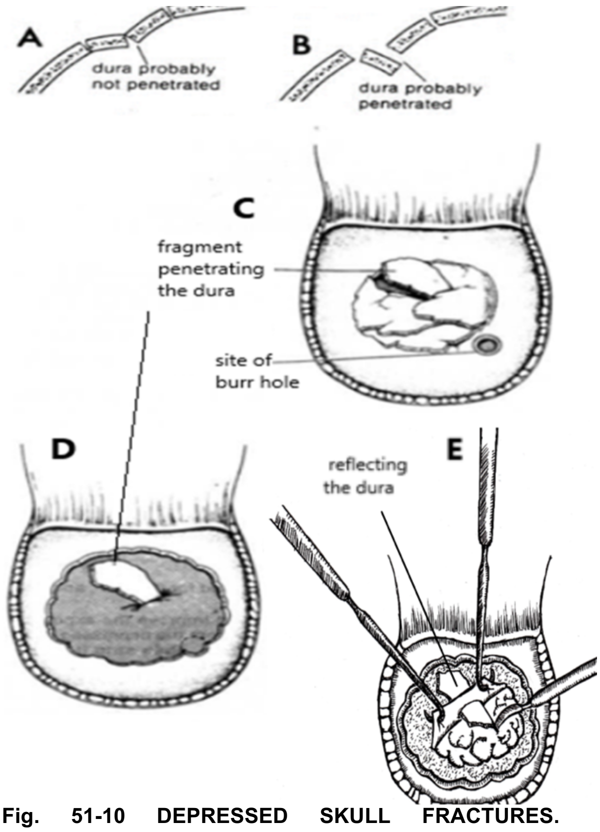


Fig. 51-10 DEPRESSED SKULL FRACTURES. A, a fracture which has probably not penetrated the dura. B, one which probably has penetrated it. C, reflect the base of the scalp flap caudally. *Don't try to pull out fragments which may have penetrated the dura.* Drill an adjacent burr hole. D, a fragment penetrating into the dura. E, reflecting a dural flap to enable you to remove the fragment under direct vision. *Kindly contributed by Peter Bewes, Gerishom Sande & A Rowbotham.*

Get another assistant to put 2 sterile towels *under* the head, pushing them down as far as the shoulders. The 1st assistant then gently lowers the head onto the now covered headring, adjusting its position.

The 2nd assistant can now remove the top layer of gloves, whilst you fold the top layer of sterile towels onto the head exposing the central part where you want to make the craniotomy.

Endeavour to reduce venous bleeding by:
(1) Positioning the head tilt-up 10º to raise it 5cm above the heart, and the head so the wound is uppermost.
(2) Use relaxant GA if possible, with slight hyperventilation. This will reduce the intracranial pressure. *If GA is unlikely to be perfect, LA may be better.*
(3) *Make sure that nothing obstructs the veins of the neck*. Raise the shoulders on sandbags.
N.B. Don't raise the head too much because air may be sucked into the veins, causing an air embolism. The first sign of this is sudden weakening of the pulse and tachycardia. Embolism will be less likely if there is fluid over the surface of the wound, so keep syringing it with saline.
(4) Irrigate the wound with 3% H_2O_2.

Make a generous incision, and if making a flap, turn this caudally (51-10C), grasping the edge of the *galea aponeurotica* with toothed forceps& then rotate these 180º; this kinks the blood vessels and stops haemorrhage.

Use a fresh set of instruments once you have debrided the scalp. Insert a self-retaining retractor to maximize the exposure.

If the fragments are loose, strip off the pericranium off the bone, starting at the edge of the depressed segment and save it as a flap. Gently lift out individual bone fragments.
(Ask your scrub nurse to clean the pieces in sterile saline and save them).

Some fragments may be wedged together. *Don't try to pull on impacted fragments!* You can usually find a gap to insert a bone nibbler, and so gently work a wedged fragment free. Scrape the pericranium off first. Nibble away badly contaminated bone. (*You don't usually destroy too much bone having to do this.*) Once the fragments are disimpacted, lift them all out and wash them thoroughly.
N.B. Don't make the burr hole in the depressed fragment. It may be loose and allow your burr to slide straight into the brain!
Alternatively, drill a burr hole adjacent to the impacted fragment (51-10C), so you can lever it out from underneath.
This is not as easy as it sounds, and you may cause damage if the dura is torn in an area which is not visible.

If a fragment has clearly penetrated the dura, and pulling it out might disrupt the dura further, lift a dural flap (51-10E) using skin hooks, in order to extract the fragment under direct vision.

Treat foreign bodies in the same fashion. *Don't search for one deeply embedded in the brain!*

If the fragments are too numerous or disimpaction is impossible, perform a standard craniotomy (51.8) around the fracture. Lift off the bone around the fragments in the normal way. This is an elegant way of removing the broken skull from the dura, but needs care if there are bone fragments penetrating the dura.

N.B. **If there are any fragments in or near a venous sinus**, *don't dislodge them:* the sinus bleeds torrentially if torn.

Remove any extradural haematoma present. Check if the dura is intact.

If there is contaminated brain tissue, handle it gently. Remove all dead tissue, clot, bone fragments, and foreign bodies that you can reach. Use a soft jet of warm saline & gentle suction from a syringe with a rubber squeezer.

N.B. Don't use H_2O_2 *inside the brain:* the release of gas may cause raised intracranial pressure.

If CSF is leaking out, there must be a dural tear. Expose the whole fracture area by nibbling away more bone to expose 2cm of intact dura all round it.

If the dural tear has ragged edges, trim them.

CLOSURE

If the dura is purple and bulging, open its surface with the point of no.11 scalpel blade. Then enlarge the opening with fine scissors to expose the haematoma, and drain it.

.

If there remains a dural defect which you cannot close directly, simply suture in a matching piece of pericranium (for small gaps), *temporalis* fascia or *fascia lata* (for larger gaps) with fine continuous monofilament. Make sure the closure is watertight.

JULIUS, 50yrs, was walking about quite fit, smiling and gesticulating, but quite unable to speak since the previous week when he had been hit on the head in a fight. Palpation showed him to have a depressed fracture of the skull. As this was being elevated under LA, a sepulchral voice from under the drapes called out, "Shikamoo" ("I am holding your feet", a local term of subservience and indebtedness). The patient went home talking volubly and everyone was happy. LESSON Aphasia is one of the indications for raising a depressed fracture.

TAKING A *FASCIA LATA* GRAFT

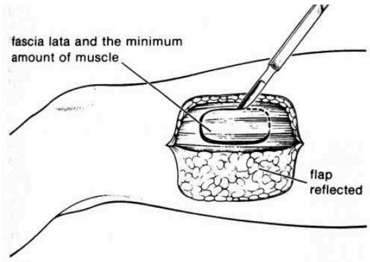


Fig. 51-11 TAKING A *FASCIA LATA* GRAFT. Prepare and towel the lateral aspect of the thigh, so that you can quickly take a piece of *fascia lata* to repair a gap in the dura. *Kindly contributed by Peter Bewes.*

The wound should be perfectly dry before you close the skull, especially after an extradural haemorrhage, and when the brain has not completely expanded. If it is not dry, a haematoma will form postoperatively, and bleeding will not stop until intracranial tension rises sufficiently to cause undesirable pressure on the brain.

CAUTION! Keep the exposed brain wet with saline.

Replace fragments of skull over the dura., and cover them with pericranium. Close the scalp as before (51.5)

DIFFICULTIES WITH A SKULL VAULT FRACTURE

If a wound has left a gap in the skull, suggest wearing a helmet. Cranioplastic repair may be necessary for cosmesis.

If a fracture enters the frontal or ethmoid sinus, rhinorrhea implies CSF leak and so danger of meningitis, brain abscess, or a pneumatocoele. Treat with 3rd generation cephalosporin. A pneumatocoele needs expert neurosurgery..

If there is a penetrating injury presenting late with contra-lateral motor weakness, there is probably now has an intra-cerebral abscess or haematoma. Perform a carotid arteriogram to locate the lesion. Then with a suitably place burr hole, open the dura and suck out the collection through a fine long blunt-ended probe.

Then syringe out the cavity gently with a jet of saline, and close his wound as above.

If there is severe bleeding, it may be arising from: (1) the middle meningeal artery, (2) the venous sinuses, or (3) the dural vessels (51.7)

FILIMON'S scalp was split and torn, the brains were pouring out of the head and dripping slowly to the ground. This is the literal truth. A tree had fallen on it, smashing it like an egg. On the operating table it became clear that the skull was in five pieces. As these were manoeuvred into position more brain kept oozing out. At last the jigsaw was complete, the dura closed and the scalp was sutured. To everyone's surprise he made a quick recovery and walked home.
He did seem to have a rather simple and euphoric personality, but his family said that he had always been like that.
LESSON Few patients are so severely injured that they must be given up as hopeless.

51.7 Burr holes

It is quite likely that when you have to make burr holes, you will not have time to read these lines immediately before operating! So, prepare yourself now! The decision to make a burr hole will be because you need to decompress the pressure on the brain. Site the burr holes according to the clinical symptoms & signs, or as more precisely indicated by a carotid arteriogram. There are standard anatomical sites (51-12).

SITES FOR BURR HOLES

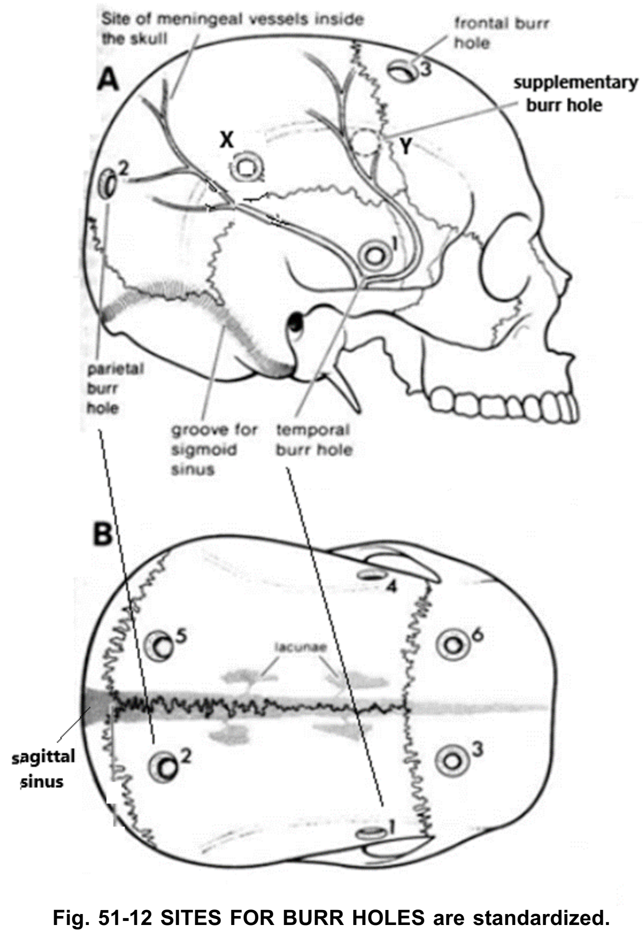


Fig. 51-12 SITES FOR BURR HOLES are standardized. You may need to make an additional hole over a fracture. *Avoid the sagittal sinus!* A, temporal, B, frontal, C, occipital sites. X, Y supplementary sites.
N.B. Don't place a burr hole over a major sinus, the orbit, the posterior fossa or the frontal sinus!

JAQUES (10yrs) was discharged following a minor head injury. He was brought back in again the following day deeply unconscious, with one fixed dilated pupil. He was rushed to the theatre, still in the out–door clothes. Within 20mins burr holes were being made. A large extradural haematoma was found and washed out. The next day, he was up and walking.
LESSON: This is what we mean by a real emergency: rush these patients to theatre, every minute matters! *Time lost is brain lost!*

NEUROSURGICAL EQUIPMENT

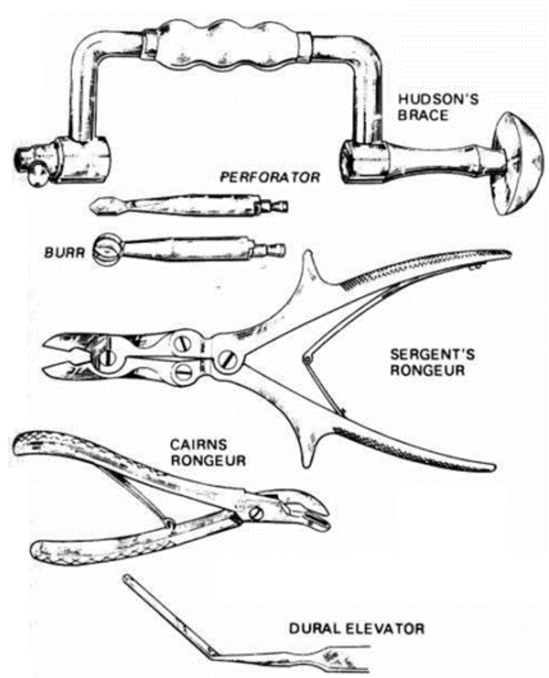


Fig. 51-13 ESSENTIAL NEUROSURGICAL EQUIPMENT. This should be in every hospital and every doctor should know how to use it.

DON'T BE AFRAID TO DO BURR HOLES: YOU CAN SAVE MANY A LIFE THEREBY!

EQUIPMENT

HUDSON'S BRACE, standard 25.4 cm is the neurosurgical equivalent of a carpenter's brace. *(You make be lucky to have an electric drill: make sure this has an automatic guard to prevent rapid penetration through the skull!)*
PERFORATOR, with standard fittings, 12 mm. Use this to start making a hole in the skull and continue immediately with burrs.
BURR, spherical, Hudson pattern, 11mm, 13mm, 16mm, 19mm, one of each size. Use these to enlarge the hole made by the perforator. *Avoid conical burrs as they are more likely suddenly to plunge through the dura and enter the brain.*
N.B. Make sure the perforator & burrs are kept well sharpened!
RONGEURS, (bone nibbler), Cairns, with fine angled-on-flat jaws and curved handles, 152mm. Use this to enlarge the burr hole. Sergent's, larger with flat jaws are for cutting bone.
ELEVATOR, skull, Penfield, double ended. Use this to elevate depressed skull fragments.
BONE WAX
LARGE SYRINGE (low pressure).
PERIOSTEAL ELEVATOR Adson's for separating the dura.
MALLEABLE GUIDES to pass over the dura between Burr holes.
GIGLI WIRE SAWS to cut through skull bone. You need several of these as they quickly go blunt or break.

Start on the side where the pupil first dilated, or the side opposite to where there is weakness or absent reflex. If a fracture crosses the route of an artery, make a burr hole relative for that artery (51-12A-C). Occasionally you need a burr hole to help elevate a wedged vault fracture (51.6)

TEMPORAL BURR HOLE

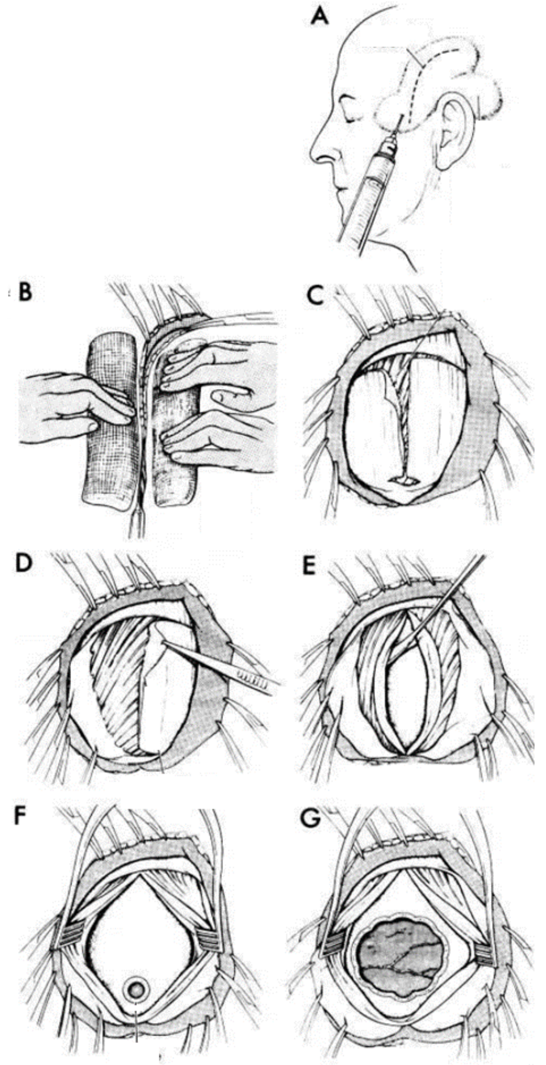


Fig. 51-14 TEMPORAL BURR HOLE. A, infiltrate the temporal muscle, including its inferior part & make a 'hockey-stick j-shaped incision. B, get an assistant to press firmly either side of your incision. C, make a T-shaped incision in the *temporalis fascia* D, reflect it. E, separate the *fascia* from the skull. F, drill the burr hole. G, enlarge it with bone nibblers. *After Rowbotham GF. Acute Injuries of the Head, E&S Livingstone, Edinburgh 4th ed. 1964 with kind permission..*

CLASSICAL TEMPORAL BURR HOLE (GRADE 2.5)
After infiltrating the temporal muscle with LA & adrenaline, make a J-shaped incision midway between the posterior margin of the orbit & the external auditory meatus, 2cm above the zygomatic arch, and 1cm in front of the ear (51-12).

N.B. Alternatively, you can make the incision more superiorly to enter the skull *above* the *temporalis* muscle: this is faster.

Control bleeding by asking your assistants to press the edges of the wound (51-14B). Pick up the edges of the *galea* in haemostats, preferably right-angled ones, and evert them. When you remove them at the end of the operation bleeding will have stopped.

Insert a self-retraining retractor, which will also stop bleeding. Make a T–shaped incision in the *temporalis fascia* (51-14C), and turn it back as 2 short flaps (51-14D).

A small horizontal incision above the zygomatic arch makes access to the inferior surface of the brain easier.

Split the *temporalis* muscle from top to bottom, in the line of its fibres, and separate it from the skull with a curved dissector or raspatory (51-14E). Reposition the self–retaining retractor, to expose c.4cm of the skull (51-14F).

DRILLING
You are now ready to start drilling a hole.
We assume you don't have electric drills. If you do, make sure they have a catch to prevent you drilling too fast right through the skull & inadvertently damaging the brain!

Ask the assistant to hold the head steady. Place the knob at the top of the brace in the palm of your left hand; take its handle in your right hand. With the perforator vertically in position at the desired site, make a backward & forward rotation to establish purchase of the perforator. Then press hard with your left hand and slowly drill a funnel shaped hole in the bone (51-15A).
Drip sterile water onto the bone as you drill to stop it overheating. When you reach the pale blue colour of the normal dura, or the dark purple of an extradural clot, stop drilling!
N.B. Don't go on any further, because you may pierce the dura and lacerate the cortex. This is very easily done. The squamous temporal bone is often thin, so *don't press too hard*!

Replace the perforator with a burr slightly larger than the size of the perforator (51-15B) and enlarge the hole. *Avoid using smaller burrs! Don't push too hard so the burr suddenly penetrates through the skull into the brain* (51-15F)! Lift the burr from time to time to check when you reach the dura. *Stop turning when the bite on the burr increases suddenly,* because this mean that you are now through the inner table.

TECHNIQUE OF DRILLING THE SKULL

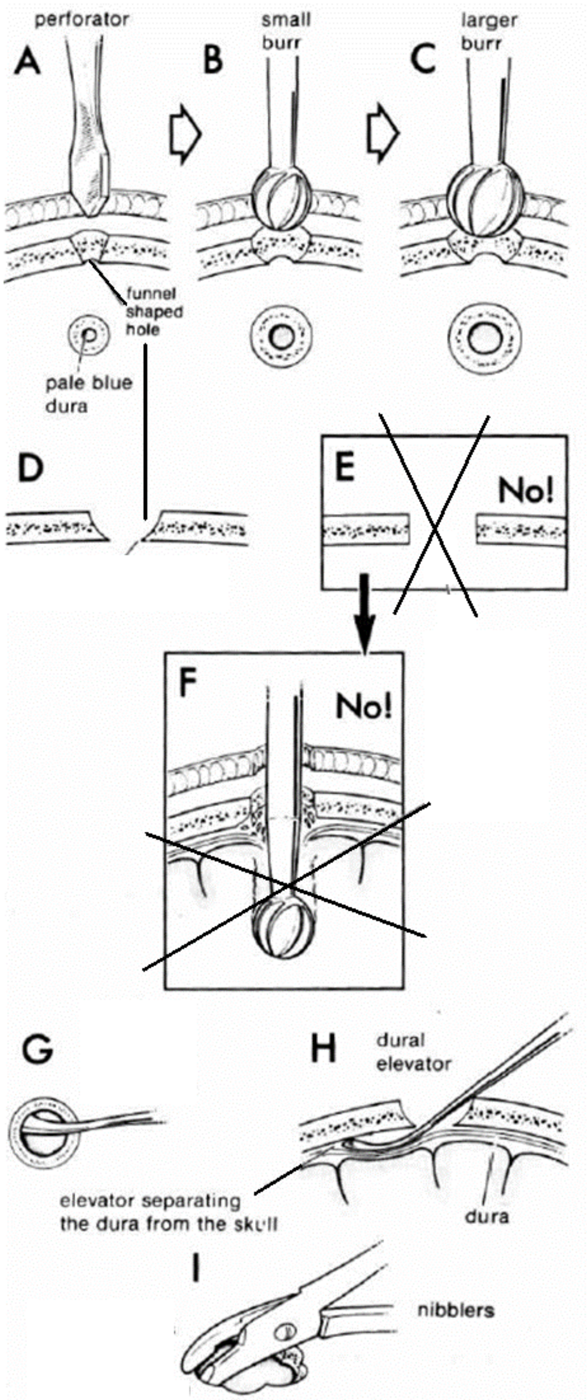


Fig. 51-15 TECHNIQUE OF DRILLING THE SKULL. A, Use a perforator initially to make a funnel-shaped hole. Stop when you see dura. B, then use a larger burr. C,D stop when you reach the inner table. E *don't make a cylindrical hole* as F, you will perforate the brain. G,H insert a dural elevator. I, increase the hole size by nibbling the edges of the burr hole in the skull bone.

Stop while there is still a rim of inner table round the edge of the burr hole (51-15D) *Don't go on until you have made a cylindrical hole* (51-15E), as the risk that the burr will slip through into the brain is high. If you have to replace a burr, choose a *larger* one.

Now nibble at the edges of the hole to give you a good view. Push the dura gently away from the inner table with a dural elevator (51-15G, H), so that it is not torn when you insert the nibbler to enlarge the edge of the hole (I).

The cut edges of the bone will bleed. Suck away the blood but *don't apply wax until you are about to close the wound*.

If you have lacerated a branch of the middle meningeal artery that runs in small bony grooves of the inner table of the skull, stop this arterial bleeding by coagulation or ligation. This means an extradural haematoma is *not* present.

EXAMINATION OF THE DURA
Make sure you have a good light. The normal brain is pink and the dura should pulsate; if they do not, suspect that there is raised intracranial pressure. If you don't see anything, enlarge the burr hole a little.

N.B. Always make burr holes away from the line of the middle meningeal artery, not over it.

If there is visible haematoma immediately under the hole, there is an extradural haematoma. You will not see the dura or the middle meningeal artery because these will have been displaced inwards.

If the dura looks purple, there is a subdural haematoma.

If the dura is torn, it needs repair (51.6)
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EXTRADURAL HAEMATOMA (51-1A)
Once you have seen the clotted blood, nibble at the edge of the burr hole to make it larger. Retract the tissues widely, so that you get a good look into the hole. Nibble away the bone in the direction of the clot; this is usually towards the base of the skull. A common error is to remove too little bone. Use a curved dissector to separate the dura from the skull each time you nibble more bone.

N.B. Don't put your finger into the wound to try to remove the haematoma, because this may increase intracranial pressure!
Instead, remove the haematoma, a little at a time with a teaspoon, curved dissector, suction or syringe of warm saline.

You may well need to make another burr hole in the direction where the haematoma seems to be spreading, in order to flush out all the clotted haematoma.

If the haematoma is coagulated and solid, as it often is, you will really need a formal craniotomy (51.8) to remove it adequately.

If there is any active arterial bleeding, nibble towards it (the middle meningeal artery, probably) or make another burr hole; this is very important, *so don't worry about how much bone you remove*. Make a dural hole, with a sharp hook, beside the bleeding vessel, and pass a needle round it, so that *you don't damage any cortical veins*. *Don't try using diathermy!*

If there is no further bleeding, after you have removed the haematoma, *don't hunt for the injured artery*.

N.B. Extradural haematoma is rare in the elderly as the dura becomes adherent to the skull bone.

If the dura is slack, fluid may accumulate again outside the dura, so pull it up with tacking sutures attaching the dura to surrounding pericranium or *temporalis* muscle

SUBDURAL HAEMATOMA (51-1B)
A purplish colour of the dura signifies the presence of haematoma under it. Extend the skin incision, and enlarge the hole a little with nibblers. It is usually not necessary to make a big hole.

Use a #11 blade on a holder to scratch an X–shaped incision in the dura. *Don't stab into the dura!* The blood will squirt out if it is an acute haematoma. The brain may be contused and lacerated, with some clots present. Remove a haematoma by rinsing it out.

If the bleeding is venous, it is coming from the veins of the dura. Push muscle grafts or pieces of surgical gauze between the dura and the skull. Keep these in place by passing a few interrupted sutures between the epicranium and the dura over the nibbled edge of the bone. These sutures will hitch up the dura, and help to keep the muscle patch in place.

If blood pours out as a dark venous stream from the sagittal sinus or lacunae, it can be very severe.

N.B. Don't apply haemostats to the sinus, because they will tear out and make bleeding worse. *Don't try to suture a torn sinus*. This will usually increase bleeding.

The sagittal sinus runs in the midline on the inner surface of the skull from the forehead to the occiput. Several irregular venous spaces (lacunae) join it on the top of the head (51-12). It is injured either from a blow to the top of the head or by a surgical mishap. *Often, a sinus only bleeds if you begin raising a depressed fracture near it!*

The transverse sinuses in the occipital region are still less vulnerable, but when they are injured, bleeding is even harder to control.
Plug the torn sagittal sinus with haemostatic gauze, a piece of muscle flattened by a hammer into a thin piece of tissue, or thin bone wax.

N.B. The muscle will be dead but its presence will promote clotting.

ALPHONSE (22yrs) fell out of a truck. Six weeks later, he went to a local clinic complaining of a severe headache.
Fortunately, they had a radio, and the pilot from the local mission hospital was in the area, so he was ableto pick up the patient. By the time the pilot brought the patient to hospital, he was in a coma, but a medical student on elective, and who met the plane, obtained the relevant history of a head injury. The signs of cerebral compression were classical. He was on the operating table within 2h, burr holes were made, and he was sitting up conscious the following day.
LESSON: A chronic extradural haematoma can follow a head injury incurred weeks, or even months, before.

If there is a venous ooze from everywhere, check the clotting time.

If you have secured the main bleeding point, but there is much persistent bleeding, *don't hurry*. Perform several dural tack-up sutures at the bony edges of your craniotomy and elevate the head.

If the clot extends backwards under the parietal bone, the posterior branch of the middle meningeal artery is probably torn. You cannot tie this from your present incision. So try to tie its main trunk. If this is impossible make another burr hole 4cm superior & posterior to the ear.
This is the burr hole marked (51-12X). Fortunately, you rarely need it.

If the vessels in a bone groove or tunnel are bleeding, apply Horsley's bone wax, or plug them with muscle.

If the surface of the brain is bleeding, place a warm pack on the brain and wait 5mins; then if bleeding continues, place a muscle patch on the surface of the brain and cover it with dura. *Don't use diathermy as it is likely to be too strong! Don't use gauze, or clips!*

If you cannot find the bleeding vessel, pack pieces of haemostatic gauze, or *temporalis* muscle, between the dura and the bone where the bleeding is coming from. Hold this in place by suturing the dura to the pericranium over the edges of the hole in the skull (63-19). Insert a suction drain and raise the head.

If arterial bleeding comes from the under surface of the brain, the middle meningeal artery may have ruptured at or close to the foramen spinosum. Try to stop it by performing dural tack-up sutures in the direction of the bleeding.

N.B. **If bleeding is uncontrollable,** it is probably coming from a torn sagittal sinus.

If torrential bleeding occurs from deep in the brain, its source may be impossible to find, or repair.

If there is pale yellow fluid under tension, suction this all out gently. It is a decomposed haematoma. Decompression is still necessary.

If you find no haematoma, consider making some more burr holes. Obviously you should not be in this situation if your pre-operative imaging has clearly demonstrated an extradural or subdural haematoma. In this case, study the images again carefully to check if you have drilled at the correct site!
Make sure you have not drilled on the wrong side (*e.g.* by inverting the pictures)!
Likewise, if you decided to proceed on the basis of a dilated pupil or limb weakness, check if you have made the burr hole on the side of the dilated pupil or on the opposite side to the limb weakness!

More commonly, you have to choose another site for a 2nd burr hole (51-12). Make a parietal hole through a separate longitudinal incision over the point of maximum convexity of the skull, above and behind the ear.
If this is also unsuccessful, make a 3rd burr hole: a frontal hole in the line of the pupil 2cm behind the hair line.

If you still find no haematoma, and you have checked the side you are operating on, and you have no images, start again on the opposite side, first with a temporal burr hole, and then a parietal and frontal.

N.B. A *contre-coup* injury (where the haematoma is opposite to the side of the injury) is rare, but may occur. However, there should still be signs of an ipsilateral dilated pupil or contralateral limb weakness.

N.B. Extradural haematoma is rarely bilateral, but subdural haematomata may be.

If the brain bulges into the wound after a craniotomy, and opening of the dura, or open skull fracture, there is either deep intracerebral bleeding or oedema. You would need to compress the brain further to close the dura, so use a periosteal or *fascia lata* graft (51-11).

Continue hyperventilation, and administer 500mL 10% mannitol (*i.e.* 50g) IV over 1h. Repeat this every 6-8h if the consciousness improves, but *don't exceed 200g in 24h*. Insert a catheter to collect the ensuing diuresis.

From the 2nd day onwards for 3-4 days add frusemide 40-80 mg IV od.

N.B. Steroids are of no help, except maybe in children.

If your burr goes straight through the dura into the brain, this is not as dangerous as you might suppose, and recovery is usually straightforward. *It should never, however, happen* (63-10F), so beware this possibility especially in a child or in the elderly.

CLOSURE
Once you have controlled all the bleeding, close the dura without a drain. Otherwise, leave a suction drain in when you close the wound. Suture it to the skin, take great care with asepsis and remove it after 24h.

Control bleeding from the cut skull bone by pushing bone wax, autoclaved beeswax, paraffin (candle) wax, or chewing gum into the bleeding cut surface of the skull.
Don't use too much bone wax or else the bone will not close over the gap.

METHODS OF HEAMOSTASIS IN THE HEAD

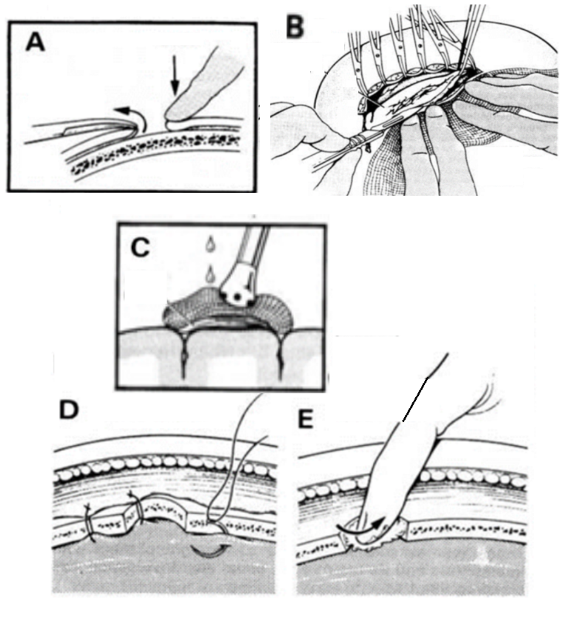


Fig. 51-16 WAYS TO CONTROL BLEEDING IN A HEAD INJURY. A, B, press on the everted edges of the scalp; apply haemostats, or clips, to the underside of the skin. C, press a flattened muscle patch on the bleeding brain, cover it with gauze, drip saline onto it, and apply suction. D, tack the pericranium to the dura. E, fill the diploe with bone wax. *By kind permission of Hugh Dudley & Gerishom Sande.*

ALWAYS OPERATE WITH THE HEAD ABOVE THE HEART

51.8 Craniotomy

INDICATIONS FOR CRANIOTOMY
(1) A solid clotted extradural haematoma.
(2) Fractured skull bones impossible to disimpact.
(3) Multiple open skull fractures.

METHOD (GRADE 3.1)
Preparation is as for open head injuries (51.5)

Make a bone flap centred on the lesion and big enough to give you good access (51-17A). You can make either a semicircular or rectangular skin incision, usually within the hair line.
Make sure the width of the base of the flap is less than its length or radius.
N.B. Don't let your flap reach the midline where the sagittal sinus lies (51-12).

Cut the skin and control haemorrhage from the scalp (51-16A,B; 51-17C): right-angled haemostats or clips are ideal.
Once you have gone round the length of the semicircular or rectangular flap, lift it off the pericranium by gentle sharp dissection, and cover it with damp gauze.

Then incise the pericranium and muscle (if necessary) except at the base of the flap; this base is usually at the same place as the skin flap base, but need not be.

Drill 5-6 burr holes around the edge of the flap c.6-7cm apart (51-17D) or nearer together if the bone is thick or the dura adherent.

Then insert a periosteal elevator gently under the bone to separate off the dura between one burr hole and the next: *take care in elderlypatients not to tear the dura if it is adherent to the bone!* In this way, go round between all the burr holes.

Now put a malleable guide along the surface of the dura through adjacent burr holes (51-17E), and pass a Gigli wire over the guide (51-17F). Attach hooked handles to the ends of the wire and saw upwards through the bone by a long firm slow jigsaw motion, beveling the angle the cut outwards, so that the bone flap will rest on the skull when put back.

N.B. Press firmly on the bone when you make the last cut, or else it may fly off! Alternatively, cut through the bony base with bone cutters, and lever it gently up, still connected by skin to the head.

CRANIOTOMY

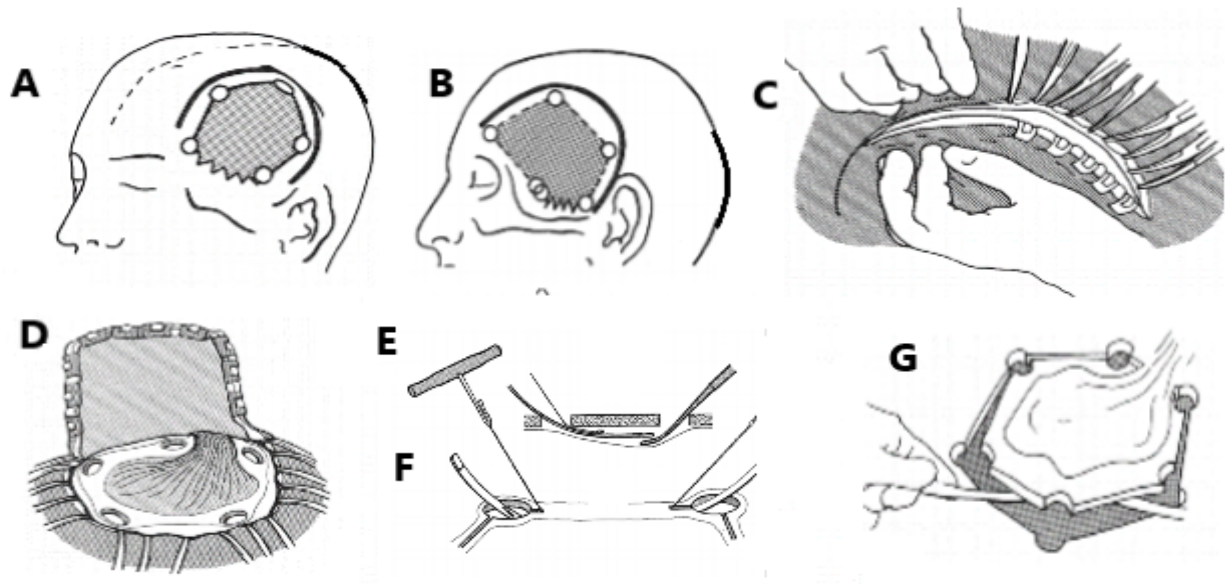


Fig.51-17 CRANIOTOMY (depending on the nature & site of the injury): make this big enough, *but avoid the midline.* A,B, possible sites for the bone flap. C, cut the skin and control bleeding by pressure & applying forceps or clips. D with the skin flap lifted up, drill burr holes 6-7cm apart. E, pass dural elevators under the skull bone to lift off the dura. F, gently insinuate a guide wire between adjacent burr holes, and glide the Gigli saw over it below the bone; saw obliquely outwards.

G, you can then lift the bone flap up gently when you have divided or cracked open the last part, and put it back at the end of the operation.

You may need to use bone wax to stop bleeding from the bone edges.

If you have power tools, these are very useful for cutting bone, and have a stop to prevent drilling the skull too deeply.

After you have completed the intended cerebral procedure, you can replace the flap (51-17G) and close the wound.

Make sure that you have good haemostasis, that you have closed the dura water-tight, and if the brain is bulging because of oedema, you don't force the flap down: you can suture the skin closed later.

If there is oedema, think of putting in an intracranial pressure monitoring catheter (33.12)

If a child needs burr holes, fit the perforator into the handle for it, and open the skull with this. Then use the nibbler, without using burrs.

A child's skull is thin with no distinct inner and outer table, *so a brace and burrs, and especially a drill, can be dangerous*.

N.B. You may be able to remove the blood from a haematoma in a baby with a large needle without using a perforator.

One type of projectile wound is a bullet striking the skull tangentially (51-18). This is like hitting the head with a hammer. The bone may or may not be fractured, and bone fragments may or may not enter the brain. The underlying brain damage is a contusion with petechial haemorrhage.

Perforation of the skull with direct injury to the brain comes in several forms. The most common, because most survivable, is a low-kinetic energy projectile that penetrates the brain for several cms, and then stops.

This represents either a bullet at the end of its trajectory or shrapnel at a great distance from an explosion. The damaged area will form a cone of tissue destruction (46.39-44). The skull wound resembles an irregular burr hole (51-19). The patient is often lucid, even walking into the emergency recept

The basic rules for management of bullet or fragment wounds of the head are the same for open wounds (51.5). There are some differences, however, due to various ballistic effects.

51.9 Projectile head wounds

The patients you will see in the hospital are a self-selected group: they are the survivors. The results of projectile head wounds are similar to brain tumours; any deficit depends on which particular part of the brain has been damaged.

TANGENTIAL SKULL BULLET INJURY

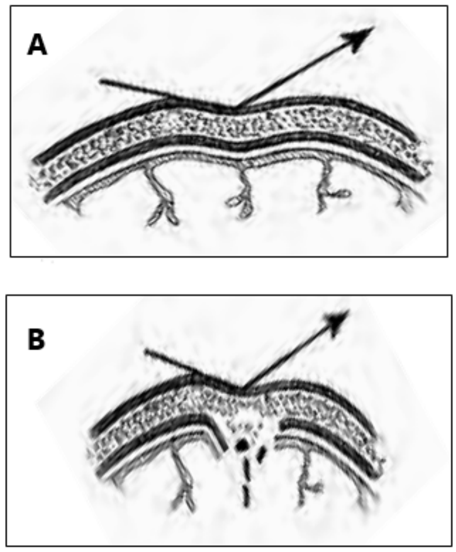


Fig. 51-18 TANGENTIAL BULLET INJURY OF THE SKULL. A, without & B, with bone fracture and penetration of the brain. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

LIMITED HEAD BULLET WOUND

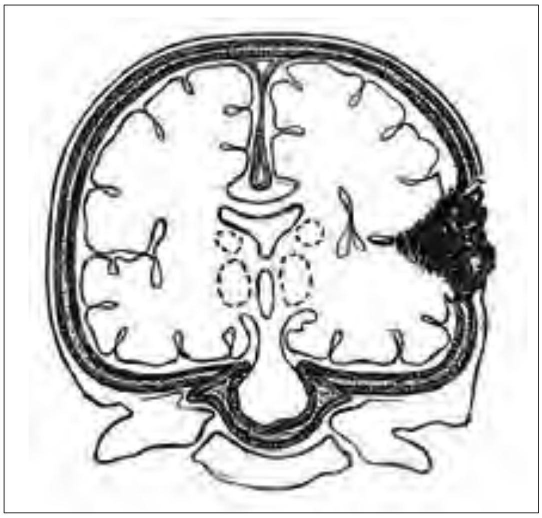


Fig. 51-19 BURR HOLE WOUND OF THE HEAD. A low-energy bullet has penetrated a few cms, and then stopped. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

Less often, you may encounter a transfixing through-and-through injury, where the bullet passes through one entire hemisphere of the brain, with a long track. These injuries are not usually survivable and if the patient does survive, the disability is significant.

Even rarer in a surviving patient is a bilateral hemispheric wound; the bullet passes through both hemispheres from side to side. Very few of these patients survive and disability is extreme.

In both these transfixing wounds, the patient is in a deep coma.

Finally, but not rarely, is a bullet stuck in the skull. In some societies, people celebrate a wedding, baptism, circumcision, or a funeral, by shooting rifles into the air. As usual, what goes up must come down, and not infrequently the bullet coming down strikes someone in the head, although the shoulders, back and chest are not exempt.

MANAGEMENT OF BULLET INJURY
Follow preparations as for depressed skull fractures (51.6); make a horseshoe or inverted "U" flap (51-20) around the bullet wound.

Debride the scalp wound, but perform an immediate 1° closure since the scalp has such a good blood supply.
The loss of tissue may make the closure of the flap difficult. A small lateral incision at the edge of the inverted U will allow you to rotate the flap slightly to make closure easier.

HORSESHOE SCALP INCISION

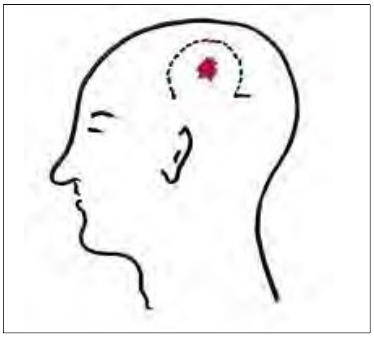


Fig. 51-20 INVERTED 'U' SCALP INCISION *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

Turn the flap down (51-17C), twisting the toothed forceps holding the flap to stop the bleeding. Examine the hole in the bone; it will bey filled with blood clot, torn skin, hair, dirt, cloth, bone fragments, & damaged brain tissue. Carefully remove these with a bone nibbler (rongeur), till you can see the intact dura all the way around.

Using *very low pressure* suction, aspirate the haematoma and injured brain tissue. Irrigate with normal saline and aspirate again and again until you have removed all the devitalised tissue, foreign matter, loose bone & damaged brain tissue. Carefully use your finger to search for any bone fragments.

N.B. Damaged non-viable brain tissue looks like yoghurt or porridge and is a semi-liquid; living brain resembles jelly and holds firm.
It is the organic introduced into the wound matter that causes infection, not the bullet or metal fragment

If you find the bullet or fragment, remove it. *Don't blindly poke around searching for it! Don't pull or tug at anything!*

A bullet has an aerodynamic shape and, at the very end of its trajectory within the brain, can easily glide between neurons without injuring them. It will then be beyond the cone of tissue destruction.
A metal fragment, however, has an irregular shape and cannot glide; it will always be inside the cone of tissue damage.

Once you have aspirated away all the damaged brain, you will see a pulsating wall of brain tissue, which may ooze blood. Pack the wound for 5 mins with a compress of warm saline, dilute adrenaline solution or hydrogen peroxide.
N.B. You can use H_2O_2 here without worrying about any increase in intracranial pressure as the skull is no longer a closed box, so gas bubbles can escape. Also loss of brain volume will allow for some cerebral oedema.

Freshen the edges of the injured dura, but *don't try to close the defect directly*: use a piece of *temporalis* muscle or *frontalis* fascia to suture into the defect. If the hole is too big, use a *fascia lata* graft (51-11).

Make sure the dural closure is watertight by using a continuous interlocking monofilament suture of 3/0 or 4/0. Then check for haemostasis and close the scalp in the usual manner. If there was much oozing, leave a suction drain under the skin flap for 24h.
N.B. The brain will swell, so don't make closure or dressings too tight!

HOPE, (9yrs) sustained a gunshot wound to the right parietal lobe, and arrived within 1h, with a GCS of 3/15, but haemodynamically stable. The range of shot or its velocity could not be determined. The defect in the skull was 4cm in size and its depth c. 10cm. No ventilators, radiographs or scans were available.
After suggesting a poor prognosis to the next of kin, with a laryngeal tube in situ, and an anesthetic assistant bagging his airway extremely patiently, the wound was irrigated gently, taking out chips of fracture, dirt, débris and even necrosed brain matter that came out spontaneously. The patient survived and so, the dura was closed with fascia lata 2days later, and the skin with an advancement flap.
Thanks to extensive physiotherapy and dedicated nursing care, the patient was discharged, ambulant with support as he had residual weakness in his contra-lateral leg. He was advised to wear a helmet outside and to not sit under any fruit-bearing tree!
LESSON: The minimum in surgery is often the maximum in results.

MANAGEMENT OF TRANSFIXING SKULL WOUNDS
Both for unilateral & bilateral wounds, the best policy is conservativee. Make an S-shaped incision over both entry and exit wounds, insert a thin catheter into the track and gently aspirate while withdrawing the catheter. Close the dura and then the scalp, but don't introduce a drain.

JANNY (24yrs) had a gunshot to the left half of face and forehead. He was fully conscious and had normal vital signs but was bleeding profusely from the entire bullet trajectory which involved the left maxillary antrum, the zygomatic arch, the left orbit, the nasal bridge and the right eyebrow. The entire eye globe was ruptured.
The wounds were irrigated in the OT under GA. The globe was completely ruptured and had to be eviscerated. The rest of the wound was debrided simply and packed. No CSF leak was found. Subsequently, primary closure was achieved, and the patient was discharged, ambulant, without any neurological deficit except for the loss of his left eye.
LESSON: *Don't be overwhelmed by the grossness of an injury!*

MANAGING A BULLET STUCK IN THE SKULL
Usually, these patients also often come walking and talking, perfectly conscious, but *never try to remove the bullet outside the operating theatre*!

Look at the skull radiograph. There are 3 possibilities where the bullet has gone:
(1) it has penetrated only the outer diploe or the entire thickness of the skull, without penetrating the dura.
(2) it has penetrated the dura and gone into the brain, away from the sagittal sinus.
(3) it has penetrated the sagittal sinus.

In the 1st case, slit open the scalp with the bullet in the centre of your incision and retract the edges. Pull out the bullet, debride the scalp wound, and close the skin.

In the 2nd case, make a cruciform incision with the bullet at its centre and one arm long enough to perform a burr hole right next to the bullet. Then nibble the bone until you have isolated it. Remove it, aspirate any damaged brain, irrigate, and close the dura and scalp.

The 3rd case is a difficult problem with several pitfalls, but you can still proceed if you take certain precautions.

Perform a formal horseshoe scalp flap (51-10C) to allow good access. Slit the flap from the bullet to its edge so that you do not push it in further. Now, perform a burr hole next to the bullet and nibble away the bone edges as necessary (51-21).

The hole in the sagittal sinus is usually too large to close directly, so you will need a graft to close it. The easiest way is to make a pedunculated flap of dura mater next to the site of the bullet with its base parallel to the edge of the sinus and long enough to cover the hole comfortably when it is flipped over.

CRANIOTOMY FLAP AROUND A BULLET

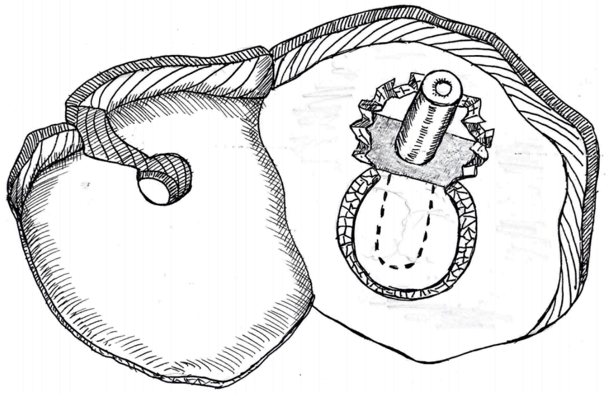


Fig.51-21 CRANIOTOMY FLAP AROUND A BULLET. Slit a flap from the bullet and nibble around it to prevent it from pushing it in further.

If you try removing the bullet while the patient is lying flat, you will cause torrential haemorrhage!
The superior sagittal sinus has a triangular cross-section with each angle tethered to keep it open. Like all intracranial venous sinuses, the sagittal sinus has no valves and ultimately drains into the jugular and brachio-cephalic veins, superior vena cava and right auricle, with only one valve in the lower jugular vein to stop backflow of blood during auricular systole.

This is the only valve in the venous drainage of the head. As a result, the pressure in the right auricle is reflected in the sinus.

Raising the head above the level of the heart decreases the pressure in the sinus. But, raising it too high decreases the pressure so much that, if you remove the bullet, air will rush in creating a massive embolus.

So, your anaesthetist should raise the patient's head slowly bit by bit, while an assistant fills the wound with normal saline. Carefully jiggle the bullet a little; blood will come out.
As you lift the head higher, the less blood flows out. At some height, c.25-30° of elevation, you will reach an equilibrium where blood no longer flows out, and saline is not sucked in.

You can now safely remove the bullet.

To close the hole in the sinus, flip over a dural flap and suture it over the hole in the sinus with continuous interlocking monofilament 5/0 or 6/0 suture. Cover the wound with a gauze compress and wait 5mins.

If bleeding from the needle holes has not stopped, repeat for 5 more mins. Now lower the head.

Debride the skin wound and close the scalp without a drain.

POST-OPERATIVE MANAGEMENT
Note that raised intracranial pressure in projectile wounds is rare. Primary blast injury, however, which may accompany a shrapnel wound or exist on its own, may cause increased intracranial pressure.

A projectile wound is dirty so administer antibiotic cover with high-dose penicillin-G plus chloramphenicol or a cephalosporin plus metronidazole for at least 10days.

51.10 Child 'ping–pong' skull fracture

A blunt object, which causes a large depressed fracture in an adult, causes a ping–pong ball fracture in a child, whose skull is soft and dents instead of fracturing. The indications for not operating on a child are even stronger than in an adult, because these fractures rarely cause trouble. If a child has a single fit, disregard it. The dent will disappear as he grows.

If fits persist, you can try to reduce the fracture with a vacuum extractor. Apply one of the vacuum cups, as you would during delivery. Pull, and hold the surrounding skull with your other hand.

If this fails or there are signs of depressed consciousness, make a hole with a perforator at the edge of the depression and elevate the fracture with a skull elevator: *don't use burrs*.

52 Eye injury

52.1 Introduction

Eye surgery is an area which many a doctor finds daunting. Whilst all operations inside the eye require meticulous expertise, you should be able to repair surrounding structures. Even if the eye seems to be hopelessly injured, there is much that you can do to preserve some useful sight in it.

You may see blunt injuries which leave the cornea and sclera intact, and penetrating injuries which damage the interior of the globe.
A blunt injury, such as that from a fist, may cause serious internal lesions, including bleeding, with few external signs.
A penetrating eye injury is always serious, but its cause differs from place to place; in rural areas causes are often from thorns, sticks or branches or in young children during play. In town, from assault or work-related accidents, and in war from missiles.
Fire burns may affect the eyelids or cornea; blast injuries may cause a myriad of problems:
(1) conjunctival or subconjunctival damage,
(2) hyphaema,
(3) lens dislocation & cataract,
(4) vitreous & retinal haemorrhage & detachment
(5) optic nerve injury,
(6) air embolism causing blindness,
(7) retrobulbar haematoma.

Prevention is not always feasible, but try to encourage the wearing of goggles at work (if sparks or splinters are flying around) & seat belts in cars. *An ounce of prevention is better than a pound of cure!*

Patients will often be anxious about visual loss. So always start by testing (and recording) the visual acuity. Make sure a victim knows what has happened, understands the purpose of treatment and you mention the prognosis for subsequent sight.

An injured eye is always an emergency, but it is rarely immediately fatal. After the necessary emergency treatment, you usually have 2-3days to refer the patient to an eye centre. So, if an operation is necessary, *make sure of the diagnosis and that both you & the patient know exactly what to do.*

JAMES (8 years) was referred with a swollen eye and a diagnosis made elsewhere of rupture of the globe of the eye. the visual acuity was tested and found to be normal. Examination of the upper conjunctival fornix showed the presence of a piece of wood.
LESSON Always test the visual acuity. In this case, the original diagnosis *could not possibly be correct*.

MANAGEMENT OF AN INJURED EYE
As in any injury, start with ABC (41.1)

Many times, you may be able to deal with the problem without incurring the patient a long, difficult & expensive trip of referral.

Take as careful a HISTORY as you can.
Pain will make a patient keep the injured eye shut.
LA will make it easier to examine.
Wash out the eye with copious clean water.
Gently pick out any loose material
Leave an embedded foreign body in situ at first.

Retract the lower lid and instil 2 drops of LA eyedrops (tetracaine hydrochloride 1%, proparacaine hydrochloride 0.5%, proxymetacaine hydrochloride 0.5%). You may have to make repeat instillations before anaesthesia is effective.
CAUTION! (1) *Don't put ointments straight away into a patient's eye;* they will make it difficult to examine later. (2) Topical anaesthetics, dyes, and drugs must be sterile; bottles can readily become infected, especially with *Pseudomonas* spp. *Don't store opened bottles >3wks*. (3) *Don't let a patient take home LA eyedrops;* this may too easily allow injury to the anaesthetized cornea.

EXAMINATION OF AN INJURED EYE
Always start by examining the visual acuity of both eyes, the normal one first. Perform your examination in good light, using whatever means of magnification you have, with both you and the patient in a comfortable position.

If the eye does not open spontaneously, gently open the lower lid by pulling down the skin over the zygomatic arch. Instil LA eye drops, which will probably relieve pain enough to allow spontaneous opening of the eyes.

If the eye remains shut, insert a Desmarre's retractor gently under the upper lid, and lift it upwards away from the globe by pressing on the upper orbit.
N.B. You can use a retractor made from 2 bent and sterilized paper clips.

If the eye still remains shut, you may have to examine it under GA.
CAUTION! Avoid pressure, either by squeezing the eye, or by letting the patient rub the eye. This might cause irreparable damage!

If the globe is perforated, *pressure may squeeze its contents out!* Temporarily cover the eye with a sterile dressing. Check for anti-tetanus coverage.

SIGNS OF EYE INJURY
(1) Examine the eyelids carefully. A tiny laceration may be the opening of a track which penetrates the globe (52-9).
Remember to remove contact lenses if present!
(2) Examine the conjunctiva for haemorrhage, foreign bodies, or tears.
(3) Note the depth and clarity of the anterior chamber. Compare the size, shape, and light reaction of the pupils.
(4) Note the movements of the eyes.
Check if the globe is intact, then examine the conjunctival fornices & evert the upper lids (28-2).
(5) Dilate the pupils and examine the fundus with an ophthalmoscope.
(6) Examine the lens, the vitreous, and the retina for signs of haemorrhage, or retinal detachment.
(7) Examine the cornea and sclera for wounds and abrasions. Use drops of fluorescein if you suspect this.
Don't try to feel the tension in the globe, because it is easy to squeeze out its contents if it is ruptured.

If there is blood under the conjunctiva, beware:
(1) Even a very small bruise may indicate where a small foreign body has entered the sclera (52-9).
(2) Haemorrhage at the limbus is itself unimportant. It is only likely to be serious if it extends far posteriorly beyond the fornix, when it may indicate a fracture of the base of the skull (62.1).

If the anterior chamber is shallow, there is a penetrating corneal injury, which has allowed aqueous humour to leak. In severe cases, where the anterior chamber has completely emptied, the iris touches the cornea.

If the iris trembles when the eye moves, the lens may have dislocated.

If there is a greyish area in the cornea with swollen margins, it is perforated.

If a black mass of tissue bulges through the lips of a wound (52-7), the iris or choroid has prolapsed. If the wound is in the cornea, the pupil will be irregular and drawn towards it (52-6J).

If the eye feels soft, the globe has probably ruptured. The rupture is nearly always curved, parallel to the limbus, and c.5mm behind it. Feel the bony borders of the orbit. Get a skull & orbital radiograph.

ALWAYS LOOK FOR OCULAR INJURY WITH ANY WOUND NEAR THE EYE

If you can see the edge of the lens with an ophthalmoscope, and there is some visual impairment, the suspensory ligament of the lens is partly ruptured. If it is also dislodged, the intra-ocular pressure may rise. If this happens, administer acetazolamide and refer.

If the lens is completely dislocated, you may see it lying in the anterior chamber, or at the bottom of the vitreous, or it may have been extruded from the eye. There will be severe visual impairment. There may be no immediate reaction, but an inflammatory response and a secondary rise in intra-ocular pressure are common. Administer acetazolamide and refer. The lens may need to be removed.

If there is severe proptosis (53.3), there is a retrobulbar haematoma.

Even if the eye appears hopelessly injured and there is no awareness of light, *don't consider enucleation* (28-19) *or even evisceration* (28-20) *at this point*.
You must wait at least 2wks to do this, and ensure there is *no perception of light at all.* If there is any perception of even a strong light, a surprising amount of vision may return by 6 months.

ANAESTHESIA
Remember that an eye injury is a strong stimulus for vomiting. Although ketamine has had a reputation for increasing intra-orbital pressure (and intracranial pressure), this is actually not a problem especially if you add a sedative such as midazolam. If the eyes move about, use a little more drug. *Don't use a retrobulbar block*, because haemorrhage may cause globe contents to extrude if it is ruptured.

Whilst you can use LA drops for simple procedures, for anything more complex you will need GA. If you use ketamine, you need an LA block also to prevent disturbing nystagmus during the examination. *Don't use suxamethonium as it raises intra-ocular pressure.*

IMAGING
A plain radiograph will show the condition of the orbit and presence of radio-opaque foreign bodies. Get 2 views with the patient looking ahead & upwards: this will show if the foreign body is intra-ocular or not (52.9).

REFERRAL
If you have an eye surgeon to refer injured patients, this may be better for all but the simplest procedures, even if this means some days' delay.

If you decide to refer such a patient, instil antibiotic drops into the eye if there is a closed globe injury, & apply a protective dressing (28-1).

If there is an open globe injury or the journey is long, or is likely to be delayed, add chloramphenicol 500mg initially, followed by 250mg qds for 5days, and administer anti-emetics. Avoid anything that might increase the intra-ocular pressure, such as urinary retention.

FOR EYE SURGERY, YOU MUST HAVE A BRIGHT LIGHT AND GOOD MAGNIFICATION

52.2 Eyelid haematoma ('black eye')

A 'black eye' is the result of a blow by a blunt object. By itself it is not serious, but check if there is an associated head injury (51.1), a maxillofacial injury (53.1), or rupture of the globe (52.6). This may be difficult to diagnose if there is much swelling, so if you suspect this, use LA and use eyelid retractors. Mild ptosis (drooping of the eyelid) is common after a black eye. If it lasts more than a month, refer.

52.3 Eyelid, canaliculi & conjunctival injury.

SUTURING THE EYELIDS (GRADE 2.2)

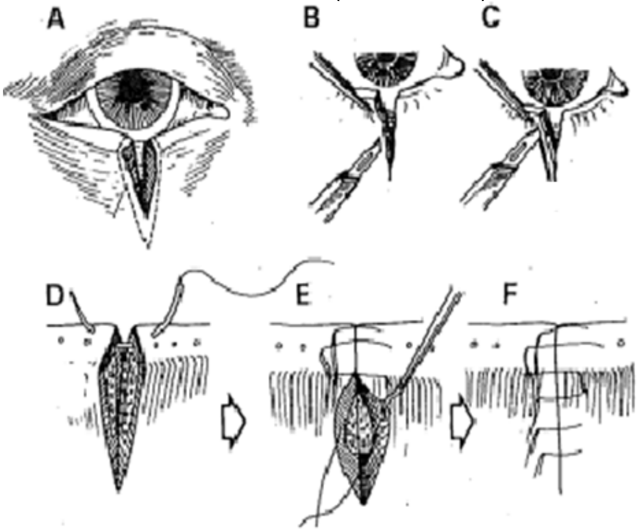


Fig. 52-1 SUTURING THE EYELIDS (GRADE 1.2**). Little tissue has been lost in this injury, so that bringing the edges of the patient's lids together is not too difficult. A, excise a 'V' of tissue. B,C, make a clean edge *taking care not to damage the cornea with the tip of your scalpel.* D,E,F, make sure you align the eyelash line carefully.** *Partly after Hill with kind permission.*

Eyelid injuries are common, and may be serious because of the danger to the eyes under them, either immediately, or later if scar tissue distorts the lids and exposes the cornea. The injury can involve part of the thickness of a lid, or its whole thickness, including its tarsal plate, sometimes with tissue loss.

To repair a torn eyelid, start by putting a stay suture in the lash line immediately behind the eyelashes. If you align the lash line correctly, it will align the other structures. The secret of success is using multiple small sutures and accurate apposition. *A common mistake is to use large instruments and coarse sutures.*

REPAIRING EYELISD TISSUE LOSS
(GRADE 2.3)

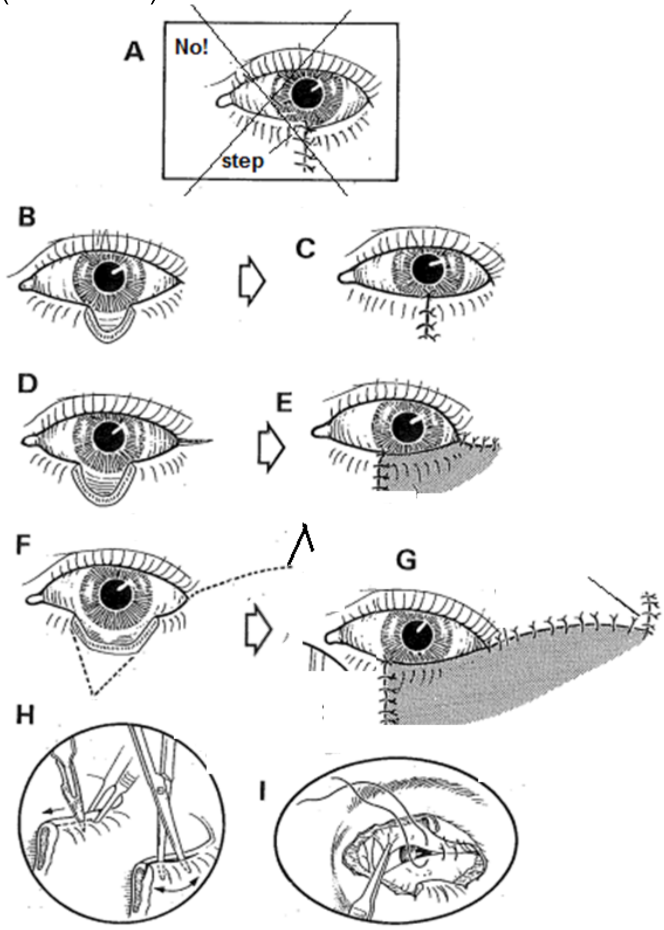


Fig. 52-2 IF THERE IS EYELID TISSUE LOSS. A, *don't create a step in the eyelid edge.* B,C, if <¼ is lost, close the wound directly. D,E, if ¼ to ⅓ is lost , make a lateral relaxing incision. F,G, if >⅓ is lost, make a long relaxing incision and undermine the cheek tissues. Make allowance for the 'dog ear' laterally. H, If both lids are lost, to cover the eye, incise the lower eyelid in the lash line & in front of the tarsus. I, if there is not enough eyelid left to cover the cornea, cover it with conjunctival flaps. *Partly after Mustardé JC, Reconstruction of eyelids. Ann Plas Surg 1983; 11(2):149-169 with kind permission.*

If there is a severe injury to the eyelids, clean them thoroughly. *Don't remove any skin, unless it is obviously dead or detached*. Use fine instruments, and 6/0 monofilament; bring the edges of the wound together with great care.

CAUTION! Always use a lid guard to protect the eyeball when repairing the eyelid. Don't allow it to become inverted or everted.

If the injury has involved the whole thickness of the eyelid, approximate the tarsal plate, the muscle layer and then the skin. Disregard the conjunctiva. It is stuck to the tarsal plate, and if you align this, it will align itself.

If the wound gapes, it will do so because the fibres of the *orbicularis* muscle have been cut. Use 6/0 buried absorbable to bring the edges of the muscle together, before you suture the skin.

You must ensure that the eyelids can cover the cornea. This may mean a tarsorrhaphy (28-13). **If there is not enough eyelid left for a tarsorrhaphy,** grasp the conjunctiva at the upper fornix, with forceps, pass a suture through it, bring it down, and pass it through a similar fold from the lower fornix, in the same vertical line. Use several interrupted sutures to bring a double thickness of conjunctiva across the globe (52-2I).

If the lid is greatly swollen & presentation is late, clean the wound, excise the minimum amount of tissue, administer antibiotics, and repair the lid when the swelling has subsided.

LATERAL CANTHOTOMY (GRADE 2.2)

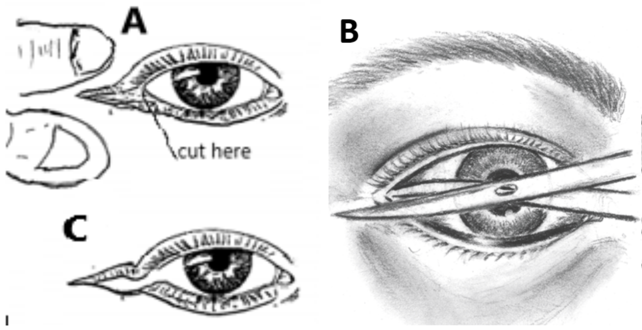


Fig. 52-3 DIVIDING THE OUTER CANTHAL LIGAMENT. A, Infiltrate LA with adrenaline into the conjunctiva & ligament of the lateral canthus, and hold the lids open. B, cut the lateral canthus down to the orbital rim the full depth of the conjunctiva, dividing the lateral canthal ligament. C, appearance of the lateral canthus after incision: the globe drastically reduces in size.

CANALICULAR INJURIES

If the canaliculus is injured, this needs microsurgical repair. Otherwise, pass a fine monofilament suture through the punctum, out through the wound and across the divided canaliculus into the lachrymal sac just below the attachment of the medial canthal ligament to the nasal bones. Suture the wound and leave the monofilament in place for 7days.

CAUTION! If you don't repair the lower canaliculus, tears will flow continuously.

CONJUNCTIVAL INJURIES

Most conjunctival lacerations will heal without suturing.

If a laceration is extensive, expose the eye with lid sutures (23-2). Dissect the conjunctiva away from the globe and search it for a perforating wound. Gently probe the wound and extend it if necessary. Suture the conjunctiva with continuous sutures of 5/0 plain absorbable.

CAUTION! (1) Sometimes a major injury is hidden under a small conjunctival wound, so probe it carefully. (2) *Don't probe around inside the eye.* Only probe to see if the sclera has been perforated.

SUTURING THE CONJUNCTIVA (GRADE 1.4)

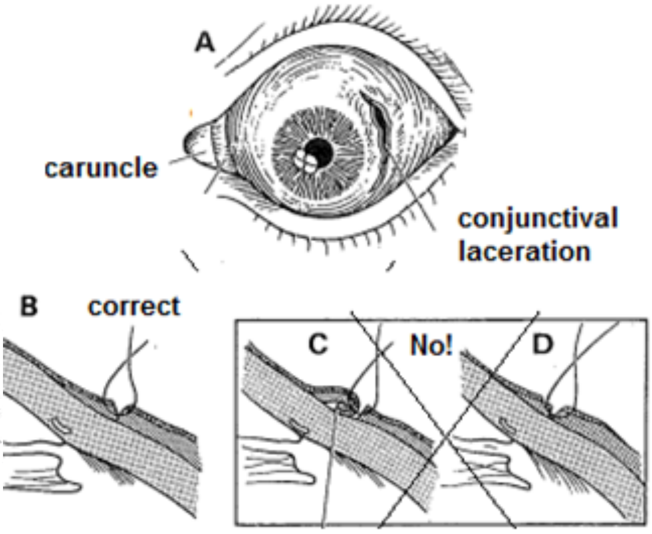


Fig. 52-4 SUTURING THE CONJUNCTIVA. ***Don't suture small lacerations.*** **A, preserve the caruncle and the plica if you can. B, a correctly placed suture. C, if the conjunctiva is folded over like this, an inclusion cyst may develop. D, this suture will allow Tenon's capsule to herniate into the wound.** *After Peyman GA, Principles & Practice of Ophthalmology, WB Saunders, London 1980 with kind permission.*

52.4 Retrobulbar haemorrhage

Bleeding behind the eye can easily result within 2h in its irreparable damage. This is in effect an acute orbital compartment syndrome. The eye is extremely painful, grossly swollen with proptosis, firm to touch, with loss of light pupillary reflexes, and paralysed. There is rapidly deteriorating vision. You will see a collection of fluid behind the white rim of the orbit easily with a bedside ultrasound.

IMMEDIATE DECOMPRESSION UNDER LA IS IMPERATIVE.

Use small straight scissors to divide the lateral canthus down to the bone of the orbital rim and to the depth of the lateral conjunctival sulcus. Protect the globe by spreading the eyelids with your index and thumb, in order to avoid a corneal abrasion or conjunctival damage (52-3). Administer 500mg acetazolamide & then 250mg every 4h x4, to lower the intra-ocular pressure.

52.5 Corneal & scleral injury

The common corneal injuries are abrasions and lacerations. Most abrasions heal in 24-48h.
The danger of an abrasion is that it may become infected, result in a corneal ulcer and may develop into endophthalmitis. Chemical & thermal injuries may only be visible after 3-4days. Wash these with copious amounts of water *in an eyewash cup or the shower.*

N.B. Alklali penetrates the cornea but acid mixes with surface proteins to produce a gel.

A corneal laceration is the most difficult eye injury that you may have to treat. If a laceration perforates the cornea, allowing the aqueous to escape, the iris may dislodge against its posterior surface, or prolapse (52-6J). If a laceration is small, and its edges are not separated, you may not need to suture it. A clean wound of the cornea heals rapidly, especially if only the epithelium is injured. If a wound is deeper, a scar is inevitable.

CORNEAL AND SCLERAL INJURIES

The eye is red and watery and the lids tightly closed. There may be ciliary injection, but the visual acuity is normal. After looking at the eye carefully, you find no foreign bodies on the surface of the cornea, or underneath the upper lid, but instead see an abrasion, which you may only find after you have stained it with fluorescein

2 CORNEAL INJURIES

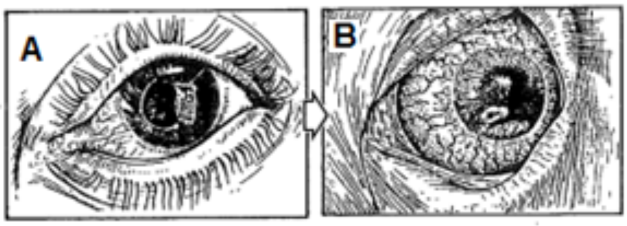


Fig. 52-5 TWO CORNEAL LESIONS. A, a corneal abrasion. B, a corneal ulcer. ***If you are not careful, an ulcer can follow an abrasion.***

If an abrasion is clean, and is only visible after staining with fluorescein, and there are no signs of infection, instil chloramphenicol eye drops and shield the eye (28.1). Check it daily, and instil chloramphenicol, until it no longer stains with fluorescein. **If the cornea becomes cloudy,** it has become infected. This is now a corneal ulcer.

CORNEAL ULCERS
There is a hazy white spot on the cornea; it may be hollowed out, or there may be a yellowish area, or pus in the anterior chamber.
The eye is painful, photophobic and red with ciliary injection. Try to send a pus swab from the ulcer for bacteriological and fungal examination. Instil atropine drops, topical broad spectrum antibiotic drops (neomycin, bacitracin, or chloramphenicol) hrly for 1-2days & then less frequently as it improves.

CORNEAL LACERATIONS (GRADE 2.5)
Corneal lacerations need repair under the operating microscope using 9/0 or 10/0 monofilament sutures. This may well be beyond your means, so try to refer them as soon as you can, instilling chloramphenicol as you wait.

If a corneal laceration is <1mm, the anterior chamber is of normal depth, there is no iris in the wound, & it retains its normal curvature, *it does not need a suture*.

If the normal curve of the cornea is angled or tented, if the anterior chamber is shallow, if the iris has prolapsed, or corneal stroma has been lost from the edge of the wound, repair it by inserting a tight horizontal mattress suture, using 9/0 monofilament for the limbus and 10/0 for other parts of the cornea. You will find this difficult task easier if you use interrupted sutures. One length of atraumatic suture material will be enough for the whole injury.

CAUTION! Don't suture the cornea with short-absorbable because the wound will take 6wks to heal.

Use a small curved cutting needle. Grasp it at its mid-point, so that the convexity of the jaws of the needle holder is towards the tip of the needle. This will give you more control.

CAUTION! Aim to bring the cut edges of the endothelium on the posterior surface of the cornea together, without actually going through it.

The way to do this is to pass the needle across the wound in its posterior ⅓.

CORNEAL & SCLERAL SUTURING

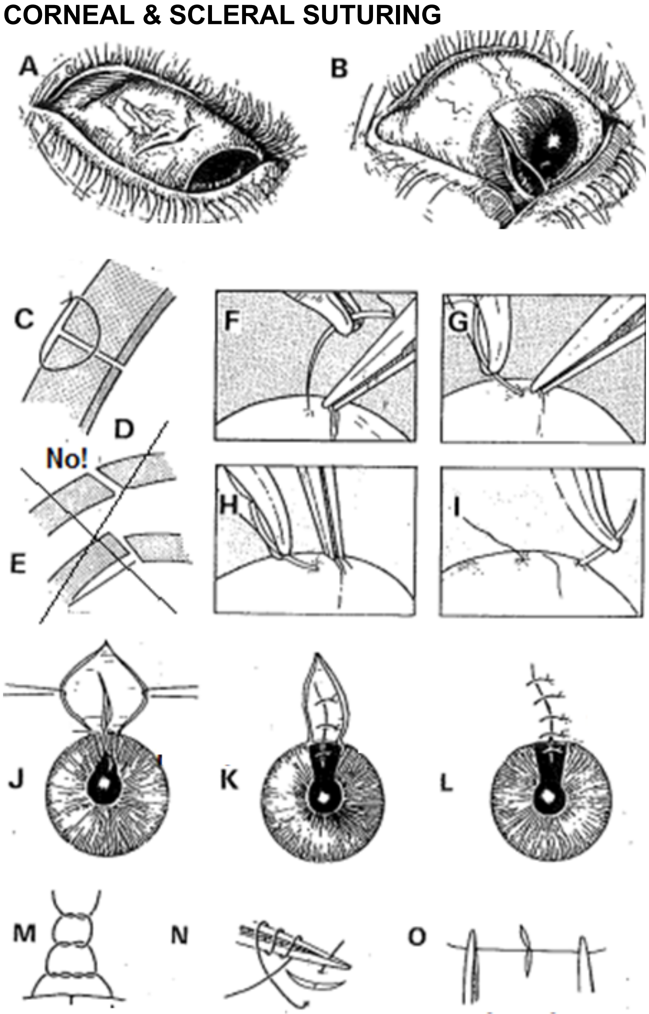


Fig. 52-6 SUTURING THE CORNEA AND SCLERA. A, a scleral laceration. B, a corneal laceration and the eyelid. C, try to make the suture cross the cornea in its posterior ⅓. It is only about 1mm thick, so this will not be easy. D, if the normal curve of the cornea is maintained, there is less need to suture. E, if it is deformed or tented, it needs suturing. The cut edges of the endothelium on the posterior surface of the cornea should be in contact. F, the needle entering at 90° to the cornea. G, the needle about to cross the wound. H, entering the other side of the wound. I, pulling out the needle. J, the conjunctiva retracted to show a wound of the cornea and sclera with prolapse of the iris. K, the prolapsed iris excised, and the cornea and sclera sutured. L, the cornea closed over the wound. M, a triple throw knot for tying 10/0 monofilament. N, wind the suture three times round the forceps. O, pulling the suture tight.
Partly after Galbraith JEK, Basic Eye Surgery, Manual for Surgeons in Developing Countries, Churchill Livingstone, 1979 with kind permission.

The whole thickness of the cornea is maximum 0.7mm, so that this will not be easy. *If your sutures are too superficial they will pull out; if they are too deep*, they will enter the anterior chamber and damage the endothelium on the back of the cornea. You will need a steady hand, so support your wrist on the patient's forehead, or on a sandbag underneath the drapes beside the head, or support your wrist on your assistant's fist.

Hold the edge of the wound (not the whole thickness of the cornea) obliquely with fine toothed forceps, so that one blade enters the wound (52-6G). While you are holding the edge of the wound undistorted with forceps, insert the needle at almost 90° into the cornea 1.5mm from the wound edge. As the needle goes through it, let the needle holder follow its curve. Aim the needle to enter the wound in the posterior one third of the cornea. It should then pass across the wound to the matching opposite edge, and come out at 90° to the cornea. If the wound is vertical, bring the suture out 0.5mm from its edge. If it is oblique, bring it out 1mm from the wound edge.

Pull the suture material through the wound, until only about 1cm remains. Tie the suture in three throws by winding the monofilament round the needle holder or the suture tying forceps. Use 3 turns for the first throw, then one, and then another one, (52-6M,N).

CAUTION! Don't pass sutures through the iris. If this happens, remove it.

Use the first throw to bring the tissues together without any tension. Leave a tiny loop between the 1st & 2nd throws to make sure that no undesirable tension is transmitted to the 1st throw. Pull the 3rd throw down and hold it down so that it can mould into a knot. Pull one side of the suture, as it emerges from the cornea so that the knot just enters the needle track. This will make the patient more comfortable while the eye heals. Instil cycloplegic such as cyclopentolate or atropine drops.

CAUTION! Don't try to reconstitute the anterior chamber by injecting air or saline. This is a highly skilled task, and you are likely to do more harm than good.

SCLERAL LACERATIONS
Suture the sclera in the same way as the cornea, but use 5/0 sutures of atraumatic monofilament. Cover the sutures in the sclera by repairing the conjunctiva over them with fine silk (6/0-8/0, 52-52). Leave the scleral sutures in place, but remove those in the conjunctiva.

If vitreous prolapses through a scleral wound, excise it. Dip a swab into the wound and lift the vitreous away. If a strand of vitreous is pulled from the wound, cut it off with scissors. The proximal end of the strand will retract into the eye. Repeat this until you have removed all the vitreous that has escaped from the globe. If some still oozes out or sits on the wound, aspirate it using a wide bore needle. Then suture the sclera as above.

CAUTION! Don't allow vitreous to remain trapped at the wound edges, because healing will be poor.

POST-OP CARE FOR CORNEAL & SCLERAL WOUNDS
Instil cyclopentolate, antibiotic, pad and bandage the eye. Leave the sutures in for 2 months if the eye is comfortable and quiet. To remove them, lie the patient flat, infiltrate with retro- or peri-bulbar LA and insert a speculum. Use the bevel of a 25G needle as a blade to slide under the suture and cut it. Pull it out with a suture forceps.

52.6 Iris injury

The iris can be torn, detached from the ciliary body, or it can herniate through a wound in the cornea & sclera. There are usually a hyphaema and other eye injuries present. Sometimes, the lens is also dislocated & the vitreous is herniating into the anterior chamber. If the iris or ciliary body remain prolapsed, the risk of infection and sympathetic ophthalmitis (52.10) is greatly increased.

IRIS INJURIES
If the iris has prolapsed through a corneal wound (52-6J) <24h before, and it is clean, put it back in the eye with an iris spatula. Try to separate the iris from the rest of the wound, to prevent the formation of anterior synechiae (adhesions). This is difficult. Excision is simple, and may be wiser.

If the iris is obviously damaged or contaminated, excise it. Grasp it with fine toothed iris forceps, draw it a little further out of the wound, and cut it with spring scissors flush with the cornea. Stroke the wound, so that the cut edges of the iris retract back. Or, gently push them back with an iris spatula. Provided there is no blood in the anterior chamber, instill sterile atropine 1% bd.

If the cut edge of the iris bleeds, put a drop of 1/1000 adrenaline into the conjunctiva. It will control bleeding and dilate the pupil.

POSTOPERATIVELY, shield the eye for 3days, or until pain stops. If light disturbs, pad both the eyes.

52.7 Penetrating injury of the globe

The anterior part of the globe is most at risk. The lens may be injured, and there may be a foreign body in the globe (52.9). Delay after 24h worsens the prognosis for sight. You may see the injury, and if it is in the cornea, it may be plugged by iris. It may be small, so look carefully. All you may see is a tiny hole in the iris and a lens opacity. Provided you are sure that there is no foreign body, suture any lacerations (52.4)

52.8 Blunt injury of the globe

A blow to the eye may:
(1) rupture the globe parallel to and just behind the limbus, causing black uveal tissue to prolapse (52-7B). The conjunctiva over it may or may not be torn.
(2) rupture the globe near the optic nerve. You may see this injury with an ophthalmoscope, but no repair is possible.
(3) detach the retina without tearing the choroid. The detached part is grey, instead of its normal red colour, and the vessels over it are dark, almost black.
(4) lacerate the choroid & retina without rupturing the sclera.

Again, the common sites are near the optic disc, and peripherally near the limbus, where the retina is inserted into the ciliary body. You can only see the central ⅓ of the fundus with an ophthalmoscope, so you will see tears near the optic disc, but not peripherally.

At the start, blood in the vitreous may obscure a central tear, but when this has cleared you will see it as a semicircular slit in the retina exposing the white of the sclera (52-7A).

Keep the patient in bed until the blood has cleared. A retinal tear never heals and is almost always followed by retinal detachment from the choroid, perhaps years later. No repair is possible without sophisticated equipment.

N.B. Blunt eye injury can also occur from sudden deceleration, e.g. in diving, sky-falling, & bunjee jumping. If the injury is unilateral, it may not be noticed for some considerable time.

BLUNT EYE INJURIES

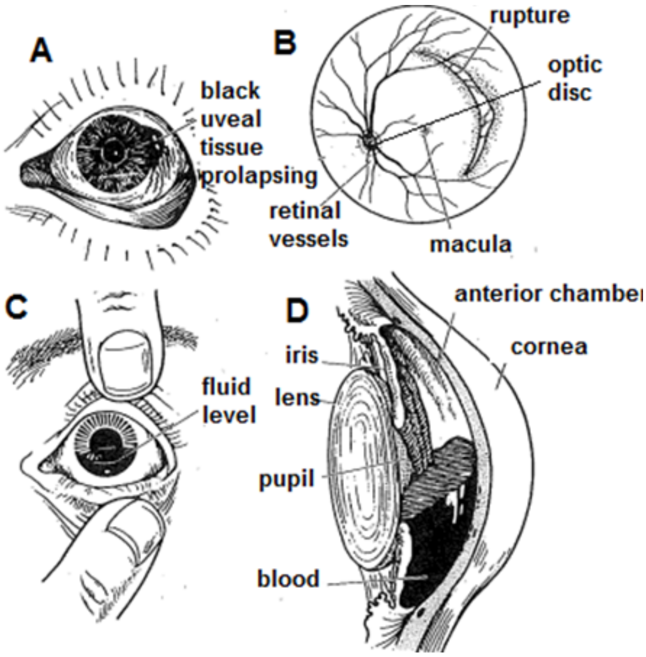


Fig. 52-7 VARIOUS BLUNT EYE INJURIES. A, the globe has ruptured just behind the limbus. The iris & ciliary body have prolapsed through the tear and lie under the conjunctiva. B, choroid rupture exposing the white of the sclera (often by a blow from a fist). C,D, hyphaema with an obvious fluid level.

MANAGEMENT

If the eye is so hopelessly injured that any useful sight is impossible, enucleate it (28.14), but wait a while before you do this.

If the globe is less severely injured, expose the scleral wound by making an opening through the conjunctiva parallel to it. Divide Tenon's capsule, and clean its lips. Gently replace any undamaged prolapsed uveal tissue with a blunt spatula.

Excise any damaged tissue and remove any prolapsed vitreous. Close the sclera with interrupted sutures (52.4), then suture the conjunctiva.

CAUTION! Don't try injecting air into the eye to restore its intraocular pressure.

Administer a course of subconjunctival antibiotics (28.1).

If you suspect a retinal injury, refer to an eye centre with the eye properly padded as soon as you can. Provided the macula is not involved, the retina can be repaired.

If a lens opacity develops after a blunt injury or electrocution, this is a traumatic cataract (28-10).

52.9 Bleeding into an injured eye

Bleeding from the iris into the anterior chamber (hyphaema) is common, and can occur immediately after injury, or later after some hrs or days. If the blood fills <⅓**,** the hyphaema is mild but indicates an iris tear (which may be obscured by blood); this may be partial or complete. The patient will complain of poor vision.

On examination, there may be:
(1) a diffuse reddish haze in the anterior chamber (mild bleeding).
(2) a settled layer of blood (52-7C)
(3) the anterior chamber entirely full of blood or clot, obscuring everything; the eye may feel abnormally hard.

Fortunately, bleeding into the anterior chamber usually stops spontaneously, but in 20% of cases it starts again during the following week. If it does start again, it is likely to be more severe than after the original injury. So, to prevent this, test for sickle cell disease & blood clotting disorders. Keep the patient on bed rest with the head elevated at 30^{o} for 1wk, use cycloplegic & antibiotic drops & put a pad over both eyes. Avoid aspirin & NSAIDs which may promote bleeding.

If the hyphaema does not resolve after 4wks, insert a very fine butterfly needle into the anterior chamber at a tangent & wash it out with sterile saline. If there is clotted blood, make a small incision in the lateral limbus, extract the clot with fine forceps, and close the wound.

Follow up the patient for glaucoma.

52.10 Ocular foreign bodies

Foreign bodies are often missed, because nobody looks for them. They can be embedded in the cornea, or lodged in the upper conjunctival fornix, and are then only seen when the eye is everted and examined using a slit lamp.

Always instil some LA drops into the eye before you try to remove any foreign body. The risk is infection. Fortunately, most foreign bodies do not penetrate deeper than the conjunctiva or sclera.

The commonest penetrating object is a piece of steel which breaks off a cold chisel on hammering. When this happens, there may be a stained area in the cornea, a tiny hole in the iris, and signs of an early cataract. This may have been misdiagnosed as conjunctivitis.

The history, and the fact that the eye remains red and watery should however make you suspicious. If a patient has a painful eye and has been doing anything which might have caused a foreign body to enter it, assume that there is one until you have proved otherwise.

OCULAR FOREIGN BODIES

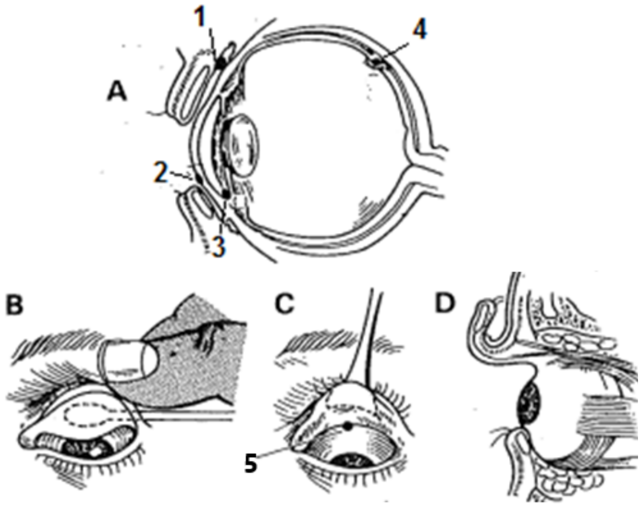


Fig. 52-8 FOREIGN BODIES. A, common sites for foreign bodies: (1) the conjunctival fornix, (2) the cornea (foreign bodies here usually lie within the fissure formed by the lids), (3) the anterior chamber, (4) the retina. B, single eversion of the lid. C, D, double eversion (5) the conjunctiva. *After Peyman GA, Principles & Practice of Ophthalmology, WB Saunders, London 1980 with kind permission.*

Look for an entry wound in: (1) the lids, (2) the sclera, or (3) the cornea. Stain the cornea. Feel the tension in the globe. Examine the anterior chamber for a hyphaema, and the iris for a tear. Look for the foreign body with an ophthalmoscope.

CAUTION! The entry wound in the cornea may be a very small one indeed. Look for a tiny haemorrhage.

CONJUNCTIVAL FOREIGN BODIES

If a patient complains that something has got into the eye, you will probably find it in the upper or lower conjunctival fornix, usually the upper one. Search both, and evert the upper lid (52-8B). You will probably find the foreign body c.3mm from the lid margin. Brush the foreign body away with a cotton wool swab on a matchstick. *Don't be content with only finding one foreign body*; expect to find several more.

If there is a foreign body but you cannot see it, *be sure to instil fluorescein*. You may see an abrasion, a laceration, or the foreign body itself.

If the foreign body is embedded in the conjunctiva, instil a few drops of LA, pick it up with forceps and snip it out with the overlying conjunctiva, if necessary.

If fragments of spectacle glass have entered the eye, remove them with forceps, and sweep them out of the fornices with a cotton wool swab on a match stick.

CAUTION! Always examine the cornea carefully, and stain it with fluorescein, even if you find a foreign body in the conjunctiva.

CORNEAL FOREIGN BODIES

The eye is painful, red, tearful, and photophobic. You will need great care, a steady hand, LA eyedrops, good magnification, and a strong light and preferably a slit lamp.

Stain the cornea with fluorescein, hold the eye open, and examine the cornea.

If you can see a corneal foreign body, wipe it away with a swab or moist cotton tipped applicator.

If the foreign body is firmly attached to the cornea, put the tip of a sterile disposable hypodermic needle under it, and lift it out of its small pit in the cornea.

CAUTION! (1) *Don't damage the surrounding normal cornea.* (2) The cornea is thin (1mm) and tough, so *don't push the foreign body through it into the anterior chamber*. (3) Use a fine sharp needle, not a corneal spud.

If fluorescein shows vertical corneal stains, a foreign body has stuck to the deep surface of the upper lid, and is scratching the cornea. Evert the upper lid, and remove the foreign body by rubbing it with a swab.

If an iron containing foreign body has remained in the cornea for any length of time, a ring of rust forms. You must remove the foreign body, but if you cannot easily lift out the rust ring, leave it.

CAUTION! Whenever there is or has been a foreign body in the eye, instil antibiotic drops, and pad it.

POSTOPERATIVE CARE

On the following day, stain the cornea with fluorescein.

If there is any area of staining and the eye looks irritated, dilate the pupil with a short acting drops such as tropicamide and bandage the eye.

A PENETRATING EYE INJURY

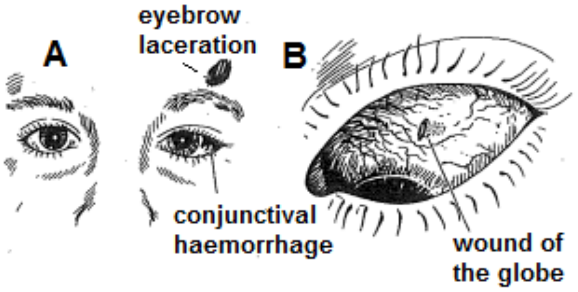


Fig. 52-9 A PENETRATING INJURY OF THE GLOBE. This patient has a penetrating injury well above the eye. A, conjunctival bleeding should make you suspicious. B, only when the patient looks down and inwards, will you see the injury of the globe. *After Goldberg S, Ophthalmology made ridiculously simple, Medmaster, Miami, FL, 1982*

INTRAOCULAR FOREIGN BODIES
Take lateral double exposure radiographs of the orbit with the eye looking up and down. If the foreign body changes its position in these two views, it is probably inside the eye.
If it is a metallic foreign body, refer for its removal.
If it is a small splinter of sand or glass, you may leave it.
N.B. Leave any orbital foreign bodies.

52.11 Endophthalmitis after injury

This takes two forms, the 1st very common and the 2nd very rare.
(1) Bacteria may invade the eye through even a minor injury, which is one of the reasons why these injuries should be treated so carefully.
(2) An immune reaction (sympathetic ophthalmitis) can involve the normal eye 4-8wks after the original injury.
When this happens, it becomes sensitive to light, red (with ciliary injection), and painful; its near vision is transiently blurred. *Don't remove the injured eye*; it may in the end have better vision than the other one. Use steroids.

BACTERIAL ENDOPTHALMITIS
If the cornea is cloudy, there is an abscess in it, or there is pus in the anterior chamber, start a course of subconjunctival chloramphenicol or gentamicin (28.1). If possible, culture the conjunctiva. Instil drops of atropine 1% into the conjunctiva.

52.12 Orbital fracture

Direct blunt force against the globe may result in a 'blow-out' fracture where the fine bones of the orbital floor are broken. This typically happens with a punch, or a squash ball hit straight at the orbit. If the orbital contents fall into the maxillary sinus underneath, the eye will look sunken (enophthalmos), and upward movement will be impaired, causing diplopia.

ORBITAL FLOOR BLOW-OUT FRACTURE

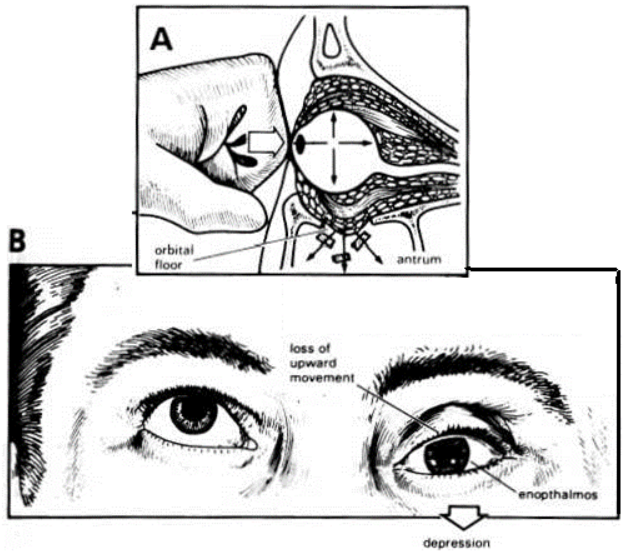


Fig. 52-10 ORBITAL BLOW-OUT FRACTURE. A, B, a blow to the orbit has broken its floor, so that its contents have prolapsed into the maxillary sinus. *From Accident & Emergency Medicine, Rutherford, Nelson, Weston & Wilson eds. Pitman 1980 with kind permission.*

REDUCTION OF A BLOW-OUT ORBITAL FRACTURE (GRADE 2.4)
Under LA, or better, ketamine, make an opening into the maxillary sinus (29.8) and insert a Ch12 Foley catheter. Inflate the balloon with water very slowly while watching the eyes from above the patient's head. Stop when their protrusions are symmetrical. *Don't exert excess pressure* as this may compress the eyeball. Check the vision regularly post-op.
N.B. You can also pack the maxillary sinus, but this is more difficult & less easy to monitor.

Significant missile injuries to the orbit may involve the frontal sinus, and brain. The eye is often totally disrupted. Packing & damp dressing the wound is all that you can do in the first instance.

52.13 Eye injury in children

All the described injuries may occur in children, but certain specific trauma should give rise to the suspicion of non-accidental trauma (47.2):

(a) Periorbital bruising
(b) Hyphaema
(c) Traumatic mydriasis
(d) Lens subluxation
(e) Retinal detachment
(f) Retinal, subhyaloid or vitreous haemorrhage

Such trauma may later lead to optic atrophy and squint.

53 Facial injury

53.1 Introduction

A patient with a severe facial injury may make you think you can do nothing for him. *This is not so!* Such injuries are usually the result of road accidents, assault or gunshot wounds.
Remember to protect the airway & cervical spine while assessing any maxillofacial injury.

Facial deformity will affect someone's life forever and has very personal consequences. Furthermore, not only breathing, but eyesight, chewing, swallowing, talking, smelling and hearing may be implicated in facial trauma.

Fractures of the middle facial ⅓ are complex and invariably multiple, sometimes with >50 fragments. The oral cavity and the sinuses have very specific bacterial flora and contamination from these sources is always an issue in facial trauma. A good blood supply usually prevents infection, but may provoke serious haemorrhage (which may be hidden, in the mouth or sinuses). Cranial nerve damage is not infrequent, and the infra-orbital and superior dental nerves are often affected. As the face is not limited by bony structures, post-traumatic oedema is usually gross.

If the maxilla is pushed downwards, the soft palate is pushed against the tongue (53-1D) and the airway is blocked.

If the alveolus becomes loose & drops onto the lower teeth, the upper molars jam into the lower and prevent jaw closure.

If the orbital floor breaks, the eye muscles may be trapped and cause diplopia (52.12).

If the temporo-mandibular joint is injured, the jaw may dislocate and make chewing impossible.

If the ethmoid bone fractures, the dura mater may be torn, and CSF leaks from the nose. (Drop the fluid emerging onto a filter paper: CSF will make a large ring around the central blood clot)

If the naso-lachrymal duct is injured, tears will flow out of the eyes.

MIDDLE FACIAL INJURY

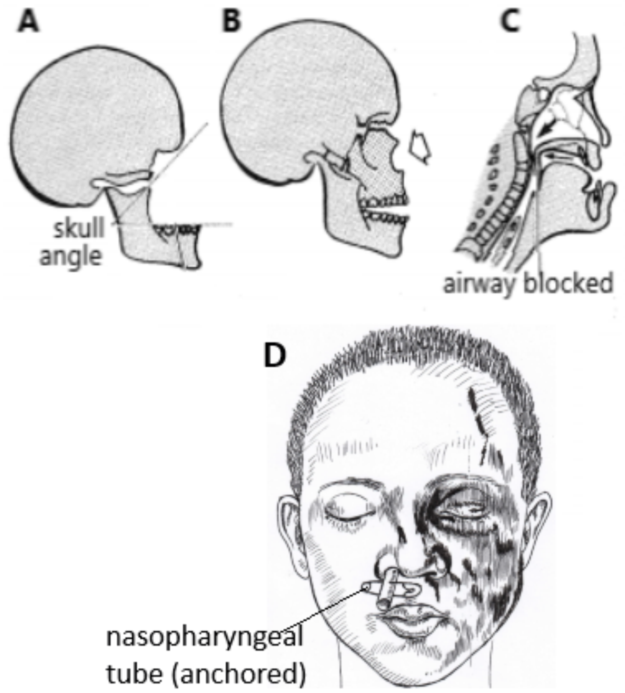


Fig. 53-1 MIDDLE FACIAL INJURY. A, the angled plane of the front of the skull. B, the maxilla pushed back, C, causing airway obstruction, D, relieved by nasopharyngeal intubation. *After Killey,HC, Fractures of the Middle Third of the Facial Skeleton, Wright, Bristol 2nd ed, 1971, with kind permission.*

IMMEDIATE TREATMENT
With facial injuries, *always pay attention to the airway! Ask the patient to say his or her name!*
N.B. Oedema may cause respiratory problems later!
Check to see if obstruction is due to:
(1) blood, vomit, debris, loose teeth, dentures or foreign bodies in the pharynx,
(2) the soft palate pushed onto the back of the tongue,
(3) the tongue falling back because the mandible is loose.

TRANSPORT OF FACIAL INJURIES

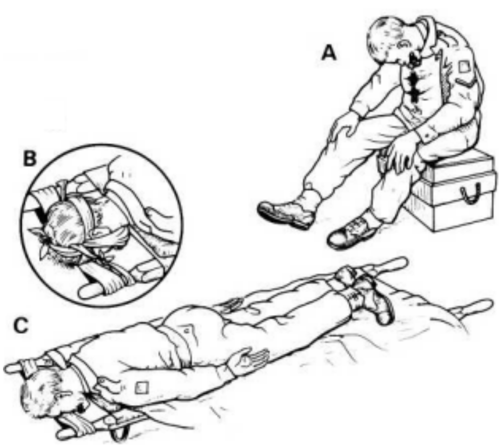


Fig. 53-2 TRANSPORT OF FACIAL INJURIES A, the conscious patient sitting up & leaning forwards. B,C the severe injury lying prone with the forehead supported. *After After Killey,HC, Fractures of the Middle Third of the Facial Skeleton, Wright, Bristol 2nd ed, 1971, with kind permission.*

Aspirate the mouth & pharynx, and remove any loose objects. *Take care not to provoke retching* as this may provoke more bleeding or vomiting.
If there is a mechanical obstruction, *push a nasopharyngeal airway down one or both sides of the nose.* Place a safety pin through the tube to prevent it slipping down the nose.
N.B. Keep the tube sucked out frequently!
If the tube kinks or you cannot pass it easily, proceed immediately to a cricoido-thyroidotomy (42.3) or tracheostomy.
(1) *Don't try inserting a Guedel oropharyngeal airway: it won't work!*
(2) If the tongue keeps falling back because the mandible is loose in an unconscious patient, pull it forward with a suture, or towel clip and attach this to the chest wall.
(3) A conscious patient may be much more comfortable sitting up (53-2A).
(4) A severe jaw injury may be best transported lying prone, with the forehead supported (53-2B).
(5) *Don't try to pass an endotracheal tube (especially through the nose)!*
(6) Most major facial injuries & those with significant bone loss to the mandible need a tracheostomy.
N.B. An immediate life-saving procedure is to hook 2 fingers round the back of the hard palate, and pull the maxilla back up the inclined plane of the skull. This however needs considerable force and the fracture may be impacted. In this case don't waste time trying.
For troublesome haemorrhage, place adrenaline packs against the bleeding site, or as nasal or anterior & posterior postnasal packs. .
If there is an injury cavity, insert a Ch20 Foley catheter and inflate the balloon to produce tamponade.
N.B. A conscious patient can swallow a large amount of blood, which may reappear as a haematemesis!

HISTORY
Try to obtain a reliable history of what happened.
N.B. A patient may not be able to talk because of:
(1) an obstructed airway,
(2) cerebral trauma, or
(3) a dislocated jaw.
Is movement of the jaw painful?

Once you have followed the ABC rules, gently wash the face with clean warm water.

LOOK
Look inside the mouth with a good light for loose objects, lacerations, or bruising. See if the tongue moves normally.
Gently swab away any clotted blood. Lift any loose pieces of tooth and alveolus out of the mouth.
Check for facial asymmetry.
Look if the nose is flattened or deviated. Check if the septum is in the midline. Is there a fluid leak?
Check for jaw opening & closure. See if the teeth occlude properly. Does the jaw open abnormally?
Is there dribbling of bloody saliva? Is swallowing or talking easy or not?
Check for depression or angulation of the zygoma (53-3D, F)
See if the palpebral fissure is oblique (53-3B)
Look at the eyes and check the vision (52.1)
Examine the ears for bleeding. Put both your little fingers into the ears and compare the movement of the condyles.
(If you cannot feel a condyle moving, suspect a fracture.)

EXAMINATION OF A ZYGOMATIC INJURY

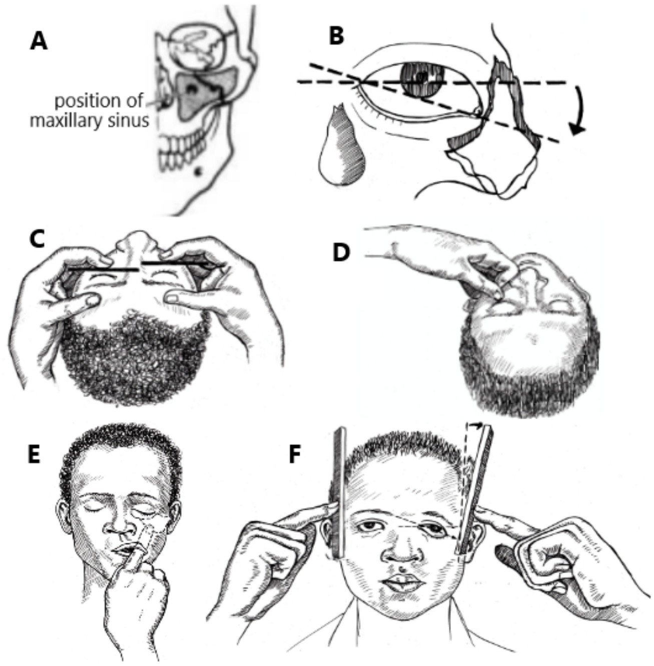


Fig. 53-3 EXAMINING A ZYGOMATIC INJURY A, the zygoma forms the prominence of the check and the floor & lateral orbital wall. The maxillary sinus extends into it. B, if a fragment of the zygoma is displaced downwards, the lateral canthus will also be displaced downwards, and the palpebral fissure will be oblique. C, press gently: i the body of the zygoma is depressed, one finger will be lower than the other. D, press gently on the lower border of the orbit, you may elicit tenderness and feel a fracture between the zygoma and the maxilla. E, feel inside the mouth for a fracture in the lateral wall of the maxillary sinus. F, place rulers against the zygomas to check deviation (if the patient has a slim face). *After Watson-Jones R, Fractures & Joint Injuries. Churchill Livingstone 6th ed. 1982.*

FEEL
Palpate the bones of the maxilla & mandible externally. Are they abnormally mobile?
Feel both the condyles with the tips of your fingers. Feel downwards along the borders of the mandible.
Feel for tenderness, step defects, alterations in contour, and crepitus.
Feel inside the mouth for the lateral wall of the maxillary sinus. Examine the buccal and lingual sulci.
N.B. Bruising in the buccal sulcus does not necessarily indicate a fracture, but in the lingual sulcus almost certainly does.
Palpate the mandible down the whole length of each sulcus carefully. If you suspect a fracture, can you make the fragments move relative to one another?
Palpate all the teeth & check if they are mobile. Tap them to hear a 'cracked cup' noise.
Check for sensation on the cheeks & upper gums.

N.B. Radiographs are difficult to interpret, and involve turning the patient into a position which may obstruct the airway. Try to get: (1) AP & oblique views of the mandible. (2) An occipto-mental (Waters/Blondeau) view of the skull (29-8) to look for filling of the maxillary sinuses, and irregularities in the outlines of the mandible.

TREATMENT
(1) Attend to airway problems & haemorrhage immediately first.
(2) Thorough wound toilet in theatre is mandatory. This is not usually possible without GA. Unless the wounds are relatively simple, you should secure the airway, best by a tracheostomy. Scrub the skin with a toothbrush; only remove clearly necrotic or detached pieces of tissue. Use fine instruments & hooks to handle the skin.
(3) Extract any foreign bodies, but leave any bone still attached to periosteum.
(4) Repair mucosal lacerations with absorbable sutures.
(5) Put petroleum jelly on the lips to stop them sticking together.
(6) Commence antibiotic prophylaxis (gentamicin & metronidazole).
(7) Protect the eyes if the patient is unable to close them or he is unconscious.
Remove all packs within 48-72h.
It is usually better to delay reduction and fixation of fractures till after 24-48h when swelling has subsided.

N.B. Most conscious patients can suck fluids round the sides and back of the jaw. The mouth needs rigorous rinsing after food.

If part of the cheek Is missing, try to close the mucosa and muscular layers. Suture the buccal mucosa to the skin (61-4). If necessary, do the same with the nose.

53.2 Maxillary & zygomatic fracture

(1) Unilateral maxillary fracture
Here the alveolus holding the teeth becomes loose (53-4A). Reduce it to the correct position of bite and fix it by interdental wiring to the mandible (53-12); if this is also fractured, you need to fix this first (53.6)

(2) Bilateral maxillary fractures
Here there is gross malocclusion of the teeth (53-4G) and reduction may be difficult to hold by interdental wiring alone, so wire the zygomatic arch to the mandible, provided this is intact.

TYPES OF MAXILLARY FRACTURES

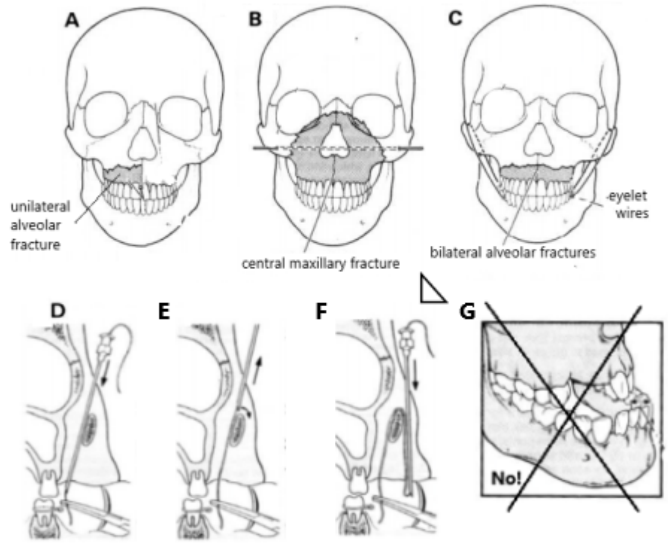


Fig. 53-4 MAXILLARY FRACTURES. A, a unilateral fracture in place. B, central maxillary fracture (which may occasionally be held with a transverse K-wire). C, wire round the zygomatic arches holding a bilateral alveolar fracture in place. D, pass a wire threaded in a needle medial to the zygomatic arch into the upper buccal sulcus, and down it. E, withdraw the needle partially. F, pass the needle lateral to the zygomatic arch pulling the wire along. G, *don't leave this gross malocclusion unreduced*. *Kindly contributed by Susan Likimani & Andrew Curnock.*

ZYGOMATIC ARCH WIRING (GRADE 3.1)
Use ketamine with LA to the gums.
Fix wire eyelets to the teeth on both sides of the lower jaw (53-12). Thread wire along a blunt aspiration or large lumbar puncture needle: push the needle through the skin just above the zygomatic arch and posterior to the outer canthus (53-4D), downwards medial to the zygomatic arch into the superior buccal sulcus. Thread the wire through the needle and grab it with a clamp; remove the needle gently to a point above the zygomatic arch, and push the needle down, pulling the wire with it, lateral to the zygomatic arch (53-4E), so that it emerges at the same point where it perforated the buccal mucosa before (53-4F). Hold this end of the wire in another clamp, and remove the needle; then tie the wires to the eyelets you have prepared.
Repeat the procedure on the other side of the face.

(3) Central maxillary (Le Fort II or III) fractures
These may be very difficult to reduce if impacted.

(4) Zygomatic fractures
A blow to the side of the face drives the zygoma inwards. The zygomatic bones are so closely joined to the frontal and temporal bones, that these bones usually fracture at the same time also. The displaced zygomatic fragment can rotate clockwise, or anticlockwise, and its orbital rim can be inverted or everted. *The floor of the orbit is always partly comminuted*. There may be diplopia & trismus.

Early on, the prominence of the cheek is flattened, but oedema fills it out within 3h. There is swelling & bruising beneath the eye. Test for deviation of the zygoma (53-3F) The maxillary sinus fills with blood, and there is epistaxis on the same side. Damage to the infra-orbital nerve makes the cheek numb, and displacement of the lower part of the orbit pushes the eye downwards, and restricts its movements (52.12).
In a gunshot injury, the maxillary sinus may be shattered, requiring packing. If the sinus remains relatively intact, you should drain in to avoid inevitable infection.

DRAINING BLOOD FROM THE MAXILLARY SINUS (GRADE 3.1).
Bleeding into the maxillary sinus may become infected, and may hide an orbital floor fracture. If the sinus is full, the space normally filled by air becomes full of blood: it sounds dull to percussion, and a lateral radiograph of the head will show opacification (29-8).
Make an opening under LA into the maxillary sinus (29.8) and wash out the cavity with warm sterile water.

If there is continued copious bleeding into the maxillary sinus, pass a Foley catheter into the sinus and inflate the balloon for a tamponade effect (52.11)

If only the zygomatic arch is fractured, movement of the coronoid process of the mandible is restricted. Fragments are held by the zygomatic fascia, and displace solely inwards. The temporalis fascia is attached to the superior border of the zygomatic arch, whereas the *temporalis* muscle is attached to the coronoid process. This means it is possible to pass an elevator between the fascia and the muscle, and lever the zygomatic arch outwards into place.

REDUCTION OF THE DEPRESSED ZYGOMA FRACTURE (GRADE 3.1)
Don't try to elevate the fragment, unless there is difficulty moving the jaw. Occasionally, passively opening the mouth may spontaneously reduce the zygomatic fragments and allow mouth opening, thus avoiding the need for surgical reduction.
Otherwise operate within the first 48h, because after 2wks, the ends of the fragments will have softened and rounded, and will probably need fixation by wiring; after 4wks they will have malunited, requiring open re-fracture, reduction, and fixation.

Use ketamine. Protect the eyes. Make a 2cm lateral incision in the temporal fossa, just above the level of the upper border of the pinna (53-5A), anterior to the superficial temporal artery. Reflect the skin, and divide the superficial fascia, under which is the *auricularis superior* or *anterior* muscle.

Spread its fibres (53-5B), vertically in the case of the former, horizontally in the latter, so you reach the thick *temporalis* fascia, which may have a double layer, covering the *temporals* muscle (53-5C).

ELEVATION OF THE DEPRESSED ZYGOMA FRACTURE

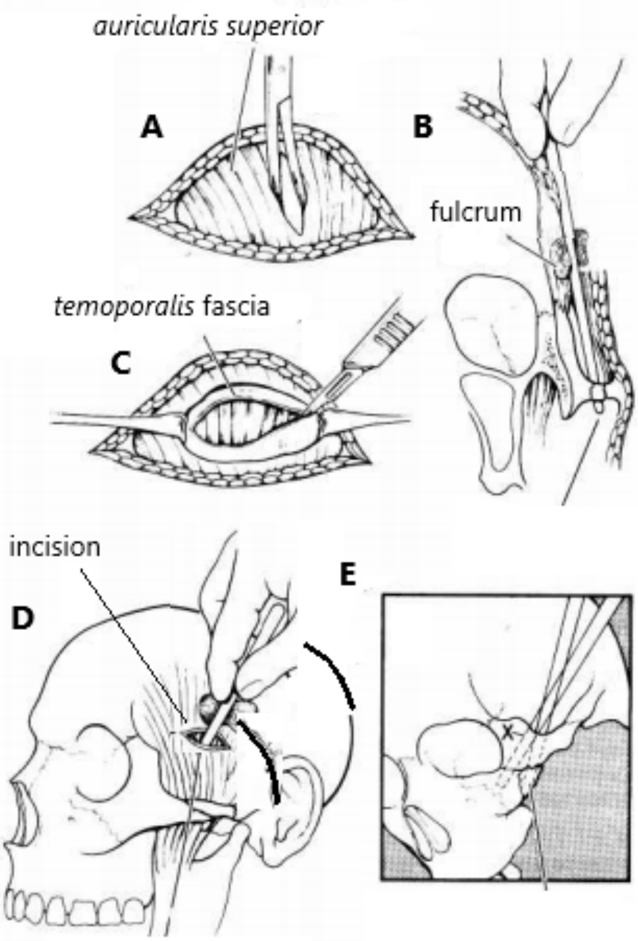


Fig. 53-5 ELEVATING A DEPRESSED ZYGOMA FRACTURE. A, separating the *auricularis* fibres. B, incising the *temporalis* fascia. D, passing the elevator through the incision along the *temporalis* muscle. E, levering the arch or body of the zygoma.
Kindly contributed by John M Lore Jr.

Cut through this carefully in the line of the skin incision: *beware: there is often a vessel just deep to the fascia!* Insinuate Bristow's or McDonald's elevator (or a long flat screwdriver) between the muscle and fascia till it reaches the level of the zygoma (53-5D). Manipulate it so it lies behind the depressed section of bone. Using a solid object protected by a gauze swab as fulcrum, lever the zygoma laterally into a slightly over-corrected position (53-5E,F). Then close the fascia with absorbable and close the skin.

If the reduction is unstable, expose the fracture by blunt dissection through an incision over it. Take care to avoid branches of the facial nerve supplying the *orbicularis* muscle. Drill small holes in the bone and fix them together with strong stainless steel wire.

53.3 Tooth injury & alveolar fracture

The front of the upper jaw is most at risk in blunt trauma. The teeth may be damaged with or without the alveolus. Injured teeth don't threaten life, unless they are inhaled and block the airway. However, they are acutely painful, especially when the pulp is hanging out. Fragments of teeth may be embedded in the soft tissue of the mouth, or swallowed.

If the oral mucosa is torn, clean it, remove any foreign bodies & suture it with 4/0 long-acting absorbable.

If the crown of a tooth is detached, its exposed pulp will be visible as a pink spot on its root surface. Clean it and make a temporary covering with zinc oxide, calcium hydroxide, stomahesive or clear nail polish or moist cotton covered in foil. *Don't use bone wax!* It will be acutely painful, so if the pain remains intolerable, touch it with phenol on a small piece of cotton wool. This will kill and anaesthetize the nerve. Obtain a chest radiograph in case a fragment is missing.

If a denture is missing, it can likewise be inhaled or swallowed, but *may not be visible on a radiograph!*

If a tooth is loose, push it back it in place; it will probably tighten up and survive. If it is still loose, with LA, fix it in place with interdental wiring and/or an arch bar (53.6).
In a child, extract any loose non-permanent teeth.
N.B. Beware of damaging tooth buds with drills or screws!

If a tooth is avulsed, and out of its socket <2h, clean it *(but don't scrub, touch or hold the root surface)* and applying LA to the socket, irrigate the socket of debris and push it back firmly in place. *Don't delay doing this waiting for radiographs! Don't let the tooth dry out!* Ask the patient to bite down onto gauze over the replaced tooth. Advise prophylactic penicillin V 500mg qds, and mouthwash. Brushing of adjacent teeth is still necessary! Remember protection against tetanus, and to provide analgesia.
N.B. Don't re-attach non-permanent children's teeth.

If a tooth is avulsed, and out of its socket >2h, the periodontal ligament and pulp will have died, so remove these. Soak the tooth in 5% sodium hypochlorite for 30mins. Then, if possible, for 5mins in each of saturated citric acid, 1% stannous fluoride, & 5% doxycycline before re-implanting the tooth.
N.B. Don't re-attach an avulsed tooth if there is a complicated crown fracture, a fractured root or an alveolar fracture.

If there is an opening between the sinus & the mouth, close this temporarily by packing with ribbon gauze impregnated with povidone. Change this daily with Bismuth iodoform paraffin paste (BIPP), or with petroleum jelly gauze. Provide prophylactic antibiotics. When the patient's general condition is stable, close the gap with a flap of mucosa from the adjacent cheek. Suture it carefully, with 4/0 long-acting absorbable. Advise against blowing the nose or sneezing with the mouth open.

If the sinus is already infected, leave it open and irrigate it daily. *Don't pack it.*

If there is a comminuted alveolar fracture, and the bony fragment with its teeth is still attached to periosteum, leave it, and splint the teeth with an arch bar (53-12). If the alveolar fragment is completely detached, dissect it out and remove it.

53.4 Nasal fracture

Suspect a fracture after any blow on the nose. The nasal bones are superior to the nasal cartilage and form a tent-shaped covering for the upper nasal passages.
Sometimes the swelling hides the displacement of the nasal bones; there may be blood in the orbits and under the medial halves of both conjunctivae. Unreduced fractures result in deformities (53-6). Radiographs are usually unnecessary.
A severe force may:
(1) Fracture the frontal processes of the maxilla.
(2) Displace the nasal cartilages.
(3) Dislodge the septal cartilage from its groove in the vomer.
(4) Fracture the vomer.
(5) Fracture ethmoid bones so CSF leaks in the nose.

CONTROLLING BLEEDING
Insert a gauze with LA & adrenaline for a few minutes, then pack the nose (29.7, 53-6). Treat the patient as soon as possible without waiting for the swelling to go down.

ANTERIOR & POSTERIOR NASAL PACKING

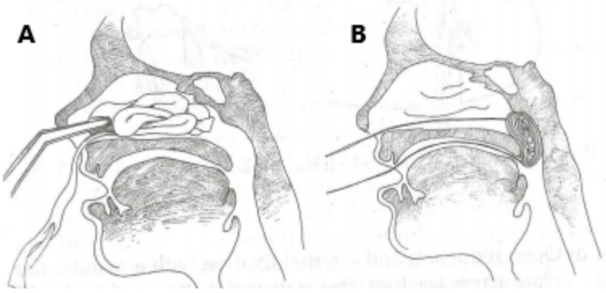


Fig.53-6 NASAL PACKING. A, anterior. B, posterior.
After Szul AC (ed) Emergency War Surgery. US Army 3rd ed 2004.

REDUCING NASAL FRACTURES (GRADE 2.3)
Spray LA into the nares. Protect the eyes. Clean the face thoroughly. Inject LA above the philtrum & above the bridge of the nose.
Use guarded Walsham's septal forceps (so their blades don't meet & crush the fine nasal bones) and pass the thin blade into the nose leaving the thicker guarded blade outside; disimpact the bones by a medial-lateral rocking movement (53-8A), and then lever the fragments into place.

DEFORMITY FROM UNREDUCED NASAL FRACTURES

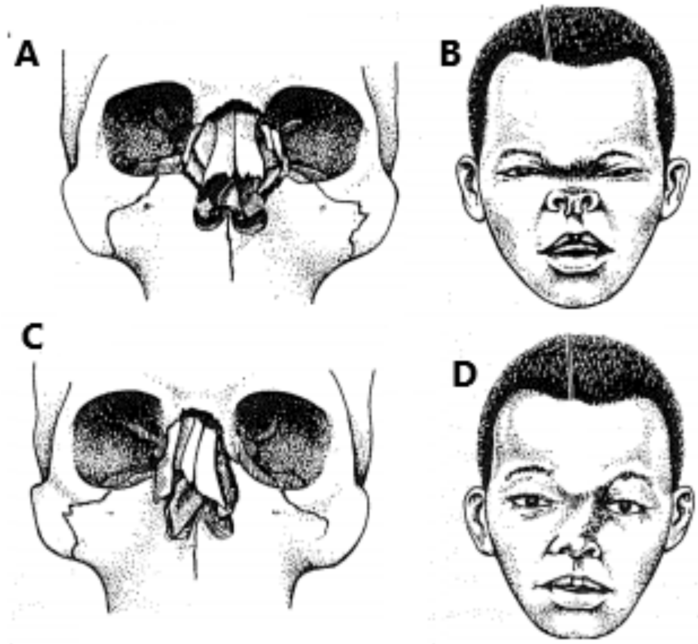


Fig.53-7 UNREDUCED NASAL FRACTURES. A,B depressed bridge from an anterior blow. C,D, deviation from a lateral blow. *After After Killey,HC, Fractures of the Middle Third of the Facial Skeleton, Wright, Bristol 2nd ed, 1971, with kind permission.*

Repeat the process on the contralateral side. Mould the bones into a symmetrical position with your thumbs. (53-8B).

Inspect the septum. If it is not reduced, pass both blades of the forceps, or any other suitable instrument, down each side of the septum and straighten it, so that it lies in the midline. If necessary, grasp the septal cartilage and bring it forward, to replace it in its groove in the vomer.

Then restore the full height of the bridge of the nose if this is collapsed by passing the thin blade along the nasal floor, closing the forceps and swinging them downwards to push the bridge up (53-8C)

Check there is a clear nasal airway by looking up & passing an instrument in the nasal passage. Pack both nostrils gently with BIPP to maintain the position for 48h. Splint the nose if the depression or deviation was severe. Get a malleable plastic and mould this into a T–shape to fit onto the nose.

If there is a septal haematoma, evacuate it immediately through a small mucosal incision, otherwise it will destroy the septal cartilage and produce a saddle nose (53-7B).

REDUCING A NASAL DEVIATION

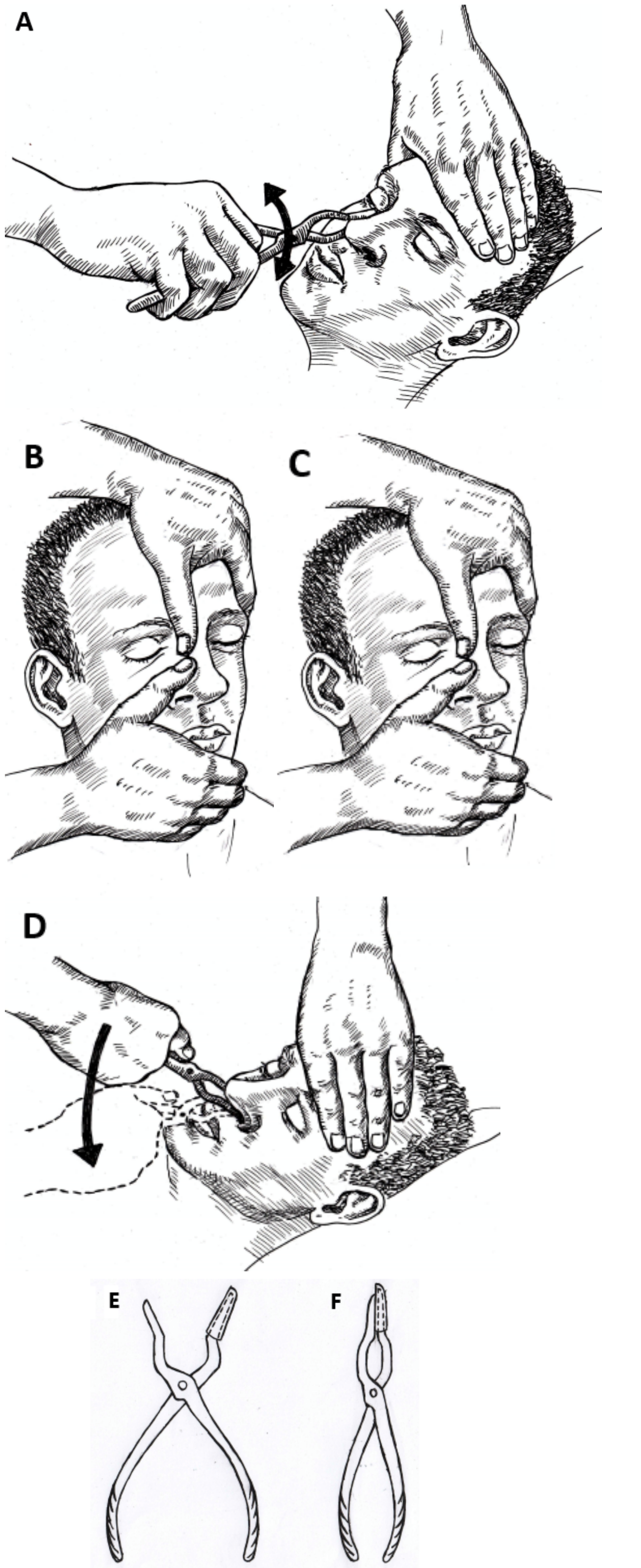


Fig. 53-8 REDUCING A NASAL FRACTURE. A, inserting the forceps and disimpacting the nasal bones by a medial-lateral motion. B, manipulating the bone into place. C, moulding out any asymmetry by the thumbs. D, raising the depressed bones by a downward movement of the forceps. E, Walsham's forceps and their guards, open but never completely closed *After McGregor IA. Fundamental Techniques of Plastic Surgery.. Churchill Livingstone 7th ed 1980.*

53.5 Jaw dislocation

When the mandibular condyles slip forward in their sockets over the articular eminences of the temporo-mandibular joints, the jaw dislocates. This can happen on laughing, yawning, or being hit in the face with the mouth open.
The mouth remains permanently half-open in an anterior open bite. Swallowing and speaking is difficult, so that saliva dribbles from the corners of the lips. On examination there is a small depression over the temporo-mandibular joints.

JAMES, 28 years, was brought to hospital on a stretcher by his work colleagues because all of sudden he could not talk, though he was gesticulating wildly. Most of them thought he had had a stroke, though one was of the opinion he was bewitched! His mouth was half-open and fixed. There was obviously no neurological deficit.
The duty medical officer pulled gloves out of his pocket, grabbed the man's lower jaw and eased it back into place, whereupon the man cried, "Alleluia". The work colleague was now convinced that the evil spirit had been exorcised!

If the mandible dislocates on one side only, it deviates away from the midline.

Try first to get the patient to roll a large plastic syringe between the upper & lower molars; this action may reduce the dislocation spontaneously.
If this doesn't work, sit the patient forward in a chair. Most patients need no anaesthetic, though some may need a sedative. Ask an assistant to stand behind and hold the head. Put on gloves. Place some gauze over the lower posterior teeth on each side. Press the premolar teeth downwards. At the same time press the underneath of the chin upwards and backwards (53-8).
Advise the patient not to open the mouth too wide again, for the dislocation may recur.

REDUCTION OF A DISLOCATED JAW

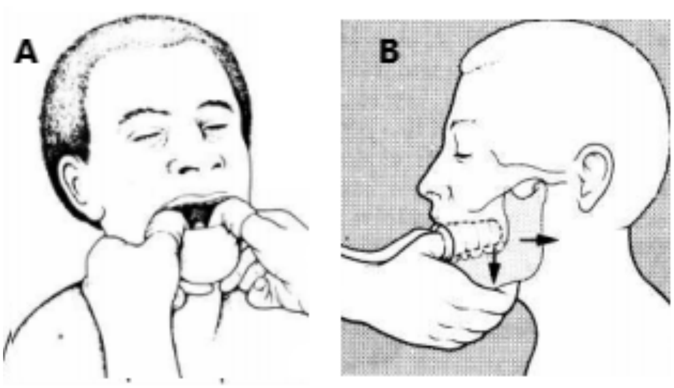


Fig. 53-9 REDUCING A DISLOCATED JAW. A, press the premolar teeth downwards and B, press under the chin upwards & backwards.

REDUCTION OF A DISLOCATED JAW (GRADE 1.2)
N.B. **For old dislocations**, where the masseter muscles are contracted and hold the jaw dislocated, fix arch bars to each jaw (53-14). Cut an ordinary rubber eraser (or cork) into 2 pieces, and put a piece between the posterior molars on each side to act as a fulcrum.
Fix steel wires between the arch bars in front, and Tie them together firmly. The next day the wire will be loose, so tighten it by a complete or half-turn every day. By steady traction, the anterior open bite will gradually close.

53.6 Mandibular fracture

Treat fractures of the oral bony structure as 'facial orthopaedic injuries' and apply the same general principles, especially regarding soft tissue injuries in the presence of contamination. Every fracture in the toothed parts of the facial bones is a compound fracture.

Fractures of the angle and body of the mandible are therefore open, but not those of the rami, condyles, or coronoid processes. Often, the patient has other injuries too, and the combination of a jaw injury and a head injury is common. But, provided there is no gross comminution or tissue loss, you should be able to treat most of these fractures successfully.
The mandible remodels readily, even after a comminuted fracture, and left untreated, many fractures heal by themselves, but often with considerable disability if there is malalignment.
The purpose of the mandible is to bite, so *decide whether or not the patient has a normal bite. If not, think how best you can restore it.* The methods described are for single fractures. For multiple fractures, adapt the techniques to obtain as good occlusion as you can.

TYPES OF MANDIBULAR FRACTURE

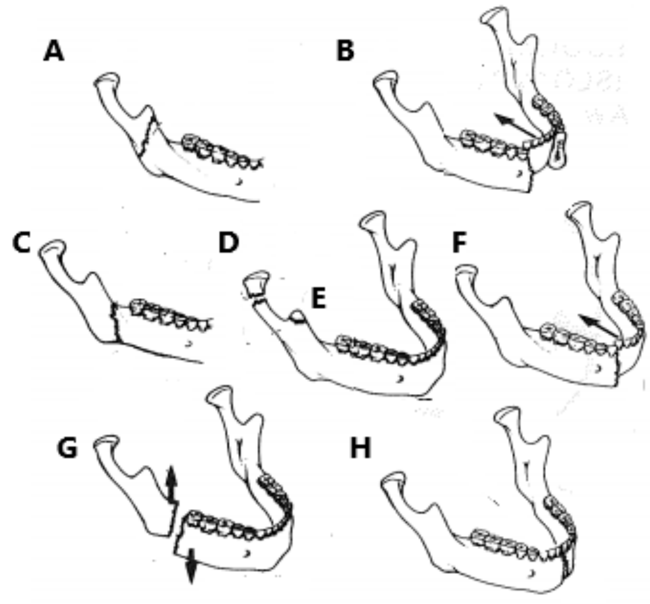


Fig. 53-10 PATTERNS OF MANDIBULAR FRACTURE. The principle of reducing these fractures is to make the bite normal. A, fractured ramus. B, displaced bilateral central fracture. C undisplaced fractured angle. D, fractured condyle. E, fractured coronoid process. F, displaced unilateral fracture. G, displaced fractured angle *(note the muscle pull)*. H, minimally displaced midline fracture.

TREATMENT

For undisplaced fractures where the bite is normal, use a skull-jaw bandage (53-11). This is also useful for temporary immobilisation, or when other methods of immobilisation are impossible. Add fixation if the fracture is unstable.

For displaced fractures or where there is a mandibular fracture or dislocation with an open bite, use maxilla-mandibular rubber bands or wiring, provided there are enough teeth to which you can make the fixation. (You can make these by cutting small circular pieces from the latex rubber parts of used intravenous infusion sets). The wire or band is thin enough to pass between the teeth, but strong enough to hold bone fragments stable. It is usually 0.4 or 0.25mm in diameter. Although special wire-cutters and surgical pliers are useful, you can use Kocher or haemostat forceps, or even ordinary pliers properly sterilised.

If you can obtain them, arch bars are a useful adjunct, but not as simple to use as it may appear.

It is possible to drill holes through the bone to find anchor for the wires, but this is not as strong as fixing them to the teeth, and you should not rely on the former alone. External fixation is preferable.

Study the way a patient's jaws fit together, because occlusion of the teeth is not the same with everyone.

Remember you should immobilize the jaw before closing the skin, but after repairing lacerations inside the mouth.

N.B. Beware the dangers of not being able to open the mouth in the event of intra-oral bleeding or vomiting! A tracheostomy is therefore mandatory if there is much oedema, or depressed level of consciousness (especially due to alcohol)

N.B. If you have used wire, keep a wire cutter and scissors at the patient's bedside in case of emergency!

A SKULL-JAW BANDAGE

Fig. 53-11 A SKULL-JAW BANDAGE. Use this for undisplaced fractures (53-10A,E,H). ***You may still need fixation by wiring, or banding, though.*** **The straps of the bandage intertwine, and must support the whole chin.** *After Giannou C, Baldan M, Molde Á War Surgery ICRC Geneva 2013*

INTERDENTAL WIRING (GRADE 1.4)

When you work with wire, stretch it a little before you use it. *Remember always to protect the eyes*, as a piece of wire may suddenly spring out of position.

There are 2 main techniques for fixing the wires on teeth: the Ivy and the Ernst ligatures.

In the former, use a loop on the labial side to capture the wire which has passed round the tooth from the lingual side, and twist the two ends together as well as the loop to secure the fixation (53-12A-D).

In the latter, there is no interdental loop; one large loop encircles two adjacent teeth on the labial side, and the free ends pass between the teeth and are twisted together (53-12E).

Remember always to make all twists in a clockwise direction. The Ernst ligature is useful as a temporary holding measure. Tuck the wire ends towards the gum, so that they don't cause irritation. You need 2-3 eyelets on each side for proper fixation; when fixing maxilla to mandible, *don't put eyelets directly above & below each other* for this will not anchor the fragments.

INTERDENTAL WIRING

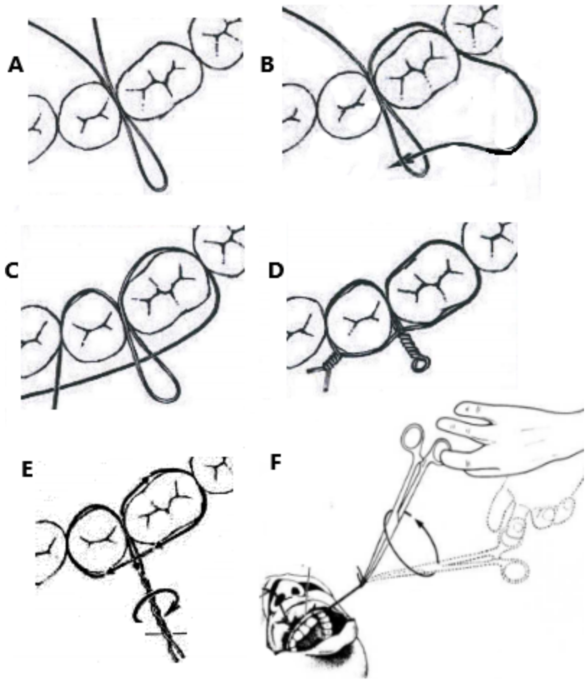


Fig. 53-12 INTERDENTAL WIRING. A, the Ivy ligature: pass a loop between adjacent teeth from the lingual to labial side. B, pass one free end round the tooth between the next tooth gap to the labial side and through the loop. C, pass the other free end through the next tooth gap on the other side. D, twist the free ends together and the loop *in a clockwise direction.* E, the Ernst ligature: 1 large loop encloses 2 adjacent teeth on the labial side, with both free ends passing between the teeth, one above and the other below the encircling wire, to be twisted together on the labial side. F, a technique for twisting the wire. *After Giannou C, Baldan M, Molde Á, War Surgery ICRC Geneva 2013. F, contributed by Frederick Onyango.*

N.B. You can apply circular rubber elastic cut from parts of IV infusion sets instead of wire! This is cheaper and elastic bands are easy to cut out in an emergency if there is airway compromise.

CAUTION!.
(1) *Check the occlusion before you tighten the wires!* Do this little by little, first with the molars on one side then the other, then with the incisors, *or else you will create a cross-over or posterior bite*.
(2) *Don't twist the wire too tightly on a single-root tooth:* you may pull it out!
(3) *Don't include dentures with your interdental wiring:* they are loose and provide no proper fixation.
(4) *Make sure you have not trapped the tongue!*
(5) Check that there are no loose wire ends by running your finger inside the mouth.

RISDON WIRING
Here the wire is used to reduce a mandibular fracture rather than bringing the maxilla & mandible to close opposition. Anchor a 0.25mm wire round a stable pre-molar or molar tooth and twist it on the labial side to make its hold secure.

RISDON WIRING

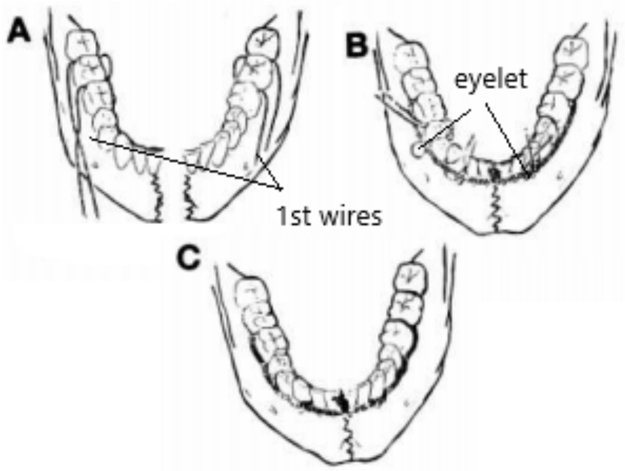


Fig. 53-13 RISDON WIRING A, on both sides of the mandible, pass the wire round a premolar (or molar) tooth and twist it. B, create eyelets between more anteriorly placed teeth. C, pass the double-stranded wires through the eyelets, so that they meet in the midline and twist both double strands together to reduce the mandibular fracture into its correct position.

Do the same on the opposite side of the mandible; then bring both double strands of wire towards the midline and twist them together. You will gain more stability, and have less risk of the wire slipped off, if you pass the wire strands through eyelet loops you have created along the more anteriorly placed teeth (53-13)

ARCH BARS
Commercially made arch bars are made of malleable metal available in specific lengths. They are very useful for patients with missing teeth
Cut the bar so it is long enough to span the whole length of the tooth arch for each jaw: bend it to shape, *but remember its shape must conform to the reduced,* not the displaced*, mandible or maxilla. Make sure you place it with the hooks facing the gums.* Make it long enough so you can bend it round the last posterior tooth (15-14C).

Place the bar on the necks of the teeth. Fix it to each remaining tooth by passing 0.4mm wire loops above the bar from labial to lingual side, round the tooth and out again lingual to labial side below the bar (15-14D), and twisting the wire onto the hooks (15-14E). You can combine fixation with eyelets for extra security. At the time of wire insertion, circle one end of the 1st wire, then pass the 2nd wire and bend its end. This way, alternative wire-ends are circled or bent, making it easy to identify correct ends for tightening.

ARCH BARS

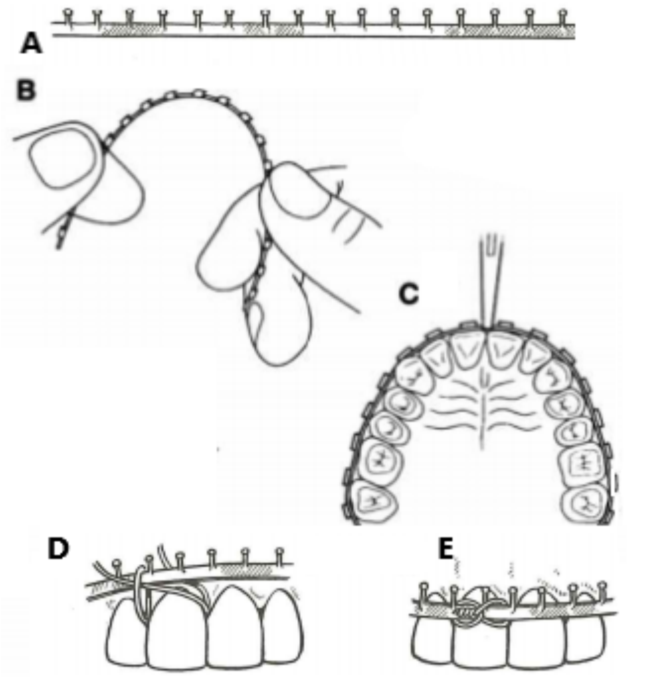


Fig. 53-14 ARCH BARS. A, malleable pre-fabricated arch bars with hooks. B, bending it into shape, C, round the last posterior teeth. D, fixing it to the teeth by passing one wire above the bar and one below, E, twisted onto the hooks. *After R.O. Dingman RO, Navig P. Surgery of Facial Fractures Saunders 1965 & McGregor IA. Fundamental Techniques of Plastic Surgery. Churchill Livingstone 7th ed 1980*

N.B. You may not be able to make a loop hold on the incisors, unless you lift the gum with a periosteal elevator. *Take care the bar does not irritate the gums.*

EXTERNAL FIXATION
This is useful where there is extensive bony or soft tissue loss. Make sure the mucosa is closed. Ensure correct occlusion by immobilization using temporary wiring. Repair soft tissue injuries and close the skin (to prevent cosmetic malpositioning of wounds), and insert pins in a 3-dimentional manner.

INDICATIONS FOR INTERNAL FIXATION
(1) Condylar displacement into the middle cranial fossa (with or without fracture),
(2) Where obtaining proper occlusion by closed techniques is impossible,
(3) Condylar fractures associated with comminuted fractures of the mandibular body or symphysis.

ANAESTHESIA
Ketamine is not ideal as you will not be able to pack the throat. Where there is bleeding in the mouth, there is always risk that fluid passes into the airway unless you protect it.

The safest method is to use a cuffed endotracheal tube but this may interfere with your surgery unless it is a nasotracheal tube (which is contraindicated if there is suspicion of ethmoid fractures), so a tracheostomy is usually safer, also for the post-operative period.

To avoid the danger of a closed mouth after the operation, you may delay maxilla-mandibular fixation till later, and perform this under LA. Or alternatively, you can use strong short rubber bands.

POSTOPERATIVE CARE
N.B. In major injuries, oedema may cause late airway obstruction.
Check occlusion. Encourage the use of chewing gum. Oral hygiene is crucial; use an antiseptic mouthwash several times a day, and always after food. Use a soft toothbrush likewise several times a day.

Make sure the patient can receive enough high energy, high protein liquidized food, either by straw (round the back of the jaw) or by nasogastric tube.
Keep the wires in place 4-6wks.

53.7 Difficulties with facial fractures

If opening of the jaw is difficult, this may be simple *trismus* which improves with exercises. It may be due to coronoid process hyperplasia where the *temporalis* muscle becomes calcified, and require excision of the coronoid process. Alternatively, it may be due to ankylosis of the temporo-mandibular joint, which does not respond even to condylectomy. *Make sure there is no chronic dislocation* here.

If osteomyelitis develops in the bone, it is usually combined with a salivary fistula. Remove any sequestrum and lay open the infected area, and make sure the patient remains well-nourished. Copious mouth irrigation is necessary until the mucosa closes.

If there is severe malocclusion of the teeth, you can try to grind down the cusps of the affected teeth. Alternatively remove any teeth preventing mouth closure, or in the last resort, arrange for re-fracture & re-fixation of the mandible.
In edentulous patients, make Gunning splints, moulded to fit the existing mandible & maxilla, and cut the splint at the site of the bony fracture. Attach the mandibular (or maxillary splint to its bone base with circular wires. Then fix the splints to each other by wires or elastic bands.

53.8 Soft tissue facial injury

NATURAL LINES OF THE FACE

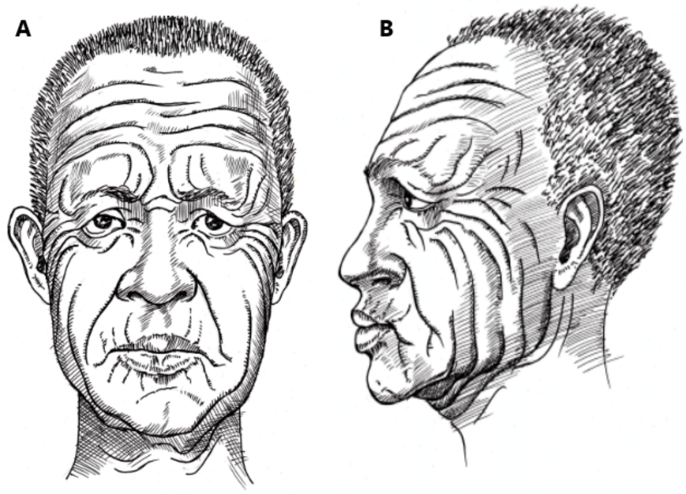


Fig. 53-15 Natural crease (wrinkle) lines in the face. A, frontal view. B, lateral view. Try to place your sutures along or parallel to these lines.

Don't think wounds of the face are just for plastic surgeons! Don't try to repair such wounds without a good light, and don't rush!

The principles of wound care (46.2) apply just the same, but adhere to certain rules:
(1) *Pay great attention to detail!*
(2) Toilet dirty wounds carefully to avoid 'tattooing' the face.
(3) *Be very gentle with skin edges using hooks if possible. Use fine instruments & sharp scissors.*
(4) *Don't excise more tissue than absolutely necessary!*
(5) *Approximate wound edges precisely,* so that unseemly steps don't ensue. *Avoid 'dog ears'.*
(6) *Don't shave the eyebrows,* or else you will lose the landmarks to approximate a wound.
(7) *Don't allow a deep wound to heal by secondary intention,* as scarring is then inevitable.
(8) *Don't attempt a flap closure as the initial procedure.*
(9) *Don't make 'relaxing' incisions to get a wound to close.* Use subcutaneous 4/0 absorbable sutures where the wound is deep.
(10) *Don't leave dead spaces.*
(11) *Regard all bite wounds* (including human bites) *as septic, and don't be tempted to close them primarily!*
(12) Remove skin sutures at 5days.
(13) *Avoid haematomas* by pressing on wounds long enough for haemostasis, aspirating collections, and firmly applied postoperative dressings.
(14) Try to place your suture lines along the natural wrinkles of the face (53-15)

EXAMINATION
The wound may be so obvious, that you forget to look elsewhere! Check the eyes (52.2), the facial nerve (by asking the patient to smile & noting any asymmetry, and a leak of saliva from the parotid or submandibular glands.

ANAESTHESIA
You can use LA on most wounds, and ketamine for more extensive procedures. Where there is risk to the airway, perform a tracheostomy and use endotracheal intubation so you can pack the pharynx.

(a) Lips
Be careful to align the skin & vermilion border very accurately. Mark the points with a fine indelible ink pen *before you insert LA solution.*

Teeth often cause the lip lacerations and occasionally a loose tooth remains *inside* the lip!
Use absorbable sutures.

For a full thickness lip injury, put the 1st suture in to approximate the vermillion-skin border. If this looks wrong, *don't hesitate to pull the suture out and do it again!* Then the 2nd suture onto the labial sulcus and the 3rd to approximate the *orbicularis oris* muscle. Place the mucosal sutures so the knot is buried.
(53-16)
N.B. You can repair up to ¼ of the missing lip primarily.

ANATOMY OF THE LIPS & THEIR REPAIR

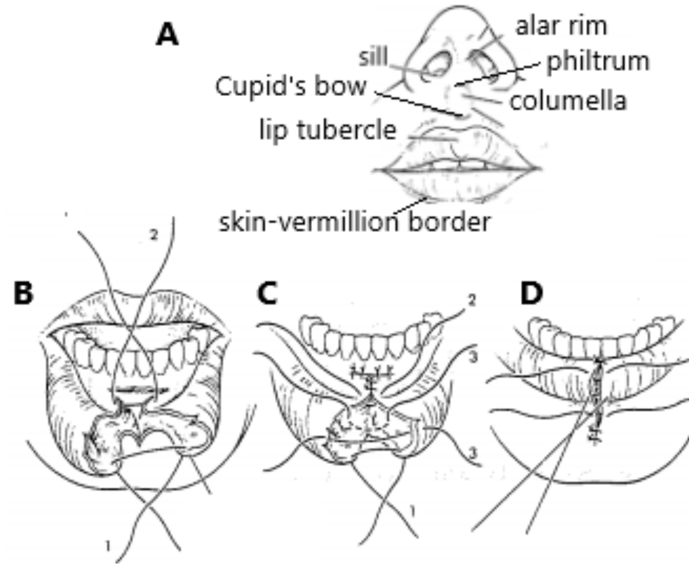


Fig. 53-16 ANATOMY OF THE LIPS & THEIR REPAIR, A, the anatomy of the lips. B, Place the 1st suture carefully at the skin-vermillion border, & the 2nd at the labial sulcus. C, approximate the *orbicularis oris muscle* 3rd. D, finally close the mucosal surface.

V-SWITCH LIP FLAP (GRADE 3.2)

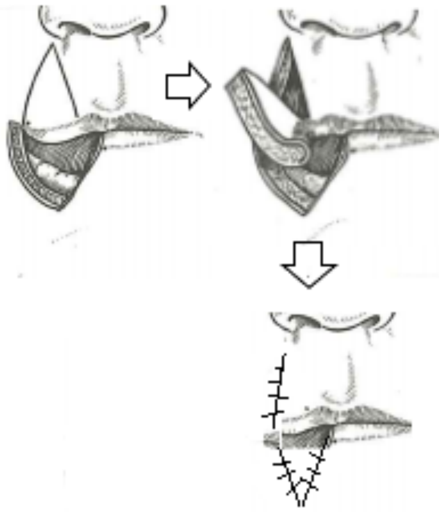


Fig. 53-17 SWITCH LIP FLAP USED TO CLOSE A DEFECT.
A, cut out the flap leaving it pedicled on the labial artery. B, swing it round to make the new angle of the mouth. C, close in layers.
McGregor IA. Fundamental Techniques of Plastic Surgery. Churchill Livingstone 7th ed. 1980

If there is a significant defect of the lower lip, *don't try to close it primarily*: it will produce an ugly appearance of the mouth. Mark out ½ of the equivalent portion on the upper lip, and cut it out carefully, leaving the base attached with its blood supply of the labial artery. Then swing this V-switch flap round to make a new angle of the mouth & close the defect (53-17)
N.B. Do this only as a delayed repair.

(b) Gums
If a laceration of a patient's gum retracts and exposes the alveolar margin, *don't leave it exposed*. If there is a big defect which you cannot close, advance a flap of mucosa to cover the gap.

(c) Tongue
Unless a laceration involves the edge of the tongue, makes a free flap, or is >2cm long, *don't suture it.* Otherwise repair it with buried long-acting absorbable. This may be possible under LA, but usually needs ketamine and suction, or if the wound is on the back or underside of the tongue, endotracheal intubation & GA.

If the anterior ⅔ of the tongue bleeds, hold it in a piece of gauze and pinch it between your finger and thumb posterior to the laceration. Put in a mouth gag and repair it with long-acting absorbable, if necessary in layers.

If the tip of the tongue is almost completely avulsed, re-attach it, as it will probably survive.

If the tongue laceration bleeds continuously, use LA with adrenaline, and place a figure-of-8 suture.

If the lingual frenulum is torn in a child, think of child abuse (47.3); it rarely needs repair.

(d) Cheek
Deep lacerations of the cheek may divide a branch of the facial nerve or the parotid duct, or both. Asymmetry in the smile will tell you that the facial nerve has been cut. Its temporal branch is the most important because it controls eyelid movement, and its division will expose the cornea. Division of its marginal mandibular branch will make the lip droop. The parotid gland and its duct lie more superficial than the facial nerve, and are more easily injured.

Repair the muscles of mastication and facial expression if these are lacerated with long-acting absorbable sutures.

Large defects of the cheek will need an advancement flap, but repair the mucosa in the mouth first, and then any laceration of the lip.

ANATOMY OF THE PAROTID GLAND & FACIAL NERVE

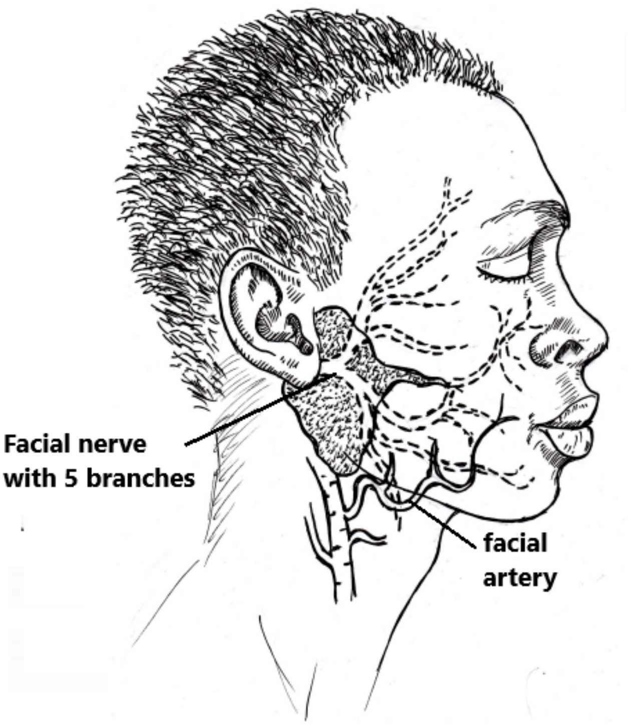


Fig. 53-18 ANATOMY OF THE PAROTID GLAND & FACIAL NERVE. The parotid gland lies anterior to the ear below a line between the tragus and the angle of the lips, The facial nerve is embedded inside the gland in the fascio-venous plane & has 5 main branches.

PAROTID GLAND INJURY
If fluid leaks from a posterior wound of the cheek, the parotid gland is injured. Suture the wound as usual. If a fistulous leak of saliva does develop, it will probably heal spontaneously within a few days, and almost always does so within a month.

PAROTID DUCT INJURY
However, an injury to the parotid duct will *not* close spontaneously. The duct runs under the middle ⅓ of a line from the tragus of the ear to the commissure of the lips. Press on the wound to see from where the saliva leaks.

Therefore, try to repair an injury to the duct with 6/0 non-absorbable over a stent (*e.g.* an 0 nylon suture) passed into the mouth. You can pass this from the laceration or from the mouth (opposite the crown of the 2nd upper molar tooth), whichever is easier. *This is not simple*, but easier if you pull the check outwards to straighten the duct. If this fails, you can re-implant the proximal end of the duct through a new opening into the mouth.

Both methods need the catheter to be kept in place for 1wk as a stent. If you tie the duct, the gland will swell painfully before shrinking from atrophy, but producing a dry uncomfortable mouth.

FACIAL NERVE INJURY

If the laceration is anterior to a line dropped vertically from the lateral canthus of the eye (53-16)**,** only the peripheral branches of the facial nerve can have been injured. Deformity will be minimal and repair impractical.

If major branches of the facial nerve have been cut posterior to this vertical line, explore the wound and try to repair the nerve (48.1)

NOSE GLABELLAR FLAP (GRADE 3.2)

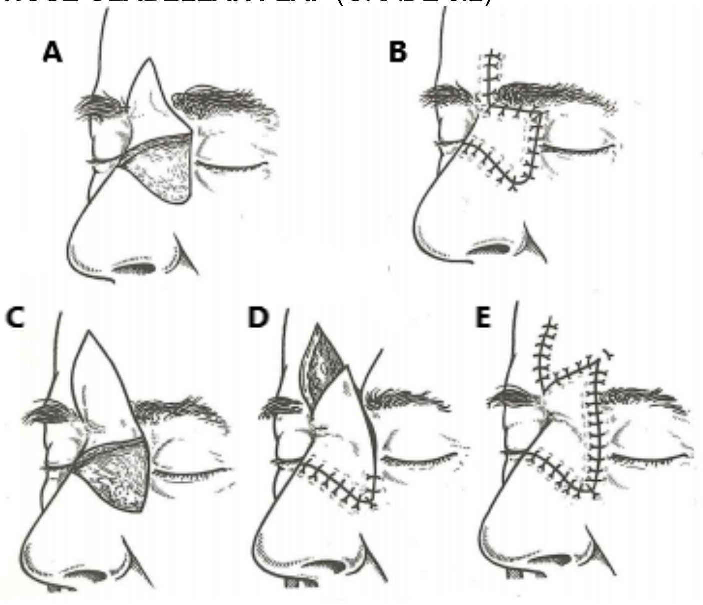


Fig. 53-19 NOSE GLABELLAR FLAP. A, mark out the advancement flap. B, primary closure. C, if the secondary defect is difficult to close, D, include a Z-plasty onto the advancement flap. E, the end result. *After McGregor IA. Fundamental Techniques of Plastic Surgery. Churchill Livingstone 7th ed. 1980*

(e) Nose
Align the edges of a laceration of the nose accurately, inserting the 1st suture at both edges.

If an injury penetrates all the layers, repair the mucous membrane first using 4/0 absorbable. Bring the nasal cartilages together, and hold them in place by suturing the skin with 5/0 monofilament.

If there is skin loss in the upper part of the nose, swing a rotation flap from the forehead, which you can usually close primarily (53-19)
Avoid leaving packs in the nasal passage unless they are needed for bleeding (53.4).

(f) Chin
If a submandibular gland is found injured by penetrating trauma, remove it to prevent a salivary fistula (17.4)

(g) Ear
In a major explosion, the ear frequently suffers ototrauma; together with vertigo, tinnitus, hearing loss, there is usually a perforated eardrum (46-48).
An injured pinna has curves in 3 dimensions and is difficult to repair. Lacerations are often jagged and skin or cartilage may be missing. Haematomas are frequent, and may become organized forming a 'cauliflower ear'. Exposed cartilage readily becomes infected causing major deformity. Secondary reconstruction is difficult and not readily available. Fortunately, the ear has a good blood supply, so flaps with even a short pedicle will survive.

Repair a laceration of the helix by inserting the 1st suture at the edge of the helix. This will avoid a ridge forming which can be very conspicuous when the wound has healed. Then align the antihelix.

In a full thickness injury, suture the perichondrium, and 5/0 monofilament for the cartilage. Pack the ear with moist cotton wool to maintain its shape, and bandage it firmly to prevent haematoma formation.

If a minor part of the pinna is missing, cut a V-segment out & suture the edges together in layers (53-20A,B). A defect of ≤⅓ will not be very noticeable.

If a major part of the pinna is missing, toilet the wound, and close it without the missing cartilage (53.20C,D)

If this leaves an ugly shape, disguise this by suturing the pinna back in 2 layers and enclose it in a postauricular skin pocket, or attach it to a postauricular advancement flap (53-20E-G).

If a haematoma forms, with or without a laceration, aspirate it and apply a pressure dressing. If it recurs following aspiration, incise it and insert a short rubber drain.

LACERATIONS OF THE PINNA (GRADE 2.1)

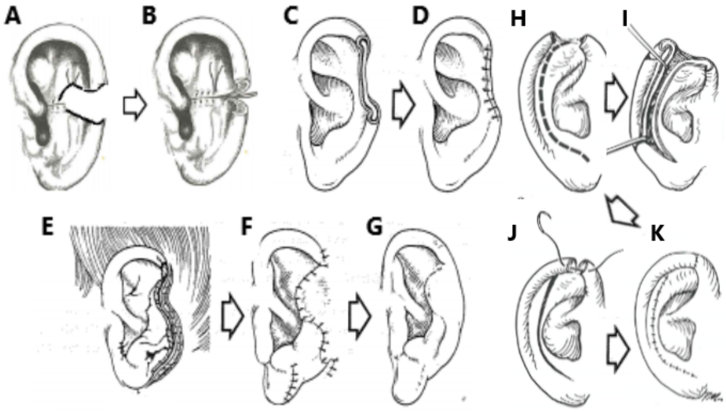


Fig. 53-20 WOUNDS OF THE PINNA. A, a segment missing. B, converted into a V-shape and sutured. C, the cartilage exposed. D, covered with skin brought from posteriorly. E, a large part missing, F, excised. G, sutured to postauricular skin. Alternatively, H,I, make an advancement flap by incising the helix. J,K, close the defect. *After London PS, A practical guide to the care of the injured, E&S Livingstone, Edinburgh 1967 with kind permission.*

Repair a laceration of the earlobe by placing your 1st suture at the most inferior portion, making sure the edges are carefully aligned.

Where a pulled earring has produced a defect, excise the wound edges and convert the rent into a neat V-shape, and suture this as before.

N.B. You can salvage the old earring piercing hole by leaving a 2/0 suture thread along it for 4wks. *Don't allow re-piercing through the scar; delay re-piercing for 3months.*

54 Spinal injury

54.1 Introduction

The spine is protection for the all-important spinal cord, and the nerves arising from it. Your main responsibility is:
(1) *Not to make patients with spinal injuries worse unnecessarily.*
(2) To recognize stable fractures of the cervical spine and immobilze them.
(3) To apply neck traction to the occasional patient who has an unstable cervical spine fracture, without neurological deficit.
(4) To give good treatment for all injuries of the thoracic and lumbar spine.
(5) To care assiduously for paraplegics.

Unfortunately, there is little you or anyone else can do for a totally quadriplegic patient to recover neurologic function (54.13). Operations on spinal injuries are not indicated in a district hospital, and for only a few in a referral hospital. *Any manipulation of the spine, whether under GA or not, is very dangerous, even in the hands of experts.*
A common error is to fail to fit a collar when needed.

The only special equipment you need are Gardner Wells tongs, or Hoen's traction using a brace and burrs.
These expensive tongs are the most practical way of applying traction to an unstable cervical spine fracture. The alternative, Crutchfield tongs are less satisfactory, but are easy to apply and will hold for about 6wks.
Alternatively, you can make a halo (54-12). It is best if these halos are made centrally and distributed to district hospitals so that you have one when you need it, as there will not be time to make one in an emergency.

54.2 Syndromes of spinal injury

The spinal cord, the soft tissues, and the bones of the may all be damaged by compression, shearing, or hinge forces, as well as by missiles. Occasionally, in a hyperextension injury, the vertebrae subluxate momentarily and then return to their normal position, so that a severe cord lesion may be combined with a normal radiographic appearance, especially in the neck.
The opposite is also true, and a gross spinal bony injury may leave the spinal cord intact.
Fortunately, most spinal injuries don't damage the spinal cord.

If the cord is affected, this dominates the treatment, and prognosis.

A spinal injury may be stable or unstable. In the latter, the spine cannot sufficiently protect the cord from bony or ligamentous displacement that arises in normal movement.

Act safely and assume that: (1) any spinal injury is unstable, until proved otherwise, and (2) make sure that a patient is moved only by keeping the spine rigid. *This is of the utmost importance!*

N.B. Many a vehicle accident victim with an intact spinal cord has been pulled out of a wreck carelessly (without protecting the spine) and made para- or quadri-plegic! Any wrong movement might prevent the recovery that would otherwise have followed!

ALL SPINAL INJURIES ARE UNSTABLE UNTIL PROVED OTHERWISE

REMOVING A HELMET

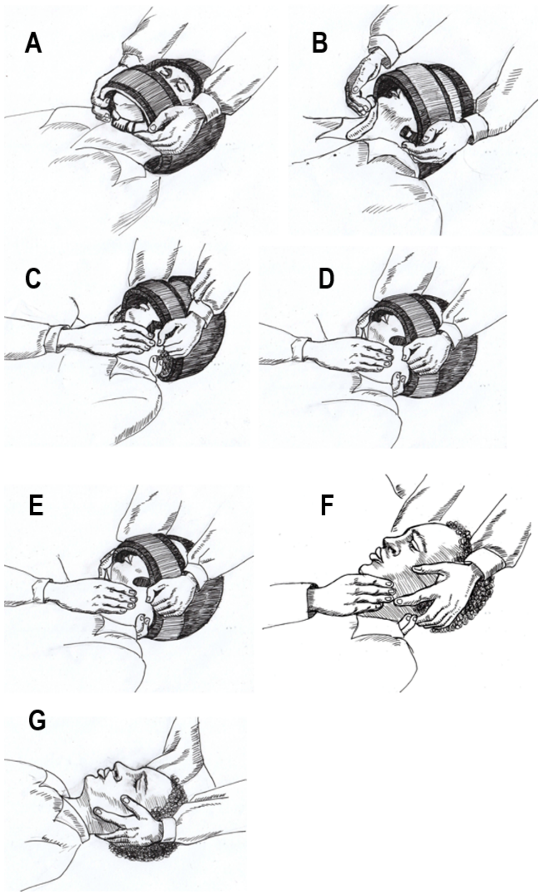


Fig. 54-1 REMOVING A HELMET. ***If you don't do this properly, you can aggravate a cervical spine injury after a motorcycle accident.*** **Find an assistant. A, apply traction in the line of the cervical spine. B, loosen the straps while maintaining traction. C, ask an assistant to hold the neck and exert traction. D, remove the helmet. (It is egg shaped, so expand it to clear the ears). E, get your assistant to keep the head still. F, take over traction from your assistant. G, continue to exert traction until you can support the head properly (54-5).**
Kindly contributed by Nancy Caroline.

Serious spinal injuries can harm: (1) the spinal cord tissue, (2) the tracts within it, & (3) the nerve roots. Some or all of these can be injured, either completely or partly, at any level.
The critical diagnostic steps are: (1) to find the sensory level (to pinprick) and the motor level, (2) to find the bony level of the damage, and then (3) to compare these.

If the bony level is below the sensory level, look more superiorly. You have probably missed a 2nd injury there.

Later, reflex activity of the bladder and bowel reflexes return. The knee & ankle jerks recover and then become exaggerated; the muscles become spastic.
If bladder or bowel reflexes return without any sensation or motor power, this is an almost certain sign that the cord injury is complete.

INJURIES ABOVE C3
These injuries paralyse all respiratory muscles (inytercostals & diaphragm) completely and often result in death before admission to hospital. There is also quadriplegia.

THE DERMATOMES

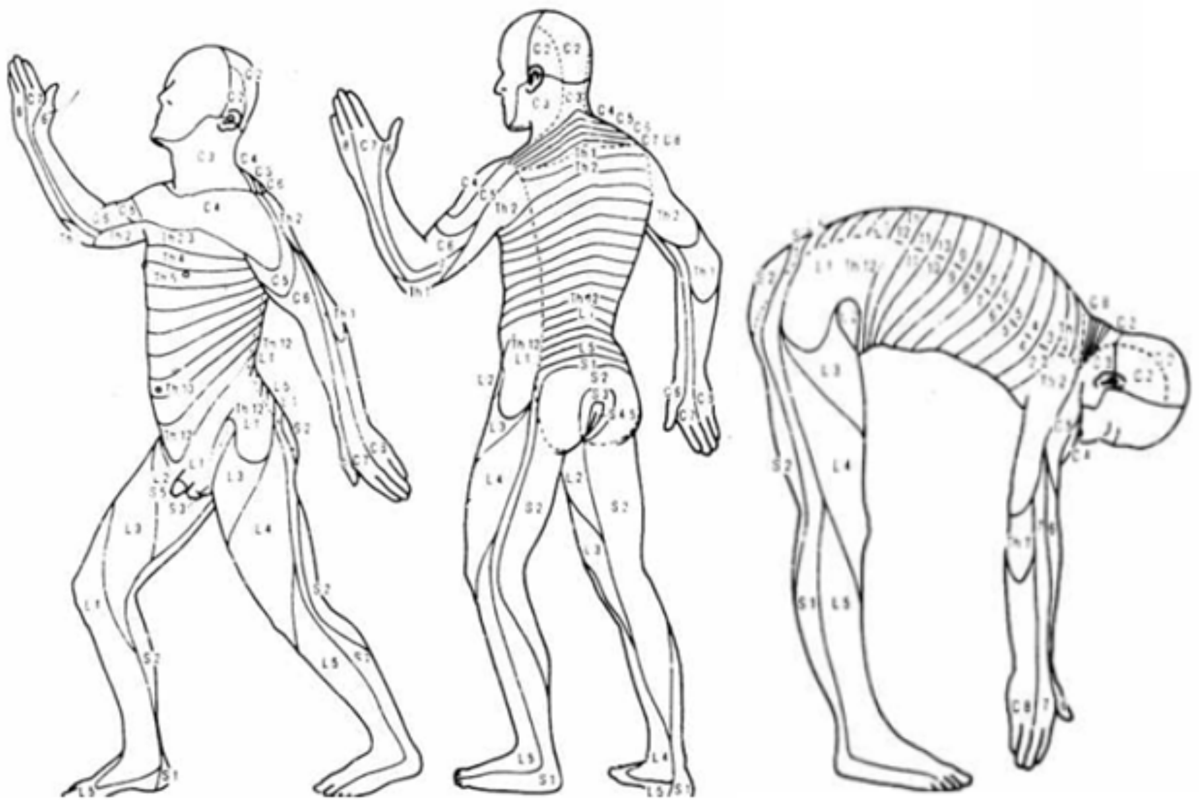


Fig. 54-2 THE DERMATATOMES. In a paraplegic, test the sensation with a pin from below upwards and use this chart to find the neurological level of the lesion. *After Netter FH, CIBA collection of medical illustrations. with kind permission.*

The further inferior an injury is the better the chances for walking, but the worse the outlook for bladder control.

A complete cord injury remains so. There is immediate flaccid paralysis in the lower part of the body, with no sensation whatsoever.

If the anal or penile reflexes remain despite para- or quadriplegia, it is further indication that the cord transection is complete and recovery is unlikely.

INJURIES ABOVE C5
Lesions above C5 cause quadriplegia. Below, it causes quadriparesis. A common site of injury is at C5–C6. This paralyses the hands, the intercostal muscles, and partly paralyses the diaphragm.

INJURIES ABOVE T10
Here, the important injury is the complete or incomplete division of the tracts within the spinal cord, destroying sensation and causing an upper motor type of paralysis.
Great force is needed to fracture the thoracic spine, so that the cord inside it is either normal, or completely transected.

INJURIES AT T10-L1 (54-3)
These are more often incomplete, and some sensation and muscular power usually returns slowly over many months.
An adult's first lumbar segment is at the level of the 10th thoracic vertebra, and the end of the cord is at the lower border of the 1st lumbar vertebra. Trauma here can injure the nerve cells of the lumbar enlargement or the nerve roots of the cauda equina, or both. A severe fracture with marked displacement will sever the conus and the spinal nerve roots down to T10, so that the fracture and dermatome levels are not the same.

LEVELS OF SPINAL INJURY

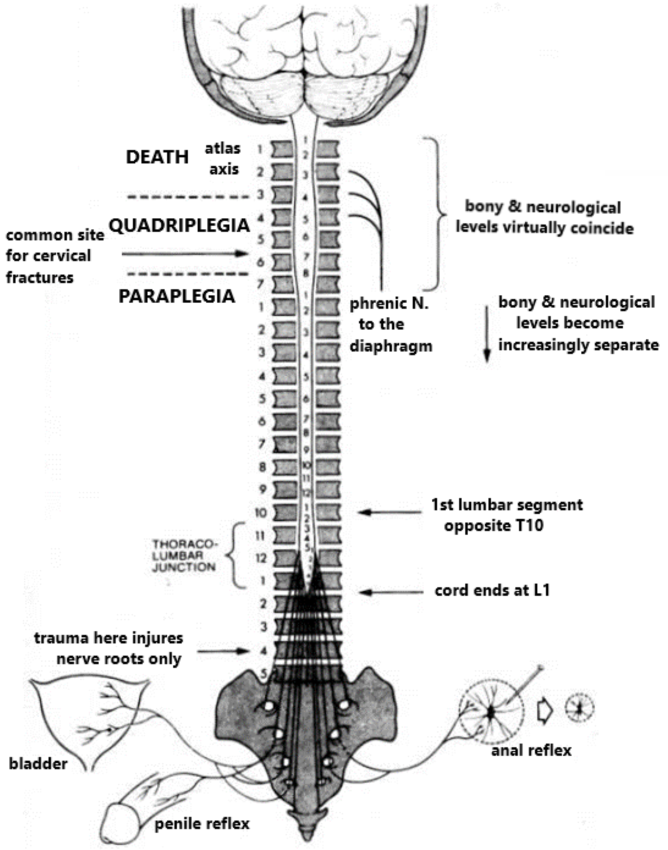


Fig. 54-3 LEVELS OF SPINAL INJURY. Note that the cord ends opposite the T12–L1 vertebrae. A fracture dislocation here causes a neurological lesion at this level—unless some roots escape injury.

DOES THE PATIENT HAVE MORE THAN ONE SPINAL INJURY?

Occasionally (especially at T12–L1) the nerve roots escape and only the conus is injured (known as 'root escape'). This makes the lower sacral segments anaesthetic (saddle anaesthesia) and destroys the central bladder reflex. It may however spare just enough of the nerve roots supplying the legs to allow walking. Pain suggests a root rather than a cord injury.

INJURIES BELOW L1
Trauma here may only injure the lumbar and sacral nerve roots of the cauda equina. If they have only been bruised they recover slowly, and the prognosis is good.

If the roots have been divided, they isolate the bladder from the reflex centre in the cord and bladder control is less satisfactory than it would be if the cord had been severed higher up.

The paralysed legs remain permanently flaccid.

54.3 Caring for a spinal injury

Spinal injuries are often missed for 2 reasons:
(1) An injured patient may be unable to say that he has lost the feeling in part of the body. The other injuries may be so much more visible than the fractured spine that, unless you routinely exclude a spinal injury in all severely injured patients, you will easily miss one.
A routine check is very quick: check movement of the legs? If you pinch one, does it move?
If there is no movement of the arms nor legs, the cord is almost certainly injured.
(2) *A patient with an unstable injury of the cervical spine may walk into hospital after a seemingly minor injury*.
Immediately fit him with a soft collar and X–ray the neck. There may only be a minor soft tissue injury, or there may be an unstable fracture in danger of causing instant paralysis.

A spinal injury is terrifying for a patient because he may be completely paralysed and yet fully conscious. The prognosis and management are determined by the following facts:

(1) **If the injury is severe enough to cause immediate total paraplegia, or quadriplegia**, the spinal cord is almost certainly damaged beyond repair, and no treatment, surgical or otherwise, is going to make it recover.
(2) **If any function remains immediately after the injury**, the prognosis is completely unpredictable. There may be substantial recovery or none at all. So you must test if any function still remains.
(3) **If there are signs of recovery during the 1st few days**, the outlook is much better. The earlier and the more rapid the early recovery is, the more hope there is.

REFERRAL
Compare the care you can give with that likely in the referral hospital (1.8). Your care may be better: there is much greater need of devoted nursing than skilled surgery.

There is seldom any advantage in referring a patient with a serious spinal injury immediately, because you can probably do as much for him, or more, than a referral hospital. Injured nerve cells cannot regenerate, so there is little to be gained by trying to decompress the spine in the hope that they will regenerate. Immediate laminectomy may do more harm than good. Some weeks later an operation to fuse an unstable spine may occasionally be useful.
The only procedure that is practical in the acute phase is cervical traction. Although this needs only simple equipment, it needs great skill.

MOVING A PATIENT WITH A SUSPECTED SPINAL INJURY

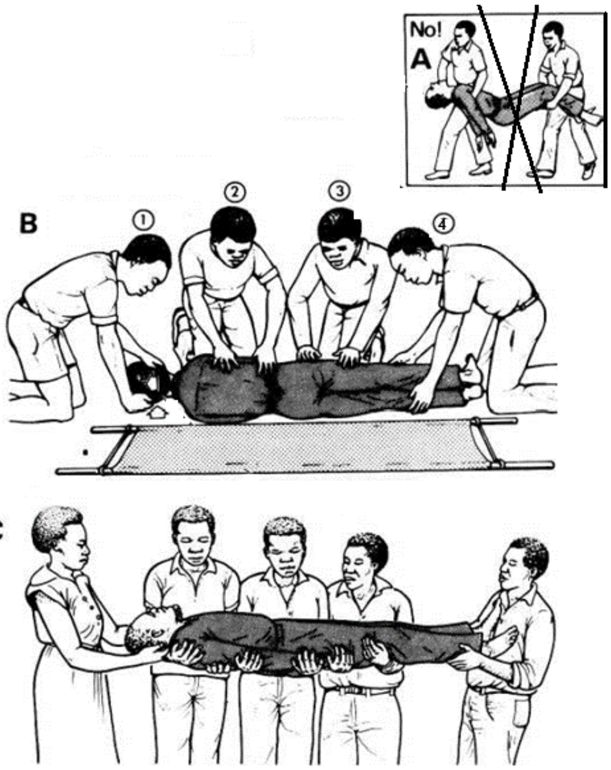


Fig. 54-4 MOVING A PATIENT WITH A SUSPECTED SPINAL INJURY. A, *If you move a patient with a spinal injury incorrectly, you may convert a partial transection into a total one.* B, note the number of people needed; exert gentle traction to the head while carrying the patient. *It would be better for a cervical collar to be applied.* C, Lifing the patient like a log; *better to log-roll him onto a board.* Kindly contributed by James Cairns.

N.B. Familiarize yourself with management of a severely injured patient (41.2,3)

MOVING AND UNDRESSING A PATIENT
To move or turn a spine injury patient you need 4 helpers. Move the whole body as a log. Minimize any movement of the spine, especially the neck. It is best to 'log roll' the patient from the ground onto a firm stretcher, or stretched blanket (54-4).

Fit a firm neck collar in place: You can improvise one with a rolled towel & safety pins (54-5C). *Do this before moving him!*
If you suspect that a neck injury, place one hand under the chin and the other under the occiput (54-5A), exert gentle traction on the neck, and lift and turn the head whilst the others turn the body: *don't let the head drop to one side.*

N.B. Holding the head is the task for the most skilled person in the team.
Steady the head with sandbags at its side, and a small roll under the neck (54-5B)

SUPPORTING AN INJURED CERVICAL SPINE

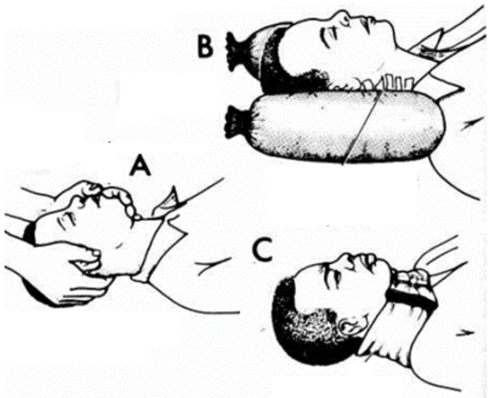


Fig. 54-5 SUPPORTING AN INJURED CERVICAL SPINE. A, holding the head is the task for the most skilled person in the team: one hand behind the neck and one on the chin. B, after rolling the patient onto theback, wedge the head between 2 sandbags. C, then fit a collar (improvised if necessary). *After de Palma AF, Management of Fractures & Dislocations, An Atlas, WB Saunders 1970 with kind permission.*

If you suspect a thoracic or lumbar spine injury, transport the patient prone with a pillow under the shoulders and pelvis to hyperextend the spine at the site of the injury, unless there are multiple injuries or the airway is in doubt. If so, retain the supine position.

HISTORY AND EXAMINATION
Leave the patient on the stretcher until you have examined him. Enquire carefully about the circumstances of the accident. This will tell you what type of injury to suspect. If conscious, ask where the pain is. A patient may be able to indicate that the body feels dead below a certain level. Signs of injury on the face and skull may help you to decide the kind of force responsible.

Look for:
(1) Bruising, swelling, tenderness,
(2) A disruption in the line of vertebral spines,
(3) Any soft 'doughy' areas,
(4) Movement in the legs,
(5) Sensory loss on pinching.

DON'T FORGET TO EXAMINE THE BACK

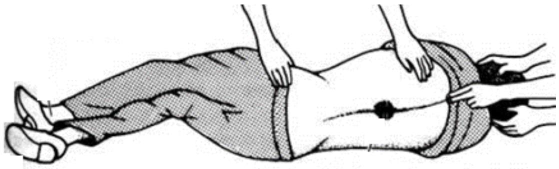


Fig. 54-6 EXAMINING A SPINAL INJURY Feel for any local bruising, swelling, or tenderness along the spine. Examine the spinous processes systematically from neck to sacrum. Look for a disruption in the line of the spine. Feel for any soft 'doughy' areas. Test for movement & sensation in the feet. *Kindly contributed by Ronald Huckstep.*

Examine the spine: carefully slide your hand underneath the back, or, better turn him as a log with assistants (54-4A).

If the patient vomits and you need to turn him on your own, cross the right leg over the left, flex the left elbow to put the hand under the head, & then then take the right shoulder and right hip and turn him gently towards you.

Feel for any local bruising, swelling, and tenderness along the spine. Examine the spinous processes systematically from the neck to the sacrum. Look for any disruption in the line. Feel for any soft 'doughy' areas between the spinous processes into which your fingers can sink. You may feel a palpable gap. These last two signs indicate an unstable fracture.

CAUTION! Don't test the movements of the spine!

Then make a directed neurological examination. This has 2 stages and if there is an associated head injury, interpreting either may be difficult.
Make a rapid test to check movement of equal strength in the legs, and reaction to pinching the skin.

If you suspect a spinal injury, test the sensation on the trunk with a pin, starting from below and working upwards. Find the sensory level, using the dermatome chart (54-3). Is there any recognition of foot or knee movement? Test the knee and ankle reflexes and the plantar responses. Prick the para-anal skin with a pin to test the anal reflex, which in the presence of paraparesis indicates 'sacral sparing'.

If there is severe continuous pain radiating from the neck to both occipital regions, suspect a fracture dislocation of the atlas on the axis.

N.B. Dislocations from C3-C5 cause quadriplegia. A C5-C6 dislocation produces a weak or paralyzed biceps. In a C6-C7 dislocation, the biceps is normal.

In dislocations above T1, Horner's syndrome (ptosis, a constricted pupil, anhydrosis on the affected side of the face, and enophthalmos) may be present.

N.B. Lumbar nerve roots supply**:**
(1) leg sensation except the sacral segments,
(2) hip & knee muscles,
(3) cremasteric, knee & ankle reflexes,
Sacral nerve roots supply:
(1) saddle sensation & a strip down the back of the leg and thigh,
(2) ankle & foot muscles,
(3) ankle, plantar, anal, cremasteric & penile reflexes, (squeezing on the glans causes the *bulbocavernosus* to react)
(4) bladder control.

LUMBAR OR SACRAL PAIN SUGGESTS ROOT RATHER THAN A CORD INJURY

RADIOGRAPHS
Don't ask for an immediate image. Find the level of the neurological lesion first. It is possible to have leg problems but have an upper thoracic fracture! Examine the spine with care before deciding which part to X–ray. It is good policy to X–ray the entire spine routinely, if you have enough film, because fractures are often multiple. Position the patient onto an X–ray table yourself.

DECIDE IF THE FRACTURE IS UNSTABLE

N.B. 30% of patients have other severe injuries, particularly of the head (51.1) and abdomen (55.1), so look for them: this is critically important.

IMMEDIATE PROGNOSIS
If a patient is paralysed with a sharp line of anaesthesia, no reflexes, and no bladder control, with anal and penile reflexes present, the cord is probably transected completely.
Priapism (persistent painful erection of the penis) is another bad sign.

Firmly hyperextend the big toe. Test sensation in the toes, heels & perineum with a pin. If this is present despite paralysis, the cord function will recover.

24h PROGNOSIS
If at this time, there is still no perianal sensation, no voluntary control of the toe flexors, or anal sphincters, there is a 90% chance of having a permanent paralysis. If any responses are spared, or there is improvement in the first 48h, significant recovery is possible. But if there is no sign of improvement at 4 wks, (unless there is an overriding head injury) further recovery is very unlikely.

IMMEDIATE TREATMENT OF THE FRACTURED SPINE

(a) Cervical spine
Indications for neck traction:
(1) any unstable fracture or any dislocation,
(2) incomplete paralysis whatever the radiographic findings.

(b) Lumbar and sacral spine
Lie the patient in the most comfortable position.

INITIAL TREATMENT OF PARAPLEGIA & QUADRIPLEGIA

Immediately start 2hrly turning to prevent bed sores. These can develop in the 1st few hours after the accident only too easily. *Don't let the bladder fill up*; start intermittent sterile catheterization, if you have the staff and committment to manage it (64.16).

For a quadriplegic, also pass a nasogastric tube to prevent aspiration. Supplement IV fluids to counter sympathetic vasodilation from transection of the cord. Watch for common abdominal distension and absent bowel sounds caused by ileus. On the 5th – 7th day administer an enema, or manually remove faeces.

A NORMAL NECK

N.B. Transporting a cervical spine injury patient is never easy, eve by air. If the roads are bad, the journey long, and the quality of care at the other end uncertain, the patient will probably be better off with you, especially in the earlier stages. For transport, you need a rigid well-fitting cervical collar to travel as well and ensure that *the neck must be kept straight, and not flexed, extended, or rotated*.

NORMAL CERVICAL VERTEBRA

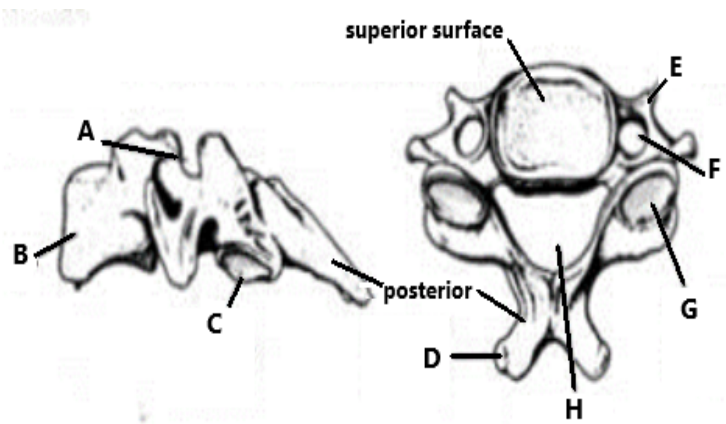


Fig. 54-8 NORMAL ANATOMY OF A CERVICAL VERTEBRA. A, superior vertebral notch. B, vertebral body. C, inferior articular surface. D, spinous process. E, anterior tubercle. F, *foramen transversum* (for the vertebral artery). G, superior articular facet. H, vertebral foramen- *Kindly contributed by John Stewart & James Cairns.*

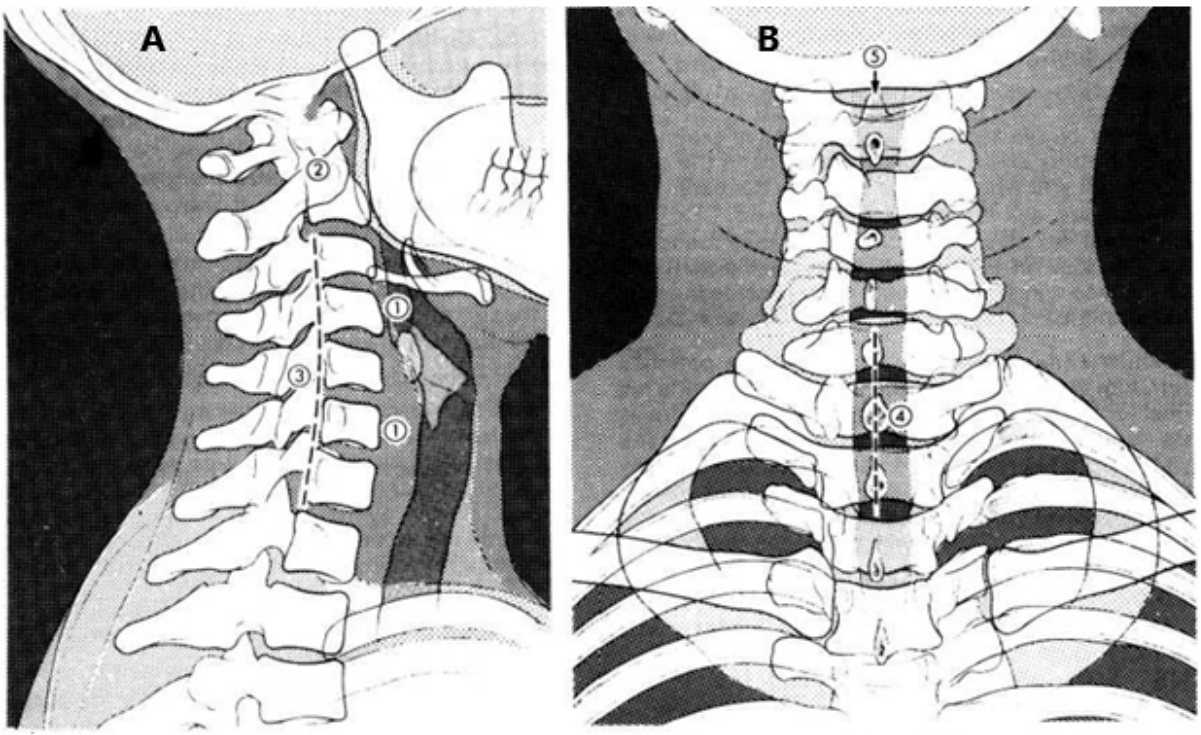


Fig. 54-7 A NORMAL CERVICAL SPINE. A, lateral view: (1) the normal soft tissue shadow in front of the cervical vertebrae. (2), the relation of the odontoid process to the rest of C2. (3), the posterior margins of the vertebral bodies form a smooth curve. B, AP view: (4), the spinous processes are in line. (5), the normal odontoid. *Kindly contributed by John Stewart.*

54.4 Interpreting the radiographs

You must decide if a neck injury is stable or not.
(1) Dislocations are always considered unstable, as are bending or twisting injuries of the posterior elements of the spine, which are what makes these injuries unstable. These include its pedicles, laminae, facets, and ligaments.
(2) Compression injuries of a vertebral body are usually stable. In a flexion injury, the posterior ligament is particularly liable to be ruptured, and in an extension injury, the anterior ligament.

Both types of injury can damage the intervertebral discs.
Radiographs should be good; those from a portable machine are usually useless. Even radiologists have difficulty interpreting radiographs of the spine, so you will probably have difficulty too.
The standard views in acute injuries are AP and lateral with the head in its normal position.

Finally, remember that a normal radiopgraph does not necessarily mean a normal spine.
N.B. Beware of any careless spinal movement & supervise the Xray assistant yourself!

Take one good AP view and two lateral views with the patient lying, one lateral view centred over the vertebral bodies at the site of maximal pain and tenderness, and another over the spinous processes at this level. Also take an open mouth (odontoid peg) view.

You must see the whole cervical spine, so make sure you pull the shoulders well down. Examine the vertebral bodies from top to bottom: they should have a normal box-like appearance.

Lesions at C6–C7 & C7–T1 are often missed. *Don't try to take oblique views*; they are difficult to take and interpret. If possible, take a 'swimmers (supine oblique) view'; this requires considerable experience and ability.

Count the vertebrae in the lateral view to make sure that you have not missed C7. If necessary, take another view with downward traction to the arms. You should see C7 and perhaps the upper border of T1. As always with difficult films, sit down and look at them on a viewing box, or with an electric light bulb, while you have no other distractions. Start at the extreme edges of the film, and work in towards the middle. It is quite common for the injury to be at the edge of the film.

UNSTABLE CERVICAL SPINE INJURY
In the AP view, look for:
(1) Displaced vertebral bodies (54-9A)
(2) Spinous processes out of line (54-9B)
(3) Pedicles on either side of the spinal canal displaced laterally out of the line, compared with those above or below (54-9C)
In the lateral view, look for:
(1) A multifragmented 'burst' fracture of the vertebral body (54-9D),
(2) Vertebral body slipped forward (54-9E),
(3) Unequal gaps between vertebral spines (54-9F),
(4) Bases of spinous processes broken (54-9G),
(5) Fractured articular facets (54-9H)
(6) An abrupt change in the smoothness of the spinal curvature (54-14A)
(7) An enlarged space between the back of the pharynx & front of the vertebral bodies (54-8A)

UNSTABLE SPINAL FRACTURES

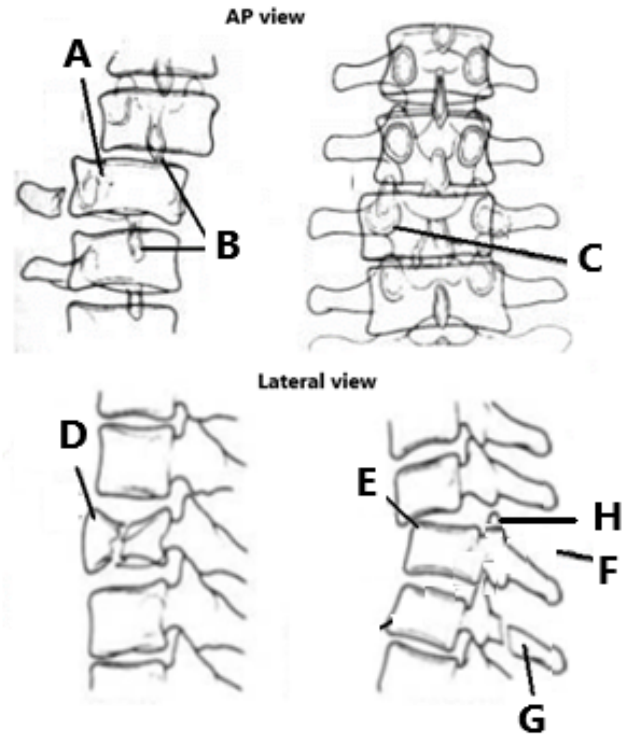


Fig. 54-9 UNSTABLE SPINAL FRACTURES. A, vertebral bodies displaced. B, spinous processes out of line. (A rotational injury can twist them out of line, especially in the cervical spine, even though the vertebral bodies themselves are still in line. C, Both pedicles displaced. *(They are either both broken or not at all!)*. D, a burst fracture. E, one vertebra slipped forward, F, with unequal spaces between vertebral spines or, G, spinous processes broken at their base. (Usually with a ruptured posterior longitudinal ligament, perhaps with dislocation of the articular facets, or with fractures of the laminae and pedicles. The posterior intervertebral joints may have subluxed or dislocated on one or both sides. If displacement =$^1/_2$x the vertebral body, one intervertebral joint has probably dislocated. This is seriously unstable, especially in the cervical spine.) H, fractured articular facets. *Kindly contributed by John Stewart & James Cairns.*

STABLE SPINAL FRACTURES

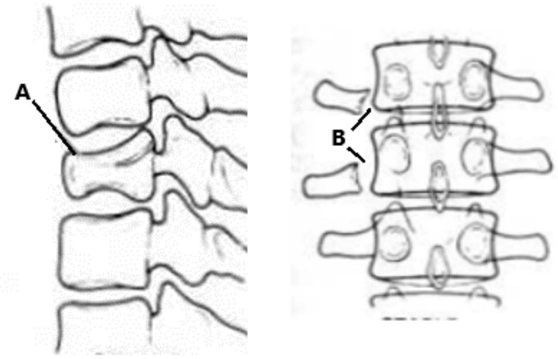


Fig. 54-10 STABLE SPINAL FRACTURES A, wedge fracture. B, transverse process fracture. *Kindly contributed by John Stewart & James Cairns.*

If the vertebral body is wedge shaped, this is a compression fracture, which is usually stable (54-10A).

Broken transverse processes of the lumbar vertebrae make no difference to the spine (54-10B), but suggest possible retroperitoneal injury, especially of the kidneys (55.15).
Fractures of the spinous and transverse processes are unimportant: they imply muscle injuries.

Look carefully at the base of the patient's odontoid, and at the arch of the atlas.

If you suspect a cord injury clinically but cannot see one in the films taken, take more films higher up the spine.

A NORMAL RADIOGRAPH DOES NOT NECESSARILY MEAN A STABLE SPINE

54.5 Management of cervical spine injury

UNSTABLE FRACTURE
You should treat all cervical injuries as unstable if:
(1) the radiological signs (54-9) are suspect,
(2) there are neurological signs (the only exception is an acute extension injury (54.8).
(3) there are signs of instability on clinical examination, such as:
(a) disruption of the smooth line of spinous processes from the neck to the sacrum,
(b) any soft doughy areas between the spinous processes into which your finger can sink. (This implies that the strong ligaments between the vertebral spines are ruptured.)
.
If there are (rarely) no neurological signs, put on a plaster neck cuirasse (54-11). Continue to monitor their neurological signs, as any slight cervical movement may be catastrophic. At the slightest evidence of a deficit, apply traction.

If there are neurological signs, the injury is unstable, even if radiographs look normal. Apply traction, even if you are uncertain about the instability.

If quadriplegia is complete, apply traction for 7days only. There is no point in continuing beyond then because it will make nursing care more difficult.
N.B. Complete or partial recovery is more likely with cervical than with thoraco–lumbar injuries.

If there is a burst fracture & no neurological signs, apply traction for 6wks, followed by a collar for 12wks.

STABLE FRACTURE
These are generally wedge or transverse process fractures.

If there is pain but no neurological signs, fit a firm neck collar.

If there is an extension injury, with injury of the anterior longitudinal ligament, fit a collar for 2-3 months.

If there is no other reason for bed rest, encourage mobilization with the collar.

54.6 Neck collars & traction

An ambulant patient with an unstable or doubtfully stable cervical fracture needs protection against sudden sharp movements which might injure the cord. The choice is a collar or plaster neck cuirasse (54-11).

The rigid collar is a neck brace, which ideally immobilizes from the sternum to occiput and mandible.
N.B. A soft collar is inadequate!
You can distract an unstable cervical fracture satisfactorily with Crutchfield or Gardner Wells tongs.

N.B. A halo, which you can make locally, has a big problem in that it tends to slip off the head. A halter (effectively a strap round the chin and back of the head*) is useful for temporary use only. There is not enough traction to reduce a dislocation, and it becomes very uncomfortable after a short while. If you apply too much traction with a halter for too long, it can cause pressure sores.*

Traction is pointless for complete quadriplegia.
CUIRASSE

Apply a layer of stockinette and pad the bony points over the lower jaw, occiput, and clavicle. Apply a broad slab down the front of the neck from the chin to the upper sternum, and another down the back of the neck. Bind these slabs in place with circular plaster bandages. Let the cuirasse set with the chin up (54-11). Finally trim it to shape, turn over the edges of the stockinette and bind them in place.

A PLASTER NECK CUIRASSE

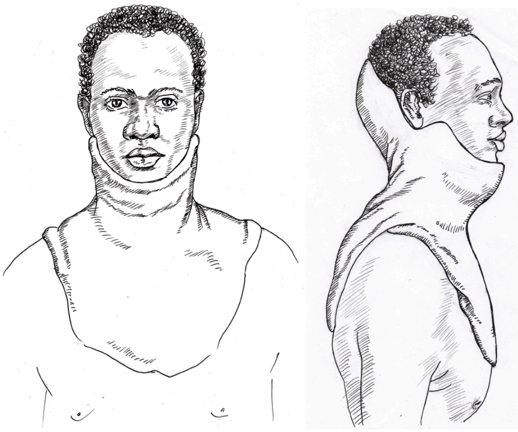


Fig. 54-11 A PLASTER NECK CUIRASSE.
Kindly contributed by John Stewart.

N.B. A Minerva cast (plaster down to the waist) has no real advantage over a neck cuirasse, and is far too hot to wear & a problem if there is cutaneous sensory loss.

SKELETAL NECK TRACTION
Use tongs for successful cervical traction.

Good nursing care is vital for successful cervical traction!

Apply only just enough weight to reduce the displacement. If you apply too much too suddenly, you may increase the soft tissue injury, and harm the cord.

CAUTION! (1) Monitor the neurological state carefully. (2) *Never apply more traction than the maximum indicated*. (3) If at any time there is deterioration in the neurological state, reduce the traction immediately. (4) If you are in doubt as to what to do, be safe and reduce the traction or take it down.

Apply traction on a bed with boards covered with ≥10 cm of foam rubber, and large castors. You should be able to adjust the height of the pulley vertically.

CAUTION! Don't use traction unless you are able to take bedside radiographs!

By applying traction, you aim to draw the cervical fragments apart with steadily increasing traction over some hrs, then to maintain traction with a smaller weight for several wks.

Then protect the neck within a firm collar or cuirasse for 8-12wks, for the spine to stabilize.

CERVICAL TRACTION WITH TONGS

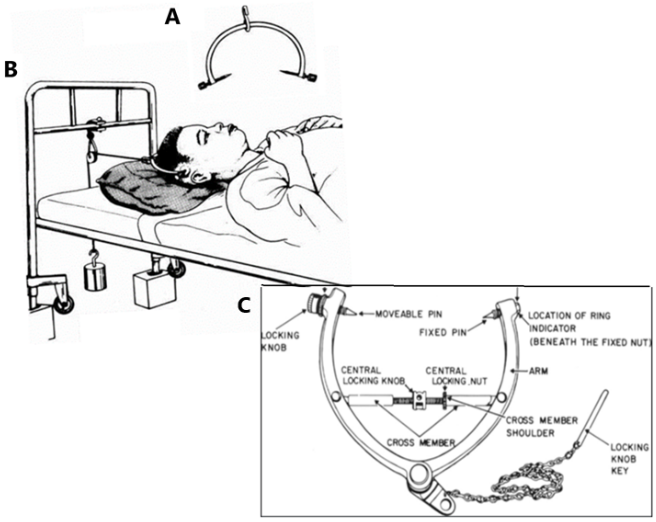


Fig. 54-12 CERVICAL TRACTION WITH TONGS. A, the Gardner Wells tongs. B, Crutchfield tongs C, for a fracture dislocation, apply only just enough weight to reduce the displacement. Note the blocks to raise the head of the bed. *After de Palma AF, Management of Fractures & Dislocations, An Atlas, WB Saunders 1970 with kind permission. B, After Rinnel RW, Butler AB, Wilson HR et al. Modified skull tongs for cervical travtion. J Neurosurg 1981; 55(5): 848-9.*

APPLYING GARDNER WELLS TONGS FOR CERVICAL TRACTION (GRADE 2.3)

METHOD
Sedate the patient with diazepam. *Don't use GA.* Fit the tongs on the ward. *Don't shave the scalp.*

Disinfect the skin. Introduce some LA 2cm above the ears in the line of the mastoid processes, just caudal to its maximum diameter, right down to the periosteum.

Disinfect the points of the screws. One screw is spring loaded, so that as the tension is increased a small nipple protrudes. Twist the screws so that their points go through the anaesthetized skin, & grip the outer table of the skull. Tighten them until the small nipple in one of the screws protrudes 1mm, then tighten the locking nut.

HOW MUCH TRACTION?
This depends on the build of the patient, the position oft he injury and whether you are reducing a dislocation or maintaining traction:

C1	C2	C3	C4	C5-7
2.5-5kg	3-5kg	4-7kg	5-10kg	7-15kg

Apply the weights over a pulley. Raise the head of the bed c.4cm/kg.

Apply traction in a straight line, avoid flexion, extension or, rotation. For a C4/5 lesion, *e.g.,* start with 7kg. Cautiously add 2kg every 15mins, checking constantly for neurological changes. When you have applied 15kg for 30 mins, get a radiograph.

REDUCING A FRACTURE DISLOCATION

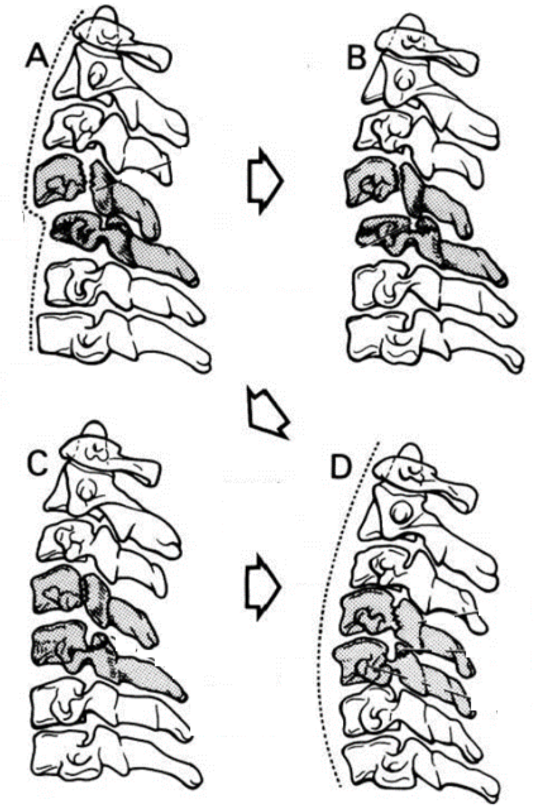


Fig. 54-14 REDUCING A FRACTURE DISLOCATION. A, before applying traction: the anterior curve is kinked. B, disengagement starting. C, disengagement complete. D, the smooth anterior spinal restored. *N.B. Unfortunately, reduction is rarely as easy as it looks here, and often fails.* *After de Palma AF, Management of Fractures & Dislocations, An Atlas, WB Saunders 1970 with kind permission.*

The facets may begin to disengage (54-14B), but you may have to wait longer.

If there is no disengagement, leave the 15kg traction for a maximum of 48h, taking radiographs at 6, 12, 24h.
As soon as the articular processes are completely disengaged, the overriding is corrected, and the distance between the fragments of the pedicles is narrowed, reduce the weights, keeping the neck in a straight line. Usually, the facets will come into line.

At 2-3wks, you can reduce traction to 3-5kg. Get weekly lateral check radiographs for the first month, or after altering the weights.
At 6wks, replace traction by a cuirasse or a collar (54.6).
Leave this on for another 6wks. Then remove the cuirasse or collar. Get AP & lateral radiographs.

NURSING
Turn the patient 2hrly: left side, supine, right side. Alternate periods in which turning is completely left & right with periods in which turning is partly left & right. Take great care to move the head 'in one piece' with the rest of the body. You will need 3 nurses while you do this, with you to look after the head and neck.
At 6wks, when you replace traction with a cervical collar, add the prone position during turning. Rub the pressure areas 2hrly.

If the vertebrae show no signs of slipping in normal or in flexion or extension views, advise a gradual increase in the movements of the neck but to avoid sudden movements, & to restrict outdoor activities.

If the neck is still painful & unstable after 12wks, (i.e 6 in traction & 6 in a collar or cuirasse), cervical spine fusion may be needed.

If the injury is mainly bony, the fragments will eventually fuse and the injury will become stable.

If the injury is mainly ligamentous, you may not achieve stable union. A collar is necessary for up to a year in case late displacement occurs.

DIFFICULTIES WITH CERVICAL TRACTION

If you have made the diagnosis late, the fracture may not be stable. Fit a collar for 12wks. *If this does not relieve symptoms in 2wks*, apply traction for 2wks more and then replace the collar.

If a patient with a recent cervical injury has other serious injuries which make cervical traction impossible, fit a cervical collar.

If a fracture redisplaces, immediately when traction is reduced, or later, or if a dislocation of the articular facets recurs, reapply traction, especially if nerve root symptoms recur. Apply more weight (≤17kg). The danger of quadriplegia is great, so refer him if you can.

54.7 Atlas (C1) & axis (C2) fracture

Some injuries of of the 1st 2 cervical vertebrae are instantly fatal. If a patient survives, there is often a stiff painful neck following a head injury. The patient supports the head in the hands and has difficulty turning it, and may say the head feels wobbly. Although there may be no neurological symptoms, if the neck is jerked suddenly, there is danger of sudden paralysis. There may be a fracture of the atlas, or the odontoid process of the axis.

The atlas is seldom injured, except by impact on the top or back of the skull (*e.g.* in a fall, road accident or diving injury, or by a child against playground equipment), or in severe hyperextension. Analgesia is the only requirement, with immobilization in a soft collar and bed rest for comfort.

If there are neurological signs (*e.g.* Horner's syndrome or ataxia) a firm collar or even traction is better.

The odontoid process of the axis is its most vulnerable part, and is usually injured by a direct blow to the front of the skull, which hyperextens the neck, e.g. in a fall, or a head-on car crash. As the skull moves backwards, it carries the atlas and the odontoid process backwards also. Either the odontoid process fractures, or, more seriously, the retaining transverse ligament tears and allows the odontoid to press on the cord and kill the victim instantly. If he survives, the injury is probably stable enough to be treated in a cuirasse until there is bony or firm fibrous union.
Radiographs of most fractures of the upper cervical region are difficult to interpret. You should, however, be able to recognize an odontoid fracture. If in doubt, always fit a collar.

RADIOGRAPHS
You need special views. If the films are bad, try again. *You cannot make the diagnosis from poor films.*

Take an AP view through the open mouth to avoid the teeth. Place a cork between the rear teeth to hold them open. Place the head in moderate extension, so that the edge of the upper teeth falls in line with the base of the skull as it joins the cervical vertebrae.

Look for a crack through the odontoid peg, or a step at its base. The odontoid ossifies from a separate centre, so in a young person *don't interpret the normal growth line as a fracture*.

N.B. This growth line sometimes persists into adult life.

FRACTURES OF THE ATLAS & AXIS

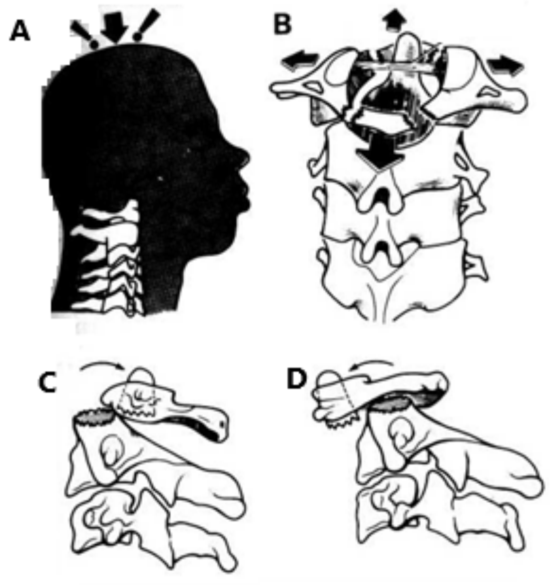


Fig. 54-15 FRACTURES OF ATLAS & AXIS. A, trauma to the vertex. B, AP view: posterior odontoid displacement. C, lateral view: posterior odontoid displacement. D, lateral view: anterior displacement with posterior arch fracture. *Adapted from de Palma AF, Management of Fractures & Dislocations; An Atlas, Saunders 1970 with kind permission.*

If the lateral masses of the atlas are spread significantly, there is a burst fracture, which has torn the transverse ligament.

Focus the tube on the lobe of the ear which overlies the odontoid. A visible prominence of the soft tissues at the back of the pharynx suggest an injury to the cervical spine.

ODONTOID PEG FRACTURE
Use traction as for other fractures and dislocations of the cervial spine. Even if there is no neurological defect**,** it gives better stability and prevents backward displacement and angulation.

BURST ATLAS RING FRACTURE
The ring bursts at its weakest point where its posterior and lateral masses join. This is the Jefferson fracture; the classical 'hangman's' fracture is of the C2 pedicle, although in hanging, death is generally by strangulation.

N.B. Radiographs of C2 are particularly difficult to interpret.
Fit a collar.

IF AN INJURED PATIENT IS SITTING UP HOLDING THE NECK, FIT A COLLAR

FOLLOW UP THE PATIENT CAREFULLY

54.8 Cervical hyperextension injury ('Porter's neck')

Where people carry large loads on their heads, this is quite a common injury. The patient, who is usually a woman, stumbles and falls. The heavy load falls backwards and extends or rotates her head violently. On arrival, she is usually found to have a quadriparesis. Fortunately, the cord is not often, injured, and even if it is, there is some hope of recovery.

HYPEREXTENSION INJURY (PORTER'S NECK)

Fig. 54-16 HYPEREXTENSION INJURY A heavy load falls from the head when the person carrying it stumbles. Hyperextension or rotation causes a transient quadriparesis. Radiographs are usually normal. *Kindly contributed by John Stewart.*

Radiographs may show no fracture. The likely narrowing of the cervical disc spaces together with osteophytic overgrowth are not responsible for the symptoms, which are due to a sudden infolding of the *ligamentum flavum* pressing on the cord. The prognosis is usually good. Fit a soft collar, and *care for the quadriparesis until it recovers.*

Another variety of cervical hyperextension is the **'Whiplash'** injury, caused by sudden hyperextension followed by hyperflexion, as in a head-on collision. The cervical spine is distorted into an S-shape with the lower part in kyphosis and the upper part in lordosis.

Typically pain & stiffness in the neck comes on some days after the event. Radiographs show no fracture. Active early mobilization gives better results than a soft collar.

54.9 Torticollis (Wry neck)

(a) At birth

This is the end result of the birth injury known as 'Sternomastoid tumour', which is a haematoma into the *sternomastoid* muscle. Make every effort to try to turn the baby's head the opposite way to the deformity. For example, if the head turns to the right, have him nursed on the left.
If the condition lasts >2 months, refer the baby for lengthening of the sternomastoid.

TORTICOLLIS

Fig. 54-17 TORTICOLLIS Spasm of the sternomastoid causes the neck to remain flexed sideways. *Kindly contributed by John Stewart.*

(b) In older children

Torticollis can follow a variety of neck or throat infections, such as peritonsillar abscesses, or it can follow an injury.

If the distance between the odontoid peg and the back of the anterior axis (C1) is >3mm in adults or >4.5mm in children, the transverse ligament has been stretched and the ring of the atlas has slipped forward.
Atlanto–axial subluxation is serious, because paraplegia may follow, and because the torticollis may last weeks, or occasionally permanently, if you don't treat it.

The differential diagnosis includes TB, but here collapse is much more usual than subluxation.

(c) In young or middle-aged adults

This may present with gradually increasing neck pain & inability to turn the head, holding it twisted and flexed to one side. This may come on after injury, vigorous exercise or sleep, but may be spontaneous.

EXAMINATION
Spasm in the neck muscles may be visible. Look for a 'trigger point' which causes the patient to wince (*don't overdo this!*).

Test for any neurological deficit (especially after trauma), and if so, obtain cervical spine radiographs (54-8,9,10). Ask if there is dysphagia. Very occasionally an unusual disc herniation may cause a torticollis.

Look for signs of infection (fever, lymphadenopathy, tonsillitis, pharyngitis, trismus)

MANAGEMENT

If there are no other signs but trigger points inject these with 5mL 0.5% bupivocaine + 20mg prednisolone.

N.B. This may cause initial exacerbation of pain before relief!

N.B. Don't allow violent manipulations of the neck!

N.B. Don't confuse torticollis with a dystonic reaction to chlorpromazine or haloperidol!

54.10 Thoracic & lumbar spine fracture

The spinal cord ends at L1. A patient with a fracture at or above this level is usually either grossly injured and paraplegic, or has a stable fracture. Below this level it is possible to have an unstable fracture and a normal cauda equina.

If there is no cord injury, you can easily miss these fractures, especially if there are severe injuries elsewhere, or also, unconsciousness.

The spine can be injured by a force which compresses or flexes it, usually at:
(1) T7–T8, the apex of the thoracic kyphosis,
(2) T12–L1, the thoraco-lumbar junction, or
(3) L4–L5.

The result can be a fracture dislocation (54-9A) a burst fracture (54-9D), or a wedge fracture (54-10A).

Suspect a spine injury if there is a calcaneal body fracture (72.6), and a history of fall from a height.

If there is a fracture, especially an anterior wedge fracture, after only a minor injury, suspect that it may be pathological: the result of TB, secondary tumour or osteoporosis.

If all you can see is a widened disc space, count the spinous processes, and see if they match the vertebral bodies. *The widened disc space may be all that remains of a vertebral body!*

If the fracture is stable (54.4), an active regime of movement will give better results than a plaster cast and be cheaper.

If the fracture is unstable (54.4), *the accompanying paraplegia must dominate the management.* Conservative management almost always leads to stable union in 6-10wks. The position in which the fracture unites is unimportant.

MANAGEMENT

STABLE FRACTURE

Treat the patient in bed with fracture boards under a rubber mattress ≤10cm wide. Put a pillow between the legs and a pillow under the back when lying on the side. Retain bedrest until arching the back is sufficient for you to be able to put your hand underneath it, and until sufficiently pain-free to walk, if necessary, with crutches. Allow getting up when pain allows, usually in c.3wks.

UNSTABLE FRACTURE

If the patient is not paraplegic, maintain bedrest. Turning 2hrly in one piece, using at least 3 people, is essential. Use the right and left sides, the supine, the lateral, and the prone positions. At c.3wks, turning alone using an overhead beam attached over the bed & a handle should become possible.

When pain at rest has gone and light percussion with a clenched fist causes little pain, usually by 6-10wks, start mobilization, at first with someone either side, and then using crutches.

If the patient is paraplegic, concentrate on morale, the skin, the bladder, and the bowels, rather than on the fracture. Turning 2hrly and care for the skin (54.12) are as essential as before.

Put blocks of foam rubber underneath the patient, to minimize displacement of the spine. For example, put a block under the fracture when supine. This will encourage moderate extension and reduce the tendency of the spine to collapse. Change and adjust these blocks at each turning.

If you cannot get foam rubber blocks, or if adjusting them at each turning takes too long, continue nursing on a thick rubber mattress.

After 6-8wks in bed, when the spine is no longer painful or tender, start mobilizing as effectively as the paraplegia will permit.

CAUTION! Never apply a cast in a paraplegic. It will rapidly cause ulcers in the anaesthetic skin.

54.11 Paraplegia

The arrival of a paraplegic patient is bad news in a district hospital because it means that a bed will be occupied for a very long time. But you can work to prevent bedsores, contractures, a small contracted bladder, and all the other miseries that are only too common!

There are some very simply equipped hospitals, with very dedicated workers, who turn their patients every 2h, and *they don't get bedsores*!

It is demanding, no doubt. The care of the paraplegic is perhaps the ultimate test of the real nursing quality of your hospital, and of the morale and dedication of everyone in it.

Your aim must be for your patient:
(1) no bedsores,
(2) no contractures,
(3) an uninfected bladder, with the early onset of reflex micturition in upper motor neuron lesions,
(4) self-motivation,
(5) mobilization,
(6) gainful employment.

Death in paraplegics is usually from renal failure that follows chronic urinary infection; but they may live many years.

MANAGEMENT
Make your first paraplegic patient your top priority.

JABULANI (34 yrs)
Admitted with quadriparesis (not quadriplegia) one year earlier in fairly good shape, he developed pressure sores over the sacrum, both hips, both knees, and both ankles. The joints under all these lesions were open and suppurating. He developed more sores on the back and forearms, and then flexion contractures of both hips and knees. He had a chronicly infected, small contracted bladder, an indwelling catheter, chronic urethritis, and supurating paraphimosis. He soon died.

Although quadriplegics should never reach an abject state of neglect, their outlook is much worse than for paraplegics, and without sophisticated technical support, always leads to an early demise.

If not because of the complications mentioned, without intensive physiotherapy, they develop hypostatic pneumonia, and die.

Don't try to set yourself impossible targets. Paraplegics, on the other hand, are very well worth fighting for. The key to success is to prepare your staff and the patient psychologically.

DISASTER FOR A PARAPLEGIC

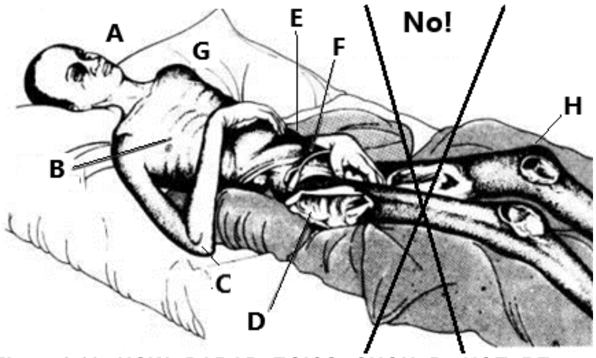


Fig. 54-18 HOW PARAPLEGICS SHOULD *NOT* BE TREATED. They can be saved from A, despair, B, chest infection, C, contractures, D, a dislocated hip, E bedsores, F, urethritis & a small contracted bladder, G, generalized wasting, & H, exposed joints. All it needs is turning the patient every 2h, & providing physiotherapy with a good diet. *Kindly contributed by Peter Bewes*

MORALE
The most critical days are the 1st few days, especially the first 2wks of admission. The whole battle may be lost by careless treatment then. Leaving a patient unturned for only 4h can start complications that need a series of surgical operations lasting many years. Moreover, if a patient develops a bed sore, you will be deemed responsible, and no other hospital will want to accept him.

A severe spinal injury is so disastrous that doctors and nurses are often too embarrassed to discuss it with the patient. Nevertheless, as such a patient is usually completely conscious and aware, you need to treat him or her with more than usual kindness!

Reassurance that you have properly diagnosed the condition, and you have urgently and carefully initiated treated is important. *Don' t try to belittle the problems;* you must explain there is a serious injury, and that the carers around understand the demands of someone paralysed. When asked whether the injury is going to be permanent, *don't be too pessimistic too early, and don't be too optimistic either!*

If, especially in spinal injuries above T6, the autonomic reflexes produce a hyperreaction to stimuli (such as a blocked catheter), causing a sudden rise >20mmHg in systolic BP, with bradycardia. If this persists, use nifedipine to lower the BP.

During the entire course of treatment, keep morale uppermost in your mind. *Don't just pass by the foot of the bed & say: "Ah, yes, the paraplegic. . . ", and then pass on!*

MAKE A PARAPLEGIC'S LIFE COMFORTABLE

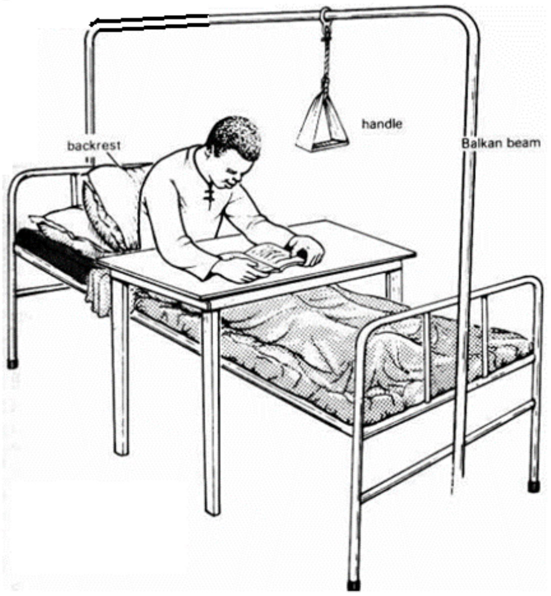


Fig. 54-19 STIMULATION FOR A PARAPLEGIC. Make sure he is always stimulated. Here he can move himself with the beam & handle. *Kindly contributed by Peter Bewes.*

Talk to such patients often, if not about their condition, then about their family.
Always bring encouragement and hope, not necessarily that the legs will eventually recover, but plans one day to rejoin society, and find there a place anew.
The relatives need encouragement too. It is tragic when they stop coming to visit, so make sure that someone explains your plans to them, and how long it might take.
Meanwhile, make the life as comfortable & stimulating as possible. Get in a teacher, so that the victim may learn something new (whatever level). *Don't let a patient ever get so depressed, that he or she stops eating!* Then death will be near. Make sure feeding is adequate, and watch for anaemia.

Comparing notes with other patients is very helpful. Try to organize a rota of visitors, and help in terms of entertainment. Much is made easier through mobile phones & internet!

NEVER PASS BY WITHOUT SAYING HELLO TO A PARAPLEGIC

THE SKIN
Bedsores occur in paraplegics whose skin sensation is diminished or absent, as well as any very sick or very old patient who is left in the same position too long without being turned (34.16). You can prevent them completely, even in complete paraplegia and quadriplegia, but, only provided you turn a patient every 2h *day and night*.
Get an alarm clock to alert the times for turns!

The cause of bedsores is clear. The pressure of the body on any part of the skin and subcutaneous tissue causes temporary ischaemia. In a normal person this causes mild discomfort, so that people shift about every 15mins to let another part of the body bear the weight. Because a paraplegic patient cannot feel discomfort from denervated skin, & cannot move, the skin surface subjected to pressure remains ischaemic for hrs at a time, and so becomes necrotic, breaks down, and causes a pressure sore.

If you interrupt this period of ischaemia, you can prevent a sore forming. Explain the pathology of pressure sores carefully to all your nurses and aides. Later, explain it to the patient too, so that prevention becomes part of the recovery routine. Otherwise, pressure sores become infected, and can easily reach bone or joint cavities.

TURN A PARAPLEGIC EVERY 2H & CHART THAT YOU HAVE DONE SO

Prevention must be a high priority! Put a chart at the foot of the bed, with intervals of 2h marked on it. Get nurses & aides to sign this chart each time they do the turning, and to record the side onto which they have turned the patient: left side, back, front, etc. At least 2 people are needed, and 3 are better. During the night the nurse on duty will need help, any help, even that of a relative, a watchman, a porter, or another patient. Show them how to turn gently, so that they *don't twist an unstable spinal fracture and injure it further*. In this case be sure everyone knows how to 'move someone like a log' (54-4).

ENORMOUS PRESSURE SORES CAN DEVELOP IN A VERY SHORT TIME

The discipline of absolutely invariable 2hrly turning is difficult to introduce because many nurses have seen paraplegics develop pressure sores, and think it inevitable.

Gloom and hopelessness often pervades the experience of nursing personnel. So take the initiative yourself: *lead by example!* Turn a patient yourself the first time, and next time, and perhaps the time after that.
Ask a nurse to help you. If you show yourself prepared to get up a few times at 4am and help (as some doctors have done), your nurses will play their part. Come early into the ward the next morning and inspect the pressure areas. If you find no inflammation or blistering, congratulate the nurses, and help them with their plans for turning during the rest of that day.

Offer to help turn the patient at night, if staff are short. This will prove a huge investment later! If you are called, appear delighted, and conceal your distress! Inspect the pressure areas on every ward round, and if they are healthy, congratulate the staff. At the slightest sign of inflammation, help to prepare an alternative routine of turning that will spare that part of the body from pressure for a few days.

If any important persons visit the hospital, make sure to show them the paraplegics. Involve the nurses in explaining how they turn the patient every 2h. They must follow a routine: 'left-supine-right-supine-left' for the cervical spine & 'left-supine-right-prone-left' for the lumbar spine. They will soon realize that they are becoming experts in this exacting field. Such co-operation will speak volumes to the visitors!

After a month or two, the patient, and the relatives will work out their own routine for turns, and plan how to manage at home.

After a few months it will become almost a reflex for turning to be carried out in bed at home.

Try to get your patient into a wheel chair or calipers quickly. Then teach how to avoid getting further pressure sores.

If there is only paraparesis and calipers are worn, inspect where they press on the skin, to avoid pressure sores at that site.

Each time you turn a paraplegic, put all immobile joints through a full range of passive movement, concentrating on hip and knee extension and dorsiflexion of the ankles.
Make sure the bed support is firm but soft. A covered mattress with 20cm foam interior is ideal. Put soft pillows or foam rubber cushions between the legs and under the back.
Try to keep the patient's bottom sheet tight, dry, and free from creases, crumbs, and bits of food. *Avoid plastic draw sheets, incontinence pads, & starched sheets.* Use real sheepskin if possible; medically treated, and washable, the woolen fibres help to distribute pressure, absorb moisture and promote air circulation, improving comfort overall.

Pad the pressure points with cotton wool, gauze, or pieces of fleece, but watch these pads carefully. *Don't allow them to become creased*. Remove them at least once a day and check the skin under them.

If the heels show any sign of pressure sores, put a pad under the ankles, or a ring pad around the heels. *Don't pad pressure points*: pad around them.

Watch the skin over the sacrum, iliac crests, hips, sides of the knees, malleoli, and the penis if a there is a condom catheter in place.

The first sign of a sore is skin inflammation; this might be difficult to spot on dark skin; it is characterized by a loss of natural shininess. Treat any such areas by careful massage and then apply soap and water followed by careful drying and powder.

For an established sore, keep pressure off it until it has healed. Keep it clean. Use paraffin gauze dressings. Honey and the fruit of the papaya (paw-paw), which contains the enzyme papain, are also useful.
Small sores may heal slowly, if you keep them clean and protected.

If a sore is necrotic, remove all the dead tissue. You may well find a much larger area of necrosis or sepsis underneath. Such large sores need debridement in theatre, and later closure by flaps (34-19 to 25).

TURNING A PARAPLEGIC NEEDS AT LEAST 3 PEOPLE

THE BLADDER
With any significant degree of paraplegia, a patient will be unable to urinate voluntarily from the moment of the injury. The bladder will fill up slowly and will be full by about midnight on the day of admission. If you leave it, it will overflow, so anticipate this and prevent it.

The best way of emptying the bladder to minimize introducing infection is to use regular intermittent *sterile* catheterization. Infection is rare with this method. It imitates the natural cycle in which the bladder fills and empties. By leaving it almost empty for a significant period, this method relieves the pressure on its walls, both that of urine filling the bladder and pressure from the the balloon of a Foley catheter on the urethra.

Use a Ch14 soft rubber Jacques catheter. Boil it and use gloved hands or sterile forceps. Pass it every 4-6h from the moment of the patient's injury. Later it can be every 6-8h. Empty the bladder completely by suprapubic pressure and then remove the catheter. Repeat the process 6h later, and again and again, x4/day. Record that catheterisation has been done on the chart which is used to record when you do the turning.

The disadvantage of this method is that it requires more nursing care, and if the patient is to do it himself, he must be cooperative.

Some smaller hospitals have managed this excellently.

CAUTION! When you make rounds, check the bladder from time to time to make sure that it really is being emptied. Continue, either until the spinal cord recovers, or until an automatic bladder develops, usually in 2-3months.

Don't use either an indwelling catheter or continuous suprapubic drainage, because their inevitable result is chronic or recurrent ascending infection & a small contracted bladder.

CATHETERIZE THE PARAPLEGIC WITH FULL STERILE PRECAUTIONS

RESULTS OF 2 REGIMES FOR A PARAPLEGIC BLADDER

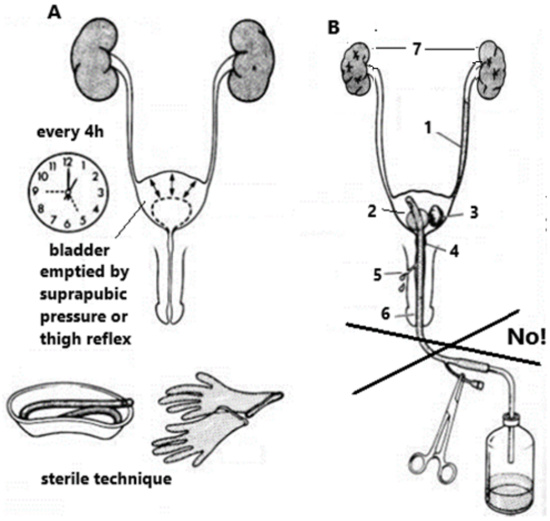


Fig. 54-20 RESULTS OF 2 REGIMES FOR A PARAPLEGIC BLADDER. A, Bladder emptied by suprapubic pressure or thigh reflex, or intermittent catheterization. Early on, get the ward staff to do this in a sterile manner. Later, get the patient to do it himself in a clean manner. B, an indwelling catheter can produce complications such as: (1) ascending urinary infection, (2) small contracted bladder, (3) bladder stone, (4) urethral stricture, (5) urethral fistula, (6) urethritis. (7) small contracted kidneys. *Kindly contributed by Peter Bewes.*

TYPES OF NEUROGENIC BLADDER

(a) Spastic bladder

If the spinal injury is above T10, the *detrusor* muscle does not work in harmony with the sphincter and produces a hyper-reflexive 'upper motoneuron' bladder. This will usually eventually develop its own micturition reflex.

After 2-8wks' intermittent catheterization a method of initiating micturition may be possible by the patient. Fit a condom catheter or a Paul's tube and encourage tryig, *e.g.* by stroking the side of the thigh, or the penis, or by pressing suprapubically.

Such training may take a long time; it is not easy, and may require considerable persistence and patience.

Although training may be difficult, it will save time in the end. After finding a method which works, encourage its use more and more. *Allow this without a cather in situ.* Don't stop using intermittent catheterisation until the residual urine after micturition has fallen to ≤75ml. Even when it has fallen to this volume, catheterize once a week to make sure that there is no urinary retention.

If you find that the residual urine is >75 ml, consider a bladder neck incision (27.21).

(b) Flaccid bladder

If the bladder is disconnected from its peripheral nerve supply, the bladder distends and the patient becomes incontinent because of overflow. The bladder needs catheterization.

A patient can do this either by sterilizing a catheter in boiling water each time and passing it in a sterile manner, or by a clean no-touch technique.

Suprisingly perhaps, because a patient does not need to sterilize the catheter each time, he can catheterize himself more often, whenever he needs to, and so does not allow the bladder to fill up. In practice, he becomes infected less often than if he waits and tries to sterilize a catheter.

For this method to succeed, *he must empty the bladder as completely as possible with the help of suprapubic pressure* continued until the moment that he pulls the catheter out.
An incompletely emptied bladder will retain some organisms, but a bladder that is completely emptied will contain very few.

JOHN (45 yrs)
As a former league football player before the accident which left him paralyzed, John just had to go to the semi-final match. Here he could cheer wildly with his mates, and in the interval go to the toilet, catheterize himself, and then return to the match! If he'd have had to sterilize the catheter, he just would not have been able to go to any such matches ever, or go and allow the bladder to fill up, cause reflux & infection, and run the risk of embarrassing overflow incontinence. Alternatively, he would have had to carry the catheter with a bag, and empty it at half time, running all the risks of longer-term catheterization.

Many patients easily learn this method which has the principal advantages of allowing them freedom & independence.

INTERMITTENT SELF-CATHETERIZATION
Provide a man a Jacques rubber catheter, or if there is difficulty, use one with a small beak, such as an oliviary tipped Tiemann, or a coudé catheter. Teach him which way to point the beak.
A woman may use a small handbag mirror to help her locate the urethral meatus.

Encourage the patient to keep the catheter clean, wash the hands and the urethral orifice.

If the urine becomes cloudy or smelly, encourage more frequent catheterization. (The usual reason for the infection is infrequent drainage). Use an antibiotic depending on a culture & sensitivity test.
Don't try to prevent infection by administering prophylactic antibiotics, but alkalinizing the urine may help.

If these 2 methods fail, admit for continued, intermittent, non–sterile catheterization under supervision, together with bladder wash-outs.

If this also fails after 1-2yrs, the spinal injury is below T12 & there is no bladder outlet obstruction & no incontinence, surgical augmentation of *detrusor* bladder contraction may be possible:

RECTUS ABDOMINIS DETRUSOR MYOPLASTY (GRADE 3.1)
Through a midline abdominal incision, open the rectus sheath and expose the left *rectus abdominis* muscle. Free it from surrounding structures, but *not from the posterior rectus sheath.* Mark the resting length of the muscle with stay sutures. Identify, ligate & divide the superior epigastric artery. Dissect out its entire length and divide it at its superior end. Identify & carefully preserve the intercostal nerves on the surface of the *rectus abdominis* (54-21). *Don't disconnect the muscle from the symphysis pubis.*

Now mobilize the bladder & fill it with 100mL of saline. Noting its resting length, use the *rectus* muscle flap to wrap around the upper $^{2}/_{3}$ (the dome and lateral walls) of the bladder. As you fix the flap, if you can, anastomose 2 intercostal nerves of the upper part to 2 intercostal nerves of the lower part with 8/0 nylon. You can check muscle contractility by stimulating the muscle or nerve.
Finally close the abdominal wall. Keep an indwelling catheter in place for 3wks.
Then teach the patient to empty the bladder as completely as he can by squeezing the *rectus* muscle.

***RECTUS ABDOMINIS* DETRUSOR MYOPLASTY**

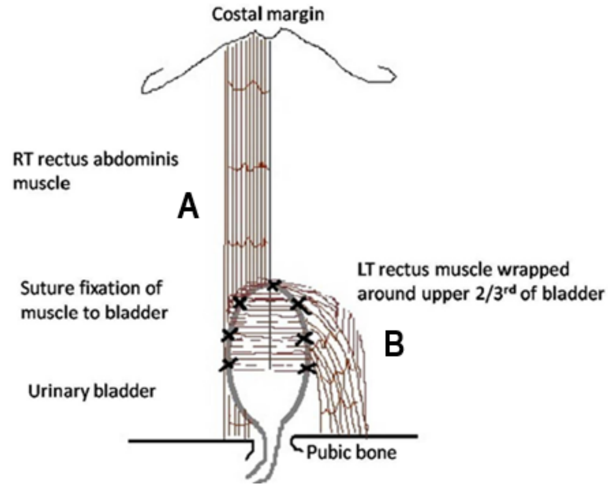


Fig. 54-21 *RECTUS ABDOMINIS* DETRUSOR WRAP. A, the right *rectus abdominis* muscle undisturbed. B, the left *rectus abdominis* muscle, after being divided at its upper end, wrapped & fixed around the upper $^{2}/_{3}$ of the mobilized bladder. *After Agarwal P, Husain S, Wankhede S, Sharma D. Rectus abdominis detrusor myoplasty for acontractile or hypocontractile bladder in spinal cord injury patients. J Plas, Reconst Aesth Surg 2018; 71: 736–742.*

BOWELS & NUTRITION
After a spinal injury, the bowel quickly becomes loaded with brick-like faeces. Distension may become so severe that the sigmoid colon presses on the left iliac vein and may cause a thrombosis in it.

Administer an enema x3/wk until bowel function has returned, usually in 3-6wks.

Glycerine suppositories later on may help develop a defecation reflex. It may be possible for the patient to start this reflex by inserting a suppository and sitting on the lavatory 15mins later.

Even so, faecal impaction is always a danger, and you should teach the patient or the relatives the unpleasant task of how to remove faeces manually. *This is so important that it should be part of the routine teaching of everyone who cares for paraplegics.*

You can do much by, occasionally, manually removing faeces yourself (without demonstrating your disgust at doing this) and so encourage the nurses to follow your example.
Make sure that the patient has a high residue diet
and uses non-irritant laxatives if necessary.

Also make sure the patient has a high protein, high calorie diet in the first 3 months of the injury. You may need iron supplements to keep the Hb level >120g/L.

MUSCLES AND JOINT PHYSIOTHERAPY
From the very start, get a concerned person (or team of people) to move all the paralysed joints passively through a full range of movements several times a day. This will become more difficult as the patient becomes more spastic. *If this is neglected, the hips, knees, and ankles will roll up like a hibernating hedgehog.*

Established contractures are readily preventable, and therefore are a sign of neglect. Where possible, sit a patient up out of bed. Although physiotherapists are useful, you can trach any doctor, nurse, or relative how to put the joints through a full range of movements every day, and so prevent contractures. *Avoid force*, because this may damage a joint.
Encourage movement of the non–paralysed joints as much as possible,
The hips of a paraplegic tend to flex; *so, don't provide a pillow under the hip when the patient is lying prone!*

MOBILIZATION & REHABILITATION
If you don't interest yourself in what happens to a paraplegic after discharge, there is a very great chance that all the care and attention received while in hospital may be wasted. This is especially likely to happen in rural areas. So arrange a visit the patient's home, and try to make sure that he has a suitable bed and toilet, and can get involved in daily household duties.

REHABILITATING A PARAPLEGIC

Fig. 54-22 REHABILITATING A PARAPLEGIC is critically important. All wheelchair users need a cushion (preferably with gel-foam) to sit on. Failure to do so after discharge will be fatal, owing to sure development of pressure sores. *Kindly contributed by Peter Bewes.*

The process of rehabilitation requires solutions to various issues. Can a wheelchair come into the front door? Are there steps? Can you fit parallel bars? Can you adapt things for a lower (chair) level, such as mirrors, handles etc.? Can you fit hoists & monkey poles for the patient to transfer himself?
Often, money will be the major factor. If a patient was injured at work, a workmen's compensation fund may be able to support him.

Start to mobilize a patient when the fracture is reasonably stable and it is clear that the paralysis will be permanent.

Stand a paraplegic up regularly when the arms are strong enough to hold crutches. Use gutter plaster splints or walking calipers to support the knees and ankles.

Involve the whole family in rehabilitation. There will be need of a wheel chair, and perhaps calipers and crutches to take home. Start thinking early about how to finance these. The 1st week of the illness is not too early for this, and often the best time when people's emotions are raw.

Early on during the stay in hospital, encourage developing extraordinary strength in the unparalysed parts of the body.

Encourage pulling up using an overhead beam, or lifting weights with the arms, so that they are strong enough to support the body when using crutches or a wheelchair. Calipers may help to keep the knees straight and the feet in neutral positions. Teach some skilsl with the hands, such as making articles for sale, basket making, weaving, or leather work. Encourage finding markets for the things produced, so that later on this means earning a living.

Aim for a date of discharge 4-5months after admission. Try to get the community involved in re-integrating the patient with suitable employment.

Success in rehabilitating paraplegia is one of the best indicators of high quality care. Where it fails, a district hospital accumulates 3-4 paraplegics, and a provincial one perhaps 12, each with an average total stay of perhaps 10 years, with all that this means for expense, and for the other patients who have to be denied treatment.

WHEELCHAIR USE
Start a patient in a wheel chair slowly, 2h od to begin with, then 2h bd. It is important to lift up the buttocks a few times every 15mins.

Sitting needs to be on 2 foam rubber cushions, or on an inflated inner tube of a motor cycle that has small wheels and wide tyres.
Cover this with a foam pad. Provide a washable rubber bag for those times the bladder works unexpectedly.

If skin sores or a urinary infection develop, a rapid return to hospital is mandatory.

If a leg becomes hopelessly infected, and a liabilty, this is an indication for a through-knee or above-knee amputation (35.6). It may not only remove a life-threatening source of sepsis, but allow better and easier mobilization. Sitting may still be difficult.

N.B. Don't remove both legs on the same occasion.

PARAPLEGIA CAN BE TREATED PROPERLY IN A DISTRICT HOSPITAL

55 Abdominal injury

55.1 Introduction & anatomy

The abdominal organs can be injured by penetration by a sharp object (*e.g.* knife or bullet), or a blow from a blunt instrument. As Hippocrates knew, the bowel can be ruptured, even if there is no visible mark on the abdominal wall.

Bleeding into the peritoneal cavity, especially from splenic or hepatic rupture, or leakage of intestinal content may be fatal.

Your main tasks will be: (1) to diagnose when a patient has a serious abdominal injury, (2) to stop the bleeding, and (3) to repair a bowel injury.

Your primary goal is not to make a clear-cut diagnosis pre-operatively, but rather to establish promptly whether serious abdominal injury is present. *Always have a very high index of suspicion*.

If your patient has one serious injury, he has a 50% chance of having at least another severe injury, which will need treatment too, perhaps simultaneously, so assume there is an abdominal; injury until you are certain otherwise.

Blunt injuries are particularly difficult:
(1) There may be no clear history of abdominal trauma, especially in a frightened child. The injury may initially be so mild that you have to take a very carefully history and make meticulous frequent examinations of the abdomen. The victim may even walk into hospital.
(2) Other more obvious injuries, such as a fractured femur, may distract your attention.
(3) The victim may be drunk, or unconscious from a head injury and unable to describe the symptoms. If you anaesthetize him to treat the other injuries, he cannot complain of increasing abdominal pain.
(4) For the first few hrs after a blunt injury, the abdomen may be deceptively normal. Although a haemoperitoneum usually causes pain, tenderness, guarding, and absent bowel sounds, these symptoms and signs may be absent, especially early on, in children and the elderly.
(5) Distinguishing between muscle pain and peritoneal irritation may be very hard.
(6) Some injuries may not present for several days, especially a subcapsular splenic haematoma, or a retroperitoneal injury of the pancreas or duodenum.

Blunt abdominal injuries arise in road traffic crashes, falls from a height (especially in children), assaults, wild animal attacks, sports, farm or industrial accidents, natural disasters, and in blast injuries following explosions.

(Special features of penetrating injuries are specifically dealt with in 55.3)

For all these reasons, abdominal injuries need clinical judgment, care, and skill. So, be vigilant and suspicious. *You will need a watchful eye, a light touch, and a sympathetic ear. Don't let a patient go home if there is even a slight possibility that there might be an injury to the abdomen*. If you are in any doubt, observe carefully and use the special methods described below. They will be particularly useful if there is also a head injury, and may indeed be life-saving.
The decision to operate will be much more difficult if you have already administered an anaesthetic. If someone needs a laparotomy, *do it early*.

A CLOSED ABDOMINAL INJURY CAN EXIST WITHOUT ANY EXTERNAL SIGNS

ANATOMICAL ZONES
To identify & localize an abdominal injury, you must get well acquainted with anatomical surface markings of the abdomen, as well as the internal spaces (10-3).

Divide the abdomen into 2 regions:
(1) external - anterior abdomen, flanks and back,
(2) internal - peritoneal cavity (upper and lower), retroperitoneal space and pelvis (55-1).

(a) The anterior abdomen extends from the trans-nipple line superiorly, inguinal ligaments and symphysis pubis inferiorly, & anterior axillary lines laterally.
(b) The flank lies between anterior and posterior axillary lines, from the 6th intercostal space to the iliac crest.
(c) The back lies posterior to the posterior axillary lines, from the tip of the scapulae to the iliac crests.

CAUTION! It is essential that your abdominal assessment should always include concealed areas such as flanks and back so that you don't miss potentially life-threatening injuries in these areas.

(d) The upper peritoneal cavity (otherwise known as the intra-thoracic abdomen) is covered by the lower aspect of the bony thorax, & includes the diaphragm, liver, spleen, stomach, and transverse colon. *But note that a pathologically enlarged liver or spleen extends beyond the protection of the thoracic cage and is more prone to injury!*

EXTERNAL ABDOMINAL ANATOMY

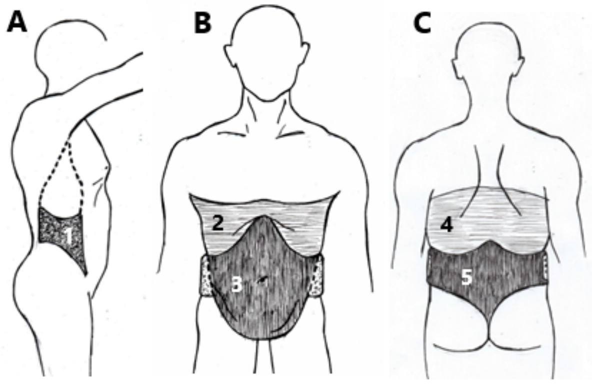


Fig. 55-1 EXTERNAL ABDOMINAL ANATOMY: A, flank (1). B, anterior thoraco-abdominal area (2) & anterior abdomen (3). C, posterior thoraco-abdominal area (4), back (5). *After Legome E, Shockley LW. Trauma: a comprehensive emergency medicine approach, CUP 2011 with kind permission.*

N.B. In full expiration, the diaphragm rises to the level to the 5th intercostal space, making the viscera susceptible to damage especially from an object which penetrates the chest and the diaphragm (i.e. a thoraco-abdominal injury).

N.B. If there are lower rib fractures, you must always suspect injury to the liver or spleen.

(e) The lower peritoneal cavity contains the small bowel, ascending and descending colon, and the female Fallopian tubes.
(f) The pelvic cavity contains the rectum, urinary bladder, male prostate, iliac vessels, and the female uterus & vagina.

ZONES IN THE RETROPERITONEAL SPACE

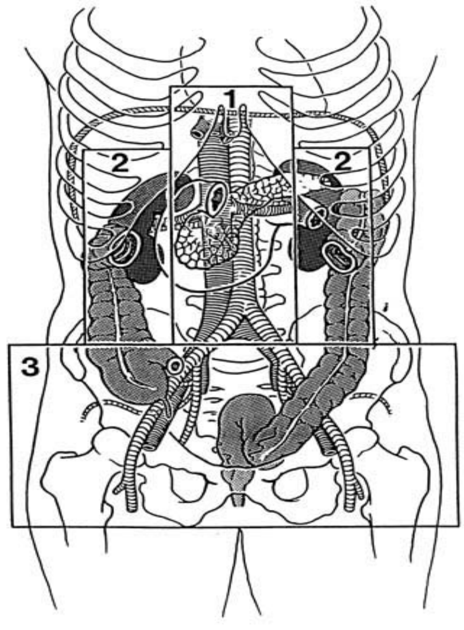


Fig. 55-2 THE RETROPERITONEAL SPACE, divided into 3 zones: 1, Central zone I: explore all supracolic haematomas, but only infracolic haematomas in penetrating injury or if expanding in blunt injury. 2, Lateral zones: *don't explore*. 3, Pelvic zone III: *don't explore*. *After Tomado de Sheldon GF, Blaisdell WF, Trunkey DD; Abdominal trauma, Thieme, New York, 1982 with kind permission.*

(g) The retroperitoneal space contains the abdominal aorta, inferior vena cava, most of the duodenum, pancreas, kidneys, ureters, and posterior aspects of the ascending and descending colon.

CAUTION! Injuries to retroperitoneal viscera are difficult to recognize because of limited access by ultrasound, diagnostic peritoneal lavage (DPL) & even at laparotomy.

Divide the retroperitoneal space further when you have to consider exploring a haematoma subdivided into 3 imaginary zones (55-2).

MURAV ULAL (40) was a sailor who fell on to a crate. In the casualty department, no injuries were found and his blood pressure was normal. However, the casualty officer was worried about the possibility of an abdominal injury, because there was an abrasion on the epigastrium, so she admitted him. When the registrar saw him in the ward 30mins later, the patient was severely shocked. Urgent laparotomy revealed a ruptured spleen.

MOHAN (25) had been kicked in the abdomen during a fight. His abdomen was bruised and the skin damaged, but he did not look as if he had been seriously injured. The medical assistant who saw him gave him aspirin and sent him home. Three days later he was admitted with severe peritonitis. At laparotomy, much pus and intestinal content were washed out of the abdomen, but he died soon afterwards.

LESSONS (1) Any abdominal abrasion after a blunt injury should make you suspect an internal injury. (2) A young adult can maintain his blood pressure for some hrs after an injury, and it may even rise (because of pain) before it falls catastrophically.

INJURY PATTERNS
Get an idea of how the injuries occurred. This will provide you with a critical insight into the level of energy transfer and gauge the likelihood of underlying tissue damage. You will then be able to recognize patterns of injury and be forewarned of likely organ damage.

Falls from a height, particularly in children and especially road traffic crashes, account for most blunt injuries of the abdomen and pelvis.

Motorcycle injuries are also very common, affecting principally the lower leg and forearm, thorax and spine. Such wounds may be severely contaminated.

Typical patterns of collisions are frontal, lateral, rear, rotational and rollover. Rear impact is associated with less chance of abdominal trauma, especially if the victim is properly restrained. In rollover, there is a high chance of lethal injury.

Visceral disruption often occurs in rapid deceleration, which is frequent in road crashes.

A shearing injury occurs where internal organs are fixed, for example at the renal pedicles, or in intimal vessels with subsequent organ infarction of liver, kidneys, spleen, or small and large intestine.

Crushing injury occurs between the anterior abdominal wall and the vertebral column or the posterior thoracic cage. Solid organs (liver, spleen or kidneys) are more susceptible to this type of injury.

Compression injury may result from a direct blow or external compression from a fixed object such as a seat belt, or after a fall. This may cause lacerations and subcapsular haematomas in solid visceral organs, or rupture to hollow organs such as bowel.

N.B. Whereas, undoubtedly seatbelts and child seats have reduced mortality by preventing much head and maxillofacial injuries, their incorrect use or poor design leads to a specific pattern of injury to the lower thoracic cage, lumbar spine, liver, spleen, or mesentery. Loosely fitted lap belts may lead to pelvic and urinary bladder trauma, or even abdominal aortic dissection.

CAUTION! Always look for bruising from the seat belt, as this implies a significant underlying intra-abdominal injury.

Blast injury affects principally air-containing organs (lungs & intestines), but also the brain. They are much worse in underwater blasts, because water is relatively incompressible, and so transmits the pressure of the shock wave rather than absorbing it as air does.

Penetrating injuries may of course affect any organ. Details of ballistics need understanding (46.14).

55.2 Management of abdominal injury

HISTORY
Ask the patient about the injury if conscious. Otherwise, try to get information from eye witnesses at the scene. Get details of the overall mechanisms of injury. In a road crash, get the estimated speed of the vehicles, the nature of the impact, whether the collision involved a truck, bus, car, motorcycle, bicycle or pedestrian, and whether it was a frontal, lateral, sideswipe, rear, rotational or rollover type of collision. Was a seat belt worn, an air-bag deployment, or impact on the steering wheel? What was the victim's position in the vehicle and the extent of its destruction? Establish if the victim was ejected from the vehicle, or extricated himself.

Enquire if there were other victims and any fatalities (and ask if they are expected to arrive at your hospital).

In the case of falls, establish the height of the fall. In blast injuries, ask how far away the victim was from the explosion.

In direct blunt impacts, ask what struck the patient's abdomen, and where (think especially of an injury to the spleen after a blow to the left lower chest). In assaults, ask how much force was used, and if it was repeated.

Such information is relevant for initial evaluation and management of blunt abdominal trauma and you should always seek such when taking a history.

PAIN is usually present following an abdominal injury, so assess its intensity by a scoring method (2.11), its location, factors exacerbating it, and whether it is getting worse.
Ask about pain at the tips of either shoulder (*but make sure that this is not caused by an injured shoulder!*), because this is typically caused by diaphragm irritation by blood from the liver (right side) or spleen (left side), especially if tilting the patient's head down makes it worse.

CAUTION! Almost all patients with significant abdominal pathology after a blunt injury have persistent pain and may vomit. These are very important symptoms, though vomiting without abdominal pain is very unspecific.

N.B. A victim with multiple injuries may not complain of abdominal pain when he has even more painful injuries elsewhere!

N.B. Adequate pain relief minimizes stress responses and facilitates patient co-operation during the physical examination. *Judicious use of analgesia does not mask or alter physical examination findings.*

ABDOMINAL EXAMINATION
Carry out a full clinical examination, including inspection of the abdomen, flanks and back.
Do this as part of your assessment of the circulation (43.1), but *do it again if the patient is unstable or deteriorates.*
Record any noted abnormalities including their size, shape and location.

(a) Inspection
Remove all the victim's clothes, but avoid hypothermia and safeguard the patient's privacy. Carefully observe breathing; *N.B. shallow, irregular, or grunting respiration is typical of an abdominal injury,* owing to restricted abdominal excursion during breathing.

Check if the abdomen moves with respiration: if it does not, this suggests peritoneal irritation. Check if one hemidiaphragm moves less than the other.
If the patient is bleeding, he is likely to be pale, anxious, and still, with cold extremities (43.1).

N.B. Remember that large amount of blood may be present in the peritoneal cavity without any change in girth or abdominal appearance.

Systematically inspect the:
(1) anterior abdomen (and urethral meatus in males),
(2) flanks,
(3) axillae,
(4) posterior structures including the back, skin folds, buttocks and perineum, for distension, bruises, abrasions, contusions, lacerations, tyres and steering wheel, seatbelt or handlebar marks, localized swelling or penetrating wounds.

Look for ecchymosis on the lower flanks (Grey-Turner's sign) or around the umbilicus (Cullen's sign) which suggest retroperitoneal haematoma.

Cautiously log-roll the victim to examine the back, and perineum. If there is a spinal deformity or a paravertebral haematoma, this may suggest retroperitoneal bleeding.

Examine the rectum (and vagina in a female) to assess its integrity, and the presence of blood on your glove. You may be able to feel pelvic bone fragments in cases of pubic rami fracture from inside the lumen. Fulness, boggyness or tenderness in the rectovesical (or rectovaginal) pouch may indicate a haemoperitoneum.

N.B. The rectum (& vagina) is completely out of sight at laparotomy.

In a male, feel if the prostate is further from the anal margin than usual, indicating urethral disruption. Also, remember to assess reduced or absent anal sphincter tone if there is a spinal cord injury.

N.B. Proctoscopy & sigmoidoscopy may be necessary to evaluate a severe anorectal injury.

Look for wounds of the perineum or buttocks at the same time. *Remember that disruption of the pubic rami or symphysis may cause a vaginal or rectal injury.*

(b) Palpation

Palpate to elicit tenderness; even minimal guarding or rigidity suggest peritoneal irritation from bleeding or visceral rupture. Start furthest from the site of injury.

N.B. Initially blood is not a peritoneal irritant!

Check the lower ribs for fractures. Assess integrity of the pelvic ring by applying direct pressure in 2 planes to both anterior superior iliac spines. Palplate the superior pubic rami in addition to the *symphysis pubis*.

N.B. Findings may be equivocal or unreliable if there is a reduced level of consciousness secondary to alcohol or drug intoxication, head or spinal injury.

N.B. Don't forget to examine the male urethral meatus, and look for the presence of blood and for a scrotal haematoma, and evidence of lacerations or bruises in the perineum. If there is evidence of urethral injury then don't rush to insert a urethral catheter; this is contraindicated as it may further injure the urethra.

(c) Percussion

Percuss gently to elicit subtle signs of tenderness, or ask the patient to cough. (*Rebound tenderness is unreliable and may arise from muscle injury*).

(d) Auscultation

This is not very reliable. Bowel sounds may be absent after trivial trauma, and may occasionally be present even with serious injury. In the rush of the trauma situation, you may anyway not be able to be patient for enough time to be sure, nor hear well enough!
In a more stable patient, though, an abdomen which becomes silent where there were previously audible bowel sounds suggests peritonism.
However, *always listen to the chest*: you may hear *borborygmi* in the thorax if the diaphragm is ruptured and stomach or bowel has herniated into the chest.

N.B. If while completing your full abdominal examination as part of the secondary survey (45.1), *you discover signs of on-going intra-abdominal bleeding or peritonism, you must take the victim to theatre for an exploratory laparotomy. You should not delay to complete a protocol!*

N.B. Always consider that a female of child-bearing age may be pregnant!

CAUTION! Retroperitoneal injuries are rather difficult to diagnose by physical examination alone. But you should always have high index of suspicion if there is evidence of associated spinal deformity or paravertebral haematoma.
The mechanism of injury may suggest the possibility of damage to the retroperitoneal structures.

CAUTION! Even minimal tenderness and guarding are significant.

(e) Supplementary actions

Pass a nasogastric tube (or an orogastric tube where there is a serious frontonasal head injury), if there is vomiting, or evidence of a full stomach where the conscious level is impaired.

Don't insert a tube to look for gastric bleeding: this may damage the oesophagus, promote vomiting or even bleeding!

Perform a FAST (44.3).

Pass a urinary catheter to monitor urine output in an unstable patient (44.1). *Don't insert a catheter for diagnostic purposes! Don't insert a catheter if there is blood at the external urethral meatus or suspicion of an 'open-book' type of pelvic disruption.*

If there are no definite signs, and a FAST did not help and you suspect bleeding in the abdomen, perform a DPL (44.3)

MANAGEMENT
The critical question is whether the patient needs a laparotomy or not, and if so, how soon.

If in doubt, look & see rather than wait & see. An occasional negative laparotomy is better than waiting till it is too late!

If a patient is unconscious, you have to rely on clinical signs, increasing abdominal girth (measured 4hrly at umbilical level with a centimetre), oft repeated examinations, DPL & supplementary tests.

DON'T PERFORM UNNECESSARY INVESTIGATIONS IN AN EMERGENCY!

MISSED INJURIES MAY KILL A PATIENT

LAPAROTOMY FOR ABDOMINAL TRAUMA (GRADE 3.2)

INDICATIONS
(1) Signs of internal abdominal bleeding.
(2) Signs of peritonitis.
(3) Perforating injuries by bullets or multiple objects (such as knives), or by a foreign body not identified on radiography, or by cow or buffalo horn.
(4) Herniation of viscera through the abdominal wall or diaphragm.
(5) Thoraco–abdominal wounds.
(6) Penetrating anorectal or vaginal injuries.
(7) Obvious blood on rectal examination.

If there is a clear indication for laparotomy, then start immediately. *Don't delay longer than is necessary to organize the theatre and cross match more blood.*
The principles for trauma laparotomy are:
(1) control haemorrhage,
(2) limit contamination, &
(3) repair visceral damage

If there are signs of peritonitis, administer prophylactic chloramphenicol or gentamicin IV & metronidazole PR, preferably with the anaesthetic as a single dose.
N.B. **If laparotomy shows no contamination,** stop the antibiotics.
N.B. **If peritoneal contamination occurs during surgery,** but you have dealt with it adequately, administer antibiotics as above, if you have not already done so.
N.B. **If there is established contamination** (duration >6h), continue antibiotics for 5days.

It is much more important to start antibiotics early than to continue for long. Starting them after the patient returns to the ward is certainly too late.

If the patient is unstable, your aim is to complete your intervention in 45mins. In this case, you must practice damage control (41.5). So, you should transfer the patient to the operating theatre while you are continuing resuscitation.

If the result of your FAST (which may miss solid or hollow organ injury) **or DPL** do not give you an answer, observe the patient closely and repeat the examinations every 30mins, or every 15mins for children.

PATIENT PREPARATION
Make sure the theatre & IV fluids are warmed. Place the patient supine on the operating table with arms abducted at right angles on arm boards (*don't forget restraints so the arms don't slip off*).

Be prepared to allow exposure to the chest, abdomen and groins. For perineal or rectal injuries, get leg stirrups & put the patient in lithotomy position.
Make sure the electrocardiogram leads, monitoring equipment and tubes are NOT present on the anterior or lateral chest wall.
Make sure you have plenty of swabs & packs.
Remember you are a team, so *communication is the key to success*. It's up to you to make sure if the right instruments are ready.

Check this list:
(1) Make sure the airway is clear (42.1).
(2) Insert a chest drain if necessary (43.2).
(3) Cross-match blood.
(4) Make sure you have 2 IV lines running.
(5) Pass a nasogastric tube.
(6) Introduce a urinary catheter.
(7) Explain the procedure to the patient (even if he appears drowsy) and get consent.
(8) Make sure the suction is functioning.
(9) Have auto-transfusion equipment ready.
(10) Tell the theatre sister what special instruments you need.

N.B. Don't delay surgery to put in a central venous line.

Remember, emergency laparotomy is not just performing a laparotomy quickly. You must combine rapid intervention with meticulous dissection.

Remember: abdominal trauma often occurs as part of multiple trauma. Therefore, prioritize resuscitation, according to the principles of ABCDE (41.2).

This means that a patient who has blunt abdominal trauma and co-existing severe chest & pelvic injury, multiple fractures, and head injury should have treatment directed first toward the most life-threatening injury. This would probably mean inserting a chest drain, swiftly applying an external fixator on the pelvis, and splinting the broken limbs, and then proceeding with a laparotomy. If necessary, you could try to arrange a craniotomy simulataneously, starting this whilst your assistant closes the abdomen.

Clearly in such a situation, you must not use up valuable time in definitive repair (41.4).

These patients need damage control surgery (41.5)**:**
(1) Severe hypotension <90mmHg >60mins, or need of inotrope treatment.
(2) Hypothermia <35°C.
(3) pH <7.2 or Lactate >5mM.
(4) Already has a clotting disorder, or has needed >5 units of blood transfusion.
(5) Resuscitation + operating time predicted to take >90mins.

N.B. If you suspect severe haemorrhage, use a muscle relaxant only at the last minute when you are ready to open the abdomen.

Good relaxation however makes any bleeding site easier to find; and packing away the viscera, extending your incision, and tilting the table, will improve your vision.

More harm arises by not exploring an abdomen than by doing so. You will not know the extent of injury until you open the victim's abdomen.

YOUR MENTAL PREPARATION
The key decision is whether you go for definitive repair or damage control. *Make this decision as early as you can.*

DAMAGE CONTROL APPLIES TO *ALL* ORGAN SYSTEMS: (1) INITIAL EXPLORATION, (2) SECONDARY RESUSCITATION, (3) DEFINITIVE CORRECTION.

DAMAGE CONTROL SURGERY
The aims are to:
(1) Stop the bleeding
(2) Control contamination
(3) Protect the viscera

INCISION
Rapidly clean the patient from chin to mid-thighs, with aqueous antiseptic, extending down each side to the table.

Make a long midline incision extending from the xiphoid process to the pubic symphysis.

CAUTION! **If you suspect a severe pelvic fracture**, *take the incision only to just below the umbilicus* to avoid opening a potential large pelvic haematoma which may bleed torrentially if you open it. Continue downwards *under direct vision* if necessary.

Don't hesitate to extend the incision superiorly, laterally, or both ways, to give you better exposure if you need to. Balance this against the increased time it will take you to close a bigger incision. *If you are struggling, always make the incision bigger! Don't try to perform a laparotomy through a small incision*. Adequate exposure saves time.

Don't extend penetrating wounds (unless in the midline).

Don't waste time by cauterizing abdominal wall vessels: use haemostats for the larger vessels and move on.
Attempt to make 3 clean cuts through skin & subcutaneous tissue, to the *line alba*, and then with heavy scissors into the abdominal cavity.

***DEFINITIVE SURGERY IS NOT INDICATED WHERE A SEVERELY INJURED PATIENT HAS SIGNIFICANT PHYSIOLOGICAL IMPAIRMENT*.**

OPENING THE PERITONEAL CAVITY

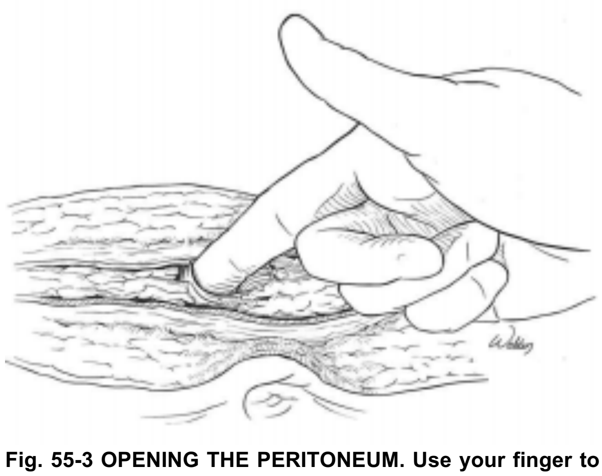


Fig. 55-3 OPENING THE PERITONEUM. Use your finger to make a hole just cranial to the umbilicus. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Make a hole just above the umbilicus with your finger (55-3) and then hold up the peritoneum with 2 fingers of your non-dominant hand and open the peritoneum carefully avoiding inadvertent trauma to any *viscera* stuck to the anterior abdominal wall.

Avoid injury to the left lateral lobe of the liver in the upper abdomen, the small bowel in the middle, and the bladder in the lower abdomen.

If there is an old abdominal scar and adhesions, start at a distance from the old scars, and open towards the scar bit by bit under direct vision. You might have to abandon one attempt, and start again at another site.

If there are multiple scars and adhesions, and you cannot proceed safely, abandon the midline and use a bilateral subcostal ('rooftop') incision.

THE 'ROOFTOP' INCISION

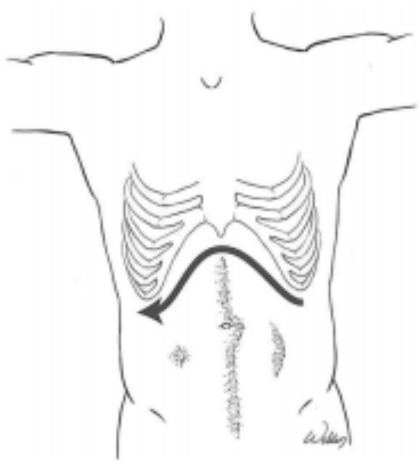


Fig. 55-4 THE ROOFTOP INCISION. If there are previous scars and dense adhesions, enter the abdomen *via* a double subcostal approach. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

EXPLORATION
When you open the abdomen, it may be full of blood, or pus and intestinal contents, or have a relatively small amount of both. In all cases, approach the operation calmly and systematically. *Note any sudden extrusion of gas, the colour of fluid present, and any odour (faecal smell indicates injury to the colon or rectum).*

You will need space to manoeuvre and to be able to diagnose the injuries. Begin by rapidly emptying the peritoneal cavity of clots and liquid blood by using both your hands or using a kidney dish or basin; then *bring all the bowel loops quickly out of the abdomen towards you and support them! Don't pull on them, but scoop them out from below with your palm.* Get your assistant to lift the abdominal wall of each quadrant in turn.

This will often give you a hint from which quadrant(s) the most blood is coming. Use an efficient sucker. Consider if you wish to re-infuse blood spilt as auto-transfusion (5-1).

PACKING THE ABDOMEN
Now place an abdominal pack over the spleen, a 2nd in the left paracolic gutter, and a 3rd over the major vessels at the root of the mesentery in the midline.

Then, gently swing the bowel loops over to your assistant and place a 4th pack over the liver, a 5th in the right paracolic gutter, a 6th over the midline vessels, and finally a 7th in the pouch of Douglas.

CONTROLLING HAEMORRHAGE
This is absolutely the first priority.

If there is severe haemorrhage from the midline, often audible, go straight to aortic compression.

If there is severe haemorrhage from a penetrating wound, follow the trajectory to try to find where the bleeding is coming from, and pack there first.

After placing your packs, you can now determine the site of major bleeding (you may already have a clue from FAST scans), and deal with it either temporarily by packing or definitively depending on the severity & site of injury.

After blunt trauma, the most common causes of haemorrhage are a ruptured spleen, liver, or kidney. In the latter case, and if it is the only injury, there will be a retroperitoneal haematoma and no intraperitoneal blood. Splenectomy (55.6) is the best treatment for severe splenic injury.

With penetrating injury (55.3), any organ including the major blood vessels are possible sites of bleeding. Upon opening the abdomen, if there is an obviously spouting blood vessel, immediately pinch it between your fingers, isolate it carefully, and clamp it. *Don't clamp blindly with frantic efforts in a pool of blood!* In penetrating trauma, you may find a single bleeding vessel, but rarely in blunt trauma.

N.B. Severe haemorrhage can be difficult to control. The secret is to control it temporarily with pressure, packing, and patience - especially patience. Then, slowly and carefully try to find the bleeding site. *Don't try to find the source of bleeding first and then use packs!*

N.B. Packing from outside the organs compresses the tissues and reapproximates tissue planes; packing from within fills a cavity.

Is this a case for damage control surgery (41.5) **or definitive repair?** *An abdomen full of blood, bile, intestinal content or urine requires an early decision!*

If there is an aortic injury, try to get formal control:
N.B. Controlling haemorrhage from the liver or spleen rarely needs clamping of the aorta (55.4). A rapid splenectomy (55.6) is the best option for a damaged bleeding spleen in an unstable patient. Likewise packing the liver (55.7) is usually the best immediate treatment for hepatic bleeding.
Once major bleeding has been controlled, by temporary packing or clamping, make a thorough systematic exploration of the abdomen (55-5, 11-2).

N.B. If blood for transfusion is sparse, use it only after you have stopped the bleeding! Think of auto-transfusion (5-1).

Now control any contamination. For an abdomen full of pus or intestinal content or both, use an efficient sucker, then a moistened abdominal pack to mop any residue. Then, using a moistened swab or compress, carefully control control any leak from the gastro-oesophageal junction to the rectum.

Use the swab to remove any clinging blood clots. Note any greenish discolouration around the duodenum, or over the pancreas, and any brownish colour around the retroperitoneal colon. *This is particularly important in penetrating injuries.*

FIND AND TREAT ALL INJURIES 'PRESSURE, PACKING AND PATIENCE'

SURVEY
Whether the case is severe or simple, you *must* identify *all* the injuries. This requires a systematic exploration of the abdomen: follow the same routine each time and *don't make a haphazard survey.*

There are 2 main compartments, supra- and infra-mesocolic. The first contains the liver, stomach and spleen; the second contains the rest.

EXPLORATION
Start by pulling the transverse colon downwards. Look at and palpate the liver, gallbladder & right kidney, then the spleen and left kidney. Inspect the whole stomach up to the diaphragmatic hiatus, and what you can see of the duodenum. Inspect the whole diaphragm, including any deformation from the thoracic side.

Then lift up the transverse colon and follow the whole bowel from the duodeno-jejunal junction (ligament of Treitz) to the rectum. For this you need both your and your assistant's hands to flip over the bowel and examimne both anterior & posterior surfaces as you progress to the rectum (55.12). It is best to palpate the bowel with your fingers, using a moist compress to remove any blood clots.

EXPLORING FOR ABDOMINAL TRAUMA

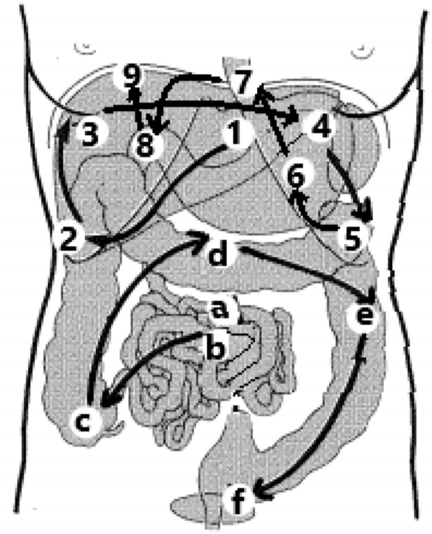


Fig. 55-5: EXPLORING THE ABDOMEN. Pull the transverse colon and follow from liver (1) to rt kidney (2) to gallbladder (3), to spleen (4) to lt kidney (5) to stomach (6) to diaphragmatic hiatus (7), to duodenum (8) to dome of the diaphragm (9). Then lift the transverse colon, and follow from D-J flexure (a) to small bowel (b) to caecum (c) to transverse colon (d) to descending colon (e) to rectum (f).
After Dudley HAF (ed), Hamilton Bailey's Emergency Surgery, Wright, 11th ed 1986 with kind permission.

If you need to explore the lesser sac (because there is a gastric perforation), make a hole in the greater omentum in an avascular area, which is usually on the left. To find this, get your assistant to lift up the stomach and transverse colon; this gives you a good view of the posterior stomach and pancreatic body & tail.

If you need to look at the posterior part of the duodenum (because of a greenish discolouration or a per-duodenal haematoma), perform the Kocher manoeuvre (13.5), but don't do this routinely.

If you find a bowel perforation, put soft clamps on either side over a gauze compress and continue the exploration. You might have noticed this earlier upon opening the abdomen and clamped the bowel already: *don't forget to continue a systematic exploration*! There may be other trouble brewing.

If you find a peri-colic haematoma or brownish discolouration, mobilize that part of the colon: you will probably find a posterior wall injury.

Lastly, remember to examine the bladder, uterus & tubes in the pelvis. For penetrating injuries with a hole in the posterior peritoneum that is anatomically close to the ureter, you will have to open & inspect for any damage.

CONTAMINATION CONTROL
After you have controlled the bleeding, you need to control the spillage of intestinal contents or urine from hollow viscus injuries. *The goal is to stop further contamination, NOT to repair the damage, so don't perform anastomoses or fashion stomas at this stage.*
We describe definitive repair under the organs concerned.

(a) Gastric injury (55.9)
If there are one or two simple perforations, it is quickest to close these with a simple continuous suture.
If a significant portion of stomach is damaged, resect it, & close off the open end with a continuous suture or with a linear stapler (4-16).

(b) Peri-duodenal haematoma (55.10)
Perform a Kocher manoeuvre (13.5) to mobilize the duodenum, as it is most likely injured.

(c) Bowel injury (55.11, 13)
If there are one or two simple perforations, it is quickest to close these with a simple continuous suture.

If there is much soiling, practice damage control and interrupt the bowel's continuity with a tape (55-6)

BOWEL INTERRUPTION

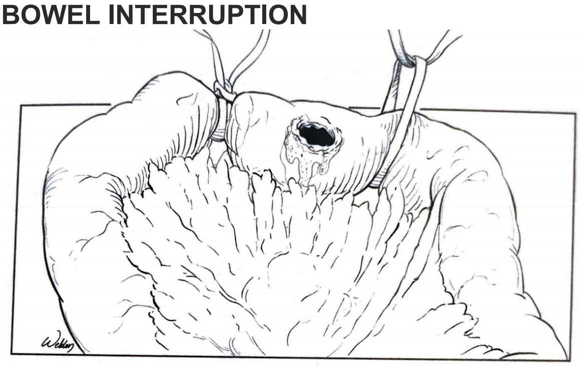


Fig. 55-6 ISOLATION OF A PERFORATED BOWEL SEGMENT. Using tape means making a small hole in the mesentery next tot he bowel, but is neat. *Clamps may slip off and get in the way.* *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If you have linear staplers, quick bowel resection is easy (55-7)

QUICK BOWEL RESECTION

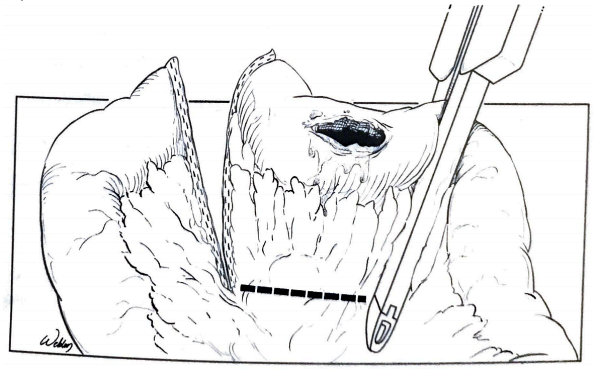


Fig. 55-7 Rapid bowel resection is easy with linear staplers. Otherwise, if there is bleeding in the near-by mesentery, use crushing clamps across the mesentery. Excise the damage portion and decide if you should perform an anastomosis *(definitive care)* or follow damage control. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If there are many perforations, resect the entire segment and simply tie off the ends with a thick ligature, tape or with a cutting stapler if you have one (4-16). Put crushing clamps across the involved mesentery, remove it and then either tie it off or use a cutting stapler. This is the same for both small and large bowel.

If you find a peri-colic haematoma, mobilize that part of the colon: you will probably find a posterior wall injury. *N.B. There is no place for a stoma – ileostomy or colostomy – as a damage control procedure, although you can bring out a loop of injured ileum.*

(d) Pancreatico-biliary injury (55.7,13)
This is often accompanied by a duodenal injury. Use a simple drain to convert these into controlled fistulae. Bring the drains out laterally through the flank at the mid-axillary line. *Be careful not to kink these drains with packs you are leaving inside*.

(e) Diaphragmatic injury (43.4)
Repair a hole in the diaphragm with continuous 0 non-absorbale, taking large bites and puilling up the suture to prevent the edges from inverting Reduce and repair or resect any organ that has herniated through the hole first, and wash out the pleural space.

(f) Ureteric injury (55.16)
Cannulate the ureter proximal to the injury (a paediatric feeding tube is ideal), and pass the catheter down into the bladder; leave it there if cystoscopy is available. Otherwise bring out the end suprapubically. Place a simple Penrose drain at the site of injury and bring this out extraperitoneally in the flank.

An alternative is simply to put in a T-tube without attempting an anastomosis, fix it with a ligature, lead the long leg out of the abdomen

N.B. A uretero-cutaneous fistula often results in ascending pyelonephritis.

In extremis, you can tie off both ends of the ureter, make a defunctioning nephrostomy, leaving an anastomosis for the 2nd look operation.

(g) Bladder injury (55.17)
Repair the hole with a continuous suture. Leave a urinary catheter. If the hole is too large to close simply, cannulate both ureters from inside the bladder and lead them to the outside suprapubically. *Fix the cannulae so they don't fall out!* Pack the bladder cavity if it is bleeding.

(h) Uterine injury (55.18)
If there is only a small hole, debride and close it in two continuous layers, as at a Caesarean section (21.10). If there is significant rupture of the uterus, pack the cavity.

REVIEW

If the patient remains stable, and is in good health, *especially if you needed no packing,* proceed to definitive repair, if you can finish this within the 90min grace period. *Check the patient's temperature: avoid hypothermia at all costs!*
Don't submit a young patient with a simple injury to damage control protocols unless he needs it!

If you have controlled bleeding after your original packing, it is wise to leave the packs alone. Write down the number of packs left inside. *Removing packs may restart the bleeding!*

If the abdomen is now dry, remove packs sequentially, starting with the quadrant where there was less bleeding. Work your way to the quadrant with the most severe bleeding/injury.

If the patient remains haemodynamically unstable, or has been significantly unstable, especially for >45mins, or there is considerable soiling, wash out the abdomen & finish the surgical intervention here. Leave the abdomen open for a second look in c. 48h (11.10).

Carry out a repeat exploration afterwards to check if you have not missed anything. Then thoroughly wash out the abdomen; you can use sterile water for this. *Make sure it is warm!*
Finally, close the abdomen (11.8)

55.3 Penetrating abdominal injury

SPECIAL FEATURES
All trauma, blunt or penetrating, is the result of transfer of kinetic energy to the tissues that causes their disruption. Sometimes this energy transfer is of a very low level (stab wound or a punch) and sometimes very high (blast or rifle bullet or high-speed vehicle crash). You should understand the mechanism of injury in order best to make a diagnosis and plan the management of your patient.

Blunt injury transfers energy in a very diffuse manner, easily affecting an entire organ. Penetrating injury generally affects only the tissues closely around the trajectory of the wounding instrument, with a few exceptions.

Blunt injury selectively affects certain organs much more than others; a fall from a height or road traffic crash often shatters the liver, but does not often affect the small intestines. The liver, spleen, kidneys, and less often the pancreas, are most commonly injured after blunt trauma.
Penetrating trauma can injure **any** abdominal organ or blood vessel. Most perforations of a hollow viscus will be from penetrating trauma. Many missile injuries also devitalize the tissues surrounding the trajectory, so these tissues will need debridement till you reach healthy bleeding tissue.

The most common penetrating injuries of the abdomen include:
(1) Stab wounds: (usually of criminal intent).
(2) Animal horn impalement: (buffalo, cow, goat: 46.10).
(3) Gunshot wounds, handguns or high-powered rifles: (criminal activity or armed conflict: 46.14).
(4) Blast injury giving off metal fragments: (bombs, shells, landmines), & rarely volcanic eruptions (46.15).

Although all of these are penetrating injuries, their consequences are very different. Some points of management are the same, but you should know the differences as well.

N.B. Any penetrating injury between the nipple line and the knees may enter the abdomen. You must carefully examine the front and back of the abdomen, chest, perineum, buttocks and upper thighs.

A PENETRATING ABDOMINAL INJURY

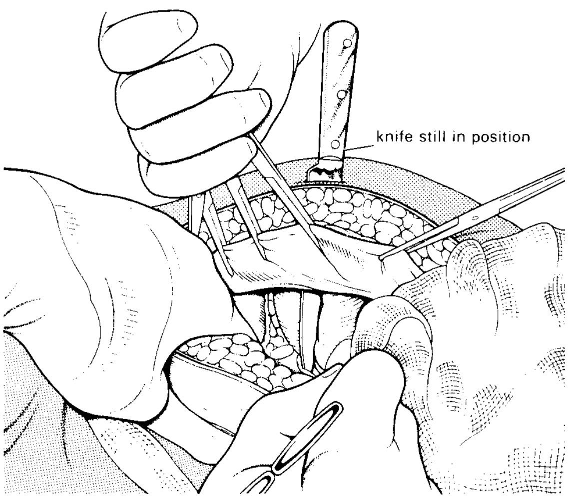


Fig. 55-8 A PENETRATING ABDOMINAL INJURY, illustrating the value of making a separate incision which enables you to see the track of the knife. ***N.B. leave the knife in place until you get the patient to theatre. Immobilize the penetrating object with adjacent bandages and pack a cardboard box around the patient if he needs to be moved.*** *Kindly contributed by Peter Bewes.*

MANAGEMENT OF STAB WOUNDS
Some knives have short blades, others long. Some stab wounds of the abdomen don't even enter the peritoneal cavity, but only damage the muscles of the abdominal wall, especially in fit muscular young men.

Up to 50% of intraperitoneal stab injuries don't hit an organ, the blade sliding between coils of the intestines or creating a superficial laceration of the liver or intestine that does not require suturing.
So some stab wounds may not need laparotomy. You must take a good history of the injury, and make a good clinical examination of the patient.

If a patient arrives with the impaled object still *in situ*, *don't take it out except in the operating theatre.* You may need to transport the victim, so fix the object with bulky dressings and hold it in place with sticky tape. Then cover the whole with a cardboard box in which you have cut edges to stop the box moving about (55-9).

A PROTECTIVE COVER

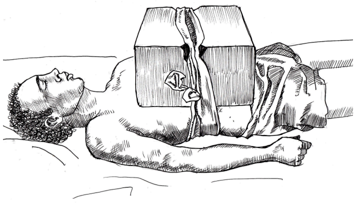


Fig. 55-9 FIXING PROTECTION for a foreign object impaled in the abdomen. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

If a patient has no signs of visceral damage and remains haemodynamically stable, you may be able to manage things conservatively. Explore the penetrating wound (which may be in the chest, flank, back or buttocks, as well as the abdomen), in theatre under LA. Use sedation if necessary.

Leave a penetrating object *in situ* if it is still there, so you can see if it has breached the peritoneum. And if it has, still leave it in place until laparotomy. You don't know where the point has reached. (This is a general rule for any impaling foreign object anywhere in the body.)

PENETRATING THORACO-ABDOMINAL TRAUMA

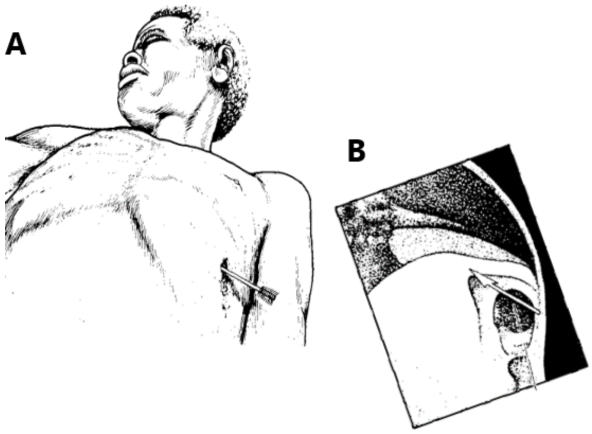


Fig. 55-10 A PENETRATING THORACO–ABDOMINAL INJURY. A, the arrow only appears to have gone into the chest, B, ***but has in fact entered the stomach. N.B. Don't think an arrow penetrating a little lower, which appears only to enter the abdomen, has not also gone into the chest!*** *Kindly contributed by Peter Bewes.*

Explore the wound down to the peritoneum, and open up the plane between the *transversus* and the peritoneum over a reasonable area and inspect it.

If the peritoneum is intact, close the wound by immediate primary suture, unless it is soiled, in which case you must debride it thoroughly and leave it open. *Continue to monitor the patient, in case your assessment of the peritoneum was wrong.*

If there are >2 perforating abdominal injuries, *don't waste time exploring each one in turn:* proceed to laparotomy. The chances of injury with two stabs is much greater than with just one.

If you have found a breach of the peritoneum or a plug of omentum protrudes through the peritoneal wound, open the peritoneum fully & proceed to a laparotomy.

If there is an intact organ herniating out of the abdomen through a stab wound, proceed to laparotomy.

Where the abdominal wall is opened, and viscera are exposed, they are in danger of getting infected, herniating out, or being damaged.

Rarely the abdominal wall may bleed, especially the epigastric arteries. You should make a separate formal laparotomy incision; don't *try to explore the abdomen through the stab wound.*

If herniated bowel is still viable, and there will be a *delay getting to theatre*, infiltrate LA in the wound from which it is herniating, and enlarge the hole to release the strangulation. Time is critical. Few patients survive if peritonitis has been developing for >12h, but most will survive if you operate within 4h.

If the herniated bowel is perforated, clamp it with a non-crushing clamp so leaking bowel content does not contaminate the wound.

If there are serious wounds on the back, explore these first, if the patient is haemodynamically stable. Otherwise, roll him on the side after the abdominal operation.

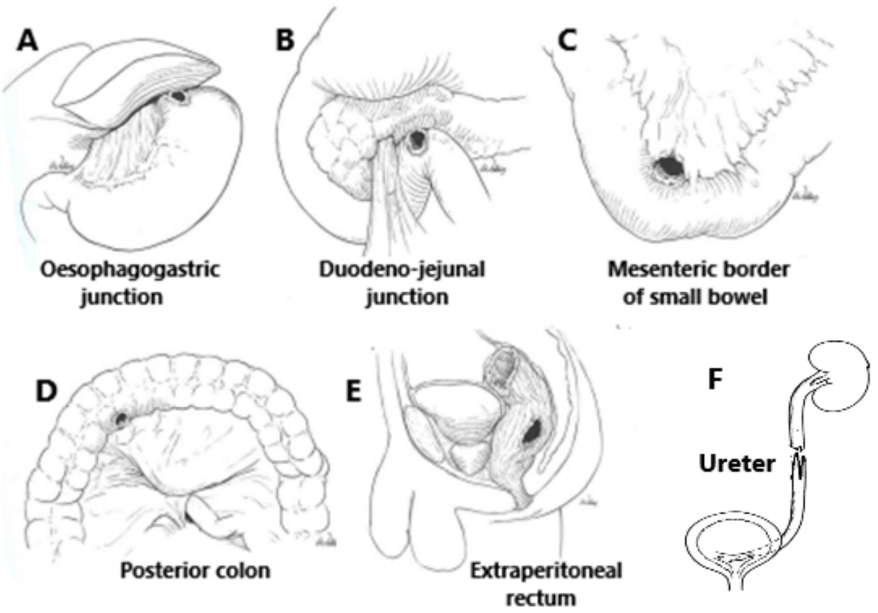
If you have found nothing amiss, repeat the exploration routine, including the Kocher manoeuvre (13.5) and exploration of the lesser sac. Check the 6 common places where you may miss an injury (55-18).

The injuries you may commonly overlook at laparotomy are:
(1) gastric perforations high up on the lesser curve or on the posterior wall,
(2) perforations at the duodeno-jejunal junction,
(3) small bowel perforations on their mesenteric border,
(4) colonic perforations, especially on their posterior wall. *N.B. any subserosal haematoma might hide a perforation:* unroof it!
(5) extraperitoneal rectal perforations,
(6) ureteric injuries.

Remember to count the number of perforations in penetrating injuries. If they are an odd number >2, keep looking. Be satisfied with an uneven number only after a very careful search. With stab wounds, the knife blade often cuts just one surface of the intestine, unlike with bullets.

Similar to stab wounds by a knife are puncture wounds from some other object: a screwdriver, a splinter of metal or wood. The latter will show up on a plain radiograph of the abdomen and should always lead you to do a laparotomy.

AMOS (6 years) was playing on a child's slide. He went down on his front, feet first, and subsequently complained of abdominal pain. There was a small laceration on the abdominal wall near the umbilicus. Signs of general peritonitis developed, and laparotomy showed a splinter of wood 15 cm long and 3 cm wide, & which had entered the abdomen and penetrated the anterior wall of his stomach. This was removed, the stomach repaired, and he recovered.



COMMON MISSED INJURIES

Fig. 55-11 COMMON MISSED BOWEL INJURIES. These places where a rushed exploration may miss include: A, oesophago-gastric junction. B, duodeno-jejunal junction. C mesenteric border of the small bowel. D, posterior colonic wall. E, extraperitoneal rectum. F, ureter. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

MANAGEMENT OF IMPALING BY ANIMAL HORNS

The upward lift of an animal horn has much more kinetic energy than a knife stab, and the horn is definitely not clean. Often, the animal strikes the victim in the buttocks or tears out a piece of the abdominal wall. You should always perform a laparotomy and debride the edges of any and all wounds, in the abdominal organs, buttocks or abdominal wall.

PROJECTILE WOUNDS

Injury is related to the kinetic energy of the projectile, bullet or metal, which is a function of its mass and velocity. Projectile wounds are dirty and contaminated and you will have to debride all wound edges in the abdominal wall and injured organs.

The wounds caused by fragments may also be accompanied by primary blast effects (46-9).
You must do a very careful examination of the patient: a close palpation, front and back and sides. A very small entry hole can easily hide in the skin folds of the groin or scrotum or buttocks. Make a note of the number and nature of the wounds, which may be small and multiple punctate holes or a single gaping wound, or even with evisceration of the abdominal organs.

Simple radiographs of chest, abdomen & pelvis are useful to locate bullets or fragments.

N.B. You occasionally find these, having ricocheted off bone in bizarre places far from the entry point.

You may be able to determine the trajectory of a bullet, but its passage is unpredictable, especially if it is still inside! People are not usually injured when standing in a textbook anatomic position! *Mark any projectile wounds with radio-opaque markers (e.g. paper clips) before taking a AP & lateral radiograph.*

MANAGEMENT

N.B. Fragments from explosions are often of low velocity, low mass and, therefore, low kinetic energy, not penetrating the peritoneum. The same rule governing a stab wound applies: explore under local anaesthesia in a non-symptomatizing patient.

N.B. The general rule is that all projectile wounds of the abdomen should proceed to laparotomy.

Any abdominal organ or vessel may be injured and injury to multiple organs is frequent. Be prepared to deal with solid and hollow organs, and blood vessels. The ballistic and blast effects of projectiles mean that you must debride all wounds of all organs back to healthy bleeding tissue, removing necrotic, devitalized and contaminated tissues.

The more focalized damage to the liver, in perforating rather than blunt injuries, means that you need to perform debridement and use liver suture techniques more often than liver packing. The spleen can sometimes be saved, but *don't attempt this unless you are experienced and have good post-operative nursing care!* (55.6)

See, for perforations of the stomach (55.9), duodenum (55.10), small bowel (55.11), large bowel (55.13), rectum (55.14), & bladder (55.17).

Remember to count the number of perforations in penetrating injuries. If they are an odd number >2, keep looking until you find one, or a foreign body (usually the bullet or fragment) inside a hollow organ! Be satisfied with an uneven number only after a very careful search.

MANAGEMENT OF THE ABDOMINAL WALL
In ordinary circumstances, close the abdomen in standard fashion. *Never close the abdomen under tension!*

If a segment of abdominal wall is missing, or if the bowel has become very distended, *don't try to stretch the abdominal wall to close it!* This is especially important if the wound has been caused by an animal or a projectile and therefore needs debridement (46.10). As with a damage control laparotomy, *leave it open as a laparostomy* (11.10) and plan definitive repair later.

55.4 Aortic control

If, when you open the abdomen, blood wells up filling the field of view (often with a 'whoosh' sound), try pressing on the aorta. Get your assistant to take over whilst you continue.

Bluntly open the avascular portion of the lesser omentum, feel the aorta immediately to the right of the lesser curve of the stomach, with a nasogastric tube within by now).

Compress the aorta against the spine, or pinch it between your index finger and thumb. If pressing on the aorta allows you to identify a vascular injury that you can repair, you will need to clamp it. *Otherwise there is no point*! *Don't bail out here thinking this is too much for you! If you have got thus far, and don't continue, the patient will die. Hold the aorta with sutures on a 4/0 round-bodied needle or with non-toothed forceps; cutting needles & sharp instruments may tear the wall & cause further damage!*

Remember when you clamp the aorta, there will be ischaemia of entire abdomen, pelvis and lower extremities.

N.B. After aortic repair, you may need to perfrom leg fasciotomies (49.6) to avoid re-vascularisation compartment syndromes.

If you have already performed a thoracotomy, an easier alternative is a clamp on the descending portion of the thoracic aorta.

AORTIC CLAMPING (GRADE 3.4)
From the abdomen, you should try to clamp the lower thoracic aorta above the coeliac axis. Make a hole in the avascular portion of the lesser omentum (immediately adjacent to gastric lesser curve) and insert a long retractor into the hole (55-12).

Retract the stomach and duodenum to the left of the abdomen. Palpate the pulsatile aorta. Make a hole bluntly into the posterior peritoneum, and separate the two limbs of the right crus of the diaphragm with finger or scissors (55-13).

OPENING THE LESSER SAC

Fig. 55-12 OPENING THE LESSER SAC. Getting access to clamp the aorta. Opening an avascular portion of lesser omentum adjacent to the lesser curve of the stomach. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

OPENING THE RIGHT CRUS OF THE DIAPHRAGM

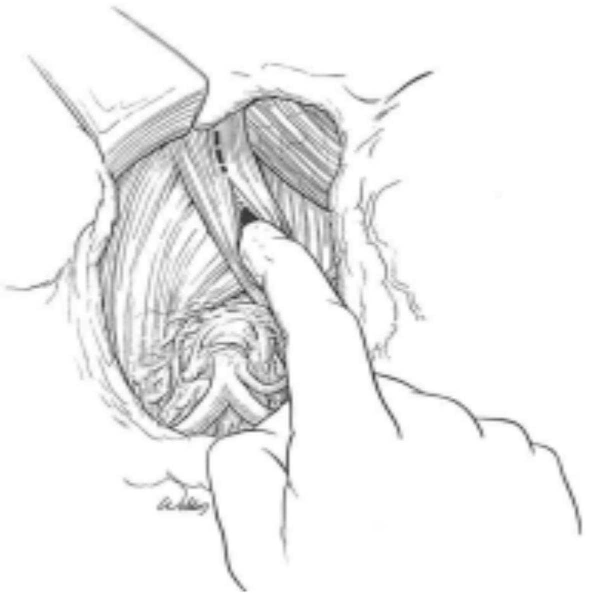


Fig. 55-13 OPENING THE RIGHT CRUS. After opening the posterior peritoneum, palpate the aorta and separate the 2 limbs of the crus over it. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Make enough space to place the clamp by insinuating your fingers on either side of the aorta, down to the vertebra (55-14).

GETTING READY TO CLAMP THE AORTA

Fig. 55-14 GETTING READY TO CLAMP THE AORTA. Make enough space with your fingers on either side of the aorta to place the clamp. Then check if there is no more pulsation distally. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Guide the aortic clamp into place using the fingers of your left hand. It's best to use a straight clamp placed vertically at right angles to the spine. Clamp the aorta carefully and check the distal aorta for pulsation. Secure the clamp with tape to the drapes to keep it from falling into your wound. *Note the time.*

Remove the clamp as soon as you can or at least place it more distally, preferably on the infrarenal aorta. *Remember when you clamp the aorta, there will be ischaemia of the entire abdominal contents, pelvis and lower extremities!*

55.5 Inferior vena caval control

If, when you open the abdomen, dark blood wells up from below, and pressure on the aorta does not make much difference, and you suspect the IVC is ruptured, you need to press on the IVC on both sides of the site of its perforation.

Press on the IVC with 2 swabs held on sponge-holding forceps (55-16) and, if this does not allow you to get adequate control for a repair, apply Rumel tourniquets above & below, and if necessary, on both renal veins. *Don't use suction as you can easily exsanguinate a patient this way!*

N.B. You need to approach a hole in the posterior wall of the IVC through the anterior wall!

CONTROLLING THE INFERIOR VENA CAVA

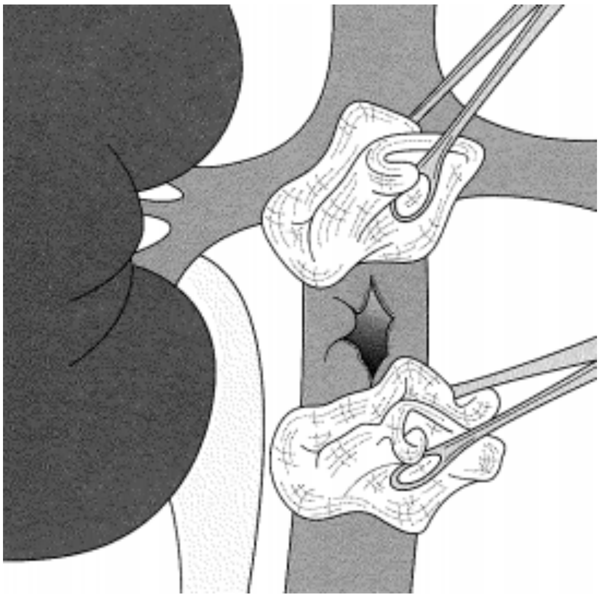


Fig. 55-15 CONTROLLING THE IVC. To get access to the IVC, perform a right medial visceral rotation (55-27) **and if you need access to the part of the IVC just below the liver, the left medial visceral rotation** (55-26)**.** *After Boffard KD ed, Manual of Definitive Surgical Trauma Care. CRC 3rd ed 2011*

55.6 Splenic injury

The spleen is a commonly damaged abdominal organ in blunt trauma. It lies under the 9th-11th left ribs and you must always think it may be injured if these ribs are damaged, or there is an impact to the lower left hemithorax.

A classic history is a cyclist who is thrown against the handlebars of a cycle. The spleen is very vulnerable in children, and in splenomegaly due to malaria. A classic symptom is pain in the tip of the left shoulder (referred pain from left hemidiaphragm irritation by collected blood)

The spleen may also be injured by knives, gunshots or animals, by excessive traction or mobilization of the colon in surgery, and occasionally by a chest drain inserted too low.

The spleen has important haematological, as well as immunological functions, protecting against pneumococcal pneumonia, *haemophylus B &* meningococcal infection, malaria & tick-bite fever, so if you can preserve it, do so. It receives 5% of the total cardiac output, and *can bleed massively* (55.2). An initial haemorrhage may be contained by the splenic capsule, which *may rupture catastrophically later* (the latent period of Baudet).

MANAGEMENT

This is not the sort of case you can safely refer! Non-operative management for minor splenic injuries with little bleeding is not an option unless you can guarantee very close observation for at least 48h.

During packing the abdomen, you should have put a back behind the spleen, thus bringing it forward. This is essential, because you need to see what you are doing, and otherwise the spleen will remain hidden.

The spleen is usually mobile, and big malarial spleens are particularly fragile (adherent tubercular or bilharzial spleens don't rupture so easily). This means you can put your left hand round the back of the spleen and bring it forwards, leaving it attached to the splenorenal ligament, which you can now divide under direct vision.

MOBILIZING A NORMAL LACERATED SPLEEN

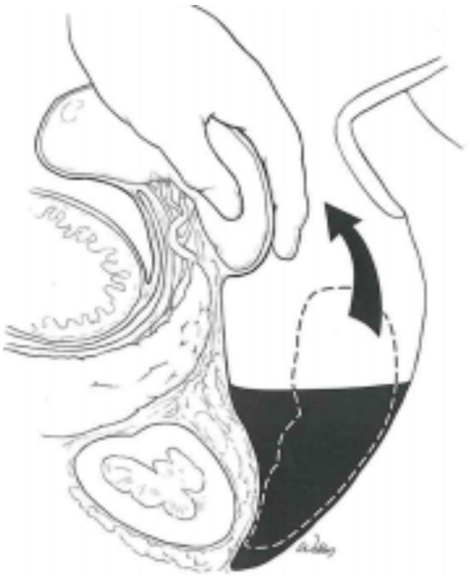


Fig. 55-16 MOBILIZING A NORMAL LACERATED SPLEEN. Bring out the spleen from its bed by pulling it out from behind. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If the spleen is adherent to the lateral abdominal wall or diaphragm, you might not be able to get your hand round it. Use long scissors (and your fingers) to prise the adhesions apart. Put a large pack behind the spleen: this controls bleeding & pushes the spleen forwards.

Even if you split the splenic capsule doing so, you will be committed to removing the spleen anyway: just work fast till the spleen is held by the splenorenal ligament (55-17A). You might have to divide this blind: just bring the spleen & pancreatic tail into the midline.

Develop the plane between the spleen and left kidney so you can mobilize it to the midline (55-17B). Now pinch the splenic pedicle (which contains the splenic & short gastric vessels), and control this with a tape or non-crushing clamp.

MOBILIZING AN ADHERENT SPLEEN

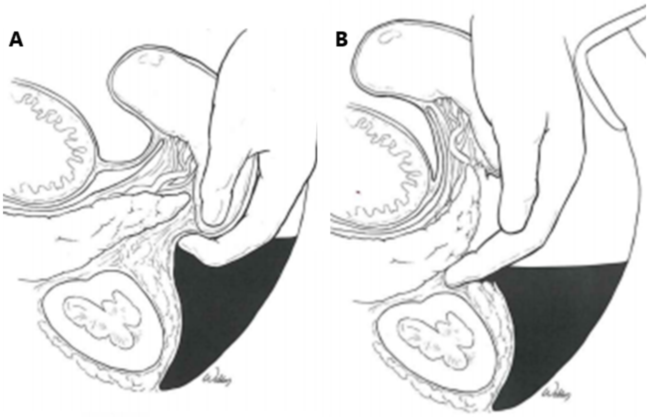


Fig. 55-17 MOBILIZING AN ADHERENT SPLEEN. A, after dividing adhesions to the lateral abdominal wall, feel for the splenorenal ligament with your fingrer and cut or break it. B, then work your finger between the spleen and left kidney. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If the spleen is totally stuck and mangled, and you cannot mobilize it, isolate the pedicle from in front first. Pull the stomach forwards, and divide the gastrosplenic ligament between clamps. Behind it is the splenic hilum; occlude this with a tape or non-crushing clamp.

SAVING OR RESECTING THE SPLEEN?
Try to preserve the spleen, especially in children. However, if a patient's life is in danger, *the safest solution is splenectomy!* Splenic repair by bolstered suture or wrapping is a specialized technique and fraught with uncertainty. Reimplantation of pieces of spleen (15.17) *protects against pneumococcal (and maybe other bacterial) infection* and may also protect against malaria.

EMERGENCY SPLENECTOMY (GRADE 3.4)
The emphasis is on speed, so *this is not like the elective splenectomy* (15.17)

To remove the spleen, put an arterial clamp across each of the vessels at the splenic hilum; stay close to the body of the spleen so you don't damage the pancreatic tail or the stomach. Cut distal to the clamps, one by one. Don't put one big clamp on the hilum and try to ligate this: *it is too likely to come off!*

Similarly clamp and divide the gastrosplenic ligament as far from the stomach as possible, and then deal similarly with the remaining splenocolic ligament.

For extra security, suture-ligate the hilar vessels. Doubly ligate the vessels proximal to the clamps and remove them one by one.

Put a big dry pack in the splenic bed, and leave it there for a few minutes. Remove it and check for any residual bleeding. Check also if there is damage to the stomach (close it) & pancreas (drain it).

N.B. Look for other abdominal injuries before you close the abdomen.

PROPHYLAXIS AGAINST INFECTION
Infants and children are very susceptible to infections after splenectomy, as are immunosuppressed adults, and those with sickle-cell disease. Follow a standard protocol, such as:
(1) Penicillin or ampicillin intra- and post-operatively
(2) Pneumovax-23 vaccine (v. *Streptococcus pneumoniae*) at day 14 post-injury or on day of discharge, whichever comes first.
N.B. Heptavalent vaccine is not effective.
(3) *Haemophilus influenzae B* vaccine only if the patient is <13yrs and not immunized.
(4) Meningococcal vaccine (v. *Neisseria meningitidis*) only in endemic areas, as the Pneumovax-23 cross-covers this as well.
(5) Re-vaccination after 5yrs for children <10yrs.

N.B. Long-term antibiotic prophylaxis is not recommended except for children with rheumatic heart disease and immunocompromised adults. Treat splenectomized children early even for 'minor' respiratory infections with amoxicillin-clavulanic acid (1g tds).

N.B. Take specific prophylactic measures where malaria, meningitis, and tick bites are common.

DIFFICULTIES WITH EMERGENCY SPLENECTOMY
If oozing is uncontrollable, insert large packs in the splenic bed and change to damage control mode (41.5, 55.2)**.**

If you have damaged the pancreatic tail, leave 2 closed drains in place till they stop draining.

If a patient suddenly becomes hypotensive postoperatively, perform a re-laparotomy immediately: a ligature has probably slipped. don't *waste time with investigations, except perhaps an ultrasound examination if you can do this very quickly.*

If a pleural effusion develops post-operatively, drain the fluid and check it for amylase levels. It usually resolves. Check for the development of a **subphrenic abscess** or **pancreatitis**.

If the wound becomes infected, suspect a pancreatic leak. Open the wound and wash out the abdomen, and splenic bed especially; leave in a drain.

If portal vein thrombosis ensues (which you may be able to diagnose with ultrasound, and is more common in cirrhotics), start heparin.

55.7 Hepatic & biliary injury

The liver has several segments related to their specific blood supply: these *don't* correspond to the anatomical lobes. It has a special double blood supply from the hepatic arteries & the portal vein. It is protected by the lower right rib cage; so anything which damages this may also injure the liver. The liver is commonly injured (especially when it is enlarged): certain injuries may cause only minor bleeding, but high-speed or penetrating injury can disrupt the liver severely.

The liver does not tolerate compression, shearing & deceleration forces well. Severe shearing may cause the hepatic veins or IVC to tear off from the posterior liver surface causing massive bleeding.
A deceleration injury may produce a stellate rupture of the liver tissue. Liver injuries, if they bleed, usually also leak bile.

The liver is commonly injured, but bleeding tends to be more obvious than from the spleen. In a cirrhotic or a patient with portal hypertension (*e.g.* secondary to schistosomiasis), even a minor injury may cause catastrophic bleeding.

Pain & tenderness in the right hypochondrium or epigastric area after trauma are highly suspicious of hepatic damage.
An associated intestinal haemorrhage suggests blood is passing into the biliary tree.

MANAGEMENT
When you have opened the abdomen, a great many liver injuries, whether due to blunt trauma or a stab wound, have stopped bleeding or present a subcapsular haematoma. *Don't fiddle with this!* Place a moistened abdominal pack on the laceration or haematoma. Nonetheless such patients still need further assessment.

In mild or moderate bleeding, look at the inferior and feel the superior hepatic surface with your hand. Pack the liver (55-18).

PACKING THE LIVER FROM OUTSIDE

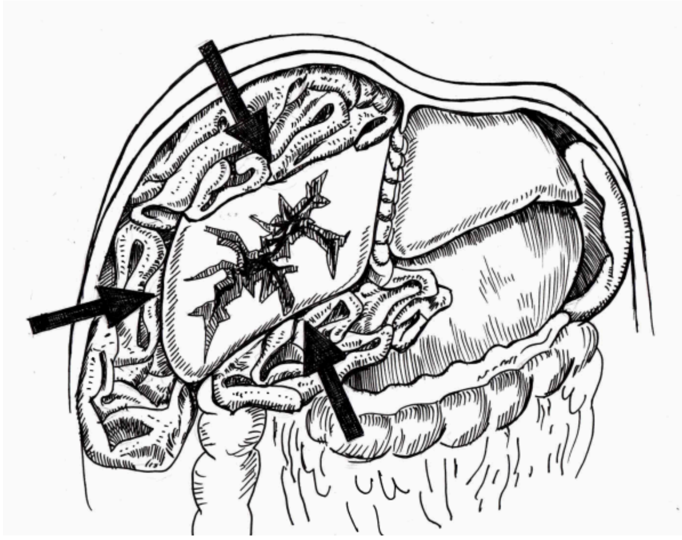


Fig. 55-18 PACKING THE LIVER FROM OUTSIDE. Compression of a fractured liver by proper placement of packs above and below the liver. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

For moderate to heavy bleeding, get your assistant to grasp the liver between both hands and compress it to re-establish the normal anatomy, whilst you pack the liver from outside (55-18). Get another assistant or the scrub nurse to lift the abdominal wall of the upper right quadrant.

COMPRESSING THE LIVER

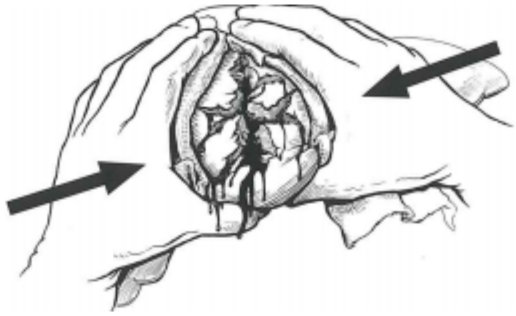


Fig. 55-19 COMPRESSING THE LIVER between both palms. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Put your hand over the dome of the liver, pulling it gently forwards, and put *folded* packs above your hand superior, and then inferior, to the liver (55-18). Then place packs between the lower ribs and the anterior and lateral surfaces of the liver: *don't cut any suspensory ligaments.*

Packs must create pressure in the right directions to be effective. Try to create a sandwich with the packs as the 'bread' and the damaged organ as the 'jam'. You need support for your packs: the diaphragm, abdominal wall, rib edge or other organs.

N.B. Packing does not usually stop arterial bleeding, but gives you time to get organized.

N.B. **Don't overpack.** *If you put in too many packs, you can create a compartment syndrome* (11.10), so watch the patient's BP.

N.B. It is also possible to obstruct the inferior vena cava when packing the liver.

So, in these instances, remove some packs and reassess the situation.

Since packs can absorb a lot of blood, *make sure they are compressing an organ and not just soaking up blood.* If you are not sure, remove the outer layers and look again. If it is obviously not working, rebuild your 'sandwich' so that it compresses more effectively. If this does not work, try manual pressure, balloon tamponade or a figure of 8 suture.

PACKING THE LIVER FROM INSIDE

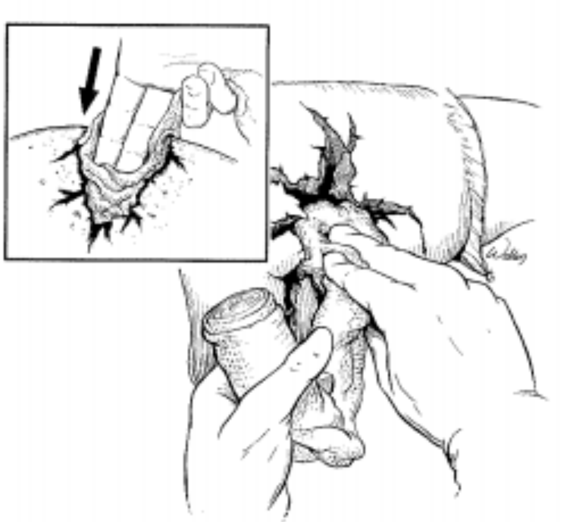


Fig. 55-20 PACKING THE LIVER FROM INSIDE. Internal packing of a stellate fracture of the liver using roll gauze. You may need to combine it with external packing. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Packing from within is the stuffing of a crevice or cavity with absorption gauze. Unfold a gauze roll (or 2 or 3, if 1 doesn't suffice) and push it in until the filling exerts outward pressure (55-20).
You always need both external & internal packing (*e.g.* for a stellate fracture of the liver), as the internal packing keeps the liver wound open.

Good packing should provide good control of most venou or solid organ bleeding. If the haemorrhage has stopped, continue your work with the rest of the abdomen and then come back to the liver. Gently remove the packs and note if you can repair the injury primarily. If not, repack.

DEEP LIVER SUTURES

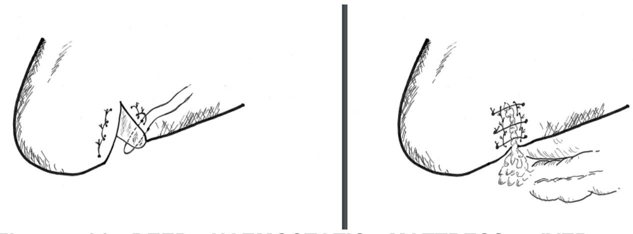


Fig. 55-21 DEEP HAEMOSTATIC MATTRESS LIVER SUTURES. A, place sutures parallel to the laceration, or B, over a leaf of omentum Tie them at right angles. ***N.B. You can make long needles by threading a suture through a spinal anaesthesia needle.*** *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

N.B. Liver suture is very useful in war situations. The liver capsule must be reasonably intact to hold the suture. Use omentum or pledgets, if you can, to stop the thread cutting through the liver tissue.

THE PEDICLED OMENTAL FLAP

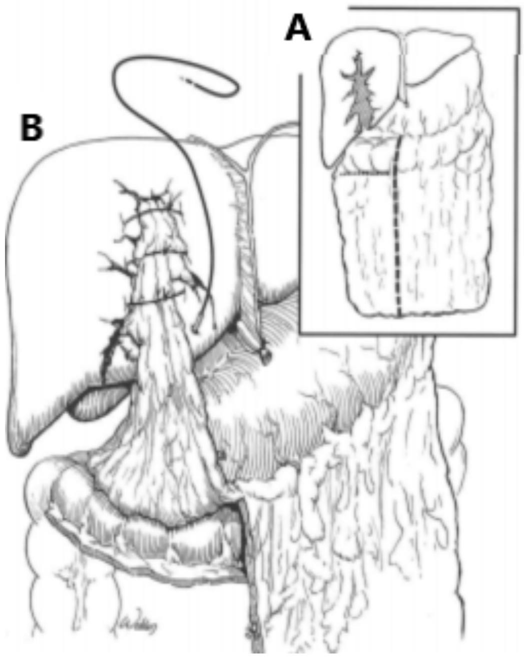


Fig. 55-22 PEDICLED OMENTAL FLAP. A, divide the omentum so both parts retain their blood supply. Use the right-sided part to tamponade a large liver injury. B, suture the omental flap, with its blood supply, onto the liver, taking wide bites of the liver capsule. ***N.B. Remove non-viable liver tissue by a finger-fracture technique.*** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

BALLOON TAMPONADE

Fig. 55-23 BALLOON TAMPONADE. Introduce a condom balloon (or Foley or Sengstaken tube) into a through-and-through liver defect and inflate it with saline to produce compression from within for haemostasis. Pass its end out of the abdomen through a lateral incision. Deflate the balloon after 48h and assess if bleeding has stopped.

See if you can (1) grasp a lacerated liver between the palms of both hands, (2) use wide deep sutures parallel to the laceration and at right angles acrossthe laceration to draw the edges together (55-21), if enough of the capsule is intact, (3) pack the laceration with a vascularized omental pedicle (55-22), or (4) tamponade a through-and-through penetrating injury with a condom balloon (55-23).

N.B. Post-opreratively, any liver injury will ooze blood and bile; place a closed drain for 24-48h.
After 48-72h, re-explore the abdomen and soak the packs with saline & glycerine, and gently remove them.

If bleeding is so severe that blood wells up in the wound or hypotension persists, try pressure on the aorta, (or pinching it between index and thumb) through a hole in the lesser omentum (55.3). Be patient, and find an assistant to take over pressing from you.

If packing of the liver fails to stop the bleeding, perform the Pringle manoeuvre: remember though that you have about 20mins only and need c. 8 units of blood to save such a patient with massive haemorrhage!

THE PRINGLE MANOEUVRE

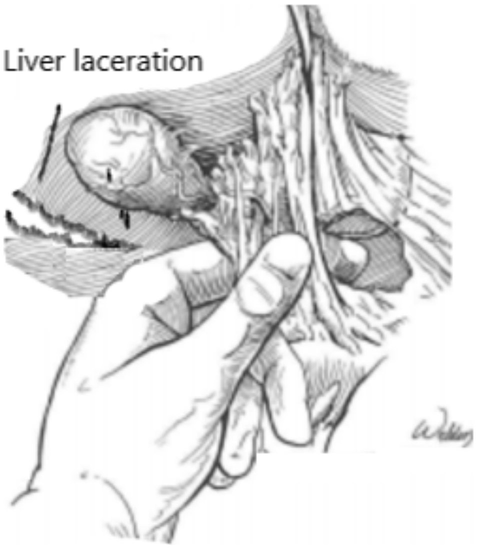


Fig. 55-24 THE PRINGLE MANOEUVRE. *This may be life-saving!* Pass a finger through a hole in the lesser omentum into the lesser sac. Pinch the vessels in the portal triad between your index finger and thumb, and clamp them in a Satinsky or bulldog clamp. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Make a hole in an avascular portion of the lesser omentum to the left of the portal triad (55-24). Put your left index finger into the lesser sac and pinch the vessels in the portal triad between your index and thumb (55-24), and then in a non-crushing clamp. Wait 10mins.

If the Pringle manoeuvre controls bleeding, it is coming from branches of the portal vein or hepatic arteries. If the blood is bright red, then selective ligation of the right or left hepatic artery will control the haemorrhage.
These are not end-arteries and will not cause hepatic necrosis. Try to avoid ligature of the common hepatic artery, however, which has a high mortality. If you have ligated the right hepatic artery, then the patient will need a cholecystectomy at definitive repair.

If pressure, packing, and Pringle don't stop the bleeding, and blood continues to well up, especially from behind the liver, bleeding is probably from the short hepatic veins entering the IVC posteriorly or the retrohepatic IVC itself. Mobilize the liver medially and pack behind and laterally with two or three sterilized gauze rolls, and bring out their ends through a lateral stab wound. Leave a drain.

Post-operatively, keep the patient lying on the back; the weight of the liver presses on the gauze packs and helps maintain the tamponade effect. After 48h, under light anaesthesia, gently pull out the gauze rolls. If the bleeding has stopped, your patient will survive. If bleeding resumes, proceed to damage control.

Proceed to damage control (41.5. 55.2) if:
(1) Bleeding has been controlled by packing, but recommences after removal of the packs,
(2) The damage is too great for primary repair (especially if you are lacking blood for transfusion),
(3) Hypothermia or acidosis supervene.
Temporarily close the abdomen and monitor the patient in a critical care facility.

If there is a bile leak, insert a closed drain. Subsequently the leak may close without further intervention. Rarely, if there is a clean tear of the common bile duct, if the duct is >Ch8 size, and the patient is stable, and access is not too difficult, you may attempt a primary repair. Insert a T-tube proximal to the repair. don't *put this across an injured bile duct*, as a stricture will follow.

The same advice follows iatrogenic bile injuries, usually following cholecystectomy. The definitive procedure, if primary repair is not possible because of loss of bile duct length, is a choledochojejunostomy-en-Y (15.4), which needs an expert.

If the gallbladder has ruptured, insert a Foley catheter into the remnants of the gallbladder, and secure the catheter in place, letting it drain into a bag outside the abdomen. *Don't attempt a cholecystectomy in difficult circumstances!*

DIFFICULTIES WITH LIVER INJURIES
If the wound discharges bile, there is a biliary fistula. Insert a drain and wait till it stops leaking. Add initial antibiotic treatment till a track has formed.

If jaundice supervenes, provided there are no other complications, support nutrition and try to monitor liver function & coagulation.

55.8 Retroperitoneal exploration

Retroperitoneal injuries after blunt trauma usually involve the kidneys, or pancreas. Penetrating trauma can injure any retroperitoneal structure. You only need to explore the retroperitoneum in exceptional circumstances; unfortunately, most patients with such severe injuries will die before they reach hospital.

The retroperitoneal space contains significant potential sources of haemorrhage: the abdominal aorta, inferior vena cava, and kidneys. Sources of contamination include most of the duodenum, pancreas, ureters, and posterior aspects of the ascending and descending colon.

Being a closed space, the retroperitoneal space often has a tamponade effect, limiting further bleeding, but this is not always so. Severe retroperitoneal bleeding is usually associated with intra-peritoneal bleeding. So, the indication for retroperitoneal exploration is usually if you have failed to control haemorrhage with packing, or if there is a perforating injury, typically by gunshot wounds.

ZONES
Deciding whether to explore a retroperitoneal haematoma can be difficult. To help you, divide the retroperitoneal space into 3 imaginary zones having the following sources of bleeding (55-2):
(a) Central Zone I: great vessels
(b) Lateral Zone II: kidneys
(c) Pelvic Zone III: iliac vessels and pelvic bones

In all cases (blunt or penetrating trauma), explore a central Zone I supracolic haematoma: likely pancreatic or duodenal injury will require contamination control.

Explore an infracolic haematoma in all cases of penetrating injury, but only after blunt trauma, if it is expanding or pulsatile.
N.B. Never explore a psoas haematoma! This is in effect an extension of an aortic or an IVC injury after penetrating injury. *Use a Foley balloon tamponade in the hole!*

In general, *don't* ***explore lateral Zone II haematomas****. Don't attempt to open a haematoma around the kidney! Don't jeopardize a patient's life to save the kidney.* There are always exceptions, of course: a pulsatile or expanding haematoma overlying the injured kidney requires exploration. A nephrectomy is necessary for a totally disrupted kidney.

N.B. Don't explore a Zone III pelvic haematoma with an intact peritoneum, usually the case after blunt trauma. If you do, you may well not be able to control the bleeding!

Explore for penetrating trauma, as after a gunshot wound, because of the possibility of injury to the iliac vessels, rectum or bladder. Control of bleeding from the pelvic bones, especially the sacrum, in these cases, is often not successful.

IN ALL CASES, OBSERVE THE HAEMATOMA. IS IT STABLE? IS IT PULSATING OR EXPANDING?

MOST MAJOR VESSEL BLEEDING PRESENTS AS A RETROPERITONEAL HAEMATOMA

Begin by packing over the haematoma and to take a moment to pause and think. Put in retractors (a circular one is ideal), if you have not yet done so.

Plan your next steps, determine what supplies you need (and wait until you get them), and let your anaesthetist catch up with the resuscitation of the patient. Notify your team of your plan and where you will need their help and attention. Gently remove the packs and look again, to confirm your decision to explore or not.

Don't attempt to open a haematoma around the kidney or a pelvic haematoma! (It will probably start bleeding again.) *Don't jeopardize a patient's life to save the kidney.*

There are 2 vital manoeuvres to expose the retroperitoneal space:

(a) The left visceral medial rotation (Mattox manoeuvre) mobilizes the left colon and mesentery, spleen and pancreatic tail. This allows access to the side of the suprarenal aorta and left kidney.

(b) The **right visceral medial rotation** (Cattell-Braasch manoeuvre) has 3 stages, mobilizing the duodenum, head of pancreas, right colon and root of the small bowel mesentery. This allows access to the infrarenal aorta, IVC, right kidney, posterior duodenum, superior mesenteric & iliac vessels.

THE LEFT VISCERAL MEDIATION ROTATION (GRADE 3.3) is easier. Pull the descending colon forwards, and divide the peritoneal line of reflection (white line of Toldt) lateral to the left colon from the pelvic brim to the splenic flexure (55-25), just as for a left hemicolectomy (12.11).

MOBILIZING THE DESCENDING COLON

Fig. 55-25 MOBILIZING THE DESCENDING COLON. Left-sided medial visceral rotation; mobilizing the descending colon along the white line of Toldt. *After Hirschberg A, Mattox KL. Top Knife. 2005 Tfm Shrewsbury with kind permission.*

Using your finger, carefully enlarge the plane between the left mesocolon and the retroperitoneum. This procedure is easier than it sounds because the haematoma will have already separated out the peritoneum from the posterior anatomic structures and you hand will easily sweep between them.

Make sure to leave the ureter and gonadal vessels posteriorly. Division of the peritoneal reflections holding the spleen will allow you to mobilize the spleen and tail of pancreas medially until you reach the aorta (55-17). This will also mobilize the 4th part of the duodenum at the ligament of Treitz.

THE RIGHT VISCERAL MEDIAL ROTATION (GRADE 3.4) allows mobilization from the common bile duct to the ligament of Treitz. If you perform all 3 steps, you can put the small bowel and the right colon upon on the chest!

Begin with the classic Kocher manoeuvre (13.5, 55-14A). Make a peritoneal incision lateral to the head of the duodenum and put your hand behind the duodenum to mobilize it and the head of the pancreas forwards.

Mobilize from the common bile duct superiorly to the superior mesenteric vein inferiorly. You may have to mobilize the hepatic flexure of the colon too. This exposes the IVC and the right renal hilum. *Avoid injury to the right gonadal vein* as it enters the inferior vena cava.

The 2nd stage continues the incision of the posterior peritoneum towards the white line of Toldt immediately lateral to the ascending colon down to the cecum as in a right hemicolectomy (12.11).

EXPOSURE OF THE PANCREATIC TAIL, SPLEEN & LEFT KIDNEY

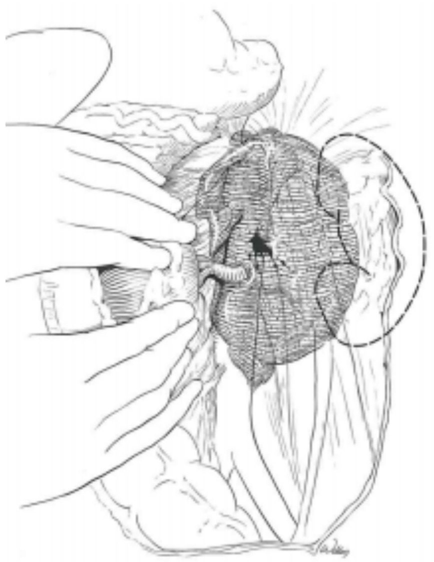


Fig. 55-26 EXPOSURE OF THE PANCREATIC TAIL, SPLEEN, LEFT KIDNEY. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Mobilize the right colon medially (55-27B). *Be careful to elevate the ureter or gonadal vessels.* This exposes the entire IVC, the right kidney and its hilum and the right iliac vessels.

The 3rd stage continues the incision round the cecum and to the left of the small bowel mesentery up the ligament of Treitz (55-27C). Retract small bowel to the patient's left side. Now you should have a view of the entire inframesocolic retroperitoneum including the infrarenal aorta, IVC, iliac vessels and right kidney.

You now have access to the 3rd & 4th parts of the duodenum and the superior mesenteric vessels.

EXPLORING HAEMATOMAS
(1) Ask yourself whether this is the correct thing to do at that moment; assess the patient's total physiological burden. Prepare your team and get the necessary instruments ready.

(2) Gain proximal and distal vascular control. You need a tape or clamp for both proximal and distal control. If distal access is difficult, then secure proximal control first and use an abdominal pack to apply pressure over the site of the lesion.
Then slowly remove the clot to isolate the tear in the vessel. Once identified, place the appropriate clamp over or across the lesion.
(3) Early on, decide if you are going to repair or shunt a damaged vessel.
(4) Before any repair or shunting, pass Fogarty (or Foley for the aorta or IVC) balloon catheters of the right size, proximally and distally.
(5) With a syringe and 18G cannula, flush arterial injuries with diluted heparin (10-50U/mL N/saline) proximally and distally to the repair.
(6) *Don't use systemic heparin IV*.
(7) Try to repair large veins if you can, although you can even ligate the IVC if necessary.
(8) Try to get a postoperative arteriogram, if you can, once the patient is stable.
(9) Always perform a distal leg fasciotomy (49.6) on the affected side if the injury involves the common iliac or leg vessels
(10) Make bilateral distal leg fasciotomies if the Injury involves the aorta, if it was clamped , or you have ligated the IVC.

N.B. An aorta in spasm in a fit young person may only be 1cm wide.

N.B. **Midline hematomas *above* the mesocolon** require exploration. You need to get proximal control by compressing the aorta above the coeliac axis. Then perform a left medial visceral rotation (55-22) to get distal control of the aorta above the iliac bifurcation.

A lateral suture repair of the aorta or IVC is the best option; anything else is difficult, bloody and often lethal.

Repair of other vessels is fraught with difficulty and needs great expertise; placing a temporary shunt is often the best damage control solution until you get everything under control. Then plan your definitive repair for the second operation.

N.B. **Midline hematomas *below* the mesocolon** also require exploration after penetrating injury. You need proximal control of the aorta as before. Pull the transverse colon upwards to the patient's left side out of the way. Check if the haematoma is more on the left side.
Get distal control and try to make a lateral suture repair of the aorta as before.

MOBILIZING THE DUODENUM, ASCENDING COLON & SMALL BOWEL MESENTERY ROOT

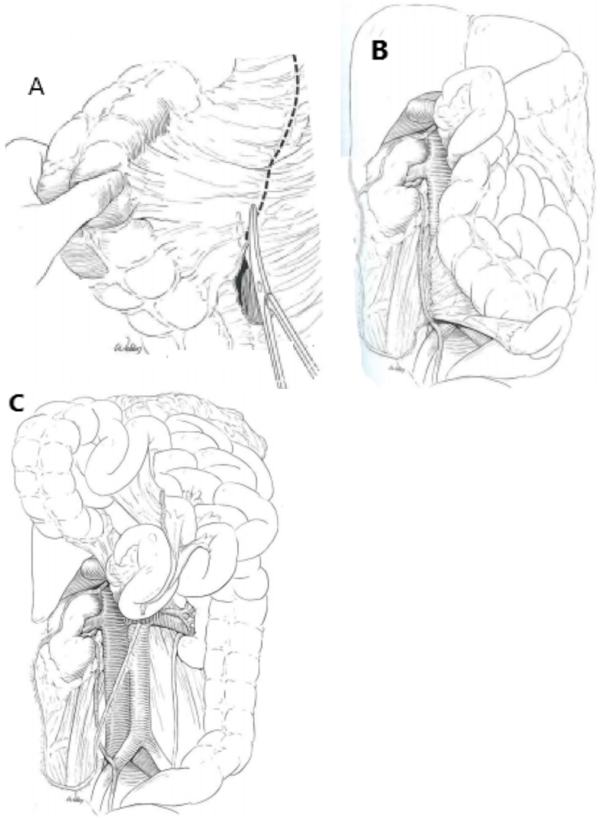


Figure 55-27. MOBILIZING THE DUODENUM; ASCENDING COLON & SMALL BOWEL MESENTERY ROOT. R**ight-sided visceral medial rotation**. **A. The traditional Kocher manoeuvre** (13.5)**. B, the extension mobilizing the descending colon. C, a further extension mobilizing the small bowel mesentery. You can then put the colon and small intestine on the chest!** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Beware of damaging the left renal vein or IVC.

If the haematoma is more on the right, behind the ascending colon, it is arising from the IVC and *you should better leave it alone*. The damage control procedure is to place abdominal packs over the haematoma for tamponade effect. When you re-explore, make sure you have plenty of blood for transfusion. This is true for all major vascular injuries.

If you are confident of your technical skills or if the haematoma is still expanding on re-exploration, then you must perform a right medial visceral rotation (55-17, 55-18). Be prepared to ligate the IVC if necessary.

55.9 Gastric injury

A missile or stab wound can penetrate thestomach or duodenum. It is also occasionally injured at endoscopy. It is very vascular, and its mucosa readily bleeds.
The presence of free air under the diaphrapm on a radiograph is a sign of gastro-intestinal perforation. If the patient cannot sit up, get a lateral view. Use the context of the injury to decide whether this is likely to be gastro-duodenal or intestinal. (You may need a laparotomy to be sure.)

If there are no signs of peritonitis, but you still suspect a perforation, ask the patient to swallow 100ml of gastrograffin and take more films.

Make sure there is a nasogastric tube in place.
Examine the stomach by lifting its wall up, using the NG tube as an anchor to hold 2 Babcock forceps.
Remember if you find one hole anteriorly; *look for another on the posterior surface.* To do this, enter the lesser sac by making a hole in the greater omentum on the left side where it is less vascular (55-28).

EXPLORING THE PROXIMAL STOMACH

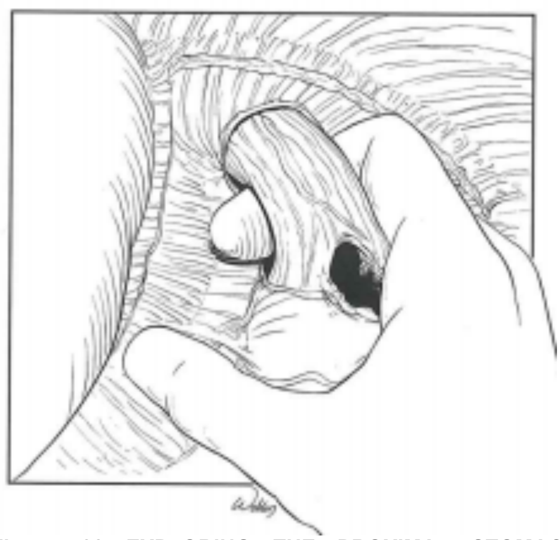


Fig. 55-28 EXPLORING THE PROXIMAL STOMACH. Lift up the left lateral liver lobe, and open the posterior peritoneum overlying the oesophagus. Get your index finger round behind it and pull it gentrly forwards. *N.B.* To look at the posterior gastric wall, and pancreatic body, get into the lesser sac (55-12) by making a hole in the left side of the greater omentum. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

This is similar to treating spontaneous perforations (13.3). Trim the edges of a perforation if they are ragged or non-viable up till fresh tissue, close the hole in 2 layers: continuous long-acting absorbable full thickness & then seromuscular sutures (11-5E), and fix some omentum around the closure with 1-2 sutures.

If the edges of the hole are very sloughy from a neglected perforation, *refresh the wound edges & tie sutures over omentum.* Divert the flow, or excise the necrotic portion.

GASTRIC CLOSURE (GRADE 3.2)

CLOSURE OF GASTRIC PERFORATION

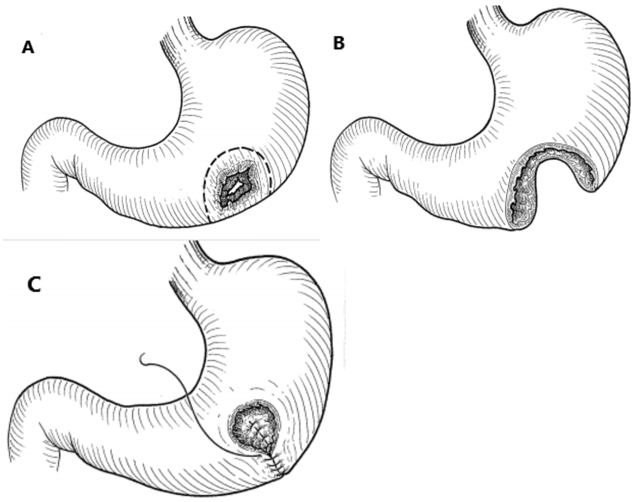


Fig.55-29 CLOSING A GASTRIC PERFORATION. A, trim back the hole to fresh tissue, B. C, close the defect in 2 layers, starting from the inside posteriorly. *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989,*

55.10 Duodenal & pancreatic injury

The duodenum & pancreatic head are so closely related anatomically that it is rare one is injurued without the other, especially in penetrating trauma. The pancreas is a retroperitoneal structure, lying at the level of L1 & L2.

It lies over the IVC, right renal vessels and left renal vein; its uncinate process encircles the superior mesentereic vessels, its body covers the aorta and left renal vessels, and its tail is surrounded by the hilum of the spleen. The body and tail are anatomically practically different organs, as resecting the tail is not so difficult, but operating on the head quite the opposite.

A missile may (usually fatally) penetrate the duodenum and pancreatic head, which are also occasionally damaged at endoscopy.

In blunt trauma, damage is usually caused by deceleration impact (*e.g.* where the steering wheel is pushed into the driver's epigastrium in a head-on vehicle collision, or where bicycle handlebars crush the midriff of a child).

A nasogastric tube may bring up blood from the duodenum, but not always. Neither US nor DPL will reliably diagnose a duodenal or pancreatic injury. Raised serum amylase levels are suspicious but *not* diagnostic, unless tested at least 3h after injury. An abdominal radiograph (especially a lateral view) may show free retroperitoneal air.

EXPLORATION

Inspect the duodenum from the pylorus to the ligament of Treitz. For duodenal injuries, a useful temporary measure is to introduce a Foley catheter proximal to the perforation and inflate the balloon. Place a feeding jejunostomy (11.7) if you can.

N.B. A perforation at the duodeno-jejunal junction needs proper mobilization, which means dividing the ligament of Treitz, or even performing a right-sided medial visceral rotation (55-18).

CHILDHOOD DUODENAL HAEMATOMA

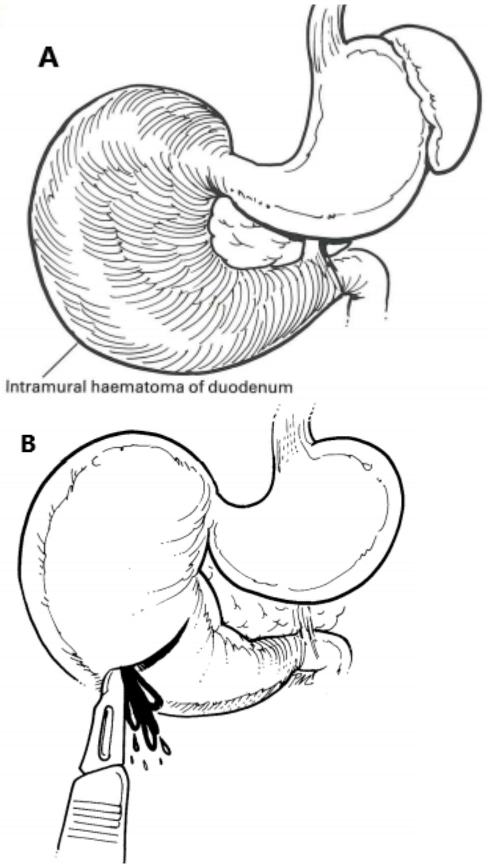


Fig. 55-30. CHILDHOOD DUODENAL HAEMATOMA: A, the swelling may completely occlude the lumen. B, a transverse incision laterally in the serosa only drains the blood. *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989,*

If non-bilious vomiting follows a direct blunt epigastric injury in a child, suspect an intramural duodenal haematoma (55-30A). Introduce a nasogastric tube.

A plain abdominal radiograph may show a 'coiled spring' sign reminiscent of an intussusception. The haematoma may completely obstruct the duodenal lumen. Incise this with a small transverse incision on the serosa of the lateral aspect of the 2nd part of the duodenum (55-30B), and drain the haematoma, which typically liquefies some days after injury.

If there is a periduodenal haematoma, or greenish discolouration, perform a Kocher manoeuvre (13.5) and look at the posterior surface of the duodenum for a perforation. Check if the pancreatic head is damaged. *If there is emphysema (air) in the tissues,* suspect a colonic injury.

Because of its location, the pancreas lies hidden. Explore the lesser sac, and look at the pancreas through the greater omentum (55-28). To expose it, perform a left medial visceral rotation (55-22).

If the pancreas is damaged, it is very likely there will be significant bleeding also. This, and any leakage of pancreatic fluid may not be evident initially, but will give rise to peritonitis and fat necrosis later.

DUODENAL CLOSURE (GRADE 3.3)

For simple perforations, proceed as with gastric perforations. *Don't struggle to make a transverse closure.* Use omentum to bolster your repair.

If the hole is not easily accessible, or not easy to close, *don't try to cobble together the wound.* Divert the gastric contents by creating a gastrojejunostomy (13-16). Close the pylorus from inside with an annular absorbable suture (pyloric exclusion), which will dissolve after 3-4 weeks, thus re-opening the pylorus.

If there is a large duodenal injury, where repair is impossible, perform an upper rectus abdominis plasty (13.3).

MANAGEMENT OF PANCREATIC INJURY

You might have to pack bleeding here; ***don't open a stable retroperitoneal haematoma!*** You will be able to do little else for significant bleeding, apart from clamping the aorta (55-12). The crucial element, apart from bleeding, is whether the pancreatic duct is damaged. However, this is often not easy to see, unless the pancreas is split in two. Remove as much necrotic pancreatic tissue and infected material as possible. A CT scan or an ultrasound will help delineate what parts need removal.

For a proximal pancreatic injury near the duodenum, leave a wide-bore drain to the pancreatic bed. This will control a pancreatic fluid leak. Often you need to leave an abdominal pack over the pancreas as well. Bypass the pylorus with a gastrojejunostomy.

Otherwise, and especially for injury to the body of the pancreas, make 2 parallel running through-and-through non-absorbable locking sutures to ligate the pancreas proximal to where you wish to divide it (or use a linear stapler across the organ).

DISTAL PANCREATECTOMY

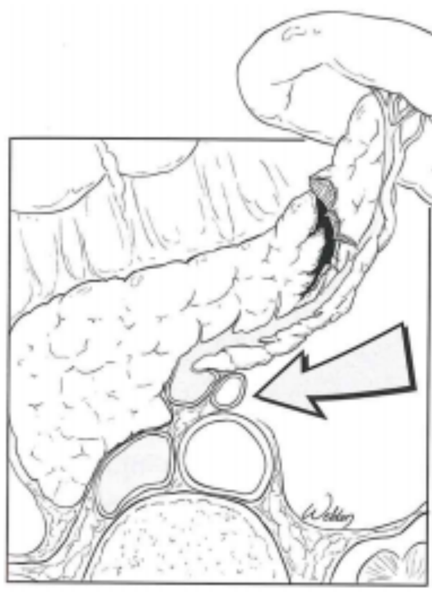


Fig. 55-31 EXCISING THE DAMAGED DISTAL PANCREAS. Hold up the spleen (with packing around it) and the mobilized distal portion of the pancreas. If you have a linear stapler, use this to amputate the pancreas; otherwise use a through-and-through non-absorbable locking suture. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

DISTAL PANCREATECTOMY (GRADE 3.5)
For a distal pancreatic injury, mobilize the spleen and the posterior aspect of the pancreatic tail from its bed *en bloc*, till you can lift it up to the midline. Then resect the injured part; a linear stapler is very useful for this (55-31).

If you can locate the pancreatic duct, tie it off doubly with a non-absorbable suture; in any event *always leave a wide-bore drain.*
Post-operatively the serum amylase level will be raised, but usually settles after 72h. Add a feeding jejunostomy (11.7) for better nutrition.

DIFFICULTIES WITH PANCREATIC INJURIES
If the drain continues to pour out >2L/day, a high output fistula has developed. This is unlikely to close spontaneously (as other fistulae will), and needs expert attention. Keep fluids and electrolytes replaced.

If a swelling develops in the left upper abdomen, this is a pancreatic pseudocyst (15.14). Drain this as non-traumatic pseudocysts through a Roux-en-Y jejunal anastomosis, or directly into the stomach. *Don't drain it externally,* especially if there might be a pancreatic duct injury.

If a fever develops whose origin is obscure, consider infected haematomas, or a pancreatic abscess owing to inadequate removal of necrotic pancreatic tissue. This needs necrosctomy & drainage of infected material.

55.11 Small bowel injury

Blunt injuries either tear or burst small bowel, especially if it is full, by pressing it against the spine. Penetrating injuries from bullets or knives frequently make holes in the small bowel and its mesentery. You must therefore take great care to look at all the bowel meticulously with your assistant.

Make sure both of you are looking at the bowel wnen you examine it on each side! It is easy to miss a perforation adjacent to the mesentery. *Be suspicious: make sure you look for an extra perforation if you count an odd number of them!*

CLOSURE (GRADE 3.2)
Don't start the repair until you have examined the entire bowel and identified all the damage!

ADJACENT SMALL BOWEL PERFORATIONS

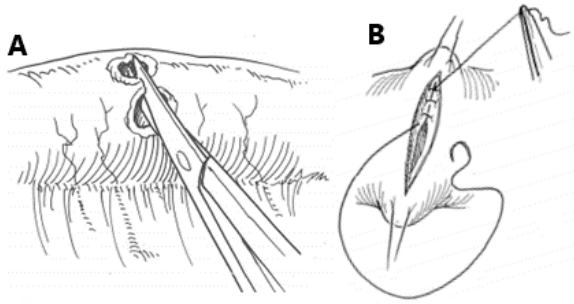


Fig.55-32 JOINING TOGETHER ADJACENT SMALL BOWEL PERFORATIONS. A, debride the edges to fresh tissue. B, close the wound *transversely* in 2 layers. *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989,*

If there are only a few small-sized perforations, repair these with 2 *transverse* continuous layers of long-acting absorbable Lembert seromuscular sutures (11-5E), *provided there is no gross soiling*. *Make sure the edges of a perforation are healthy and bleed nicely*; if it is bluish or ragged, trim it till you get to healthy bowel.

Cover the closures with omentum if you can, *but don't suture the bowel to omentum* because that creates a route for an internal hernia.

MULTIPLE SMALL BOWEL INJURIES

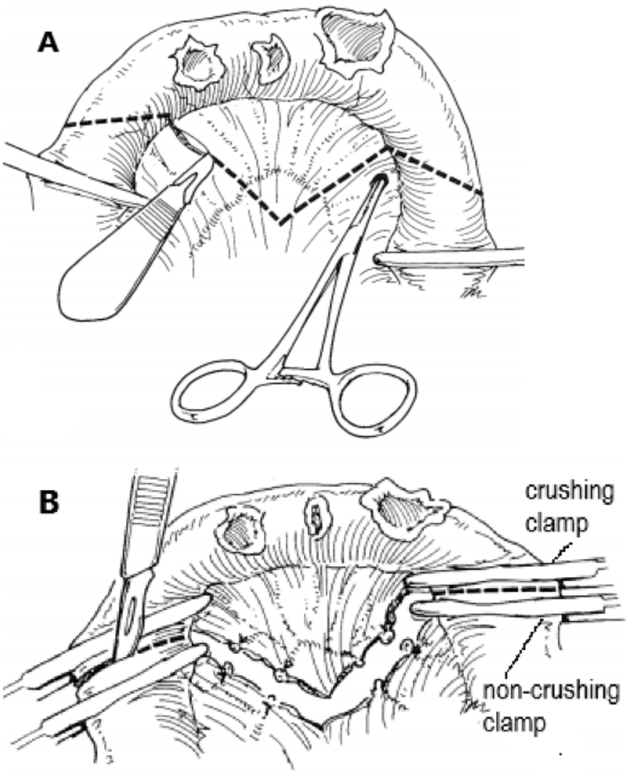


Fig.55-33 RESECTING MULTIPLY INJURED BOWEL. A, incorporate all the injuries into one segment for resection. Divide the mesentery and clamp its vessels by making holes in it. B, place a crushing clamp on the side you will remove, and a non-crushing clamp on the side you will save to anastomose. *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989,*

If there are several perforations, mark each with a suture to save time searching for them later. Try to minimize the number of anastomoses or closures by resecting a badly injured segment.

If the omentum is injured, excise the affected segment.

N.B Although your aim is to avoid contamination, make your repair carefully so it will last! This is definitive therapy.

N.B. A longitudinal closure along the bowel is likely to produce a stricture: always use a transverse closure (55-32B).

N.B. A gunshot wound may make considerable damage to bowel. *Don't leave parts, however small, whose condition is poor, or whose blood supply is suspect.*

N.B. Perforation close to the duodenojejunal flexure occurs in deceleration injuries, as this part is fixed by the ligament of Treitz. Unless you divide this ligament, you may not see the injury (55-34).

Small bowel resection (55-33B) **is indicated for:**
(1) major disruption of the bowel lumen,
(2) multiple perforations (in a segment <50% the length of the bowel
(3) disruption of the mesenteric border
(4) compromised blood supply (55-39)

If there is much soiling or bleeding, isolate the perforated segments with tapes (55-35); *close the perforations only if the patient's condition is good*. Put warm packs over bowel of questionable viability.

BOWEL INJURY AT THE D-J FLEXURE

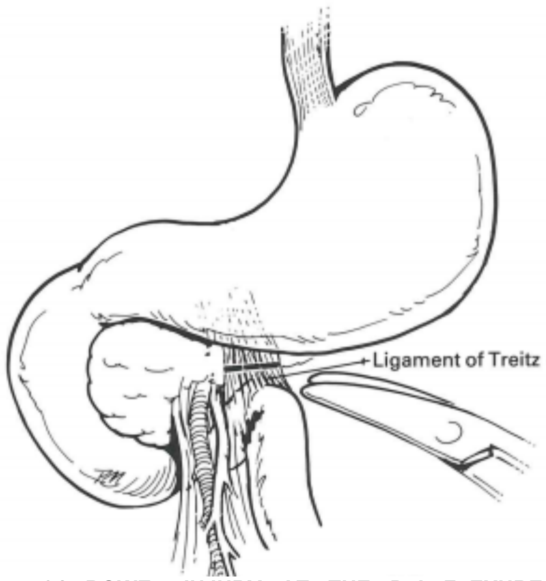


Fig. 55-34 BOWEL INJURY AT THE D-J FLEXURE. A deceleration injury may damage the bowel where it is fixed at the ligament of Treitz. Incision of this ligament will allow you to see & repair the damage. *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989,*

PUTTING TAPES TO ISOLATE BOWEL

Fig. 55-35 PUTTING TAPES TO ISOLATE A BOWEL PERFORATION. This can also be used as a damage control method. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

55.12 Mesenteric injury

INJURED MESENTERY COMPROMISING THE BOWEL BLOOD SUPPLY

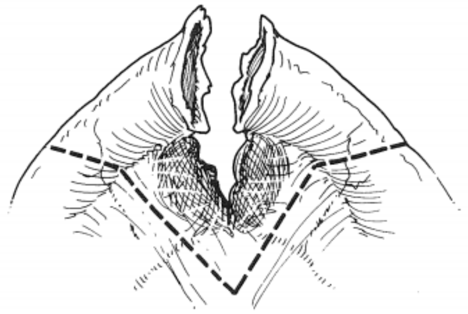


Fig. 55-36 INJURED MESENTERY COMPROMISING THE SMALL BOWEL BLOOD SUPPLY. In both circumsatnces, resect the bowel & mesentery as shown. *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989.*

The mesentery can bleed profusely after an open or a closed injury. As its vessels are loosely held in fatty tissue, they can bleed quite copiously within the mesentery and form an expanding haematoma, which itself may occlude blood supply to the bowel.

If there is a haematoma in the small bowel mesentery, grasp the mesetery between your fingers to see if you can stop the bleeding, or use a sponge-holding forceps (55-37).

Then carefully open the mesentery to find the bleeding vessel, clamp and ligate it. *Don't put blind figure-of-8 sutures in the mesentery hoping you might arrest the bleeding!* A laceration of the mesentery may impair blood supply to the bowel; check if ligating such a vessel makes the bowel become purple. If so, resect that portion.

CONTROLLING SMALL BOWEL MESENTERY BLEEDING

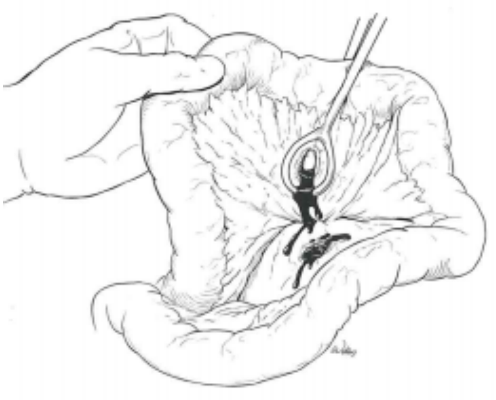


Fig. 55-37 USING SPONGE-HOLDING FORCEPS TO CONROL BLEEDING FROM THE SMALL BOWEL MESENTERY. This is a useful method if pressure with your fingers does not succeed: beware that the handles of the forceps does crush the bowel: you may need to empty that segment into a bowl outside the abdomen beforehand. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Examine the anatomy of the small bowel mesentery. You should ligate the vessels & repair short radial tears, perpendicular to the bowel (55-38A), with interrupted sutures in order to avoid any gap for a future internal hernia.

MESENTERIC LACERATIONS

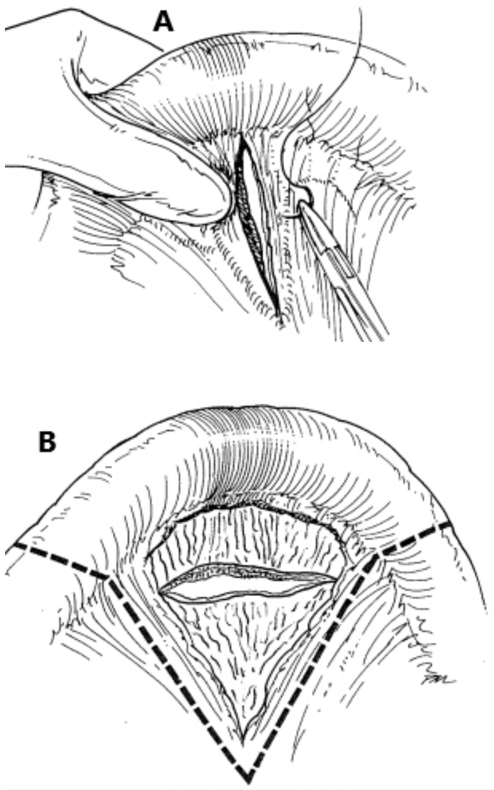


Fig. 55-38 MESENTERIC LACERATIONS. A, radial tears often allow the small bowel to receive enough blood supply through the vascuklar arcade. B, transverse tears usually cause bowel ischaemia, needing resection. *Always check the viability of bowel before closing the abdomen.* *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989.*

When the mesentery is torn, division of any of the distal vessels near the bowel is usually not a problem. At the root of the mesentery, *be very careful. Don't ligate the superior mesenteric artery;* bowel ischaemia will follow. Get your hand behind it and pinch the bleeding area between fingers and thumb. Then carefully open the serosa of the vessel to see where the damage is, and try to repair it. *Be careful with tributaries of the superior mesenteric vein which avulse easily.*

If blood is on the surface of the bowel, it is usually from a mesenteric vessel. Compress this between your fingers or clamp it with sponge forceps.
Transverse mesenteric lacerations (55-38B) often divide the blood supply producing bowel ischaemia: you need then to resect the affected segment of bowel and perform an anastomosis.

If there is a haematoma in the large bowel mesentery, especially related to a fractured pelvis, you can usually leave it alone, unless it is expanding. Palpate the artery along the colon to see if its viability is likely to be impaired.
Otherwise, explore the undelying vessels as before. *With a penetrating injury, you must explore the haematoma.*

Examine the anatomy of the large bowel mesentery; even if a supply vessel is damaged, the collateral blood supply to the colon may remain sufficient, but *this does not apply to injuries of the inferior mesenteric & left colic arteries* (55-39).

LARGE BOWEL MESENTERY LACERATIONS

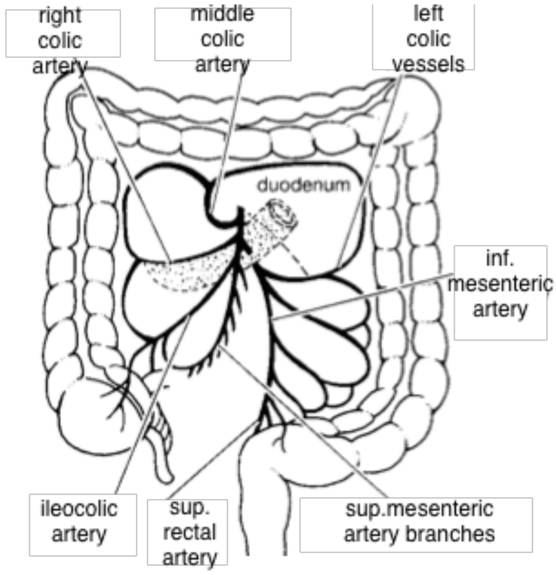


Fig. 55-39 LARGE BOWEL MESENTERIC VESSELS. Arcades near the bowel support its blood supply, but lacerations of the inferior mesenteric & left colic arteries are likely to cause bowel ischaemia.

55.13 Large bowel injury

Blunt injury rarely damages the colon (unless the caecum is distended), but penetrating injuries from bullets or knives frequently do. Perforations are also sometimes caused by endoscopy.

If, on opening the abdomen, you smell a foul faecal odour, look at the colon & rectum. T*ake great care to look at all the bowel meticulously with your assistant.*
Make sure both of you are looking at the bowel when you examine it on each side! Make sure you look for an extra perforation if you count an odd number of them!

It is easy to miss a perforation on the posterior wall of the colon, or in the pelvis. Leakage into a closed retroperitoeal or pelvic space may easily result in septicaemia.
Leaks from the large bowel contain anaerobes and other faecal organisms which are particularly lethal.
Rectal bleeding suggests an injury to the bowel, small or large.

MANAGEMENT
You must take many factors into account, because not all large bowel injuries are the same. What you do must depend on your experience, not only in performing the surgery but especially in evaluating the situation.

Your options are:
(1) Direct primary suture.
(2) Resection with anastomosis without faecal diversion.
(3) Resection with anastomosis & faecal diversion.
(4) Resection without anastomosis (Hartmann's operation or closing proximal & distal ends temporarily as damage control)
(5) Colostomy or exteriorization (either as semi-definitive, or damage control).

Your decision should depend on the:
(1) size of perforation,
(2) extent of faecal soiling,
(3) delay since the injury,
(4) presence of other organ injury,
(5) extent of blood loss & shock,
(6) need for a damage control approach (41.5).

Normally do what is safest for the patient, taking your experience & the patient's general condition into account. *Don't launch into difficult surgery for an unstable patient!*

In general:
(1) Small perforations with no, or minimal, soiling, you can close with a 2-layer suture. A perforation at endoscopy is usually clean unless the colon was not well emptied beforehand, so you can close this readily.
(2) *Don't hesitate to treat several perforations by resection* (ileo-caecal resection (12.7), right hemicolectomy (12.11), transverse colectomy, or left hemicolectomy (12.11)).
(3) After resection, if all the conditions are favourable, perform an anastomosis. If less than completely favourable, protect this with a proximal defunctioning colostomy (11.6) or caecostomy, or ileostomy (ghost or formal) (11.5)

(4) If conditions are not at all favourable after resection, bring out the cut ends as:
(a) a double-barrel colostomy or,
(b) an exteriorization (12.9) of the injured colon itself or,
(c) (for the lower sigmoid and rectum), a Hartmann's operation (12.9).
(d) (for the right colon & caecum), an ileostomy and colonic mucous fistula.

Here are some technical hints:-
(1) If there is a sero-muscular tear without penetration of the mucosa, suture-plicate it.
(2) If there is a faecal smell or a retroperitoneal haematoma (especially with surgical emphysema), mobilize the whole colon to examine the posterior walls.
(3) *Don't perform an anastomosis under tension*: mobilize the bowel adequately.
(4) Cut back the edges of the colon to where it is viable, bleeding freely, before fashioning an anastomosis; cut the anti-mesenteric border more than the mesenteric, thus creating an oblique cut.
(5) Mobilize the large bowel adequately when making a stoma to prevent retraction, especially in an obese patient.
(6) When fashioning a proximal colostomy and distal mucous fistula, place them as close together as possible in order to make the anastomosis easier later on.
(7) *In damage control, don't attempt to create any anastomosis or stoma.*
(8) *Never place a stoma inside a stab wound, or within your original abdominal incision.*
(9) *Don't forget to administer antibiotics!*

If you do find a rectal perforation, perform a laparotomy; you need to see how badly a penetrating injury has soiled the peritoneal cavity; perform a proctoscopy in the early post-operative period for an assessment.

MANAGEMENT OF A RECTAL INJURY
Put the patient in the lithotomy position, so you can operate from above or below.

If there is active rectal bleeding, try to see from where it is coming: for this you need a good light and suction. If you cannot identify the source, pack the rectum.

Begin by performing a laparotomy and wash out the pelvis thoroughly. If you find active bleeding, deal with this before controlling the contamination (55.2).

Then turn your attention to the perineum, and debride any wounds around the anus or buttocks. Palpate any deep wounds carefully: instilling dye may help you identify if they penetrate the rectum. Check for pelvic fractures, and any injury to vagina, urethra, ureter or bladder.

For an extra-peritoneal injury, debride the wound edges as necessary and attempt a closure if the wound is easily accessible. Otherwise leave it to close on its own. *Always fashion a defunctioning sigmoid colostomy* where there is a significant rectal injury (11.6)

If there is active abdominal bleeding, deal with this before trying to control the contamination (55.2).

If there is a large pelvic haematoma with a penetrating rectal injury, explore the haematoma to see if the origin is from iliac vessel branches or fractured bone. Tie a torn vessel if you can; otherwise pack the pelvis, fashion a defunctioning colostomy away from the injury, and wash out the distal colon and rectum.

If there is a pelvic fracture penetrating the rectum, but no intra-peritoneal injury, perform a defunctioning colostomy and wash out the distal colon and rectum.
Don't, in this case, contaminate the peritoneal cavity by opening the retroperitoneal space!

N.B. Don't rely on pre-sacral drains: they achieve little in practice and may complicate a rectal injury further. *Never perform an anal stretch!*

If a rectal foreign body is *in situ*, and you suspect a perforation, anaesthetize the patient, and try without force to extract the foreign body (26.11). This may mean an approach *via* a laparotomy.

55.14 Renal injury

Although the kidneys are in a protected retroperitoneal position, blunt injury to them with visible haematuria is quite common. Fortunately, you rarely have to intervene unless the injury causes serious bleeding, and then other organs are usually damaged, such as the liver or spleen, and require a laparotomy. The kidneys are more vulnerable in children.

Penetrating injury can obviously injure the kidney just like any other intra-abdominal organ.

Suspect a kidney injury if the posterolateral parts of the 10-12th ribs are fractured. A perirenal haematoma or urinoma may cause a paralytic ileus. There is usually pain and sometimes tenderness in the flanks, and scoliosis towards the injured side.

The presence or absence of haematuria can mislead you. Even in serious kidney injuries there may be no haematuria; it appears only if the calyceal system has been entered. On the other hand, any severe abdominal injury can provoke microscopic haematuria without significant damage to the kidneys.

N.B. *There may be no haematuria if shock has made the patient oliguric.*

Mild injuries cause just a small break in the renal capsule and a small haematoma (Grade 1-2); more serious injuries involve the renal pelvis or calyceal system (Grade 3-4), and may damage a major artery or vein. Most seriously, the kidney may be shattered or alvulsed from its pedicle (Grade 5) (55-40).

INVESTIGATIONS

Always test the urine. You can take blood-stained urine from the victim in test tubes, and watch if the urine becomes more diluted or not as you collect further samples.

An ultrasound scan can show a perirenal haematoma or urinoma, but tells you nothing about renal function. Provided the patient is not in shock, perform a double-dose contrast intravenous urogram (IVU, 38.1A) This is especially useful in penetrating injuries and if there is frank haematuria. You may see extravasation, a pelvi-ureteric junction rupture, or any anatomic abnormality (horseshoe or polycystic kidney, hydronephosis, or congenital absence).

It will also tell you if the contralateral kidney is functioning! But don't rely on this if the patient is hypotensive!!

N.B. (1) *A hydronephrotic kidney is more liable to damage than an unenlarged one.* (2) *A child's kidney is less protected by ribs, Gerota's fascia & less perirenal fat and so is more easily damaged.*

A cystoscopy is only useful if you find haematuria, but you have ruled out a kidney injury.

If your theatre is equipped for it with a mobile X-ray machine, you can perform an intra-operative double-dose IVU if necessary to make sure the other kidney is working.

Otherwise, an IV injection of dye (methylene blue or indigo carmine) will allow you to visualize its excretion directly: just insert a very thin needle into the renal pelvis and aspirate urine to make you are in a calyx.

MANAGEMENT

The kidneys are surrounded by Gerota's fascia, which acts as a natural tamponade in blunt injury.

Most blunt injuries are relatively minor and can be treated conservatively.

TYPES OF KIDNEY INJURY

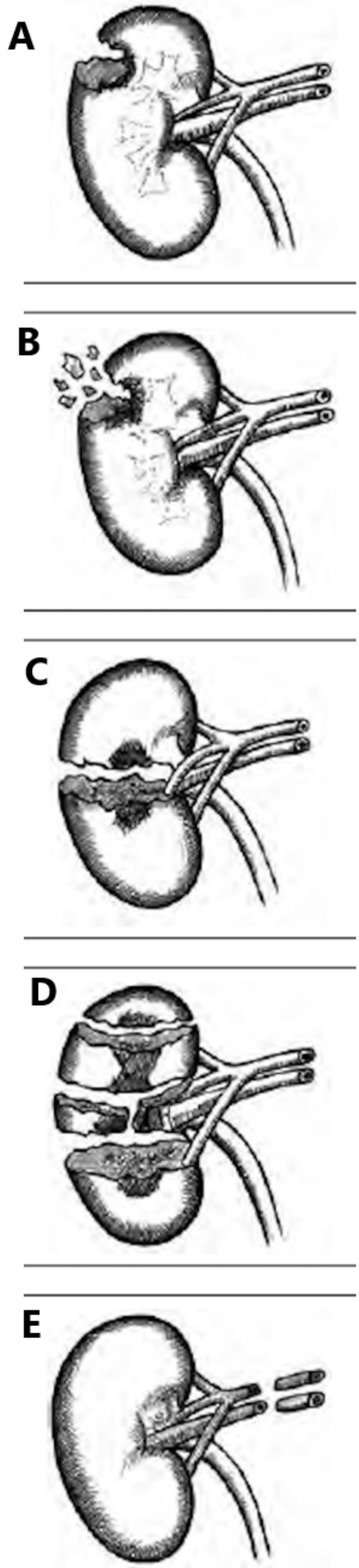


Fig. 55-40 GRADES OF KIDNEY INJURY. A, I parenchymal laceration without urine leak. B, II deep laceration into a calyx with urine leak. C, III complete rupture. D, IV shattered kidney. E, V vascular pedicle injury. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

Make sure the victim has a good fluid intake: damaged kidneys must not suffer further injury to the renal tubules because of dehydration! Closely observe the urine ouput (which should be 250ml/8h), make serial checks of Hb or haematocrit, and colour of the urine. It might take 10days till the urine clears.

If the patient becomes anxious, is in severe pain, and loses appetite, then something is wrong. Serial plain radiographs or ultrasound scans may show increase in size of a soft tissue shadow of a haematoma; a repeat IVU may be great value.

If there is severe kidney injury, and the patient is becoming unstable, or there is important injury to other organs, proceed to laparotomy. Follow the procedure for controlling haemorrhage first (55.8). Pack the abdomen and/or retropeitoneal space and inspect. *Don't rush to explore the retroperitoneum!*

N.B. Even if there is a serious kidney injury, this will buy you time!

If there is an expanding haematoma in the flank or a penetrating injury, you must explore.

N.B. Late diagnosis is not unusual.

Get control of the renal pedicle first. Open the haematoma through a medial visceral rotation (55-26,22). The presence of the haematoma makes dissection easier; sweep your hand through the haematoma to the kidney. Scoop out the blood and clots, and carefully pack the space round the kidney. Ask your assistant to compress the packs around the kidney.

Where Gerota's fascia is ruptured, the location of the kidneys in the renal fossae make for a natural space to pack during a laparotomy.

If only part of a kidney is severely damaged, debride this, performing a partial nephrectomy, and either close the cortex if you can or suture in place an omental patch, after closing the renal pelvis (55-40D,D). Alternatively, if the damage is more superficial, close the wound in layers (55-40E,F). Insert a nephrostomy drain and also a closed suction drain in the perirenal space.
Don't forget to l*abel which is which!*

N.B. Try to preserve renal tissue in children.

A shattered kidney requires a nephrectomy, and this is the usual result of injury to the renal vessels.

To attempt a repair of the renal artery, you will have to perform a left (55-26) or right (55-27) medial visceral rotation for good access. You can ligate the left renal vein without any problem if this is the only vessel injured; the gonadal and adrenal veins will assure the drainage.

REPAIR OF A KIDNEY LACERATION

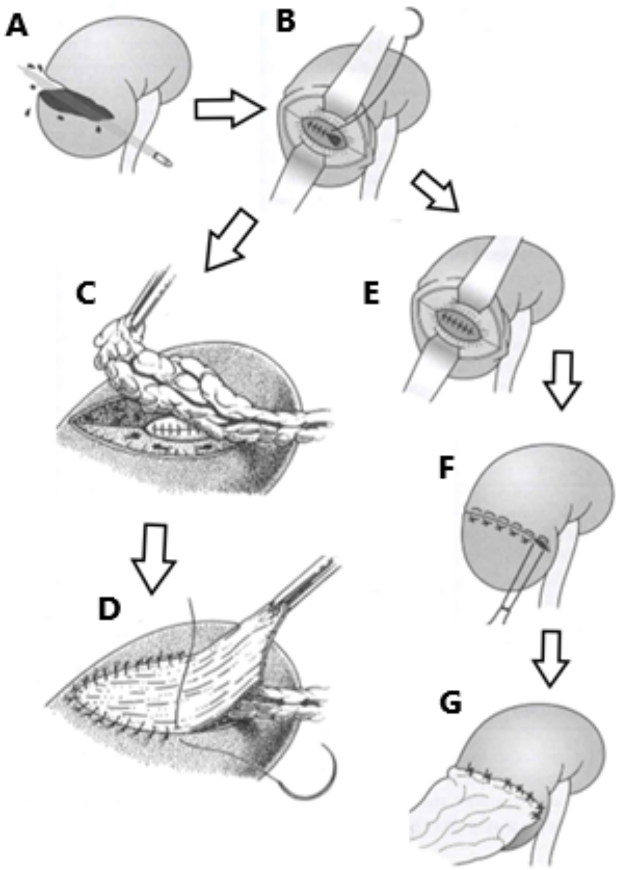


Fig. 55-41. RENAL REPAIR (GRADE 3.5**). A, gunshot injury sparing the central part of the renal pelvis. B, aftzer debridement. C,D, omental patch. E,F repair in layers. G omental cover.** *After Boffard KD ed, Manual of Definitive Surgical Trauma Care. CRC 3rd ed. 2011.*

N.B. Nephrectomy is heroic, difficult surgery. *Pack the kidneys first of all and assess the situation, especially the presence and functioning of the other kidney before proceeding to nephrectomy. Resuscitate the patient; blood transfusion is often needed. Consider if you should operate or refer the victim.*

Nephrectomy requires control of the renal hilum first: these vessels need great care; *the kidney also may easily tear on rough handling!*

55.15 Ureteric injury

Most injuries to the ureter are not diagnosed on table but delayed postoperatively because of complications. An IVU or injection of dye intra-operatively are of great help in diagnosis.

N.B. The ureter is protected behind the peritoneum, but may of course be injured by a penetrating object, or adjacent blast injury which ruptures its blood supply. Avulsion may occur in children.

Direct inspection during laparotomy is the best diagnostic tool, but you must know when to explore, especially after penetrating injury.

N.B. There is no haematuria in 50% of cases. Avulsion may occur in children. The ureter is of course vulnerable in obstetric and gynaecological (23.15) and any pelvic surgery!

The most common signs and symptoms of delayed presentation are pain in the flank, prolonged paralytic ileus, fever, urinary leakage through drains, and deteriorating renal function tests.

If there is a high- or mid-ureteric injury, excise the damaged portion, but *don't dissect off the tissues adjacent to the surviving portion of ureter* because you will then disrupt its delicate blood supply (55-41A,B).

If the damaged segment is small, perform an ureteric anastomosis with 4/0 interrupted long-acting absorbable suture. Make spatulated ends of the proximal and distal segments by an incision on opposite sides of the ureter (55-41C).

Start by putting two stay sutures (55-41D). Fashion an end-to-end anastomosis over a double-J-stent, which you must pass into the renal pelvis & and the bladder, so it does not migrate up or down, and you can retrieve later it by cystoscopy.

If you don't have cystoscopy available, bring out the bladder end suprapubically. The final anastomosis should look bulbous (55-41E).

A paediatric feeding tube is a good alternative to use as a stent. Alternatively, use a fine T-tube as a stent, bringing out the long leg of the T to the abdominal wall. *Don't fashion an external ureterostomy (uretero-cutaneous fistula)*, as this will stenose, and cause ascending infection.

Check that the other ureter is intact.

Add a defunctioning nephrostomy (27-15) if you think the anastomosis might stenose, or you have no double-J stents (or home-made variations, 23.15), or if the ureteric injury is close to the pelvi-ureteric junction.

If the ureter is damaged close to the bladder, re-implantation of the ureter is necessary. If you cannot do this, drain the urine either via a nephrostomy or a T-tube. Reflux of urine up the ureter does not normally occur because the ureter passes through the bladder muscle wall, and its contraction prevents this.

URETERIC REPAIR & ANASTOMOSIS

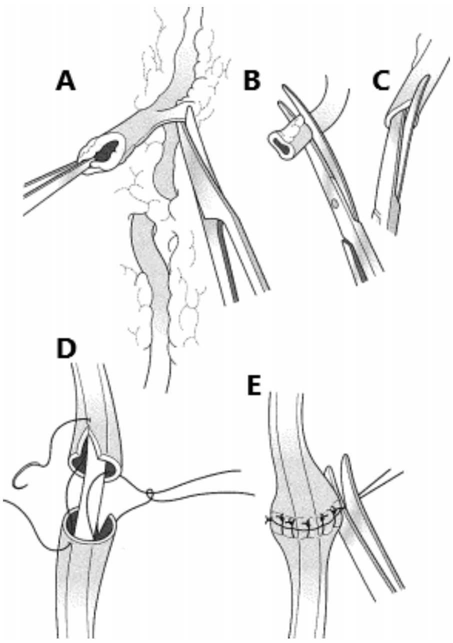


Fig. 55-42 REPAIR OF THE URETER. A, carefully dissect off tissue around the damaged ureter. B, cut off the damaged part. C, make spatulating incisions on opposite sides of the proximal & distal parts. D, make an anastomosis with interrupted sutures over a stent. E, final result. *After Boffard KD ed, Manual of Definitive Surgical Trauma Care. CRC 3rd ed. 2011.*

Therefore when you re-insert a divided ureter into the bladder, you must make a tunnel in the bladder wall to pull the ureter through. You may also have to create an elongation of the bladder to reach the ureter, particularly if some length of the ureter is lost.

URETERIC RE-IMPLANTATION (GRADE 3.3)
Open the bladder with a vertical incision, and identify the ureteric orifice. Insert 2 stay sutures above & lateral to it, and open the bladder mucosa between these sutures (55-43A). Then use a large angled forceps to create a submucosal tunnel towards the top of the bladder on the affected side (55-43B, 55-44), and make an opening there.

RE-IMPLANTING THE URETER

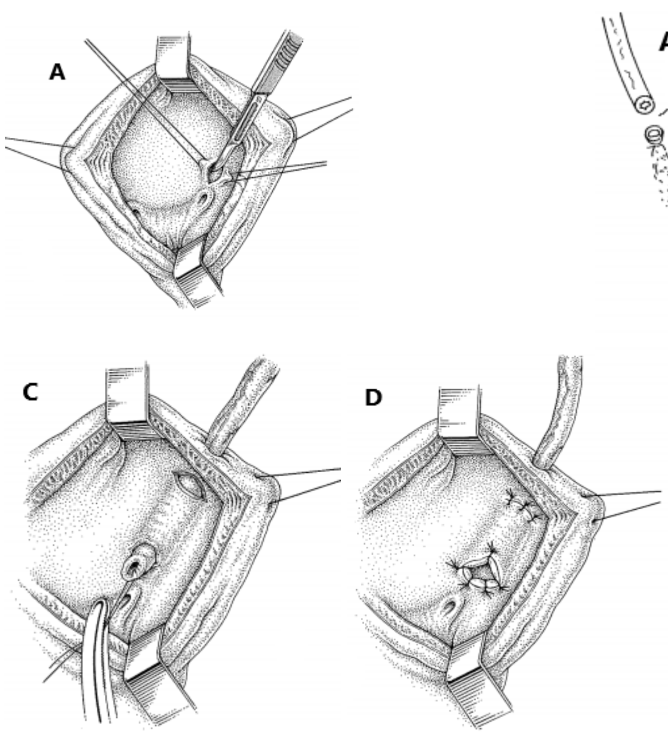


Fig. 55-43 RE-IMPLANTING THE URETER. A, make an incision above & lateral to the ureteric orifice. B, fashion a submucosal tunnel with an angled forceps. C, manipulate the ureter through the tunnel. D, fix it with everting sutures. *After Dudley H, Carter D, Russell RCG (eds), Trauma Surgery Part 1 in Rob & Smith's Operative Surgery, Butterworth, London, 4th ed. 1989.*

Attach a suture (or soft tube) to the proximal end of the divided ureter, check that you have sufficiently mobilized it, and gently manipulate it through the bladder tunnel.

Fix the end of the ureter with interrupted everting 4/0 long-acting absorbable sutures (55-43C), and close the other end of the tunnel (55-43D). Finally close the bladder in 2 layers, and leave a catherter & pre-vesical drain.

N.B. Delayed long-acting absorbable is needed for ureter repair, but catgut will work adequately!

NON-REFLUX RE-IMPLANTATION TECHNIQUE

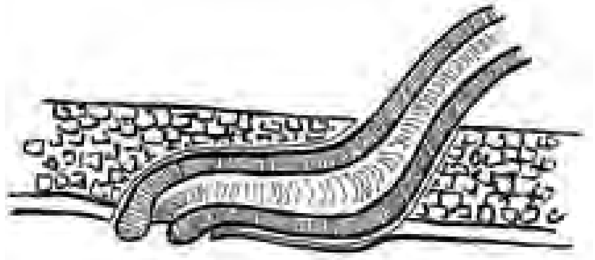


Fig. 55-44 NON-REFLUX RE-IMPLANTATION TECHNIQUE. Make a submucosal tunnel of at least 3cm lenth to prevent reflux proximally.

BOARI FLAP NEO-URETEROCYSTOSOMY

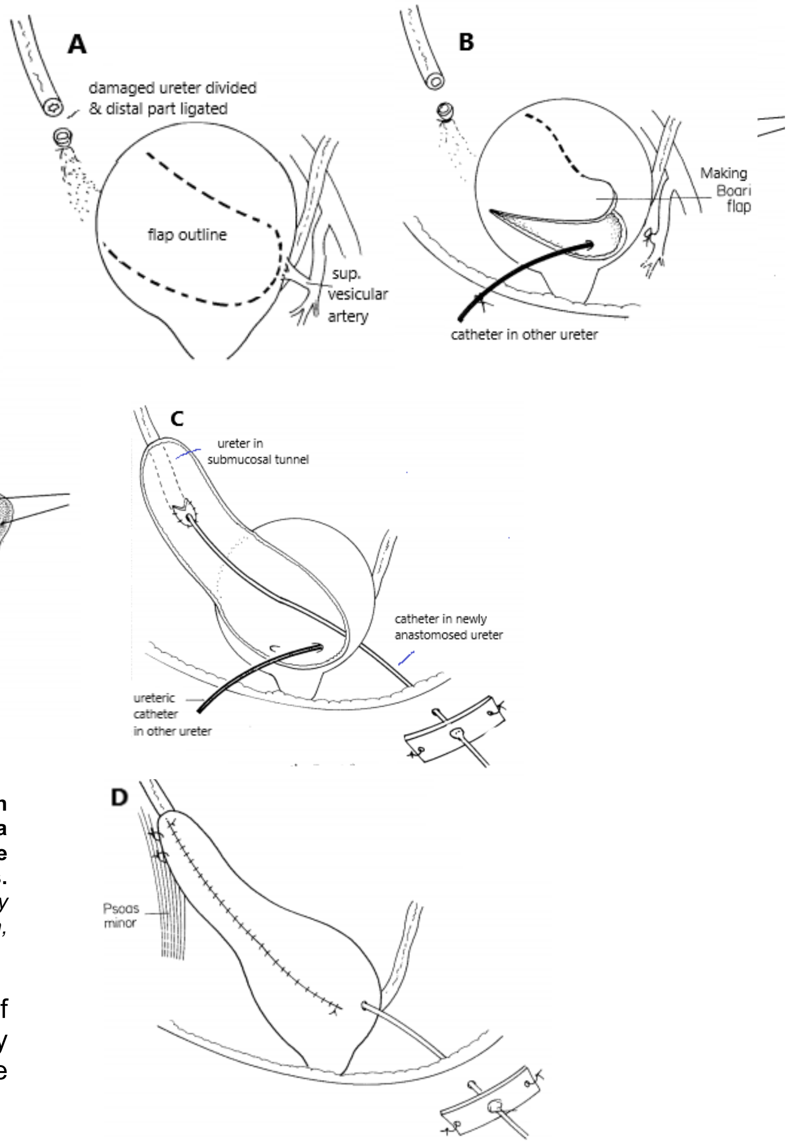


Fig. 55-45 BOARI FLAP NEO-URETEROCYSTOSTOMY (GRADE 3.4**). A, divide the damaged ureter & ligate its distal end. Mark out the flap with enough length with 3 stay sutures. B, cut out the flap, ensuring haemostasis with ligatures *not diathermy.* C, catheterize the other ureter (to protect it) & make a submucosal tunnel to pull the divided ureter through. D, close the bladder, and fix it to the *psoas minor* if there is tension on the anastomosis.** *After Blandy J, Operartive Urology, Blackwell, Oxford 2nd ed, 1986.*

Don't use other techniques such as anastomosising one ureter onto the other, or using the appendix as a conduit, or using omentum to close a perforation, as they are more likely to cause complications.

N.B. This may look pretty daunting if you haven't done any urological surgery before. However, the great advantage is you need not feel pressed for time, and you can prepare a clean field. Make sure access and light are adequate!

If both ureters are damaged, you can prepare a double Boari flap (55-46).

DOUBLE BOARI FLAP

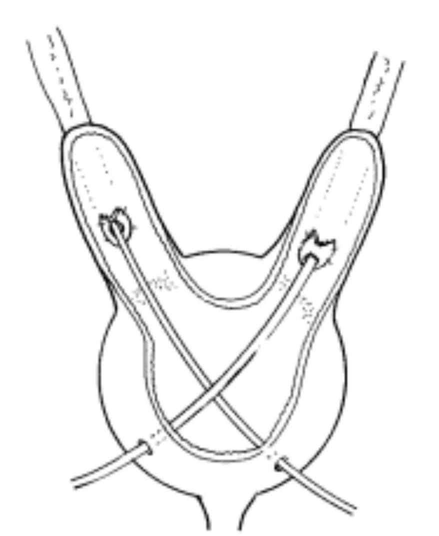


Fig. 55-46 DOUBLE BOARI FLAP if both ureters need re-implantation. *After Blandy J, Operartive Urology, Blackwell, Oxford 2nd ed, 1986.*

55.16 Abdominal closure after trauma

DAMAGE CONTROL CLOSURE

When you have finished your damage control, (also called an abbreviated laparotomy), check: Have you stopped bleeding? Are packs in place & ligatures placed? Have you counted the packs left in the abdomen, and noted their position? Have you controlled the source(s) of contamination, tied off or stapled injured gut, or placed any necessary drains over the pancreas?

Now wash out the peritoneal cavity with copious amounts of warm saline. Suction the excess saline and mop up the rest by going over the entire gut quickly (you need to get out of the abdomen as soon as you can) to confirm that you have identified all the injuries.

It is now time to decide on how to close the laparotomy incision in a temporary manner, since you are going to go back in in 24-48h for definitive repair. There are several methods, some more preferable than others.

You can use towel clips in a row to close only the skin or a continuous non-absorbable suture, again only on the skin. You can open up a sterile renal dialysis bag or several IV fluid bags and suture them to the edges of the abdominal wall (Bogotà bag). Never include the fascia in these techniques. The Bogotà bag is the surest of these temporary measures. By far the most preferable technique, if your patient can withstand the time, and you have the material available, is the laparostomy (11.10).

If the condition of the patient is stable, close the abdomen in standard fashion (11.8)

55.17 Second look laparotomy

This might still be part of damage control (41.4). Prepare the patient as before including the chest and groins. Make sure you have resuscitated your patient during the last 24-48h. Check that the physiological parameters are now normal. Your patient will now be ready for definitive treatment of injuries sustained.

If you re-open an abdomen where you have left in packs, verify how many packs were left inside.

Back in theatre, remove your laparostomy pack and gently remove any abdominal packs, carefully counting the number. Soak these thoroughly, so they don't stick to viscera, and pull them out gently one by one, starting with the least bloody (where bleeding is least likely).

Check to make sure that bleeding or contamination is controlled. If not, decide whether you need to re-pack the abdomen, or if you can control any new haemorrhage. If so, continue to explore the abdomen (55-5)

N.B. Don't dislodge clots to see what injury is underneath, except small haematomas on the bowel surface.

If massive re-bleeding occurs, pack again. *Don't attempt to repair the problem during this operation*, but you do consider restoring gastrointestinal continuity this time before you get out.

Now look for potential sources of contamination.

N.B. Take a good note of the state of the bowel. If the intestines are oedematous and engorged, you will have to continue with a temporary closure laparostomy to prevent abdominal compartment syndrome.

Look for injuries you might ave missed the first time and especially look at the areas you repaired the first time. Reprioritize your approach based on this new information.

Control any additional sites of bleeding, perform any necessary vascular repairs and restore intestinal continuity (including any stomas or feeding tubes). Cut back all intestines until you find healthy bleeding tissue.

Perform any repairs as necessary, such as hepatic suture, gastro-jejeunostomy, Roux en-Y anastomosis, arterial suture, closure of the abdominal wall defect etc.

N.B. Some temporary damage control procedures are also definitive, *e.g.* splenectomy, suction drainage for pancreatic injuries.

Closure of the abdomen without tension can be difficult. Ideally, approximate the fascial edges with gentle adduction and perform a regular fascial closure.

If the abdominal tension is too great or the anaesthetist tells you that the peak airway pressure increases by >10 cm $H_2 0$, leave the fascia open and leave a laparostomy.

If you cannot close the fascia, use aggressive diuresis (to remove the oedema as much as the patient's hemodynamic and oncotic status permits). You may need washouts of the abdominal cavity, reinspection and careful replacement of the abdominal closure devices until you can close the fascia. The goal is to get fascia closure without tension <7 days from the 2nd operation.

If you still cannot close the fascia then, close the anterior abdominal wall or allow the wound to granulate, knowing a ventral hernia will inevitably ensue.

N.B. Second-look laparotomy is a planned procedure! It is not the same as a re-laparotomy for complications of previous surgery or a new event.

55.18 Late presentation

Assess any patient who presents many hrs after an injury just like any other, according to the ABCDE system (41.1).

There may often be no need for surgery at all, but if there is peritonitis, it is likely to be severe, so apply Damage Control principles (41.4). The likelihood of overwhelming sepsis and renal failure is high.

56 Pelvic injury

56.1 Introduction

Direct force transmitted via the iliac wing, or through the femur may crush the pelvis. These are common injuries, especially with increasing numbers of road traffic accidents in the low- and middle-income countries. Alternatively, the pelvis may break in a fall from a height. In general, pelvic injuries are of 2 kinds:

(a) Acetabular fractures, with fractures lines entering the hip joint. (66.5)
(b) Pelvic ring fractures with at least 2 fracture lines: one in the anterior and one in the posterior pelvic ring or a combination of one fracture with a sacro-iliac joint or pubic symphysis disruption.

After a fall from a height, vertebro-pelvic dissociation (separation of the spine from the pelvis) with a vertical fracture line through both transalar regions including horizontal fracture components through S1 or S2 vertebrae are seen.

N.B. If you see a fracture line in an antero-posterior pelvic radiograph, look for additional fracture lines or joint disruptions!

Special fracture types with retained stability of the pelvic ring are these:
(1) iliac wing (56-1A),
(2) avulsion type (56-1H),
(3) transverse sacral or coccygeal (56-1D),
(4) those below S2.

The outcome from these fractures depend on:
(1) the stability of the pelvic ring or hip joint,
(2) whether they are open fractures,
(3) associated bleeding, nerve damage, bladder rupture, urethral or bowel damage.

N.B. These complex pelvic fractures bleed profusely! Be prepared to transfuse blood!

Typically, you can expect the following types of pelvic fracture in these circumstances:
(1) Iliac wing fractures (56-1A) from direct crush injuries or pull from a seat-belt in vehicle accidents.
(2) lateral compression or acetabular fracture from falls to the side or hip contusion (56-1B),
(3) comminuted fractures of the anterior pelvic ring (including the butterfly fracture (56-1E) or 'open book' fractures (56-1G) from direct contusion of the pubic symphysis in a motorcycle head-on-collision.
(4) acetabular fractures with or without hip dislocation from Indirect hip contusion from a flexed femur (as when sitting and being pushed against the dashboard).
(5) unstable vertical sheer fractures or vertebropelvic dissociation from fall from a height when the extended femur (as in a straight leg) is pushed up into the pelvis (56-1F).
(6) avulsion fractures of the anterior superior (56-1H) & inferior iliac spines, and of the ischial tubercle from excessively high muscle strain especially in athletes.

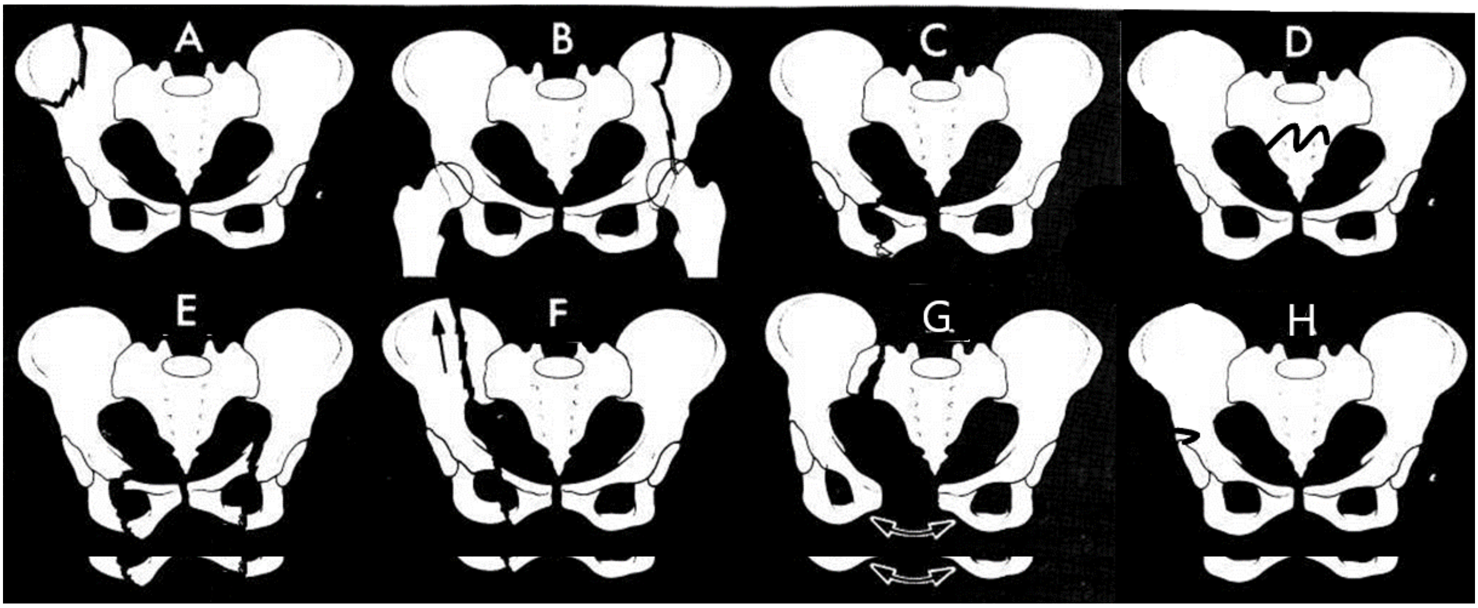


Fig. 56-1 PELVIC FRACTURES. A, fracture only of the iliac wing. B, fracture extending into the acetabulum. C, fracture of the ischiopubic rami on one side & the pubic symphysis distracted. D, transverse sacral fracture. E, butterfly fracture of both ischiopubic rami. F, vertical fracture with upward displacement of the right half. G, hinge fracture with an 'open book'. H, avulsion fracture.

INSPECTION
Look for: seat belt bruising, skid marks, open wounds, & haematomas in the pubic region, all of which are warnings of severe pelvic injury.
Look for a foot drop (in sciatic nerve injury).
Look for blood at the urethral meatus (57.1).

N.B. A perineal haematoma in the labia or scrotum is almost pathognomonic of a pelvic fracture; frank haematuria or rectorrhagia are indirect signs for a fragment piercing bladder or rectum (thus an open fracture).
Look also for leg length discrepancy in unstable or severe dislocated pelvic ring injuries; typically the hip is flexed, adducted & internally rotated (as in femoral neck fractures) in cases of acetabular fractures with hip dislocation.

If you find an unstable pelvic ring or 'open book' fracture, *immediately wrap a bed sheet or pelvic binder round the pelvis* (56-2)**:** this may considerably reduce bleeding.

If you find a dislocated hip, *reduce it and test it for stability.*

PALPATION
Try to compress the pelvis from both sides by pressing your hands laterally on both iliac crests in the region of the anterior superior iliac spines. If you feel instability or this causes pain, suspect a pelvic fracture.
If you find no instability, try to distract both iliac wings horizontally and vertically.

Additionally, palpate and press the pubic symphysis. Pain or a gap may indicate an anterior pelvic ring fracture or pubic symphysis disruption.

N.B. Compression or distraction tests for patients with diminished consciousness are very unreliable.

Perform a digital rectal (& vaginal) examination & check if: (a) sphincter tone is impaired, (b) the prostate is no longer easily palpable ('riding high'), & (c) any bony fragments are palpable?

FUNCTIONAL TESTS
An alert patient who can raise the straight leg without pain has no severe pelvic fracture!

A leg fixed in flexion, adduction & internal rotation is pathognomonic of a hip dislocation.

Passive and active hip motion is painful in *all* acetabular and most pelvic ring fractures. Check for neurological deficit especially in the L4-S2 nerve roots and the sciatic nerve.

RADIOGRAPHS:
For pelvic ring fractures, get antero-posterior, inlet and outlet views and for acetabular fractures, antero-posterior, iliac-oblique and obturator-oblique views. Use a table with the least number of metal parts.

N.B. If contrast is used for examination of a bowel injury, this may completely obscure the pelvic bones

TREATMENT
For all pelvic fractures with an intact pelvic ring (*i.e.* iliac wing fractures, transverse sacral fractures below S3 vertebra & avulsion-fractures) treat conservatively; adapt weight bearing on crutches over 4-6wks.
For lateral compression fractures with isolated horizontal instability, treat conservatively, too. After some days of bed rest, start mobilization with no weight bearing on the injured side by use of crutches over 6wks.
For horizontally unstable 'open book' fractures, apply an external fixator or fix by open reduction and internal plating, which is ideal for the symphysis disruption.
For other horizontal and vertically unstable pelvic ring and unstable acetabular fractures you will need to apply primary emergency intervention and only later proceed to definitive surgical treatment using different fixation techniques and implants.

EMERGENCY INTERVENTION
If there is any type of severe pelvic fracture, especially if complex, start blood transfusion. Bleeding from the pelvis will usually cause some sort of retroperitoneal haematoma.
Don't attempt to open the posterior peritoneum.

If there is intraperitoneal bleeding, *after you have stabilized the pelvic ring with an X-fix,* pack the pelvis (55.2) as 90% of blood loss is venous. Ligate the internal iliac arteries only if this fails.

If there is an unstable pelvic ring, support the pelvis with a bed sheet of length >1m and width >0.5m and place it under the pelvis by first gently elevating the legs and then the pelvis. Wrap the sheet over the pelvis with the greater trochanter positioned centrally (56-2).

N.B. Wrapping the sheet more cranially over the iliac crest will further distract instead of compress the true pelvis, and cause more bleeding.

For the 'open book' injury, tie the knees together using a gauze bandage with a wedge between the ankles. Apply an external fixator as soon as possible.

N.B. The pelvic sling or binder is not a reduction tool! It will cause skin necrosis if you leave it in place >24h.

PELVIC BINDING

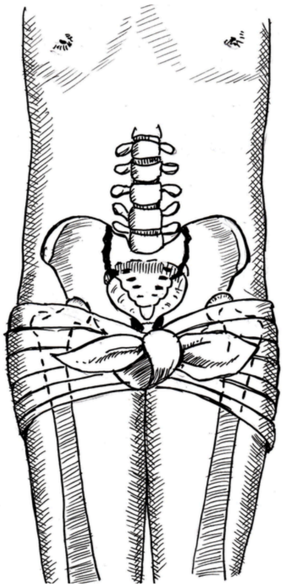


Fig. 56-2 PELVIC BINDING for unstable pelvic ring fractures. *N.B. Put the binding over the trochanters not the sacral promontories!*

If there is a posterior hip dislocation, reduce it by applying axial traction on the femur with the hip & knee in 90° flexion. It is very difficult clinically to distinguish between a dislocation & a fracture of the femoral neck.

If there is (a) vertical femoral displacement, (b) acetabular instability, or (c) still instability of the hip after reduction, apply traction on the straight leg (59.4).

N.B. Where the femoral head is dislocated centrally (a '*protrusio*' acetabular fracture), you may need additional weights for lateral traction.

APPLYING SUPRACONDYLAR FEMORAL TRACTION (GRADE 2.1)
Instil LA in the medial and lateral supracondylar regions 3cm superior to the cephalic rim of the patella, and insert a 3mm percutaneous Steinmann pin from medial to lateral. Apply $^{1}/_{10}$–$^{1}/_{7}$ body weight for constant traction. For this to be adequate, support the contralateral leg with a rigid block at the end of the bed, *but leave the foot on the injured side free for movement* (59.4).

N.B. Don't apply a Thomas splint, which may cause severe skin abrasion under traction (59.4): use a Böhler frame instead.

Traction on the leg may not prove adequate for some femoral neck fractures, or '*protrusio'* acetabular fractures. You cannot manage an unstable pelvis for long with a sling, and the ex-fix is ideal in this case

It's best to put insert a urinary catheter in a female before attaching the external fixator.

APPLYING AN EXTERNAL FIXATOR (GRADE 2.3)
Apply an external fixator in the operating theatre under fluoroscopic control (if available, and you have a radiolucent table). *This is difficult in an obese person!*

PLACING A SUPRA-ACETABULAR SCREW

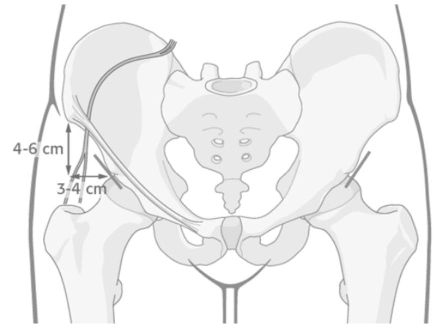


Fig. 56-3 PLACING A SUPRA-ACETABULAR SCREW. Note the position of the lateral femoral cutaneous nerve

Make an oblique 4-5cm incision 4-6cm below and 3-4cm medial to the anterior superior iliac spine, on both sides. Avoid the lateral femoral cutaneous nerve. Palpate the bone through the incision.
Place the drill sleeve on the upper border of the anterior superior iliac spine, and direct it $10\text{-}20^0$ cranially & $20\text{-}30^0$ medially towards the sacroiliac joint. Perforate only the outer cortex of the bone.

Advance two 5x240mm Schanz screws parallel or slightly converging into the posterior ilium to gain good fixation (especially on osteoporotic bone). Try to put one screw along the outer table of the iliac wing, and the other along the inner table.

SUPRA-ACETABULAR HIP FIXATION

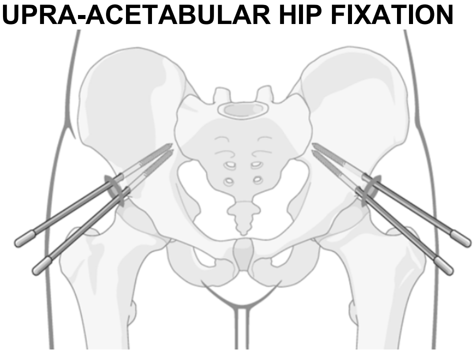


Fig.56-4 SUPRA-ACETABULAR HIP FIXATION. Place two screws on both sides into the iliac bone

Connect the screws to a bar on each side, & connect these with 2 other connecting bars (56-5). Then reduce the fracture by pressing on the iliac crests & greater trochanters; then tighten the connecting rods in place. Close the incision only partially without tension.

EXTERNAL FIXATION OF THE HIP

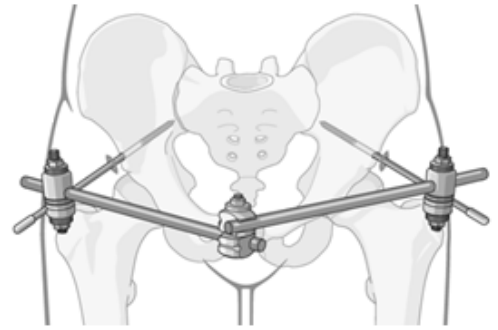


Fig. 56-5 EXTERNAL HIP FIXATION. You can use double bars for increased rigidity.

DEFINITIVE TREATMENT
Ideally, try to arrange definitive treatment for severe pelvic injuries after 4-7days, when inflammation has subsided and before an immunological response has commenced.

Earlier surgical intervention may result in a 'second hit'; delayed operative intervention makes fracture reduction more demanding and open procedures are then usually necessary.

Consequently, the external fixator or should be in place for at least 6wks with the patient remaining on bed rest. During this period, you *must ensure passive mobilization of the joints* to prevent stiffness. *Don't forget thrombosis prophylaxis* (44.7).

Most patients will need a urinary catheter at least in the first few days. You may need this to interpret radiographs of the posterior pelvic ring. Make sure the care of the perineal skin and sacral area is fastidious.

N.B. A retroperitoneal haematoma may cause an ileus.

56.2 Bladder injury

A blunt impact on a child's full bladder may rupture it; likewise, the drunk emerging from a beer hall who falls or is hit by a vehicle is similarly at risk.

The dome of the bladder, which is intraperitoneal, is its weakest part, and allows urine to pour into the peritoneal cavity where it can appear as ascites. This may occasionally present as an acute filling of the scrotum if the victim has an inguinal hernia (18.2), with a patent *processus vaginalis.*

However, a pelvic injury usually causes a bladder injury outside the peritoneum in the prevesical space and under the *transversalis* fascia.

Urine may here be mixed with a pelvic haematoma, and such a mixture is rife for infection! Once this happens, Fournier's gangrene (6.23) or septicaemia quickly follow.

N.B. Any surgery in the pelvis may injure the bladder!

If a penetrating object (including a pelvic bone fragment) perforates the bladder, *make sure you look for a second hole in its wall!* Think also of damage to the bladder in penetrating injuries of the rectum or vagina.

The patient often has a great desire to empty the bladder but nothing comes out via the urethra except frank blood.

N.B. The urethra may also be injured (57.1), in which case there is a little blood at the meatus and no urine draining at all.

N.B. Blood clot may cause urinary retention!

There is always frank haematuria. The signs may be obvious; an ultrasound scan will show minimal fluid in the bladder, with it having an odd shape.

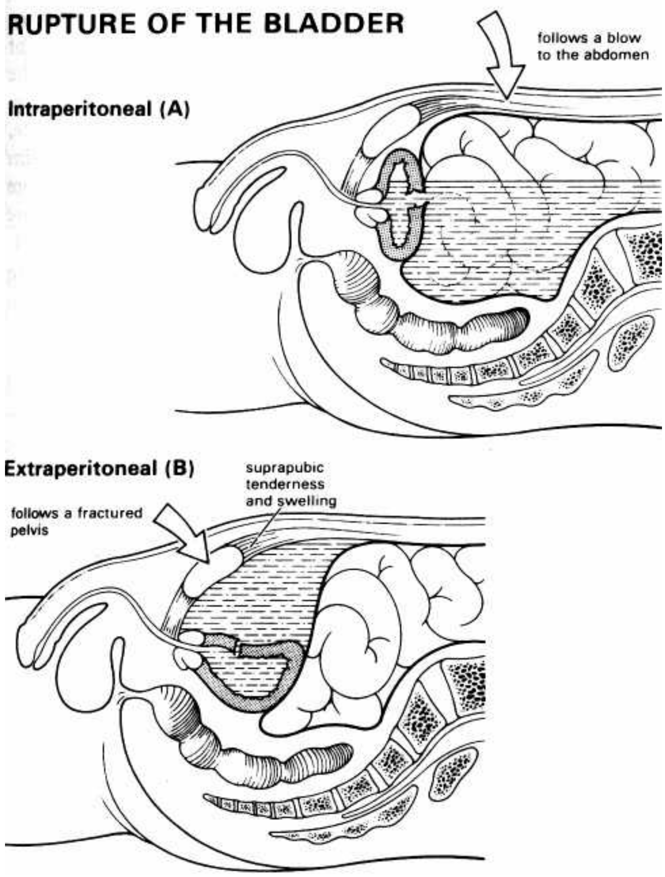


Fig. 56-6 INTRA- & EXTRA-PERITONEAL RUPTURE OF THE BLADDER. A, the dome of the bladder ruptures, and the abdomen fills with urine. This is irritant at first, but not after a while. If there is an inguinal hernia, the scrotum may fill giving the appearance of a hydrocele. B, urine leaks out into the extra-peritoneal area; there is usually suprapubic tenderness. *After Dudley HAF (ed), Hamilton Bailey's Emergency Surgery, Wright, 11th ed 1986 with kind permission.*

A retrograde cysto-urethrogram (38.1B) is more reliable: *use a very strict aseptic technique!* Place a lubricated Ch12 Foley catheter into the urethra, and inflate the balloon with 2mL in the *fossa navicularis* of a male; or at the introitus in a female. Make sure there is no leak by injecting sterile water. Then introduce 300-400mL of contrast at a pressure of 50-100cm H_2O pressure, and get films with the bladder filled and after voiding.

N.B. An IVU may have inadequate pressure in the bladder to demonstrate a leak.

A bladder rupture will show as contrast outlining bowel loops in an intra-peritoneal injury, and as wispy streaks of contrast infiltrating fascial layers in an extra-peritoneal injury.

N.B. Check for urethral injury at the same time!

CYSTOGRAM IMAGES OF BLADDER RUPTURE

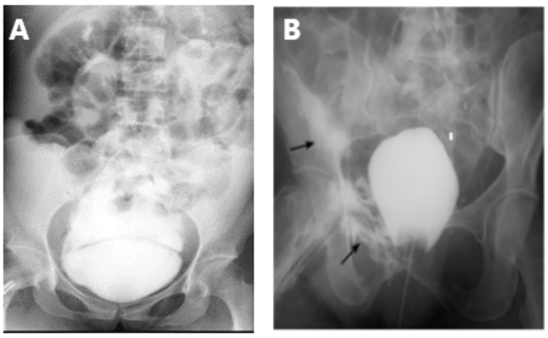


Fig. 56-7 CYSTOGRAM RADIOGRAPHS SHOWING BLADDER RUPTURE. A, intra-peritoneal rupture showing a blush of contrast outside the bladder, and outlining bowel. B, extra-peritoneal rupture showing contrast in soft tissues.

MANAGEMENT

If there is a small extra-peritoneal bladder perforation, this is often difficult to repair. For blunt trauma with a pelvic fracture, gently insert a lubricated Ch16 through the urethra (*if this is not injured)* or suprapubically. A pelvic haematoma may make inserting a suprapubic catheter difficult; use ultrasound to guide you. Then place a prevesical drain. Keep the catheter draining freely for at least 10days.

For all other bladder wounds, conservatively debride the edges and then grasp the sides of the perforation with Allis tissue forceps. Clean out the blood clots and wash with saline and then examine the inside of the bladder.

If you can see or feel another hole posteriorly, it is best to close this from the inside. Use 2 layers of 2/0 long-acting absorbable suture to make a watertight closure. Take care around the ureteral orifices; insert retrograde ureteric catheters if the wounds are near-by.

After bladder repair, insert a closed prevesical drain and leave a urethral catheter for 10days. Only add a suprapubic cystostomy if the bladder repair was difficult or you expect long-term catheterization because of other injuries, such as to the urethra. Gently insert a lubricated Ch16 (big enough to irrigate) through the urethra *(if this is not injured)* or suprapubically.

N.B. Overdistension of the bladder post-operatively may destroy your repair! Make sure your haemostasis is meticulous, and urine draining freely through large-bore catheters. Monitor urine output and if this suddenly decreases, especially in combination with increasing patient discomfort, irrigate the catheter gently with sterile water or saline to remove obstructing blood clots.

In damage control (41.5), this is *all* you should do! *Don't fiddle with a pelvic haematoma!*

N.B. (1) *A catheter balloon may neatly tamponade a bladder perforation, and so prevent any urine or contrast leak.*
(2) *Alternatively, the catheter may go through the hole in the bladder and suddenly drain ≥2L urine from the peritoneal cavity!*

If there is gross disruption of the bladder, pack the pelvis and bail out by fashioning bilateral nephrostomies: the damage control option.

If there is a wound in the rectum or vagina as well as the bladder, repair each separately and place a flap of omentum between, to prevent later development of a fistula.

56.3 Uterine injury

The non-pregnant uterus lies deep in the pelvis, and because mobile, is relatively well able to sustain blunt injury.

When the uterus is gravid, this is different. At 12wks gestation, the uterus rises out of the pelvis and reaches the umbilicus at 24wks. It is subcostal at 34-36wks. At first the uterine wall is thick, but by 30wks becomes thin, especially in the lower segment.

Unless there is a previous uterine scar (from previous Caesarean section or other surgery), the uterus usually ruptures at the fundus, usually with foetal mortality.

Of course, there are then 2 potential victims who arrive for your care simultaneously! *Remember: the best resuscitation of the foetus is resuscitation of the mother.*

The uterus may be injured by blunt or penetrating trauma. Obviously the most frequent injury to the uterus is iatrogenic: the uterus is easily perforated by a curette (23.4) for example, or by instruments (usually non-sterile) to induce a mechanical abortion, or at excision of a fibroid.

Every woman of childbearing age suffering trauma should have a pregnancy test as part of the routine paraclinical investigations.

N.B. Consider if the injury could be the result of abuse or domestic violence (47.1).

NON-GRAVID UTERUS

The non-gravid uterus is a tough bundle of muscle. Blunt injury is rare and usually accompanies a serious pelvic fracture. A car lap seat belt worn too low may produce a uterine tear after a deceleration injury.

A blunt injury of the uterus is mostly accompanied by serious pelvic fracture or retro-peritoneal haematoma.

Penetrating wounds of the uterus may be simple or devastating, gunshot wounds particularly so.
They may of course damage other important structures, especially the bladder, rectum and adnexa.

MANAGEMENT

If you find a perforation of a non-gravid uterus, repair this with a deep running 2/0 long-acting absorbable suture, making sure your suture is deep enough, just as in a Caesarean section. *Don't forget to look for a second hole*.
If there is further internal uterine haemorrhage, insert an intra-uterine balloon to tamponade further.

If you find a major disruption of the uterus, which now looks like an open book exposing the endometrium, you will have to perform a hysterectomy: *any attempt at repair is not only too risky for future pregnancy, but is likely to bleed!!*

GRAVID UTERUS

Domestic violence, falls, and traffic accidents are the most common causes of blunt trauma in pregnancy.
Of course, the introduction of any instrument into the uterus to procure an abortion is by far the commonest assault on the uterus!

N.B. Severe injury to other body parts or organs putting the mother's life at risk take precedence over any uterine injury not causing haemorrhage.

(a) Placental abruption

Many pregnant women suffering trauma will miscarry or experience a stillbirth (foetal death after 28wks' gestation). This can occur even if the uterus is not injured itself, as in placental disruption.

N.B. A central detachment of the placenta causes no visible blood loss.

Symptoms of placental abruption are constant abdominal pain; signs are of a tense, tender or even tetanic uterus, and a distressed or absent foetal heart sound.

Severe haemodynamic shock in the mother and decreased foetal movements may be the only signs of placental disruption after blunt abdominal trauma in pregnancy.

N.B. Vaginal bleeding is not necessarily present in placental disruption.

PLACENTAL DISRUPTION

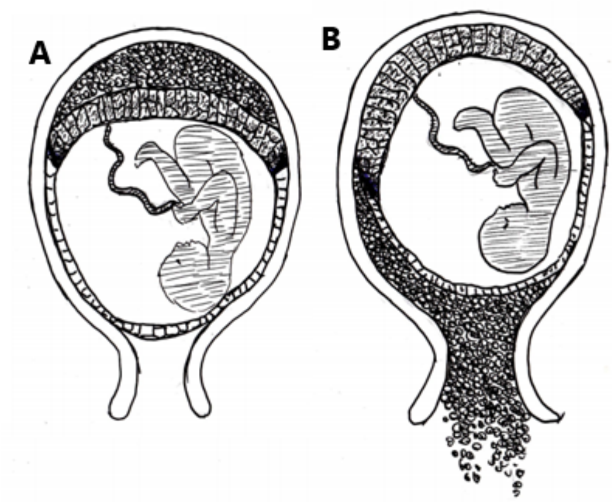


Fig. 56-8 PLACENTAL DISRUPTION. A, central. B, marginal.

(b) Uterine rupture

Unlike during labour (when the lower uterine segment tears), traumatic uterine ruptures tends to occur in the upper uterine segment or fundus leading to almost inevitable foetal mortality.
If there is no predisposing condition such as a uterine scar, uterine rupture occurs only in the most violent trauma.

SITES OF UTERINE RUPTURE

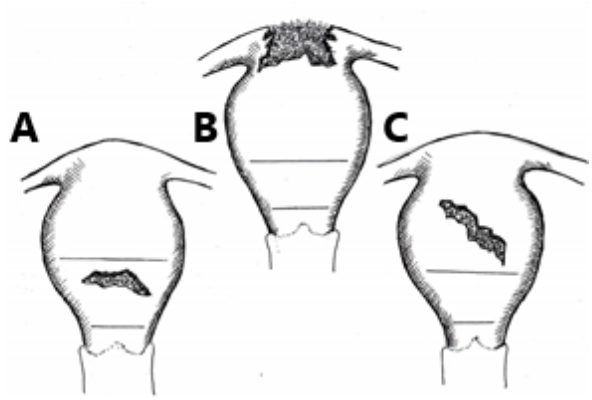


Fig. 56-9 SITES OF UTERINE RUPTURE. A, lower segment (in labour). B, fundal & C, upper segment (in trauma)

Most lacerations of the uterus cause significant bleeding, particularly if the uterus is gravid. This is usually intra-peritoneal, but may present with vaginal bleeding if the wound perforates the uterine wall, and rarely with extra-peritoneal haemorrhage.

Injury to the uterine arteries and placental abruption usually cause massive rapid bleeding.

N.B. Unless you carry out an immediate emergency laparotomy in this situation, the mother will die.

Penetrating objects may obviously damage the foetus, or the umbilical cord & placenta in a gravid uterus.

Palpation of foetal body parts or an abnormal lie are signs you may only find in slim or undernourished women; guarding may make the abdomen too tense, and there may be a discrepancy between the expected uterine size according to gestational age, and the apparent fundal height. Auscultation of the foetal heart maybe very difficult. *Don't waste much time on these details!*

Very occasionally the pregnant uterus may be completely avulsed.

If trauma is related to an unsafe abortion, instruments or objects may have perforated the uterine wall, thereby leading to vaginal and peritoneal haemorrhage (*and infection!*).

UTERINE PERFORATION IN ABORTION

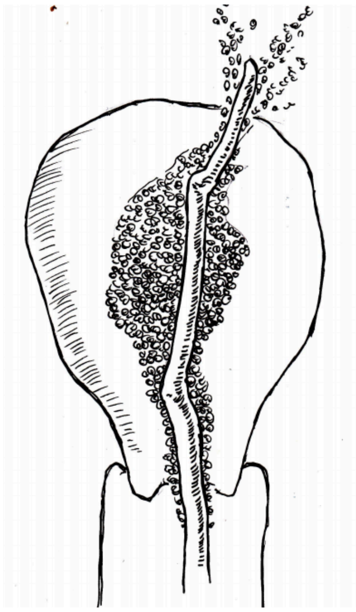


Fig. 56-10 UTERINE DAMAGE IN UNSAFE ABORTION Amniotic fluid embolism (44.5) **may occur, resulting in DIC and massive haemorrhage.**

EXAMINATION

Vaginal & rectal examination must be routine. *Vaginal bleeding in pregnancy is never normal*, and you must determine if the bleeding has been provoked by the trauma *(e.g.* abruptio placentae) or by a pre-existing condition *(e.g.* placenta praevia) and be ready to deal with it.

Place a sterile compress or ordinary sanitary pad over the vulva and extravaginally to absorb any liquid until you have dealt with the problem.

If there is vaginal bleeding, *never perform a digital vaginal palpation in the first place!* Where there is a placenta praevia, this may make the bleeding worse and *may risk the life of both mother & foetus!* Look at the vagina & cervix with a speculum or with ultrasound.

If you find a cervical or vaginal laceration, repair this with absorbable sutures, placed vaginally.

If you find fluid in the vagina and it has a pH 7-7.5, this suggests ruptured membranes.

Check for effacement & dilation of the cervix, foetal presentation and lie. *Avoid repeat vaginal examinations.*

Ultrasound is virtually mandatory (if available) for every injured pregnant woman to assess the status of the foetus, and the position of the placenta.

As well as information on gestational age, the ultrasound scan can show a myometrial or endometrial defect, a protruding amniotic sac, and fluid around the uterus.

A deceleration injury may cause serious damage to the foetus without there being any sign of injury in the mother. The opposite may also happen, that a foetus survives when the mother dies.

In this case a rapid emergency Caesarean section may save the baby.

Get plain radiographs if necessary. *Pregnancy is not a contraindication to simple radiograph*y: the benefit outweighs the risk. The foetus is most at risk during the 1st trimester, but the dose used must be very low.

MONITORING
Foetal monitoring is important: check for
(1) heart rates <120min or >160/min,
(2) repetitive decelerations,
(3) beat to beat variations,
(4) frequent uterine contractions,
Don't forget to get the mother's blood type, especially the Rh factor.
N.B. Seeing foetal umbilical blood flow on ultrasound is a helpful sign of life. If this is poor, you may be able to check for blood flow in the foetal middle cerebral artery, or monitor its maximum velocity in case of foetal anaemia.

MANAGEMENT
N.B. Your theatre temperature must be hot to prevent hypothermia!
Start resuscitation with blood transfusion, as uterine bleeding is likely to be massive. *Don't waste time!*

At laparotomy, endeavour to pack the pelvis after scooping out blood and clots, so you can get an idea where the haemorrhage is coming from.

If you find a perforation in a gravid uterus, and the foetus is still alive and >28wks gestation, perform an immediate Caesarean section. Monitor the foetus.

The most common foetal injury from a stab wound to the uterus is a compound skull fracture. Surprisingly, debridement and closure of such injuries frequently results in good recovery.

If you find a perforation in a gravid uterus, and the foetus is still alive and <28wks gestation, if the perforation is small, close it and monitor the foetus.

If the perforation is large and allows you to visualize the foetus, unless it is almost at term, it is very unlikely to have survived. If the foetus is at term, deliver it by enlarging the uterine opening if necessary and then repair the uterine wall as in a Caesarean section. If the foetus is not at term (and depending on your facilities), you may try to repair any damage (especially to the head) with absorbable sutures. Surgery on a foetus in utero does not produce scarring! This is obviously very heroic surgery, but you may be surprised by a happy result! Monitor the foetus carefully. Early labour will prompt you probably to perform a Caesarean section!

If the wound is relatively small and the foetus has died, *don't perform a Caesarean section* unless you cannot close the uterine wounds haemostatically. The woman will be able later to deliver the foetus vaginally. This carries very little risk unless the pregnancy is near term. In the case of induced abortion, add IV antibiotics.

If the wound is very large, this is the equivalent of a traumatic Caesarean section and the foetus is now effectively or actually intraperitoneal, and dies quickly.
Remove the foetus and placenta. Apply a cervical tourniquet, and see if you can repair the rupture; if not, perform a B-Lynch suture (22-14), or resort to an emergency hysterectomy (21.17) depending on the extent of uterine damage, just as in obstructed labour.

N.B. The uterus may remain atonic and bleed severely (20.12). Administer oxytocin IV (or methylergometrine), prostaglandins if available, and apply pressure to the uterus (Hamilton's manoeuvre, 56-11).

If the uterine arteries or veins are bleeding, *don't hesitate to ligate them on one side*: this will not put the foetus in danger.

HAMILTON'S MANOEUVRE

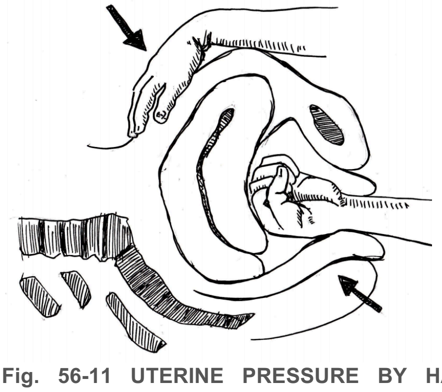


Fig. 56-11 UTERINE PRESSURE BY HAMILTON'S MANOEUVRE. Keep your hand in the vagina for 5 full mins.

If you find a simple external uterine laceration, repair this with a deep running 2/0 long-acting absorbable suture.

(c) Cervix injury
There may be a single tear, large enough to need suturing, or numerous small tears. Bleeding from small tears is most easily controlled by packing (22.11).

CERVIX LACERATION REPAIR (GRADE 2.5)
Deeper tears of the cervix can easily lead in a short time to a life-threatening haemorrhage from branches of the uterine artery, on the lateral side of the cervix.

You must visualize the cervix properly; so (1) get an assistant to push the uterus into the pelvis by pressing forcefully on its fundus. (2) insert a wide vaginal speculum.

Grip the edges of the laceration with long clamps. Often you cannot see the upper edge of the wound at the start. Place your 1st suture as high as you can reach comfortably and suture reliably. Then by retracting on this suture, visualize the top end of the wound & suture it meticulously as this is where the bleeding artery is located. Complete the repair towards the external cervix. Always use round; *never sharp or cutting* needles, as they can lead to further vessel injury.

N.B. Careful reconstruction is necessary to avoid later cervical insufficiency.

57 Perineal injury

57.1 Introduction

Owing to its different anatomy in the sexes, the urethra in a woman is vulnerable to obstetric injury, but seldom to trauma, whereas a man may sustain injury to the urethra anywhere along its course. (57-1).

MALE URETHRAL INJURY

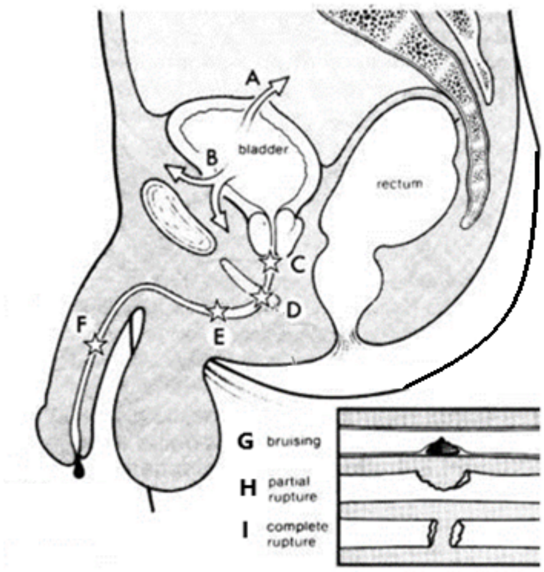


Fig. 57-1 MALE URETHRAL INJURY. A, direct abdominal pressure may rupture the bladder. B, a pelvic fracture may cause an extraperitoneal bladder injury, prostatic (C), or membranous urethral damage (D). A perineal blow can rupture the membranous, bulbar (E) or penile urethra (F). Types of urethral injury: brusing only (G), partial (H) or complete rupture (I). ***Blood at the external urethra is typical.***

More proximal urethral injury may be associated with a bladder injury or other lower abdominal visceral damage. A penetrating injury can damage the urethra anywhere. Blunt trauma to the urethra may not be complete and heal on its own.

Classically the victim is unable to pass urine, and has some blood at the urethral orifice. In more distal urethral injuries (57-1E,F), the scrotum or penis may distend with extravasation of urine.

N.B. Don't try to pass a catheter, as this may convert a partial into a complete urethral rupture. *Trying to 'railroad' a tube into the bladder is likely to fail, and will produce much scarring.*

HISTORY
Find out how the injury has occurred. Since the injury, has any urine passed? If clear urine has been voided, a urethral injury is unlikely.
EXAMINATION
Search for evidence of abdmonial & pelvic injury: these take precedence (55.2).
Look for blood at the urethral orifice; you can gently milk the penis to see this, if you suspect a urethral injury.
Check for perineal bruising, swelling and lacerations.
Look for a full bladder.
Perform a rectal examination to feel for a 'bogginess' around the prostate. You may feel a high-riding' or 'floating' prostate : it is displaced upwards, and appears to 'run' away from your examining finger (57-2).
At the same time feel for a rectal injury. Feel for a spicule of bone from a fractured pelvis penetrating the rectum. Look for blood on your glove (57.3).

INTRAPELVIC MALE URETHRAL RUPTURE

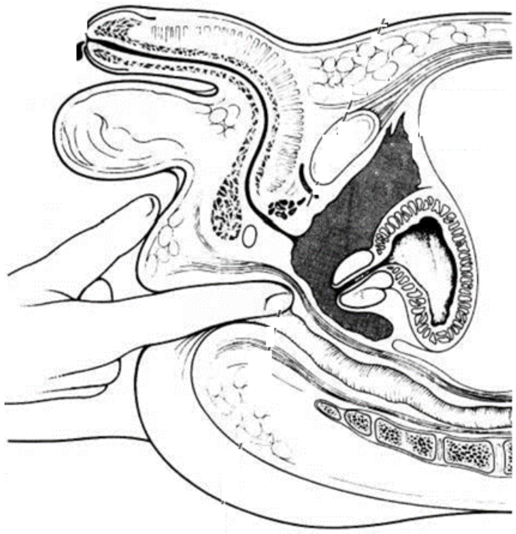


Fig. 57-2 RECTAL EXAMINATION FOR MALE URETHRAL RUPTURE. Feel for a boggy mass ar the end of your finger, with the prostate 'floating' away from your touch. Interpretation may be difficult. *After Dudley HAF (ed), Hamilton Bailey's Emergency Surgery, Wright, 11th ed 1986 with kind permission.*

RADIOGRAPHS
Perform a retrograde urethrogram (38-1) and get a radiograph of the pelvis, looking especially for signs of fracture types 56-1C & G.
N.B. A urethral injury may occur without a pelvic fracture!
N.B. An IVU is useful to establish a kidney injury, but is no help in lower tract injury.

NEVER PASS A DIAGNOSTIC CATHETER IF THERE IS BLOOD AT THE EXTERNAL MEATUS

MANAGEMENT

Once you have confirmed a urethral injury, whether complete or incomplete, divert the urine by placing a suprapubic bladder catheter.

If there is a bladder rupture, you need to deal with this first (and insert a suprapubic cather under direct vision, 27.8).

If the bladder is not full some while after the injury, there is either extravasation from the urethra, a bladder rupture, or inadequate fluid resuscitation. Make sure you infuse enough IV fluids, and arrange exploration and diversion by open suprapubic cystotomy (27.8).

If the bladder is full, perform a cosed suprapubic cystotomy (27.7). Make sure this does not block with clots by gentle irrigation of fluid into the catheter. After 3wks, clamp the urine tube to see if the patient can pass urine per urethram.

If he then can pass urine, check the bladder by ultrasound to measure the residual volume. Once this is <75ml, remove the suprapuic catheter. Follow up with a retrograde urethrogram after 3months.

If the patient still cannot pass urine *via* the urethra, refer for urethral repair

If you cannot introduce a suprapubic catheter even though the bladder is full, insert a long large bore cannula 3cm above the pubic symhysis, directed towards the coccyx, *as a temprorary measure only* to relieve a patient's distress when the bladder is very full.

COMPLICATIONS

(a) Extravasation of urine

This may be superficial or deep (27-13).

If a man presents late with a large red oedematous swelling in the scrotum or suprapubic area, this is Fournier's gangrene (6.23) and needs emergency treatment.

N.B. This is not the time to start repairing the urethra.

(b) Urethral stricture

This often occurs after urethral injury, especially after infection or instrumentation. (27.9)

(c) Urethral foreign bodies

These are occasionally left behind from ruptured catheters, or inserted for sexual gratification (27.37).

57.2 Penoscrotal injury

In general, any injury to the penis should make you suspect a urethral injury as well (57.1).

(a) Penile skin avulsion

If the skin of the penis is avulsed, its shaft is usually intact. Skin grafting is straightforward. If a piece of skin remains attached, *don't cut it off* but re-attach it: it will usually survive.

(b) Penile fracture

If there is a blow to the erect penis, blood in the engorged *corpora* extravasates and forms an eggplant-shaped deformity. This is typically associated with activity during sexual intercourse. There is typically a history of a sudden 'pop' and rapid detumescence, followed by development of the deformity.

Try to arrange operative repair as soon as possible, within 5days.

If you suspect a urethral injury (57.1) because of failure to void or blood at the meatus, and you have a straight-viewing cystoscope, perform a urethroscopy to check the urethra (27.3).

MANAGEMENT

Get consent for repair, including a circumcision. **If there is no urethral injury,** make a half-circumferential incision over the site of the penile swelling to mobilize the skin proximally & distally. Expose & evacuate the haematoma within the superficial (Buck's) fascia. Ligate any bleeding vessels. *Don't use diathermy!*

Find the laceration in the *tunica albuginea,* which is usually transverse and ventrolateral in position. Close this water-tight with a continuous long-acting absorbable suture, burying the knots. If you cannot find any tear in the *tunica,* inject saline (with dye if necessary) into the *corpora* to identify the laceration. You can use the same method to check that your repair is water-tight. Close Buck's fascia likewise. Close the skin and monitor for swelling and voiding of urine. Perform a circumcision at the end of the procedure (27.29).

If there is evidence of a urethral injury, make a suprapubic cystotomy to drain the urine and wait 3wks (57.1). The chances are that the injury is incomplete. Immediate repair is for the expert.

If the erect penis is bent post-operatively, a contracture of scar tissue has formed (as in Peyronie's disease). You can try to correct for this by plicating the *tunica* on the opposite side to compensate.

N.B. You must warn the patient that the penis will be a bit shorter.

(c) Penile amputation
This may be partial or complete.

If the amputation is incomplete, carefully dissect the damaged tissues, and debride soiled or necrotic parts. Ligate corporal arteries. If the urethra is ruptured or torn, attempt to approximate obliquely divided clean ends of the urethra together with a fine continuous watertight long-acting absorbable suture, with everted knots, over a fine urinary catheter.
Repair the *corpora* with a continuous watertight long-acting absorbable suture. Then repair the skin.

If the amputation is complete, and the distal part is preserved, and clean (preferably kept in ice), anastomosing vessels from both parts as requires magnifying spectacles.
Then spatulate the urethra and corpus spongiosum ventrally suture these to the remaining shaft skin (27-31).

Take care to ensure good hemostasis and leave a urinary catheter *in situ* for 10 days.
A stenosis of the urethral orifice frequently ensues, which will need patient repeated dilation with bougies.

(d) Penile strangulation
If the penis has a tourniquet applied or it is stuck inside a bottle, it may swell alarmingly. Decompression as for priapism (27.32) may be necessary.

(e) **Penile injection**
Palm oil is used by some to induce a chemical erection. This causes severe inflammation of the *corpora.*

(f) Superficial scrotal injury
The scrotal skin is very lax, so you can usually close a defect in it primarily in 2 layers. The scrotum often bleeds and may swell dramatically afterwards, so place a drain into the sac. *Don't try to skin graft the scrotum,*

If the testicular artery is injured, it might retract and bleed alarmingly. In this case, clamp the whole cord, and dissect out the artery in order to ligate it doubly. You will then have to perform an orchiectomy on that side.

(g) Testicular injury.
If, on exploration, you find the testis to be injured, clean & toilet the wound. Repair the *tunica albuginea* around the testis, but *don't insert a drain* (57-4). *Make sure you replace the testis without twisting its pedicle.*

TESTICULAR INJURY

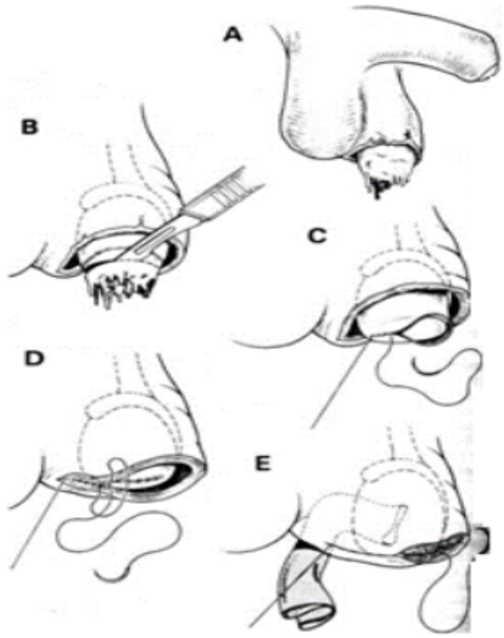


Fig. 57-3 TESTICULAR INJURY. A, open tesrticular lacetaion. B, generous debridement. C, watertight closure oft he *tunica.* D, scrotal closure. E, drain. *From Early Care of the Injured Patient, ed. Walt AJ. Committee of Trauma ACS, with kind permission*

.

If the testis is shattered, perform an orchiectomy (27.26).

57.3 Anorectal injury

Penetrating injuries of the rectum or anus may occur from outside (*e.g.* by knives, bullets, anti-personnel mines, animal horns) or from inside (by foreign bodies inserted intentionally or otherwise, sexual assault, or at endoscopy). The rectum may also be damaged in a serious pelvic fracture in blunt trauma.

The proximal part of the rectum abuts onto the peritoneum, and so perforation there is like a colon injury. On the other hand, it is easy to miss a perforation of the extra-peritoneal pelvic rectum.

A perforation of the lower posterior rectal wall may allow faecal matter to leak out into the hidden pre-sacral space and quickly result in septicaemia, but perforations of the lower anterior and lateral walls are less likely to do so.

Examine the anorectum visually & digitally (26.1). If necessary, sedate the patient. You can feel a perforation within 8-10cm of the anal verge. Test if the sphincter is still intact.

If there is blood on your examining finger, this implies, unless the bleeding existed before the injury, that there is a bowel injury somewhere (though not necessarily in the rectum)!

If you don't plan to do a laparotomy (*e.g.* in a pelvic fracture), look gently with a proctoscope (26.1); wash out the distal rectum with dilute betadine beforehand. If you are gentle, you are unlikely to make a small perforation bigger. Use a sigmoidoscope to look further but *don't try to manipulate the 'scope past 15cm beyond the rectosigmoid flexure!* If you have a flexible instrument, this is a big advantage to look at any lesion more proximal. Beware though, *inflating the rectosigmoid with air may push faecal matter through a perforation*! A tear in the anal sphincter can result in retraction of its 2 torn ends into the tissues. Locate these using a finger in the rectum.

N.B. Never introduce a barium enema!
N.B. The use of herbal enemas may lead to peritonitis & later recto-anal stricture (26.11).

If there is a foreign body in the rectum, it may be difficult to remove if round and smooth because of a vacuum effect (26.11).

Repair of a rectal Injury will almost certainly require a laparotomy and a diversional colostomy (26.1).

RECTO-ANAL LACERATION

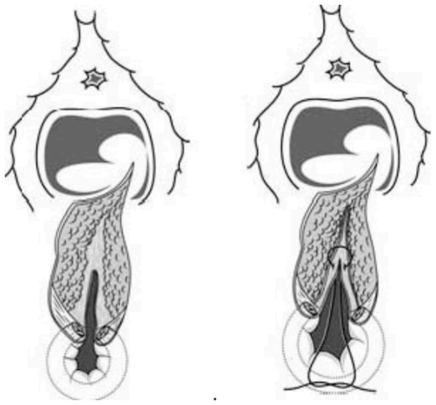


Fig. 57-4 ANORECTAL REPAIR. A, place a tampon inside the rectum, B, start with the deepest layer most proximally. *From: Médecins Sans Frontières: Essential obstetric and newborn care - Practical guide for midwives, doctors with obstetrics training and health care personnel who deal with obstetric emergencies, 2017 [15]*

ANAL REPAIR (GRADE 2.4)
Place a tampon deep in the rectum (beyond the laceration) ; *make sure a thread is attached to it*, so you can remove at the end of the procedure!
Administer gentamicin & metronidazole pre-op for 3-5days depending on how soiled the wounds are.
Clean the rectum thoroughly with povidone iodine 10%.
Establish a defunctioning colostomy first (11.15) if the wound is complex or very dirty, or in an untreated HIV+ve patient.
Repair the muscle carefully defining its edges, using long-lasting absorbable sutures, by interrupted U-shaped sutures (57-6), starting proximally high up (beyond the end of the laceration) using absorbable, interrupted sutures knotted on the rectal surface.
N.B. An anal retractor may be very useful. Make sure you separate rectum & vagina, *e.g.* by omentum; otherwise development of a fistula is very likely.
Post-operatively, after each visit to the toilet, cleanse the wound with water (shower if possible) and, if required, soap.

57.4 Vaginal & labial laceration

Anatomical alignment is your aim. Good lighting is essential to identify damaged structures. Ensure the victim has adequate analgesia and is as comfortable as possible throughout the initial assessment.

This must be a systematic examination of the perineum, vagina & *rectum*, including colposcopy & proctoscopy, if indicated and the necessary equipment is available (rarely the case).

The same principles as for a complex 3rd degree obstetric tear apply (21.16).

For minor injuries, LA might be sufficient, but for more complex 3rd or 4th degree tears, GA or spinal anaesthesia in theatre is essential.

Insert a tampon made from sterile compresses tied together with a thick thread into the upper fornix of the vagina to absorb bleeding. Make sure a string remains attached to the tampon, so you can remove it at the end of the procedure.

It is important to see the upper edge of the wound. If you cannot see that far, insert a 1st suture as high as you can, and leave the tie long. By pulling on this 1st suture, you may be able to find the apex of the wound.
Place another suture 1cm above the apex to avoid haemorrhage from retracted blood vessels.

Close the laceration with a continuous absorbable 0 suture.
Use the margins of the hymen on both sides as landmarks for correct vaginal re-adaptation (21-15).
N.B. Don't leave a cavity underneath the vaginal wall because this can produce a painful haematoma. However, *don't suture too deep and suture the rectum to the vagina!* Perform a rectal examination after the procedure to check there is no suture visible in the rectal mucosa.

Repair the *bulbocavernosus* and *transverse perineal* muscle layers with 2-3 single absorbable sutures, and close the skin at the perineum with rapidly absorbable continuous or interrupted sutures.

If there are multiple vaginal lacerations, tamponade the vagina. Catheterize the bladder. Remove the pack after 24h and re-examine the wounds.

If the cervix is lacerated, it is essential to get a good view using a speculum (22-11). Bleeding may be severe, in which case, it is best to insert a tampon (with a long string thread) for pressure haemostasis for 24h, and catheterize the bladder for this period.

FISTULA PREVENTION & MANAGEMENT

Violent rape or penetration of the vagina with foreign objects may produce a traumatic vesico-vaginal (21.18), recto-vaginal fistula (21.19), or even peritonitis.
Some fistulas arise following inappropriate instrumentation to manage rape-induced spontaneous (or induced) abortion or stillbirth.
If there is permanent leakage of urine, insert a urinary catheter. Re-assess the wound in 3 months' time.

57.5 Vaginal foreign bodies

All manner of foreign bodies have been inserted either forcefully by another person, or for sexual gratificatin, into the vagina.

Their removal may be difficult to remove if round and smooth because of a vacuum effect (26.11), though less so than in the rectum. However, a foreign body may be tolerated much longer, and i fit has sharp edges, it may penetrate into the rectum, causing a fistula. Treat this as above (26.1)

58 Limb injury

58.1 Examination of an injured limb

The principles of dealing with bone and soft tissue injury apply everywhere, but the features of each limb are different. Inappropriate treatment provides many opportunities for disaster, and these are common & serious:

(1) *Primary closure of an open fracture or a contaminated wound* (46.3).

(2) Applying, over a recent injury, *a cast without splitting it, especially in minor fractures with little initial swelling* (59.3).

(3) *Leaving a joint in a position where normal function is virtually impossible.*

N.B. Hearing the sound of a crack rarely indicates a bone has broken.

Soft tissue injuries may be just as severe, even more so, than bony injuries. *Consider an open fracture as a soft tissue wound that happens to have a broken bone in it.* Torn ligaments may make a joint unusable even when bone is not broken. Some dislocations are obvious, but others not so; good history taking will often alert you to joint injuries.

Limbs may be broken in more than one place. Several injuries may occur simultaneously. A patient may not complain of one injury if he has a more painful injury elsewhere. *You may completely fail to notice a limb injury if a victim is unconscious or paralysed.*

THINK OF A FRACTURE AS A SOFT TISSUE INJURY AFFECTING THE BONE

HISTORY

Always take a careful history. Most fractures are the result of some characteristic injury, so enquire carefully about the force which caused an injured limb.

A fall onto the heels from a height may result in a fracture of the calcaneus, and also perhaps the spinal vertebrae or pelvis.

A twist and fall playing football, may result in a spiral femoral fracture (67.1) or a ligament injury (58.4).

A fall on the outstretched hand, may result in any type of wrist fracture (64.1).

Being hit on the arm by a cricket ball, may result in a transverse fracture (63.6).

If very small force was able to break the bone, it may be weakened by some other disease (a pathological fracture).

N.B. If the patient can still move the limb normally, a fracture or serious injury is unlikely, unless distracted by other injuries.

EXAMINATION OF AN INJURED LIMB

LOOK

Remove all the victim's clothes and look for abnormal position, contour, shortening, bruising or ecchymosis. Deformity may be obvious, but need not be.

Compare one side carefully with the other. A joint may look larger than the other, either because it is swollen, or because of muscle wasting.

Measure & note shortening or thickening with a tape measure (67-3).

THE NEUTRAL POSITIONS

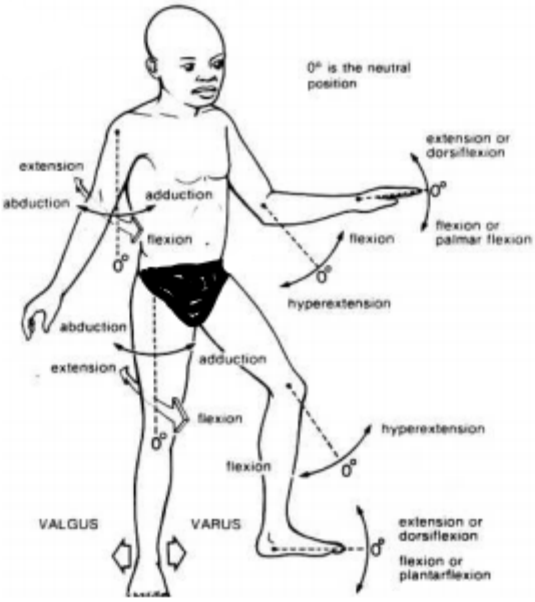


Fig. 58-1: THE NEUTRAL POSITIONS from which you can measure flexion & extension, adduction & abduction. The positions of rest, and function (for ankylosis) are both quite different (7-16), as is the position of safety for the hand (65-8). *N.B. In a valgus deformity, the distal part of the limb deviates away from the midline and in varus, it deviates towards it.* *Kindly contributed by John Stewart.*

FEEL

Ask the patient to point *exactly* to where the pain is. Important signs of a fracture are:

(1) pain: tenderness on *light* pressure at a specific site,

(2) swelling: abnormal contour (bony points not in their normal place)

(3) deformity: abnormal mobility at the fracture site,

(4) immobility: inability to move the bone actively or apply pressure on it.

Always check for distal pulses & sensation.

Note the movement possible from the neutral position for each joint (58-1). Record all your findings.

N.B. Don't forget the soft tissue injuries!

10 GOLDEN RULES FOR LIMB FRACTURES

(1) *Always follow the ABC of resuscitation* (41.1).
(2) Splint a fracture before moving a patient; *make sure the splint includes the joints above and below the suspected fracture*.
(3) Always examine for distal nerve (48.1) & vessel (49.1) injury and record your findings.
(4) Handle the injured part as little as you can.
(5) Check carefully if there is a skin perforation.
(6) Even if the fracture is obvious, examine for other injuries (*even if the victim has no other complaints*).
(7) Wash open fractures copiously with clean water, and remove any foreign material.
(8) Take note of soft tissue injury, and *don't be slow to perform a fasciotomy* (49.6) *if indicated,* especially if there is continuous severe pain.
(9) Obtain radiographs in 2 planes and include include the 2 joints above and below.
(10) Reduce any displacement; *don't wait for the swelling to go down, nor for radiographs if these are long in coming.* Place the included joints in their position of function.

If you have very limited supply of Xray film available, concentrate on getting radiographs for:
(1) hip injuries,
(2) penetrating injuries,
(3) elbow & ankle injuries,
(4) long bone injuries & proximal dislocations,
(5) severe foot injuries

Describe fractures as follows (58-2):_
(1) Open or closed?
(2) Which bone & where?
(3) Involving the joint surface
(4) Transverse (A) oblique (B) or spiral (C)?
(5) 'Butterfly' fragment, segmented (D) or comminuted (E)?
(6) Displaced by shift (F), with tilt (medial, lateral, anterior or posterior angulation, G), twist (rotation, H), overlap (I), distraction (J), or impaction (K)?

58.2 Radiographs

Always examine a patient before you order the radiographs! For most fractures take an AP (anteroposterior) and a lateral view. Look at all the films yourself, and if you are in doubt, compare them with views of the other side. *This is especially important in young children.*
In all long bone fractures, include the joints above & below the fracture.

If you are not sure if there is a fracture or not, but suspect one clinically, splint the bone in a functional position and repeat the radiograph after 5-7days. *N.B.* A normal radiograph does not exclude a ligament injury (58.3). *So always treat a patient according to function.*
A cursory look at a radiograph is not an adequate appraisal of a limb injury.

LONG BONE FRACTURE PATTERNS

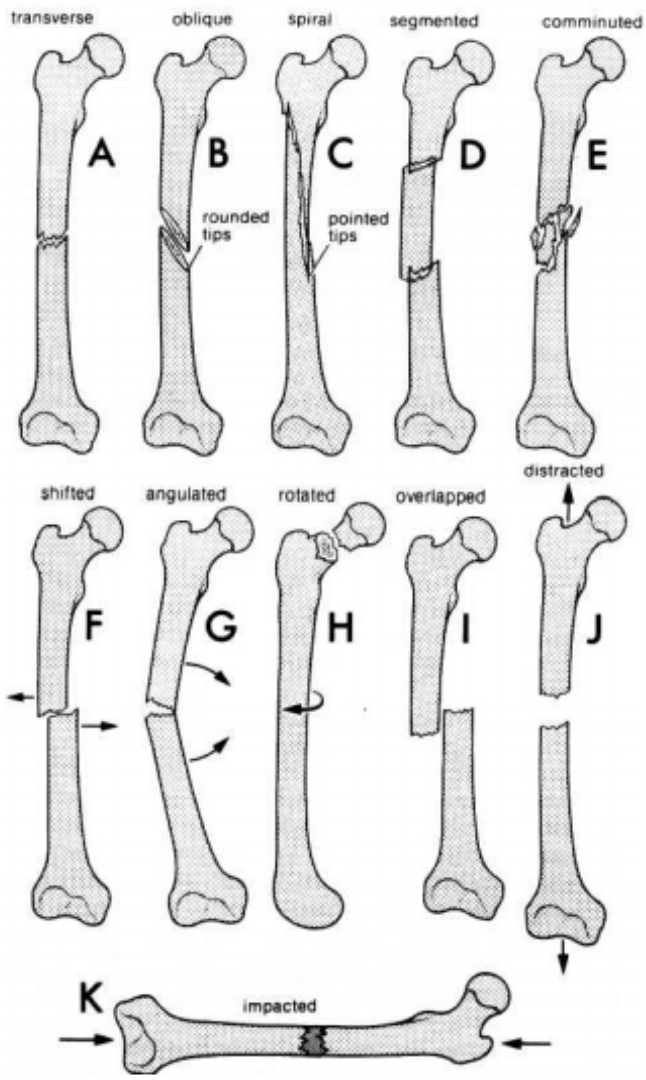


Fig. 58-2 LONG BONE FRACTURE PATTERNS. There may be several fracture types simultaneously.

58.3 Stages in bone healing

The shafts of long bones heal in 4 stages:

(a) Periosteal & endosteal disruption.
The periosteum tears away from at least one of the fragments. The endosteal circulation is also disrupted, and the ends of the fracture fragments are deprived of blood supply and die.

(b) Callus formation
During the next few weeks the periosteum & endosteum near the fracture produce soft vascular callus full of active spindle cells.
Cancellous bone only forms a significant amount of callus when the 2 bony fragments are close together; cortical bone can form callus when they are not so close. Gentle movement stimulates callus formation in a fractured long bone; complete lack of movement depresses it.

STAGES IN LONG BONE HEALING

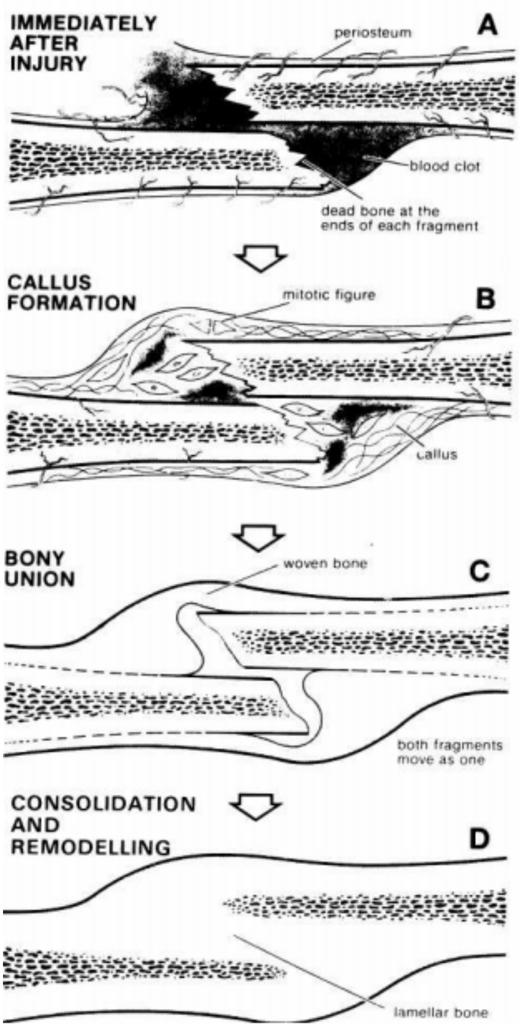


Fig. 58-3 STAGES IN LONG BONE HEALING. A, immediately after the injury. B, callus formation. C, bony union. D, consolidation and remodelling. *Kindly contributed by Peter Bewes.*

The newly formed callus forms a sheath round the broken bone, and is fixed to the fragments around the fracture, but *not to the bone at the fracture site itself*. The bone here is ischaemic and dead, and does not unite until it has been revascularized later.

After 2-3wks in adults (sooner in children), enough calcium has been deposited in the callus for it to be visible in a radiograph. This calcified callus slowly converts into loose open 'woven bone' which makes the bone ends 'sticky', and prevents them moving sideways on one another, although it still allows them to angulate.

(c) Bony union.
As time passes, the woven bone round the fracture becomes harder, and so firmly fixed to the fragments that they move as a single unit. This is clinical union and is a critical milestone in the healing of a broken long bone.
Assess union clinically *rather than on the appearances of the radiograph*. It usually occurs 4-8wks after the injury, but in the tibia it can take much longer. At this point, management changes.

(d) Consolidation & remodeling
Bone continues to heal during this stage, which lasts several months. The broken fragments remain firmly held by callus, while the dead bone ends of each fragment is slowly removed, and their ends joined by more callus and finally by solid bone. Minor limb movements encourage new strong bone growth.

Excess callus is slowly removed until the injured limb is as strong as it was before. As a general rule, consolidation takes at least as long as the clinical union period, so too much stress on the healing bone will disturb the process.

The time taken to consolidation varies with the age & condition of the patient. Limb ischaemia, & vitamin D deficiency make everything take much longer. (Osteoporotic bone joins in the same time, but is weaker.) Perkins's timetable suggests: 3wks for union of a spiral fracture in the arm, double to consolidate, double again for the leg, and double once more for a transverse fracture. Take special consideration of weight bearing bones in resuming function.

58.4 Ligament (joint) injury

Ligaments are specialized fibrous tissues which prevent excessive motion between articular surfaces. They can be sprained, stretched or partly torn, or completely ruptured.

Some ligaments, such as the collaterals of the knee, heal better on their own than others, such as the cruciates of the knee. Poor healing will result in some degree of joint instability.

JOINT ASPIRATION (GRADE 2.2)
Indications for joint aspiration are for diagnosis or pain relief. An acute post-traumatic swelling of a joint, particularly the knee or elbow, may be due to bleeding from soft tissue damage or from an undisplaced fracture not visible on radiography. Aspirating the joint will show if there are fat bubbles in the haemarthrosis, confirming the diagnosis of occult fracture. Decompressing the haemarthrosis also provides significant pain relief, which is unfortunately only temporary most of the time.

N.B. You must perform a joint aspiration only under the strictest aseptic conditions, as the risk of infecting a joint is considerable, and the consequences catastrophic.

Therefore, use joint aspiration for diagnostic purposes only, unless the swelling is really pronounced. Follow up patients carefully to see if the swelling increases.

In a dislocation the joint surfaces are completely displaced, but in a subluxation they are still partly touching one another. Both subluxations and dislocations are often combined with fractures.

Reduce all dislocations and fracture-dislocations immediately, because the longer you leave them, the tighter the ligaments will become, and reduction is more difficult or even impossible. Many dislocations put at risk surrounding neuro-vascular structures, so record any deficit *before & after* manipulation.

COMPARE THE ABNORMAL SIDE WITH THE NORMAL SIDE

58.5 Principles of fracture treatment

Principles of fracture treatment follow 3 stages:
(1) **Reduce** (if displaced),
(2) **Hold**,
(3) **Exercise**.
A conflict arises how to *hold a fracture and keep the limb moving*, followed by another conflict: the speed of mobilization against the risks.

To reduce a fracture, you need to distract the fragments to disimpact them (if necessary) and replace the correct alignment.

You may need to accentuate the fracture position to disimpact it, and will certainly need to pull on it to correct any overlap.
Relaxation with anaesthesia is usually necessary (and will prevent the patient's muscles resisting you).

Closed reduction is impossible when:
(1) a fragment is too small to manipulate,
(2) a fragment is trapped in a joint,
(3) soft tissues are stuck between the fragments.

The best time to reduce a fracture is either immediately after the injury, before the tissues have started to swell, or some days later, after the swelling has gone down.

If a fracture is undisplaced, no reduction is required.

Holding the reduction is the priority. There is no one method that is suitable for all fractures and all patients; each method has its advantages and disadvantages.

You must decide which holding technique is best for the specific bone fractured, the type of fracture (stability, bone defect), the presence of an open wound, and how much experience and training you have.

Remember: you, and the patient, want a good functional result, *not a good radiographic result*. You want a method of fracture holding that has the lowest risk of complications, is simple to apply, given your level of expertise, is relevant to the level of nursing and physiotherapy care of your hospital, keeps admission time to a minimum; and is not expensive.

Methods are: (1) continuous traction (59.4), (2) splinting (59.2,3), (3) fixation (59.5).

Whichever method you use, good physiotherapy will help give you the best results.

CONTINUOUS TRACTION
Continous traction is useful for bony shaft and articular (joint) fractures. It does not hold the fracture rigid, but stretches and elongates the surrounding soft tissues, which then pull the bone fragments into place and maintain limb length. The aim is to hold the reduced fracture in position till it is comfortable enough to exercise the muscles and move the joints.
Traction is possible by gravity alone for the humerus (61.12), by skin adhesion (up to 5kg only in children & for osteoporotic bones), or through skeletal pull by inserting pins through the tibia or calcaneum (69.5).

Traction should not be excessively strong and distract the fracture, because bone fragements that do not coapt will not heal.
Excessive weights on skin traction may deglove the skin! Also, insertion of traction pins needs care.
N.B. Traction must pull against something fixed (or else a patient is just pulled down the bed!)
Exert traction against a fixed point, or an opposing force (balanced traction), or in combined manner (by a Thomas's splint).
*Make sure you check traction frequently. Prevent ankle equinus (*limited dorsiflexion due to Achilles tendon or calf muscle tightness)*, a common and often disastrous preventable complication. Prevent shortening & rotation in the lower limb.*

SPLINTING
The most common method is to use Plaster of Paris (PoP) which sets when it dries in the shape you wish to mould it. It is very useful to hold a fracture but will not allow a limb to swell, lets immobilized joints become stiff & unused muscles to atrophy, and may rub against bony protuberances.
To avoid the limb compartment syndrome (49.6) which may cause the complete loss of a limb, *always split a plaster cast initially,* or apply a slab at first and complete the cast only when the swelling has subsided*..*
Avoid stiffness by splinting fractures only after they have become 'sticky' in traction, and some ability to lift the bone returns.

KEEP ALL OTHER JOINTS MOVING

FIXATION
Some fractures are liable to non-union or malunion:
(1) femoral neck fractures,
(2) unstable ankle fracture-subluxations,
(3) mid-shaft forearm fractures,
(4) transverse olecranon & patella fractures,
(5) pathological fractures,
(6) multiple fractures in the same limb.

The options are then (a) external fixation (59.4), (b) open reduction with or without internal fixation, or (c) internal fixation without open reduction, *e.g.* using a K-wire.
Don't forget the soft tissues: treat oedema by elevation & exercise. *Never dangle the limb nor force excessive activity.*
Debride open fractures!!
If you intend to refer a fracture for internal fixation, the sooner the patient reaches the referral hospital the better. This should be in at least 2wks, with the fracture splinted in the position of function.

58.6 Adequate function with minimum risk

Since the 1st edition of this book almost 40yrs ago, the trend in high-resource environments has been to manage the vast majority of orthopaedic injuries surgically, most commonly with internal fixation. The obvious aim of good treatment is return to good function with minimum risk.

The big advantages of internal fixation are perfect reduction and early mobilization, but the big disadvantage is the risk of infection. Because of the former, many ignore the latter.

Infection in bone is a disaster, and the presence of foreign metallic material makes it almost impossible to clean up an infection.

Avoiding complications is more important than early patient mobilization. Simple methods of fracture immobilization are best.

Alas, much experience in treating fractures conservatively has been lost and no longer appears in many textbooks. It is important to point out that: (1) *perfect radiological reduction does not always mean perfect function*, and (2) function may be perfect, even though reduction is not.

When a fracture is fixed rigidly by metal, there is no callus but primary osteoclast activity and osteoblast deposition. Thus, the bone integrity depends on the metal implant, which diverts stress from the bone, so allowing it to become osteoporotic. In contrast, the small amount of bone movement that occurs in a splinted fracture stimulates callus formation, and it is the callus that ensures mechanical strength whilst the bone heals. With increasing stress, the callus grows stronger.

INCORRECT INTERNAL FIXATION

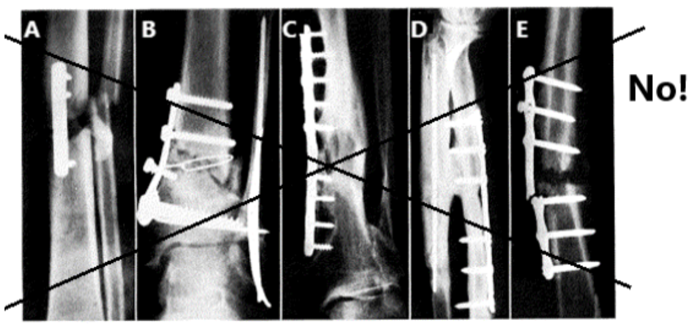


Fig. 58-4 *HOW NOT TO DO IT.* A, inadequate fixation. B, excessive use of material. C, screws too short + bone infection. D, unorthodox fixation & cross-union. E, plate fracture (bone not yet united). *After Apley AG, Solomon L. Apley's System of Orthopaedics and Fractures. Butterworth, 6th ed. 1982.*

Preconditions to successful internal fixation are:
(1) surgeons skilled in the correct procedure, replacing gloves, instruments & drapes after debridement *before* starting internal fixation,
(2) nurses skilled in assisting,
(3) a proper aseptic operation theatre,
(4) complex sets of equipment,
(5) plates, nails & screws of different types & sizes,
(6) a supply system to replace used plates, nails & screws,
(7) a mobile Xray machine with C-arm,
(8) safe sterilisation systems,
(9) good postoperative care,
(10) appropriate antibiotic prophylaxis.

If you attempt internal fixation without *all* the necessary conditions, too many of your patients will end up severely disabled by painful, malunited or chronically infected bones.

The famous AO osteosynthesis group gave a warning in its 1st instruction manual, "we cannot advise too strongly against internal fixation if it is carried out by an inexperienced surgeon and in the absence of full equipment and sterile operating room conditions".

Many of therequirements of internal fixation can be met by **external fixation** which carries much lesser risks, and is often more appropriate anyway (59.4).

Because internal fixation is such a disaster when it is badly done and infection a clinical catastrophe, even if you have equipment for internal fixation, *don't use it unless you can meet all the strict criteria*.

If you do have the necessary training and experience and your hospital has the necessary equipment, logistic supply chain for the provision of materiel, degree of cleanliness, and nursing care, then you may elect to perform internal fixation whenever optimal for the patient; it is inappropriate for this book to go into any further operative detail.
One possibility is the SIGN nail system, produced especially for use in low-resource hospitals without the need for expensive radiography machines or even electricity. SIGN is an entire programme run by a humanitarian organisation, which includes education and training, not just material for internal fixation. More information can be obtained at https://www.signfracturecare.org/. If your working conditions don't meet the above criteria, then conservative techniques, as described in this book, are for you.

DISASTER WITH INTERNAL FIXATION

Fig. 58-5 DISASTROUS RESULTS OF INTERNAL FIXATION. There were no indications for plating the humerus; the plate is now loose, and the screws have fallen out. There is a pseudarthrosis and a radial nerve palsy, so a plaster wrist cock-up splint was applied. Using active movements and a sling would almost certainly have resulted in union, and may have avoided the radial nerve palsy, besides being simpler and cheaper. *After Charnley J, Closed Treatment of Common Fractures E&S livingstone, Edinburgh & London 3rd ed.1961*

On the other hand, K-wires and nails, in contrast to plates & screws or intra-medullary nails, are usually temporary, and you can remove them after some wks. They are small and less prone to produce chronic osteomyelitis.

K-wires are useful for some hand or foot injuries (the excellent blood supply decreases the possibility of infection), and for fixation of displaced intra-articular fragments; K-nails are good for the radius or ulna.

We have collected together here a system of non-operative methods for most of the common fractures and for many of the rarer types. Fractures of the olecranon and patella, which absolutely need internal fixation, are included. The femoral neck fracture needs more skill and equipment, and will need referral.

You will find that conservative methods will give you a much lower rate of infection and non-union. The thinking behind conservative treatment is to follow the natural healing processes of the body, to use closed methods wherever possible, to encourage the patient to start using the limb as soon as he can, and to interfere surgically only if absolutely necessary, and then only in the simplest way possible.
N.B. If it is not essential to restore the exact anatomy after a fracture, the non-operative method should not try to do so.

The perfect immobilization which operative methods try so hard to achieve is seldom even desirable, as in many fractures a little movement is a good thing encouraging callus formation and union, and preventing the absorption of bone.

Despite cogent explanation of methods of conservative treatmernt by Böhler, Perkins, Charnley & Sarmiento, few systematic descriptions of non-operative methods now exist.

THE POSSESSION OF EQUIPMENT FOR INTERNAL FIXATION SHOULD NOT BE A FREE LICENCE TO USE IT

With more difficult fractures, particularly fractures into joints, your results, *and those of most surgeons*, are unlikely to be perfect. With difficult fractures your aim is to obtain fracture union in the position of function, so that the limb will still be useful even if not perfectly aligned. The measure of adequate function in a limb is its usefulness in relation to the patient's life and work, *not your own assessment*.

You may need to warn a patient that function is unlikely to be perfect. You should discuss possible problems to allow preparations to be made for the future. But you will only get good results if you follow all the details carefully.

How you apply a cast, when you should remove it, and exactly which exercises the patient should follow are just as important as the mechanical niceties of internal fixation.

Here are some important general principles:
(1) Maintenance of alignment
(2) Avoidance of rotation of fragments.
(3) Avoidance of distraction.
(4) Encouragment movement of nearby joints.
(5) Careful application of casts and traction.

In addition, each fracture has its own rules. Remember that the size of a fracture has little relation to its seriousness. For example, you can easily treat a Colles fracture in a young person, but a chip off the head of the radius may have to be removed at an open operation.

Aim always to restore function. If the arm is injured, range of motion and the use of the hand are the most important: a little bit of shortening, rotation or angulation are acceptable. If the leg is injured, try to restore painless stable weight bearing; prevent misalignment; maintaining length is desirable, but a little shortening <2cms is usually well tolerated and can be compensated by a special shoe.

Finally, remember to treat the patient as a whole person; *don't only consider the injured limb*.

THE DETAILS ARE CRITICAL

58.7 Clinical examination for union

Don't rely on radiographs to tell if union is adequate. A proper clinical examination is safer and more reliable.

*(*1) Feel the fracture site for tenderness, looking at the patient's face as you do so. If the site is no longer tender, the fracture has probably united.
(2) Feel the fracture site for warmth. If it is warm, it has probably *not united*.
(3) Put one hand over the callus and grasp it firmly. Ask the patient to keep the limb muscles loose. With your other hand, move the lower end of the broken bone from side to side. If the fracture has united, the upper end of the bone should move in the opposite direction. *Don't be too gentle, but don't move the bone too vigorously* that you cause pain, or refracture it.
Repeated examination is useful, especially in the early days, as it may also promote callus formation.
Pain, particularly at night, indicates that a fracture has *not united*.
If manipulation is painless and there is no movement, the fracture has united.

Despite clinical union, you must protect a fracture from stress, and especially from stresses that are likely to break it. For example, a patient must protect a fracture of the shaft of the humerus from the angulation stresses that dangling it out of a sling will cause while the elbow is still stiff (71.17).

Allow the bone ends to move a little, and encourage the patient to keep exercising the muscles, even if they are inside a cast. Active movements involving own muscles, are better than passive movements.

A recent fracture is painful. This pain helps to limit excessive movement of the fragments.

For the 1st 3days after an injury, pain prevents almost all movement. The limited range of movement increases the formation of callus and promotes union.

So, encourage the use of the joints on either side of a fracture within the range of painless movement. However, if this movement is excessive the bone may refracture!
Pain is subjective, so you will have to restrain some patients and encourage others.
Cautious weight bearing speeds healing, so encourage a patient to walk cautiously on the broken leg! This is only possible if you can prevent the fragments from angulating.

A plaster cast can prevent this in the tibia, but is much less satisfactory in the femur.

'Active movements' and 'weight bearing' are not the same. It is never too soon to start active movements, whereas bearing weight, if applied too soon, may be disastrous.

GENTLE MOVEMENT INCREASES CALLUS
EXERCISE IS NECESSARY,
EVEN INSIDE A CAST

58.8 Fractures involving joints

In an articular fracture, where the cracked bone disrupts the joint surface, you will be unable to reduce the fragments precisely.
The alternative, as soon as pain will allow, is active movement. This smooths the opposing joint surfaces, and lets them mould to one another as union proceeds.
Although arthrosis often follows where the broken joint surfaces remain irregular, especially in the ankle, it is less true in these situations:
(1) comminuted supracondylar humeral fractures,
(2) comminuted extension wrist fractures in the elderly,
(3) comminuted fractures of the calcaneus & the subtalar joint.

ARTICULAR INJURIES

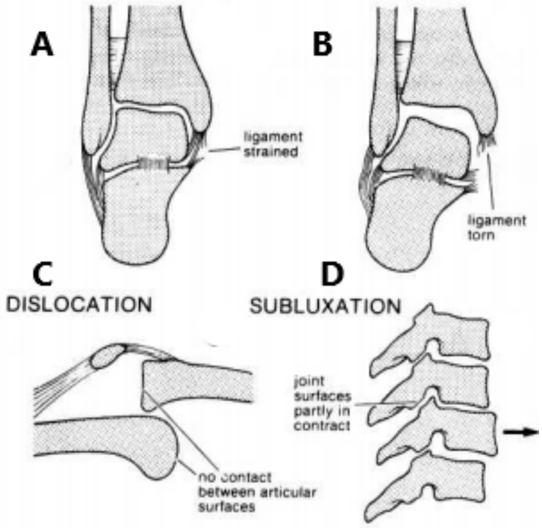


Fig. 58-6 SOME JOINT INJURIES. A,B,C, in a dislocation the joint surfaces are widely displaced. D, in a subluxation they are still partly touching one another. *Kindly contributed by Peter Bewes.*

Surprisingly good functional results often follow from accepting a poor position of fragments, and allowing early active movements to smooth out the irregular joint surfaces as union proceeds. These good results will be much better than you (and many 'experts') will be able to achieve with internal fixation.

58.9 Fracture-dislocation.

Common examples are:
(1) extension wrist fractures,
(2) clavicle fractures,
(3) humeral shaft fractures,
(4) tibial fractures,
(5) femoral shaft fractures,
(6) combined radius & ulna fracture,
(7) metacarpal & metatarsal fractures.

Some fractures also occur with joint dislocation. This is particularly common in the shoulder and less common in the wrist, hip and ankle.

Reduction of the dislocation improves the position of the fracture fragments, so that conservative management in cast or splint is usually possible.

The hazard is that, if you don't know there is a fracture present, you may inadvertently make it worse when you reduce the dislocation, so check first with a radiograph.

If the fracture is displaced and needs reduction, do this first, and hold the reduced fracture (if necessary in PoP) before reducing the dislocation.

DISTRACTION IS DANGEROUS
REDUCE DISLOCATIONS EARLY

58.10 Open joint wounds

Excise the edges of all layers of the wound, clean out the joint cavity with copious amounts of sterilized water. If necessary, extend the wound (7.17), remove any foreign material, and close synovium and capsule of the joint loosely with interrupted sutures. *Don't use a drain*, unless the joint is already infected.
Leave the rest of the wound open, as for any other contaminated wound.

If the bones in a joint wound are dislocated and the wound is open, reduce it urgently. Every hour makes the loss of the joint more certain.
Splint the joint in its functional position until delayed primary closure, at which time gentle active range of motion exercises may begin.
CAUTION! Don't forget tetanus toxoid!

AIM FOR ACTIVE PAIN-FREE MOVEMENTS

58.11 Stress fracture

These are generally fractures which occur to normal bone subjected to unaccustomed, frequently repeated normal movements, as in fatigue fractures of the tibia (70.4), fibula (70.5), calcaneum (72.7), & metatarsals (72.11).

Often the only leading clinical sign is pain on weight bearing or tenderness on palpating. Radiographs often miss these fractures but you may see a periosteal breach in early presentations or periosteal reactive thickening in the healing phase. These injuries are never of sudden onset and are the result of gradual but persistent wear and tear. Often all that is needed is rest and some pain management for c.3wks and gradual resumption of activity.

58.12 Pathological fracture

These are generally fractures which occur without major trauma in diseased bone from:

(a) primary bone tumors,
(b) metastatic cancer,
(c) degenerative bone disease (*e.g*. Paget's, vitamin D deficiency),
(d) chronic infection (*e.g.* osteomyelitis, TB),
(e) atrophy (*e.g.* paralysis, severe arthritis),
(f) osteoporosis.

The last is most common, and mostly affects the elderly & post-menopausal women. Frequent sites include the spine, pelvis and hip, proximal humerus and distal radius. Osteoporotic fractures heal in the same way and in the same time as fractures in normal bones, but the bones remain weak despite union.

BONE TUMOURS PRONE TO FRACTURE

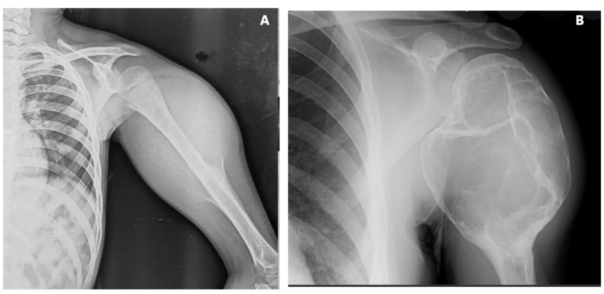


Fig. 58-7 BONE TUMOURS PRONE TO FRACTURE. When the cortex becomes thin, it can easily break without much force. A, the cortex is abnormal, so the tumour is likely to be malignant. B, the cortex, though very thin, is intact, so this cyst is benign. *Shared by Departments of Radio-diagnosis and Orthopaedics, Government NSCB Medical College Jabalpur, India*

If this is not possible, the best you can do is often to make those patients as comfortable as possible with adequate analgesia. They often present late with advanced disease and a proximal amputation or disarticulation may be the only procedure you can offer.

RADIOGRAPHS
Benign bone tumours typically have a smooth margin, and malignant ones a ragged gnawed appearance. The management of bone tumors is complicated. *Don't biopsy the lesion*, as your intervention may compromise further treatment. Try to refer such cases.

Fractures through benign lesions often heal on their own, but fractures thourgh malignant lesions rarely do.

Stress fractures rarely need more than a firm bandage and analgesia. If excessive stresses have caused the fracture in the first place, you need obviously to outline what these stresses are so that a change in life style is possible.
Fractures due to other causes need treatment of the primary condition as well as management of the fracture.

OPEN FRACTURE

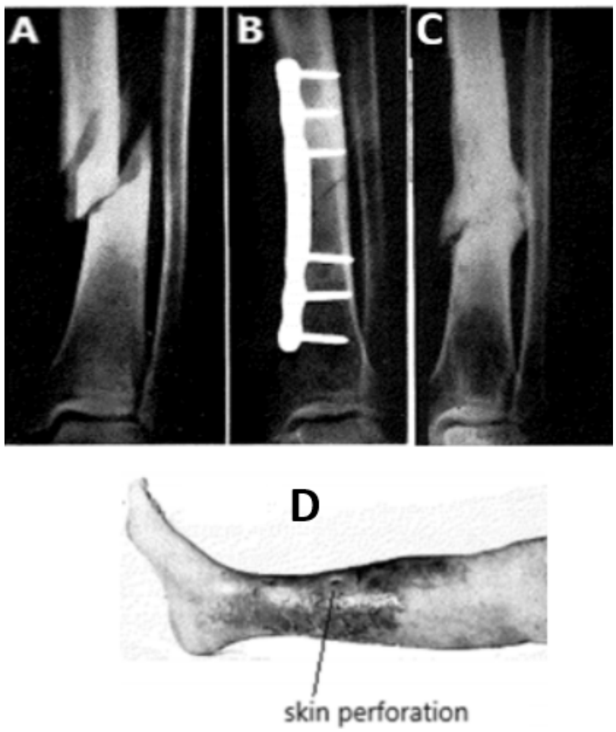


Fig. 58-8 OPEN FRACTURE WITH "MINIMAL" SKIN DAMAGE. A, a double spiral fracture of the tibial shaft. B, despite the skin perforation (D) he had an internal fixation performed. D, the skin wound healed rapidly but the bone did not; months later the skin became hot and angry. C, the plate was removed but at 1yr the fracture is still *not* consolidated. *After Apley AG, Solomon L. Apley's System of Orthopaedics and Fractures. 6th ed. Butterworth, 1982.*

58.13 Open fracture

A fracture is 'open' when skin damage allows bacteria to enter and contaminate a fracture haematoma. The skin damage may be a perforation, cut, or from tissue loss, whether from inside or out.

NEVER CLOSE AN OPEN FRACTURE BY IMMEDIATE PRIMARY SUTURE

The initial priority is ABC (41.1): the best way of controlling haemorrhage from a limb fracture is to reduce the displacement, and use a tourniquet if necessary.

Administer prophylactic antibiotics *(e.g.* a 1st generation cephalosporin) for 24h. Some very dirty or wounds >72h old may benefit from adding gentamicin and metronidazole.
N.B. Don't forget tetanus prophylaxis.

All open fractures, especially those that present late, need urgent treatment.

DEBRIDEMENT OF OPEN FRACTURES (GRADE 2.4)
The aim of debridement is to remove necrotic tissue, any loose bone fragments & all foreign material, and leave the wound open with clean well-perfused tissues.

Under anaesthesia, remove all the clothing if not yet done in theatre, while an assistant maintains traction on the limb. Wash the entire limb with soap, water and a brush and irrigate the wound initially with lots of normal saline or clean water, but *never think this is the definitive treatment*.

Remove only obviously damaged skin from the wound edges, but *don't hesitate to extend your incision to reach the depths of the wound to excise damaged muscle and to remove any foreign material.*

You must toilet all open fractures carefully: debride and excise all obviously necrotic tissue, especially muscle, and remove bone fragments completely void of soft tissue attachments and any foreign bodies. *Leaving loose pieces of bone will lead to sequestration and osteomyelitis.*

However, do leave pieces of bone that still have periosteal attachments, however tenuous, as they still have a chance to heal. Clean fractured bone surfaces, and gently re-align the bone.

If you have applied a tourniquet to control serious bleeding, this may make it difficult to decide which muscle tissue is viable and which not.
Remove it and test any doubtfully viable muscle *(which does not readily contract on pinching with tissue forceps or when touched by diathermy)* and complete your haemostasis.

Ligate large vessels meticulously with absorbable sutures. *Don't attempt to suture divided nerves & tendons initially*, unless the wound is a clean lacerated one (cut by broken glass or a knife). Mark the nerve or tendon with an unabsorbable coloured suture to facilitate finding it at a later operation.

If a joint is open, clean and irrigate this thoroughly (58.10).

Then irrigate the wound again copiously with normal saline or clean water.

Perform a distal fasciotomy if necessary (49.6).

Even if the skin wound is a small one, and occurs from within outwards, leave the wound open, making sure nerves and arteries are covered.
Don't suture the wound closed, as tension will rise in the wound leading to the compartment syndrome (49.6), which risks damaging tissues further and promoting the growth of anaerobic bacteria. Plan for delayed primary closure 2-5 days later. This is especially important if the patient presents late. If you fail to do this and the wound becomes infected, traumatic osteomyelitis will probably follow.

Failing to do an adequate toilet, and closing the wound by immediate primary suture, are very common errors.

Don't apply a tourniquet (unless to control serious bleeding) as this may make it difficult to decide which tissue is viable and which not.

HOLDING AN OPEN FRACTURE

You can immobilize many open fractures temporarily with non-circumferential PoP splinting, and perform definitive immobilization when you carry out the delayed primary closure after 5 days.

Although you can make casts to manage definitively many open fractures, with windows cut into the PoP to expose the wound, they are cumbersome and may hide part of the wound, and so be inadequate for proper wound care.

Skeletal traction using a pin through the proximal tibia can manage most isolated open femur fractures, and a pin through the calcaneum most tibial fractures.

You might be tempted to fix some open fractures internally, *but don't try it*. The wound is already contaminated, and the plates and screws will probably become infected, *and make it worse. An occasional K-wire is the maximum amount of internal fixation that is wise.*

Some wounds will be too large for simple closure and will require skin grafting or a local flap (46.5). For this wound care, external fixation (59.5) is advisable, rather than a window in a cast.

Post-operatively, raise the injured limb. Raise the foot of the bed if traction is in use.

DIFFICULTIES WITH OPEN FRACTURES
If the skin is bruised over the fracture, watch it carefuly. It may break down and a fracture initially closed becomes an open one.
If blisters develop over the fracture site, this does not mean the fracture is open. Just cover the blisters with sterile paraffin gauze.

If a large segment of bone is missing, bringing the fragments into contact with one another is more important than maintaining length, particularly in the upper limb.

58.14 Multiple fractures

Often, victims of high-energy trauma present with more than one fracture. Treat such patients following the standard ABC protocol (41.2). A secondary survey should reveal any bone injuries along with the more obvious open fractures. However, this survey may not always be reliable, particularly in unconscious or uncooperative patients.

You may find fractures of the small bones of the hand or foot, of the scapula, spine or pelvis fortuitously in radiographs or when they reveal themselves clinically when the patient is awake.

Fractures can affect >1 bone, or >1 site in a given bone. Any and all combinations are possible. *It is absolutely mandatory that radiographs include the joints above and below the suspected fractures.*

In high-energy pelvic ring injuries, >1 fracture is frequent. It is not rare to find a femoral neck injury associated with an ipsilateral femoral shaft fracture, or a tibial plateau fracture associated with a tibial shaft.
Fractures involving >1 bone are common in the hand or foot, in the forearm (various combinations of radius/ulna fractures) or in the leg (various combinations of tibia/fibula fractures).

A fall from a height with a calcaneus fracture should raise the suspicion of an associated compression fracture of a vertebral body.
Ipsilateral fractures of the femur/tibia or humerus/forearm create an unstable "floating joint" in between, which is to challenging to manage conservatively.
The segment in between is notoriously unstable and liable to rotational displacement.

Early mobilization of these polytrauma victims is the key in preventing pulmonary complications. Multiple fractures increase the risk of fat emboli and bed rest increases the risks of pulmonary collapse, pulmonary embolus secondary to DVT, and ARDS.

In low-resource environments, bed rest is unfortunately the only option for some patients: *e.g.* those with an unstable spine or pelvic fracture, and most fractures around the hip. Fractures of the femur (hip, shaft or distal 1/3), which would normally be treated in skeletal traction, represent the main challenge.

Follow a protocol of chest physiotherapy, *both active and passive*, mobilise the uninjured extremities in bed, encourage the patient to be propped-up for most parts of the day, mobilise when possible out of bed with assistance with wheelchair or walking aids: these are all small measures that go a long way!
In polytrauma and absolutely bed-ridden patients such as those with high-velocity trauma to the vertebral column or severe head injuries, consider the use of thrombo-prophylactic drugs.

Whether treated conservatively or surgically, upper extremity fractures should not prevent early mobilization. The same is true for fractures below the knee joint. You cannot over-emphasize the importance of physiotherapy, both for limbs and chest.

58.15 Neglected fractures

Sophisticated reconstructive surgery, whether of soft tissues or bone, requires specialist expertise. In addition, open reduction and internal fixation (ORIF) or external fixation (X-fix) of fractures needs special equipment and material: plates, screws, nails, fixator bars and clamps, with, often, help with C-arm radiography and fluoroscopy.
Whilst ORIF gives the best results for the correction of many malunions and non-unions, X-fix will do just as well.
What you do will depend on what you have, what you know, and the conditions where you work. We recommend conservative methods, such as using K-wires or Steinmann pins, and casting. The most important point is proper patient selection and the indication for surgery.

Many simple fractures will heal on their own. The patient finds a way to put the injured body part to rest, until it "feels better". Other fractures, however, require some intervention to avoid pain and disability. Many, if not the majority of fractures in poor-resource environments, are not treated by a trained physician, let alone an orthopaedic surgeon, but by other more available and affordable alternatives such as bone setters, nurses, therapists or even pharmacists. We do not know their success rate because we usually only see their failures.

You may well see a number of neglected fractures or dislocations, which have healed or are healing in such a way that their functional outcome is poor.
The usual complaints are pain, stiffness, instability, leg length discrepancy, visible deformity, or any combination of these. The degree of disability will vary from mild (can work but not play football) to severe (wheelchair bound).

There are several complications you may see:
(1) Delayed union
Delayed union is not a true problem; if only delayed, the fracture will finally heal. Inadequate immobilisation, poor nutrition, or tobacco use are important factors. Put the patient in a proper PoP cast or splints. Good physiotherapy, nutrition, and tobacco cessation are important adjuncts.

(2) Non-union
For long bones, refresh the ends to bleeding bone, open the medullary canal, apply a bone graft, and immobilise.

HUMERAL SHAFT:
shortening up to 3 cm is acceptable.

RADIUS & ULNA:
If one bone is healed and the patient can flex the hand and elbow, and pronation-supination is painless, leave the fracture alone. Otherwise, refresh the bone ends, apply a bone graft, and immobilise with an X-fix using Steinmann pins or K-wires. You can shorten the forearm up to 2cm, but this shortening must be equal on both forearm bones.

SCAPHOID (64.4)
FEMORAL NECK (66.6)
FEMORAL SHAFT (67.2)
TIBIA & FIBULA (70.6)

For an open fracture, the non-union is almost always infected. The wound is the essential part: by far the most important element is a good debridement with sequestrectomy. Use appropriate antibiotics. Sugar or honey dressings, and VAC (if available, or improvised) have proven useful. Then immobilise the fracture site with the best means available. Bone grafting may be necessary, but wait until at least 6 months after infection has cleared.

(c) Malunion
Does the malunion create sufficient incapacity to require corrective surgery? If yes, refracture, re-align, and immobilise the bone. If no, leave it alone. Refer to:
(1) humerus (61.13, 61-18C)
(2) radius (63.4)
(3) femur (67.3, 67-5B)
(4) ankle (71.7)

(d) Avascular Necrosis
Where the blood supply to part of a bone is cut off by a fracture, that part will inevitably die. This is seen typically in:
(1) the femoral head (58-9A)
(2) the proximal scaphoid (58-9B)
(3) the lunate (58-9C)
(4) the posterior talus (58-9D, 72.5)
(5) epiphyseal fractures in children (73.2)

(e) Pseudarthrosis
If this does not incapacitate the patient, leave it alone. If it does, resect, bone graft, & immobilise the patient.

AVASCULAR NECROSIS

Fig. 58-9 AVASCULAR NECROSIS from fractures. A, the femoral head. B, the proximal scaphoid. C, the lunate, D, the posterior talus. *After Apley AG, Solomon L. Apley's System of Orthopaedics and Fractures. 6th ed. Butterworth, 1982*

59 Fracture immobilization

59.1 Principles of fracture reduction & stabilization

Non-surgical management of fractures involves obtaining an acceptable reduction of the fragments, and maintaining it for the appropriate amount of time, either with cast or traction. Splints and casts are the cornerstone in the management of many lower extremity injuries and almost all injuries of the upper extremity. In low-resource environments, casts are mostly made of Plaster of Paris (PoP), but the availability of fibreglass is slowly increasing. PoP is dried calcium sulphate powder which forms a paste when wet and becomes hard when allowed to dry. It usually comes on impregnated gauze rolls of different sizes. It is amost universally available, cheap, easy to mould but can be heavy, cumbersome and breaks down easily, particulalrly in humid environments.

Fibreglass is a compound made of a plastic matrix reinforced with fine fibres of glass. It is stronger, lighter, water-resistant and shows better on radiographs than POP but does not mould as well and, more importantly, is much more expensive.

Reducing a fresh fracture or a fresh dislocation is painful and can be quite a traumatic experience, especially for children. Proper analgesia is mandatory. It is usually pretty clear at the time of presentation whether a patient needs to go quickly to the operating theatre (open fracture), admitted, or managed as an outpatient.

You can manage many closed injuries, particularly of the upper extremity with LA haematoma blocks (direct injection of a local anesthetic *under proper sterile precautions* into the fracture/dislocation haematoma) or conscious sedation.

N.B. Always have resuscitation equipment to hand when you use anaesthetics!

Once analgesia is adequate, the general principle of reduction is to exaggerate the initial deformity, pull, and realign the limb, using the intact periosteal hinge on the concave side of the deformity to stabilize the reduction.

It is safer to immobilize limbs in splints for a few days and have the patient come back for definitive casting at that time, unless the reduction is very unstable. If you need to put a circular cast from the start, *you should always uni- or bi-valve it* before discharge, and give clear orders on what to look for in terms of complications, and how to manage life with a cast.

Get a check radiograph after reduction to make sure the position is acceptable.

You can manage some fractures of the lower extremity according to the same principles. But most fractures of the spine, pelvis, hip, femur and many tibial and ankle fractures need admission for immediate or delayed treatment, or even just observation.

In the meantime, extremity fractures need splinting in a comfortable appropriate position, with adequate analgesia.

Whether you use a splint or a cast, the general principle is that you should immobilize both joints above and below the fracture & try to get all visible on radiographs. Pad bony prominences to avoid pressure sores. Give patients clear instructions on weight-bearing, limb elevation and cast maintenance. Importantly, give instructions on how to use the muscles inside the cast, and stress that it is not dangerous even if there is some discomfort: this will make recovery much easier and quicker.

N.B. Many childhood fracture treatments differ from those in adults: see chapter 73.

EXERCISE THE MUSCLES INSIDE A CAST

59.2 Plaster and equipment

PLASTER BANDAGES, normal, slow setting, best quality, 10, 15, & 20cm wide.

Good quality plaster bandages make the strongest casts but *using poor quality is a mistake.* If you use these, you will need twice as much plaster, and the cast will be twice as heavy. It will also break sooner, often meaning you have to apply a whole new cast, so any economy is lost!

CREPE BANDAGES come in different widths to secure plaster to a limb. *Don't apply them too tightly* in order to allow for some underlying swelling to occur.

STOCKINETTE, woven tubular, orthopaedic, of various widths is useful to put direcly on the skin, under cotton layers. It prevents hairs sticking to the cast, and skin being cut by a cast saw, *but not burns from a overheated saw blade*. It is also helpful in containing slabs of PoP used to make a splint.

PADDING: orthopaedic cotton wool rolls of different widths are very useful. If you can't get these, cut slabs of cotton of desired size & roll them up.

Make STIRRUPS locally. These support a patient's leg when he wears a walking cast. The cross pieces at the top should be thin so that they bend easily to fit the shape of the leg and spread its weight through the cast.

PLASTER EQUIPMENT

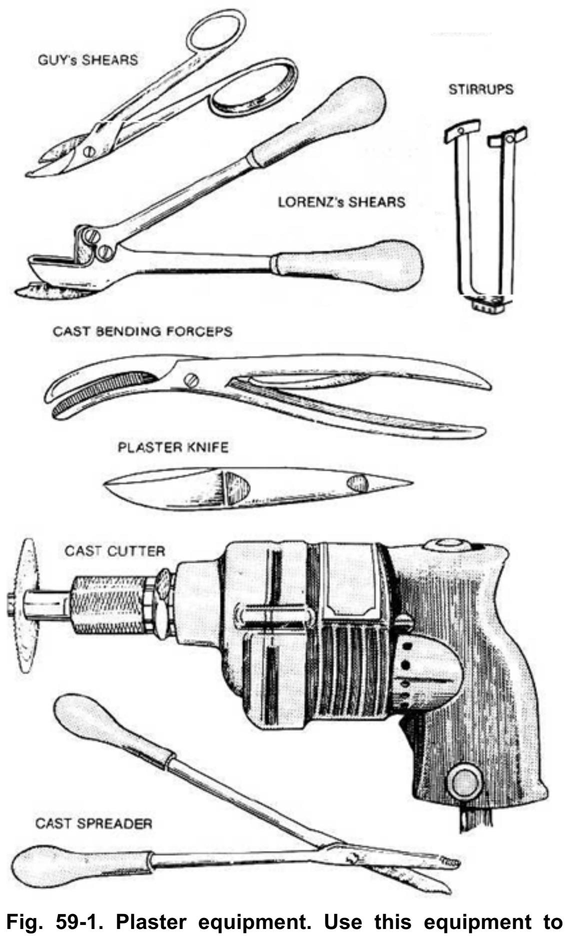


Fig. 59-1. Plaster equipment. Use this equipment to make standard casts, such as the long leg and short leg walking casts. *The indications for each of them and the details as to how you should apply them are critical.*

FOOT SUPPORTS, bars, blocks, or plates made of hard rubber are easier to use.

PLASTER CAST SAWS have an oscillating which *does not rotate* so, in theory, won't cut the underlying skin. Demonstrate this on your own forearm to a frightened patient, especially a child.

The blades become dull fairly quickly so you need to replace them at regular intervals. Dull blades overheat and do burn the skin!

SHEARS, SPREADERS AND BENDING FORCEPS are necessary if you have no electricity!

INDELIBLE PEN. When you apply a cast, write on it the date you applied it, and the date you expect to remove it, together with a sketch of the fracture inside (59-7). A permanent marking pen is ideal.

59.3 Immobilization by cast or splint

As a general rule, you can reduce & immobilize almost every fresh fracture initially in a splint or slab for a few days to allow swelling to subside. Slabs are useful for the initial treatment of a severe fracture and are safer than circular casts. But slabs don't immobilize some fractures securely enough. Slabs are weak, and easily break at the elbow or knee.

You can put a slab on one side of a limb, or on both sides, and hold it in place with a crepe bandage. The advantage of slabs is that they allow a limb to swell without obstructing its circulation (58.2). As the swelling subsides, the elasticity of the crepe bandage will hold the slabs against the limb without letting them become loose.

PADDING A LIMB

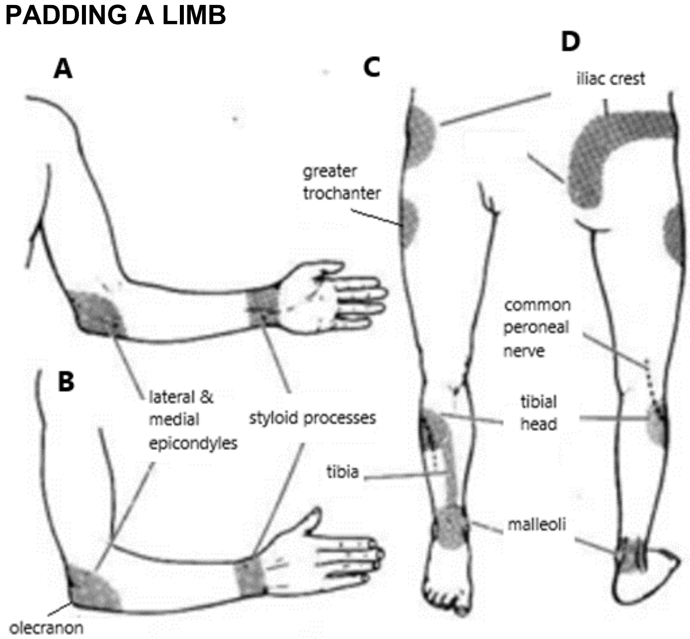


Fig. 59-2. PRESSURE SITES. A,B these need padding to make a cast comfortable and avoid pressure sores. C,D, *protection of the common peroneal nerve as it winds round the neck of the fibula is especially important*.

SPLITTING AND SPREADING A CAST

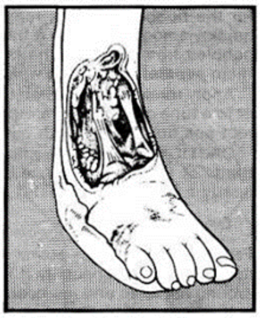
Applying a cast is always easier with an assistant to help. Every cast should be padded with cotton wool. If stockinette is available, use it; otherwise, apply cotton wool directly to the skin. Apply the stockinette or wool a few cms above and below the end of the cast, so that you can fold the stockinette or wool under the last layer or two of plaster, to make a neater finish. Roll the cotton without tension, from distal to proximal, each roll overlapping the previous one by c.$^2/_3$. Too much padding reduces the effectiveness of PoP to immobilize the fracture. Add extra padding over bone prominences, particularly the fibular head and the malleoli (59-2). Since a cast is meant to immobilize the joints above and below the fracture, put these joints in the desired position *before* padding and casting. This is where an assistant can really make your life easier. A general rule is to put these joints in the functional position, as much as possible:

- ankle: neutral flexion,
- elbow: 90° flexion in half pronation-supination,
- knee: 5-10° flexion,
- wrist: 15-20° extension.

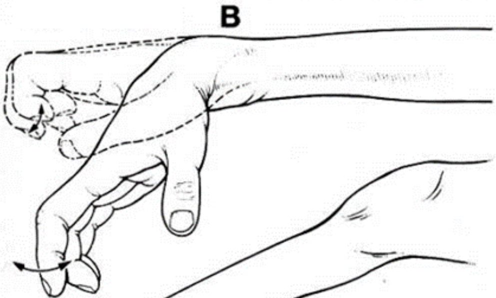
In this way, even if a patient is lost to follow up and stays in PoP much longer than should be, stiffening will occur in a functional position.

AVOIDABLE DISASTERS

A



B



C

Fig. 59-3. AVOIDABLE DISASTERS. A, a pressure sore. B, ischaemic contracture of the hand. C, ischaemic contracture of the leg.

If you decide to apply a circular cast, you *must split it immediately* so that it can stretch open a little as the tissues under it swell. Otherwise a compartment syndrome (49.6) may result.

DANGERS OF CASTS

Damage can occur even if ischaemia lasts <1h, and is a particular danger with fractures of the forearm and lower leg. An unsplit circular cast is especially dangerous if a patient already has signs of circulatory impairment.

Ischaemia results as the muscle swells, reducing the blood supply within fascial compartments. The skin remains intact till much later. The classic Volkmann's ischaemic contracture is a fixed flexion contracture of the wrist & fingers, or ankle in extreme equinus, with midtarsal flexion & dorsiflexion of the toes (59-3). *This is almost untreatable & a veritable disaster!*

In its less extreme forms, ischaemia is more common than most people think. It may only show itself later as a stiff hand or foot, that gradually begins to develop a severe contracture during months following an injury.

The forearm muscles are most commonly involved in supracondylar or forearm fractures in children (73.7,8) or thumb dislocation (65.15), and occasionally the lower leg muscles in tibial fractures (70.7) or knee dislocation (68.8), but almost never the muscles of the upper arm, or thigh, which are less firmly enclosed in fascia.

Other causes of ischaemia may be:
(1) A tight bandage (including an Esmarch bandage),
(2) A tourniquet,
(3) Gallows (73-23) or extension traction (73-24),
(4) A serious soft tissue injury (even when there is no fracture)

Splitting a cast with a scalpel will not destroy its capacity to hold the bony fragments, and is easy if you do it while a cast is still soft.

ALWAYS SPLIT THE FIRST CAST ON FOREARM AND LOWER LEG FRACTURES

Correct management will usually prevent ischaemia, but always watch out for the early signs (58.2); these are pain, disproportionate to the injury, or pain on passive streching of the intra-compartmental muscles, a pathognomonic sign.

Paraesthesiae, pallor, pulselessness and paralysis are late signs. The involved compartment will most often be more tense than the opposite side, but not necessarily.

N.B. The presence of a peripheral pulse does not exclude the compartment syndrome.

A well applied circular cast should reduce the pain of a fracture. *If a patient, especially a child, complains of pain,* take such complaints seriously: it is probably due to pressure on a bony point which may only subside as the skin erodes away, or ischaemic pain which will get worse until you remove the cast.

Pain is not an indication for analgesia; it is an indication to find out why there is pain, and to split, open or renew the cast. *So, never apply a circular cast to a patient who is unconscious*, and is unable to complain of pain. He may develop the compartment syndrome only too easily.

SHANTI (8 years) had an undisplaced fracture of the distal end of her radius. There was almost no swelling. A circular cast was applied. She returned the next day crying in pain. She was given aspirin and sent home. Three days later she returned with a gangrenous hand and sloughing forearm muscles. Her forearm was amputated.
LESSONS (1) An undisplaced forearm fracture does not require a circular cast; all she needed was a slab and a crepe bandage. (2) *Never treat a painful cast with analgesics only.* (3 If you apply a circular cast, *always split it.* (4) *Pain and pain on passive stretching are early signs of impending compartment syndrome.*

ABDULLAH (8 years) had a supracondylar fracture. It was successfully reduced within an hour and a skin tight cast was applied. He returned the following day saying that his fingers hurt, but was sent home without removal of the cast. Five days later he returned. This time all his fingers and thumb were black and gangrenous, and had to be amputated.
LESSONS (1) A cast is not the treatment for this fracture. (2) *Don't apply a skin tight cast immediately after an injury*, before the limb has had time to swell: wait at least 12h. (3) *Take any complaint of pain seriously* and split or remove the cast immediately.

Identify patients at particular risk and examine them frequently. Record your findings carefully, and note at what time you made them. *Watch for pain, pain on passive stretching, paraesthesiae, pallor, and finally paralysis,* and teach your staff to do the same.

Check for 2-point discrimination, with a pin. In injuries of the forearm, test for pain on passive extension of the fingers. Test the strength of all involved muscles. Feel the compartment for tenderness and tenseness.

If you suspect a compartment syndrome clinically, surgical decompression is necessary. *don't wait for more signs to appear!* Better an unecessary fascitomy than missing case of gangrene!

Make sure to record your pre-, intra- and post-operative findings clearly. In many places, a missed compartment syndrome has serious medico-legal consequences.

TAKE THE COMPLAINT OF PAIN UNDER A CAST SERIOUSLY

A poorly applied malleolar cast, for example, can make it impossible to reduce an ankle fracture.

BASIC PLASTERCRAFT

Some casts are really critical. Here we describe some points of technique which apply. Learning skillful plastercraft is worth learning. It is a dying art, lost even to the younger orthopedic surgeons.

For all slabs and casts, get everything ready before you wet the plaster bandages. Put stockinette on the limb, or cut and roll a layer of cotton wool directly on to the skin. Fold and trim the slab, and have your assistant ready.

WETTING A PoP BANDAGE

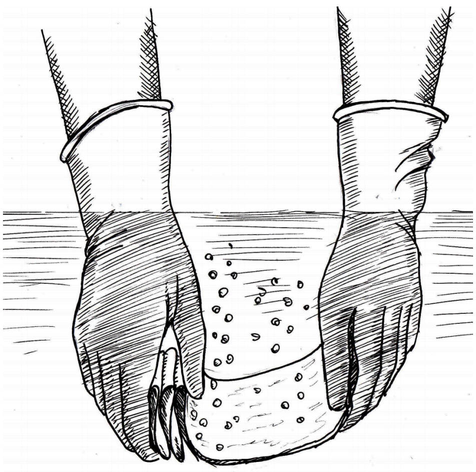


Fig. 59-4: WETTING A PLASTER BANDAGE.

Hold the bandage in your right hand. Unwind it a ½ turn, hold it with your left hand, and put both hands in warm water. Leave the bandage under the water for c.5secs until the bubbles have stopped. Hold it gently, so that water enters all its layers. Then, holding one end of the bandage in each hand, take it out of the water, and twist it gently. This will remove excess water, and yet keep the powdered plaster in the bandage.

N.B. Don't wring it out, or squeeze it, because this will leave it too dry to make a good cast.
It is a good idea to put on gloves beforehand!

PLASTER SLABS (TUBULAR/FLAT CASTS)
Take a dry bandage of suitable width, and use its loose end to measure the required length of the slab. Lay this length of bandage on a table and then double more bandages backwards and forwards over it until you have enough layers to make a slab of the right thickness. Usually, 4 layers are enough. If necessary, fold the bandage double.
Hold the dry slab in both hands, and dip it in water. Wait for c. 5secs for the bubbles to stop, hold it gently so that water enters all its layers. Then take it out of the water with both hands and twist it gently. *Don't squeeze it or wring it out* or it will become too dry to make an effective cast. Quickly smooth it out on a flat surface. This will remove the bubbles between the layers of bandage, and prevent them separating later to weaken the cast.

Apply the wet plaster slab over the stockinette or wool on the limb. Hold it in the correct position and smooth out the slab.

CAUTION! Don't let a plaster slab cover >$^2/_3$ the circumference of the limb, as even this may not allow space for enough swelling.

PLASTER ROLLS (CIRCULAR CASTS)
If you prefer to roll on the PoP, protect the bony points with particular care as in all casts (59-2), especially in a thin patient. Be sure to pad well around the knee and heel. Then pad the rest of the limb.

If necessary, cut a hole for the thumb. Roll this cotton evenly with no folds or lumps, and without obscuring the shape of the limb. *Don't pull it tight* or it will tear.

An upper extremity cast usually requires 2-3 layers, but a weight-bearing or long leg cast at least 3-4 layers (1cm width). Put extra padding over bony prominences. Apply it from well above to well below where the cast will end.

CAUTION! (1) *Don't apply too much padding* so that the limb is freely mobile inside the cast, as inside a boot. (2) If there is a wound on the limb, cover it with a dressing, over-pad it loosely with cotton creating a protuberance where you will apply the plaster. This will allow you to know where to make the window that will allow access to the wound. Unless you make the window immediately, mark its site & borders with a marking pen.

Roll on the wet plaster bandage without lifting it off the limb, pressing each fold firmly with the base of your thumb, so that most of the tension is transmitted to the middle of the bandage, and not to its edges, where it might cause a sharp ridge. The tension you need will vary with the thickness and elasticity of the padding.

CAUTION! (1) *The correct tension is important* or the cast will be loose.
(2) The inside of the finished cast must be smooth, because ridges may cause sores.
(3) *Never pull a plaster bandage tight.*

Apply each turn slowly, settle it carefully in position, and join it to the turn below by smoothing it with your hands to remove bubbles. Let it follow the way it wants to go. Cover about $^2/_3$ of the previous layer. Apply it as a spiral without reverses, and when you have to change direction, make a quick tuck, and smooth it out. *Don't twist the whole bandage, or attempt a figure-of-8 bandage, or apply 2 turns in exactly the same place,* except at the ends.

While you are applying one roll of plaster, ask your assistant to wet the next one. Bandage from one end to the other, and back again, making the cast slightly thicker at its ends, where it will be most likely to fray. *Don't build up its thickness over the fracture site,* where extra thickness will be useless.

Trim its edges while they are still wet, *not after they have dried. Don't immobilize the mcp & mtp joints*, except on very rare occasions. Bind the ends of the stockinette and cotton over into the cast with the last few turns of bandage. This will make it smooth and strong.

CAUTION! (1) *Don't press on a cast with your fingers or thumb while it is hardening*, or they will leave a crest inside it which will cause a pressure sore. Use the palm of your hands.
(2) For the same reason, *don't let a cast, especially a cast over the heel, rest on a hard surface while it sets.*
A large cast may not be completely dry for 72h, and will not be fully strong until then.

To make the cast stronger, start by placing a slab of 4 thicknesses of bandage each side of the limb to strengthen it. Or, incorporate such a slab between layers of bandage. This is particulalrly helpful around the elbow and knee areas, and when making a spica.

SPLITTING A CAST
The cast must be padded, or you will cut the patient as you try to split it!

INDICATIONS
(1) All casts put on under emergency conditions *(though it's always best to put on a slab or split cast).*
(2) A cast on a patient who is going on a journey.
(3) Casts over any recent injury, whether swollen or not.
(4) It is wise to split all first circular casts.

There are several ways to split a cast, but the easiest is to split it while it is still soft 3-4mins after its application.

If the cast is still fairly soft, use a disposable scalpel blade to make a single cut through the plaster down to the padding.

If the cast is already hard, use the cast saw, but this will be hard work as the inner layers are still damp. Use the scalpel blade again, protecting the skin by inserting a soft malleable plastic spatula under the cast.

MANAGING PLASTER

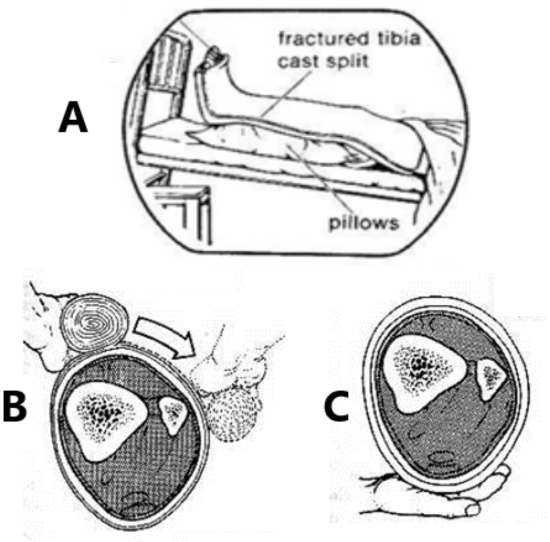


Fig. 59-5 GOOD PLASTERCRAFT A, a cast properly split. B, roll a wet plaster bandage round a cast with the base of your thumb. C, lift a wet cast with the flat of your hand.

Use the same protection technique when cutting a hard cast all the way with the saw blade. In theory, the cast saw will not cut the skin, but it may overheat and burn it. The cast saw is also quite noisy and can be frightening, particularly for children.

Demonstrate on your own forearm skin that the blade is harmless (sounds worse than it is!). In children, soften PoP casts by immersing them in warm water so that you can cut them with shears instead of the saw blade.

COMMON PLASTERING MISTAKES

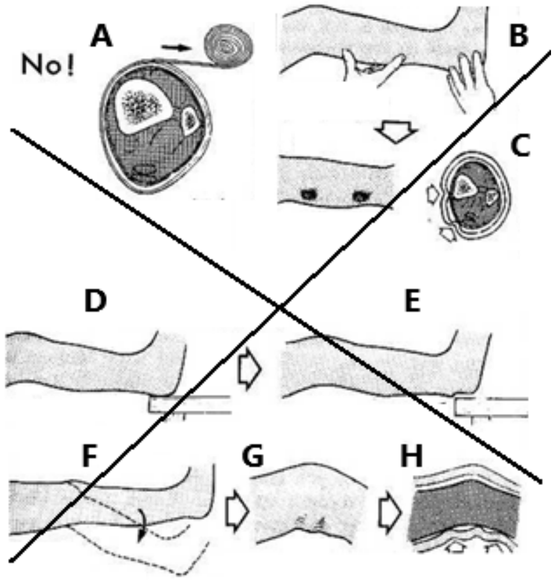


Fig. 59-6 BLUNDERS WITH PLASTERCRAFT A, *don't take the PoP roll off the limb or pull it too tight.* B, *don't use the tips of your fingers:* C, they will leave depressions in the cast, which will cause pressure points. D, *don't rest a wet cast, especially its heel, on a hard surface*: E, a depression & sore will form. F, *don't let a wet cast bend*: G, it will form folds, H, which will also produce pressure points. *After Les Agrégés du Pharo, Techniques Elémentaires pour Médecins Isolés. Diffusion Maloine, 1981.*

SITES FOR SPLITTING OR REMOVAL
Avoid the bony points, so cut an arm cast down the midline of its anterior surface. If there are anterior and posterior slabs, avoid them and slit the cast down its ulnar side. Split a leg cast down its lateral surface, cutting between the lateral malleolus and the heel.

BIVALVING A CAST
Cut the cast right down to the skin, on both sides of the limb, essentially creating two half-shells. Later on, they may be useful as splints. The patient should avoid getting the cast wet at all costs

CARING FOR A CAST
If a patient has to walk home in the rain, let the cast dry and then give it a coat of oil paint. Lice and other insects may multiply under a cast, and cause such intolerable itching that they drive a patient to remove it piece by piece. If necessary, dust some insecticide powder down the ends of the cast.

Casts often become loose in time, so oversee them regularly, and repair and replace them as necessary.

EXPLANATIONS TO PATIENTS
Explain why you are applying the cast, and when you expect to remove it.
Tell a patient not to use the limb or bear weight on the leg for 48h while the cast dries out.
Advise raising it to prevent swelling, to keep it dry, and to return immediately:
(1) if there is pain, numbness, stiffness,
(2) if the fingers or toes become cold, blue, or swollen.
(3) if the cast becomes loose.
Explain that exercising the muscles inside the cast is mandatory, as well as the joints which are not immobilized, especially the fingers and toes.
Explain these instructions, preferably in vernacular, with an instruction sheet.

CAUTION! Take any complaints about casts seriously.

DIFFFICULTIES WITH CASTS
If a cast becomes loose and plaster is scarce, cut a longitudinal strip out of it and then bind it together.

A FRACTURE PASSPORT

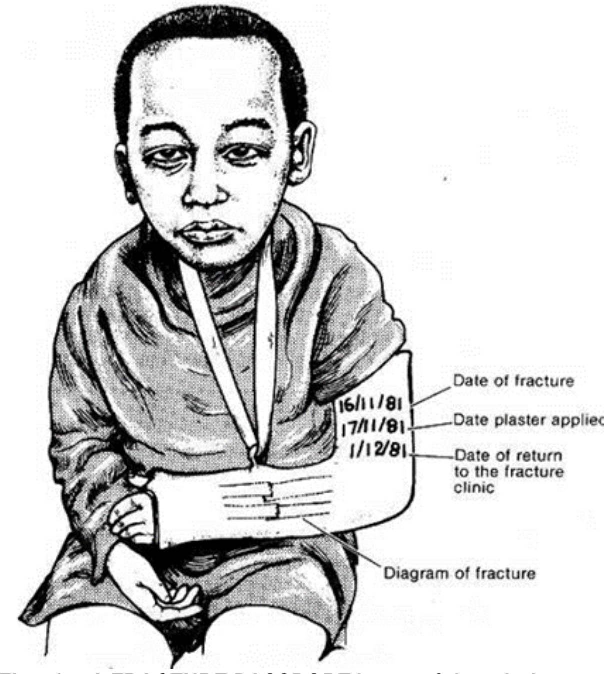


Fig. 59-7 A FRACTURE PASSPORT is a useful reminder to the patient, and yourself, especially if the notes are lost. Record all the dates of the fracture, the date the cast is applied, and the date it should be removed. Draw a sketch of the fracture. The best way to write on a damp cast is to use an indelible pen. *Kindly contributed by Rüdiger Finger.*

If your plaster bandages are unsatisfactory, use them with hotter water, make the cast thicker, and collect any loose powder that falls off, moisten it with a little water, make it into a paste, and rub it on to the outside of the cast. Use it on the less critical fractures, and keep your best plaster for malleolar fractures, and difficult forearm fractures.

If plaster bandages are scarce, you may be able to economize in their use by making casts lighter, and strengthening them with strips of wood, bamboo, or tin.

If you suspect even the possibility of ischaemia, immediately split the cast from end to end. If this does not relieve the symptoms, remove the cast entirely and examine the limb for signs of the compartment syndrome.

N.B. Loss of reduction is better than ischaemic contracture.

N.B. Pressure points inside a cast are painful for a few days then the pain tends to go away as the skin necroses. Often this is recognized only when the cast is removed, and can become a bigger problem than the fracture itself, particularly around the heel area.
This is why it is so important to take any complaint of pain seriously and look at the skin, either through a window or by replacing the cast.

NEVER SEND A PATIENT IN A CAST HOME WITHOUT EXPLAINING THE COMPLICATIONS

WINDOWING CASTS
In order to view a wound of an open fracture, a soft tissue injury, or of osteomyelitis, you need to make a window in the cast. This will enable you to tend these wounds, which otherwise may deteriorate and only come to light when they smell terribly!

N.B. (1) If a patient uses a leg plaster in walking, the soft tissues may swell and herniate through the window, preventing healing,
(2) windows not reinforced can weaken a cast so much that it bends at that point.

Overpad the dressing gauzes so that there is a bulge over which to roll the PoP (59-8C). You can window this immediately with a scalpel blade or mark it and when the PoP is dry, use the saw blade to cut the window open, *tangential* to the cast (59-8D), *not perpendicular to it*. This lessens significantly the so-called window oedema.

MAKING A WINDOW IN A CAST

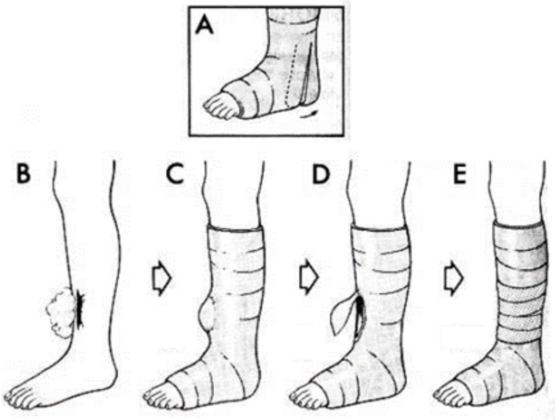


Fig. 59-8 MAKING A WINDOW IN A CAST. A, if a cast is pressing on the heel, you can open it with a saw, and then repair the cut with plaster bandages. B-E, the easiest way to make a window is to put some dressings over the lesion, make the cast, saw off the bulge, and then repair the cast. *Kindly contributed by John Stewart.*

Prevent the soft tissues herniating through the window by raising the limb and by applying firm pressure by a dressing including the window. Dress the wound and put plaster over the window to strengthen the cast, *but also to enable you to look in again through the window*.

WEDGING CASTS

If a fracture is angulated inside a cast, you may be able to straighten it inside the cast provided the fragments have not yet fully united.

This is not as easy as it looks, because you may make a wrinkle inside the cast which will cause a pressure sore, and not even budge the fracture! So wedging needs care and skill!

N.B. Alternatively, you can wait until the fracture is healed enough not to displace, but is still soft enough bend. This is 3-6wks after an injury in an adult, but sooner in a child. Remove the old cast, straighten the limb under ketamine, and apply a new cast. This is a useful method If you don’t have X-ray machines. Changing a cast is safer than wedging it.

DON’T LET WEDGES CAUSE PRESSURE SORES

Opening a wedge lengthens a cast slightly, and if the fragments are overlapped, it helps to distract them. *Don’t use this method for the forearm* because of risk of ischaemia!

Study the radiographs and plan the geometry of what you intend to do carefully. Draw a line round the cast where you want to cut.

Open the wedge on the concave side of the deformity, extending >50% of the cast circumference.

Start at two places 5-6cms apart (a line representing the base oft he wedge triangle, 59-9C). This will prevent the plaster from cracking when you open the wedge. Measure the width of the wedge by adding 1mm/° correction needed. Prepare pre-cut pieces of cork or wood of different heigths, and use them as wedges after your manipulation. They should keep the wedge open but *not touch the skin whatsoever*. Get a radiograph to assess the need for further correction. Once you are satisfied with the alignment, simply close the cast with more PoP, again making sure that the wedge does not put any pressure on the skin.

N.B. Don’t use >1 wedge in different planes: change the cast!

MAKING A WEDGE

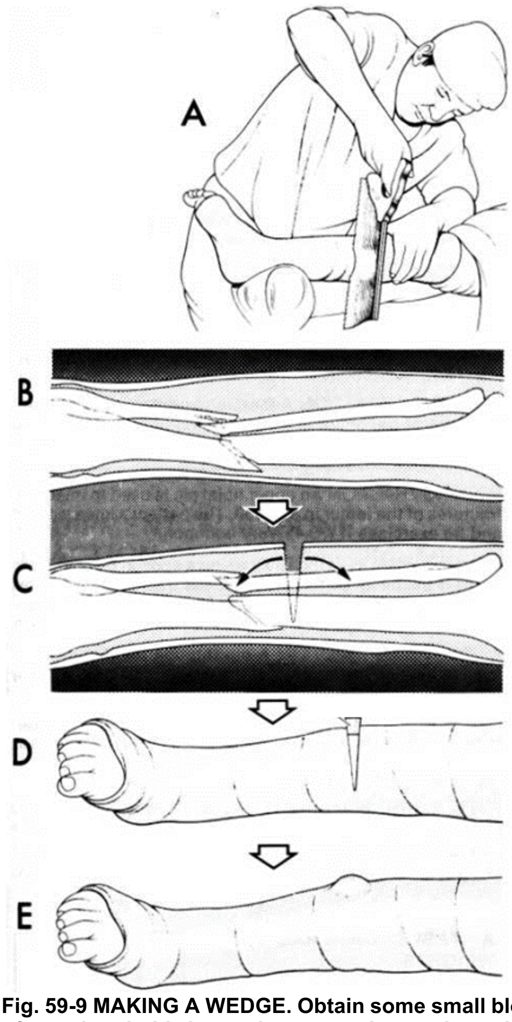


Fig. 59-9 MAKING A WEDGE. Obtain some small blocks of wood to hold the wedge open. A, cut through the whole circumference of the cast except for 2-3 cm on its convex side, B, leave a hinge on which it can bend. C, make the cut c.2 cm proximal to the fracture, so that if there is a wrinkle inside the cast, it will not be directly over the fracture, where it may erode the skin. Using a saw or plaster knife, cut down to the padding, *but not into the limb!* D, carefully bend the cast, if necessary holding it open with a block of wood, *making sure the block is clear of the skin*. E, repair the cast with a few turns of plaster bandage. *Kindly contributed by Peter Bewes.*

THE GEOMETRY OF WEDGING

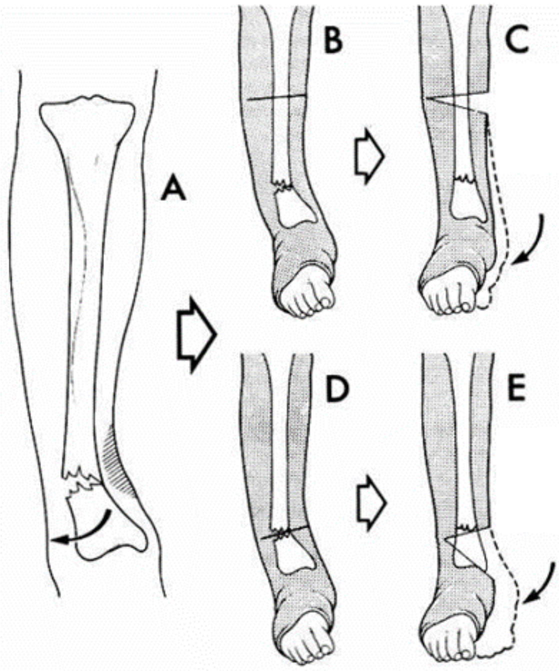


Fig. 59-10 THE GEOMETRY OF WEDGING. A, an angulation that requires correction. B,C if the wedge is far from the fracture a small movement will correct the displacement. D,E if the wedge is near or over the fracture, a larger movement is necessary. *Kindly contributed by Peter Bewes.*

N.B. Don't close a wedge by cutting a piece out of a cast and then closing up the gap. This tends to cause wrinkles & pressure sores.

WOODEN SPLINTS

You can use splints made of strips of wood padded with paper and cloth for fractures of the humerus, radius, and ulna, and for extension fractures of the wrist. There is no evidence that they are better that plaster casts, but you may find them useful for the 1st 24-48h. Wooden splints are light, tenaceous, elastic, radiotranslucent, permeable to the natural moisture of the skin, and can be moulded to the shape of the limb, but *not so effective when joints above & below the fracture need immobilizing.*

WOODEN SPLINTS

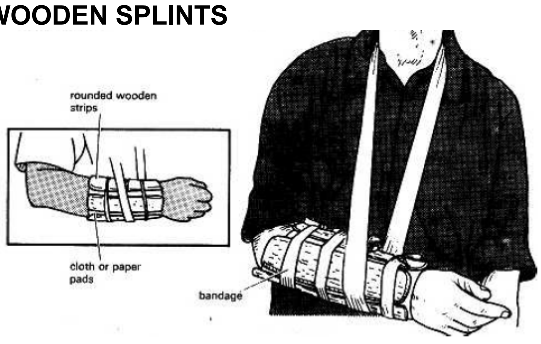


Fig. 59-11 WOODEN SPLINTS. Use separate splints padded with paper & cloth, and tied together strapping or bandage for forearm & extension wrist fractures.

59.4 Traction

To exert traction is to pull. You can use traction:
(1) to pull fractured bones into place
(2) to keep them moderately immobile until they have united,
(3) to do both, one followed by the other.
To apply traction successfully, find some way to grasp the patient's limb safely, for several weeks if necessary. You can do this by:
(1) Adhesive strapping to the skin
(2) Pass a Steinmann, or Denham pin, or K-wire through the bone.
Then attach a cord to the strapping, pin, or wire, passed over a pulley, and pull it with a weight.

SKIN TRACTION

The great advantage of skin traction is that there is no need to pass any instrument through the tissues.

As a general rule, skin traction can often be the definitive treatment in children, but should be used only temporarily in adults (≤2-3 days). *Don't use it if the circulation is impaired!*

Disadvantages are:
(1) You cannot apply >2.5-3kg to the lower leg, and even then not for long, so *it is not suitable for Perkins traction.*
(2) Joints across the strapping cannot flex and exercise.
(3) The skin may become sensitive to the strapping.
(4) In old patients, it easily causes skin blisters.
(5) It often slips off completely, if not applied properly.
(6) It is very uncomfortable in hot climates.
(7) It can occasionally cause ischaemia.

Nevertheless, skin traction is particularly useful for treating elbow and femoral fractures in children (73.4).

Orthopaedic traction strapping is very readily available. After applyingbenzoin tincture to the skin, apply it to both sides of the limb up to, but not above, the fracture line. Then, wind a crêpe bandage spirally over it. *Never wind circular turns of ahesive strapping round a limb*, because the strapping can become too tight.

Either fix a piece of wood in a loop of strapping (59-11), making it slightly wider than the ankle so that the strapping does not compress the malleoli. Or, fold each end of the strapping, and tie a cord to it.

CAUTION! (1) *Don't let the strapping extend above the fracture line onto the proximal fragment,* or it will be useless.
(2) *Don't let it press on the common peroneal nerve.*
(3) Don't let it interfere with the circulation.

N.B. GALLOWS TRACTION is useful in a small child <20kg. EXTENSION TRACTION is useful in an older child or teenager (73.4).

CHINESE FINGER TRAPS
A special kind of traction uses the ingenious bamboo traps to hold the fingers and the weight of the elbow provides the counter-traction (63-12).

These are especially useful for wrist fracture reduction (64.2), but you should not leave the traps on for more than 2h.

SKELETAL TRACTION
Make sure the joint within the traction system itself is not damaged: make sure there is no deformity, no effusion, no instability & no pain. This is not always easy, particularly with distal femoral fractures. In this case, get a radiograph of the knee showing the proximal tibia and distal femur, and look for avulsion of the tibial spines. Do the same where knee pain ensues after you have set up traction.

For definitive care, adults require skeletal traction.
N.B. Don't use skeletal traction across joints in children (73.4).

Insert the fixation pin in the metaphysis of the distal fragment. Attach the traction apparatus to a weight; this may pull the patient out of bed, so exert countertraction by raising the foot of the bed.

One of the main purposes of skeletal traction is to allow exercise of the muscles and joints, *so make sure this happens!*

Traction takes time to apply and manage, but is something easy to teach to assistants. It is most useful in the leg. In the arm it is uncomfortable, inconvenient, difficult to maintain, & frustrating for the patient, so only useful in rather exceptional circumstances.
Elaborate traction, such as that of Hamilton and Russell for the leg, require sophisticated equipment and are not described here.

PATIENTS IN TRACTION MUST EXERCISE

ARM TRACTION METHODS

FOREARM TRACTION is useful for a supracondylar fracture in children (73-8)

SKIN TRACTION FOR A HUMERAL FRACTURE is only necessary when a patient is confined to bed when a cast is impractical.

OLECRANON TRACTION
Pass a K-wire or small Steinmann pin through the olecranon for some lower humerus fractures, especially comminuted supracondylar fractures in adults (62-5).

METACARPAL TRACTION
Pass a K-wire through the 1st 2 metacarpals for some forearm fractures, especially if the circulation of the forearm is impaired (61-15)

LEG TRACTION METHODS
'90-90 TRACTION' is useful when the proximal fragment of the fractured femur is sharply flexed. Put a Steinmann pin through the supracondylar region of the femur, or the upper tibia, and flex the hip & knee both to 90° (67.7).

PERKINS TRACTION
Use an upper tibial pin to treat most adult femoral fractures. Flex the knee & exercise it (68.11).

BÖHLER–BRAUN TRACTION uses a special frame and is good for some supracondylar femoral fractures (67.3). You can also use this for tibial fractures, (69.3), although Perkins traction is usually better.

DISTAL TIBIAL TRACTION
Use a pin through the distal tibia to treat some proximal tibial fractures (70.7).

CALCANEAL TRACTION
Use a calcaneal pin to treat some tibial fractures (71.6). The purpose of the traction is to reduce overlap and bring the displaced bone ends together, not to pull them so far apart (distract them) that they cannot unite!
So: (1) Check the length of the injured limb by measuring it, or with radiographs, adjust the traction accordingly.
(2) Vary the traction to the needs of the patient; light patients need less weight than heavy ones. *Don't apply too much traction, and be prepared to adjust it.* To begin with you need to apply greater force than later, when the soft tissues have stretched. For example, for femoral fractures, the golden rule is to start with 10% of body weight and then reduce by 1kg/wk

A TABLE OF TRACTION WEIGHTS

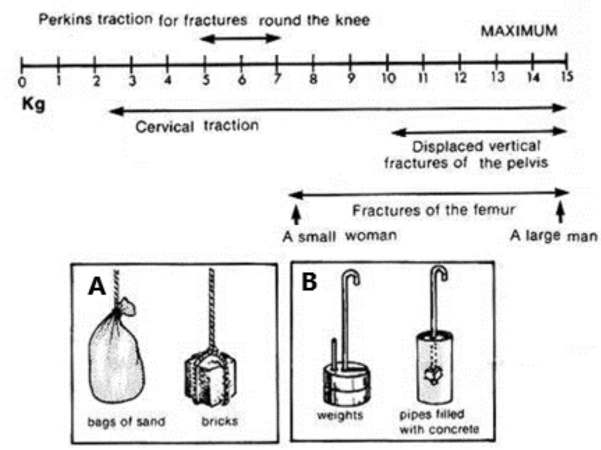


Fig. 59-12 A SCALE OF TRACTION WEIGHTS showing the range of weights needed for various fractures. Adjust them: (1) to the patient's build, and (2) during the course of treatment.

Ideally, traction should be checked with radiographs, but if you don't have portable X-ray machines, this is difficult. *There is no point of taking pictures with the traction disconnected.* The solution is to have a few beds with large castors on which you can wheel them to the X-ray department without taking down the traction.

N.B. Don't apply traction to a cast because the skin through which pressure is applied is likely to necrose. The only safe way to apply traction to a cast is to pass a pin proximal to the bone or through it, incorporating it into the cast.

EQUIPMENT FOR BONE TRACTION

•STRAPPING, traction, adhesive, 50x10mm rolls. This is elastic across its width, but not along its length. *'Elastoplast', which is elastic in both directions is useless, and dangerous!*
•PIN, Denham, (Denham is a centrally-threaded Steinmann pin), stainless steel, 4-5mm, tapered, self-tapping, with long coarse screw thread.
N.B. If you re-use re-sterilized pins, make sure they are still straight, sharp & not warped. Sharp tips create less heat than blunt.
•PIN, Steinmann, stainless steel, trocar, pointed at one end, diameter ranging 2-5mm and length 180-220mm, the smaller for the olecranon and the larger for the tibia.
•CHUCK. If you don't have a chuck, you can, if necessary, hammer in a Steinmann pin, if you follow the instructions below, but you cannot hammer in a Denham pin, because of its threads.
•HANDLE, with Jacobs chuck, 2-5 mm capacity, and key attached by chain, fully cannulated, stainless steel. This is an ordinary drill chuck on a handle. This chuck has 3 jaws, and although it is intended for K-wire and for pins & nails with triangular shanks, you can use it with square shanks. It will not grip the round section of a pin.
•STIRRUPS, Böhler, for Steinmann pins, with rotating swivel fixation pieces, of varying sizes. These can be used with Steinmann or Denham pins, the smaller for the calcaneus & olecranon and the larget for the tibia.
If you don't have these stirrups, take a wire coat hanger and bend it to shape, or tie the cords over corks (59-16E).

EQUIPMENT FOR BONE TRACTION

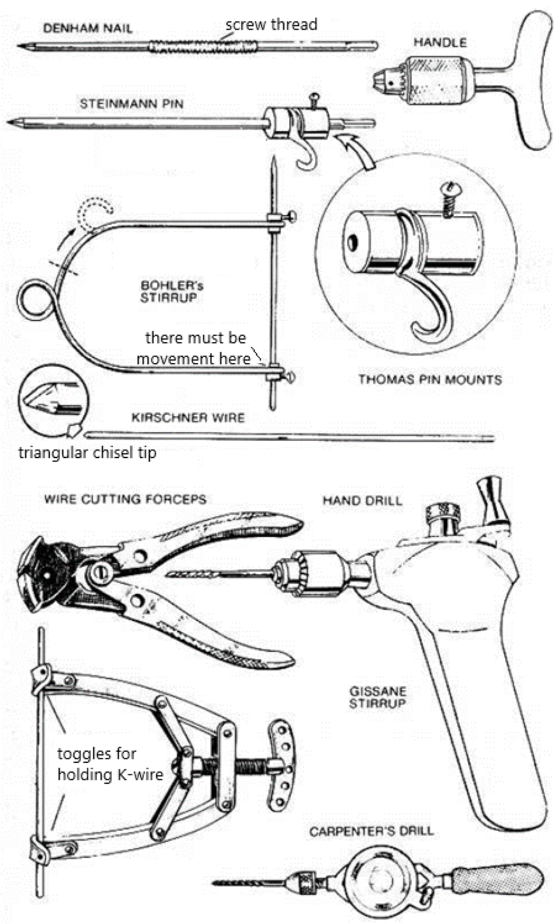


Fig. 59-13 EQUIPMENT FOR BONE TRACTION. Both the handle and the hand drill are cannulated so that a K-wire can pass right through them and be held close to the skin. If you don't have any other kind of drill, use an ordinary carpenter's drill.

•PIN MOUNTS, Thomas, stainless steel with rotating collar for Perkins traction. If you don't have them, you can make them by cutting a Böhler stirrup and bending the wire. The hooks must rotate freely round the collars.
•STIRRUPS, for wire traction, adjustable, tensioning, Gissane, with 2 cord hooks. These are for exerting tension on K-wire. They are more expensive than the standard K-wire stirrups, but there are no loose parts to get lost. Use these stirrups for exerting traction on the olecranon in fractures of the humerus, on the metacarpals in fractures of the radius, and on the metatarsals in some fractures of the foot.
•WIRE, Kirschner, plain unthreaded, stainless steel, drill pointed at one end, of diffrent diameters (usually 1, 1.6 and 2mms) and lengths. K-wires are weak and bend easily but they gain enormously in strength when tensioned by a device such as the Gissane stirrup.
Use them for traction in smaller bones or even in the tibia if Steimann pins are not available.
•WIRE CUTTERS. If you don't have these, sterilize a pair of ordinary pliers, but take care to oil them carefully afterwards.
•HAND DRILL, for K-wires and drills, up to 4 mm capacity, cannulated throughout.
Unfortunately, a carpenter's drill is not cannulated, so you can use it only with drill bits, not with K-wire. If you don't have any kind of drill, you may be able to hammer in a sharp Steinmann pin through cancellous, but not through cortical, bone to relieve osteomyelitis (7.3).

•DRILL BITS, twist, bone, 4 mm. Use these to:
(1) Drill a hole for a Steinmann pin. (2) Explore for pus in patients with osteomyelitis. Don't drill so vigourously that the bit becomes too hot, and necroses.
•CORD, braided, for traction, local purchase. If you don't have this use a length of bandage.
BED FRAME: there are many different kinds of orthopaedic bed frames, many improvised, but they all have the same purpose: facilitate mobilization and maximize the effectiveness of the traction system. It is not an absolute necessity, but makes everybody's life easier, starting with the patient himself. They are inexpensive to produce locally.
•PULLEYS, assorted, with appropriate connections for the bed frame
•BARS, for overhead traction & for a patient to pull himself up. These are needed for '90–90' traction (67.3), for some pelvic fractures (66.2), and for humeral fractures in unconscious or supine patients (61.13).
•WEIGHTS, for traction, local manufacture. Use bags of water, sand, or bricks suspended in stockinette (59-11); each brick weighs about 3kg. Or, use lengths of pipe filled with concrete into which a hook has been placed before the concrete sets. For example, 45cm of 7.5cm pipe filled with concrete weighs c.7kg.

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DON'T APPLY STRAPPING PROXIMAL TO THE FRACTURE LINE

ADJUST THE TRACTION CAREFULLY

SKELETAL TRACTION
Steinmann pins are stainless steel rods 3-6mm in diameter. Some are fully threaded but most are completely smooth. Smooth pins tend to loosen sooner, and loose pins lead to pin tract infections (and vice-versa)

A Denham pin is similar, except that it has large threads in the middle it only, which you can screw into the cortex of the bone to stop it slipping from side to side. If you use a Denham pin, be sure to identify it as such with a piece of tape, and to note it in the chart.

N.B. When you remove it, you will only see the smooth parts of the pin on either side of the limb and, unless you are aware, may be tempted simply to pull out what you think is a Steinmann pin, instead of unscrewing the inside part of a Denham pin.

Denham pins are better than Steinmann pins for Perkins traction (67.3) and for calcaneal traction (70.7). Steinmann pins have other uses, so you will need both. Insert them with the chuck.

Inserting a sharp tipped pin puts at risk neurovascular strucutres on both sides of the bone. You can control where a pin goes in the bone, but not where it comes out.

For this reason, it is safer to insert the pin on the at-risk side and exit on the less risky side:
(1) from medial to lateral for the olecranon,
(2) from medial to lateral for the distal femur,
(3) from lateral to medial for the proximal tibia,
(4) from medial to lateral for the calcaneus.

SITES FOR SKELETAL TRACTION

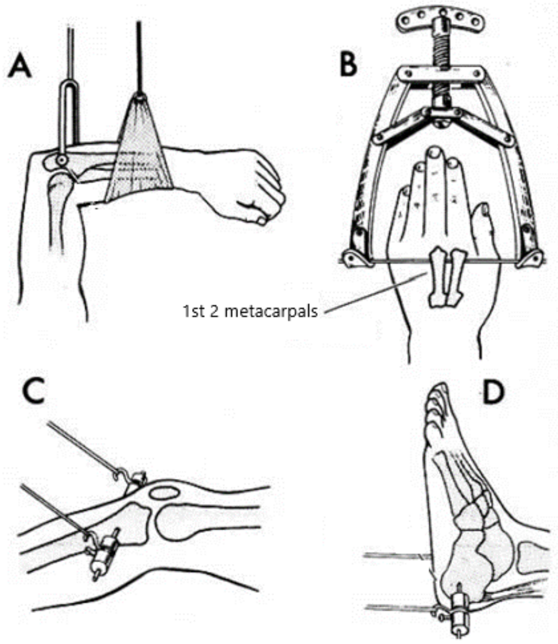

Fig. 59-14 SITES FOR SKELETAL TRACTION. A, use a K-wire or a small Steinmann pin. B, use a K-wire only for the hand. C, make sure the pin is perpendicular to the tibia. D, likewise to the calcaneus. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

These pins are stiff, so you can apply traction to them without tensioning them. You can use:
(1) A Böhler's stirrup (70-12) and a single traction cord and weight.
(2) 2 Thomas pin mounts (swivels) with 2 traction cords & 2 weights.
(3) Corks on the ends of the pin and tie the cords to them. If you tie the traction cords directly to the ends of a pin, they usually slip off and cause agony as they do so. Join the cords together and run them through a pulley attached to a single weight, so as to equalize the pull on either end of the pin (59-16B).

Pins can spread or introduce infection, so:
(1) Put them through healthy tissues some distance from a fracture, but *not through a fracture site* where the injured tissue is easily infected. You can use them to treat open infected fractures, but the further they are from the site of infection, the better.
(2) Keep pins still. The pin must stay fixed in the bone, and the stirrup rotate around it freely. This is why a Denham pin, which is firmly screwed into the bone is better than a Steinmann pin.
If your pin mounts have set screws, *don't tighten them*.
(3) *Never put a pin through a joint capsule*. The most serious complication of skeletal traction is knee joint infection, or calcaneal osteomyelitis, (7.13). If sequestrectomy does not cure this, it may be necessary to remove the whole calcaneus.

A LOOSE PIN PROMOTES INFECTION

INSERTING STEINMANN'S OR DENHAM'S PINS (GRADE 2.1)
Use a sterile sharp pin, as blunt ones promote infection. Make sure you have a strictly sterile environment (this is often best in the theatre). You can either sterilize the chuck, or use an unsterile chuck and a no-touch technique.

If you intend to hammer a pin in, do it through cancellous bone near the end of a long bone, and not through the thick cortical bone of the shaft, *because this may split*.

TIBIAL TRACTION − RIGHT & WRONG

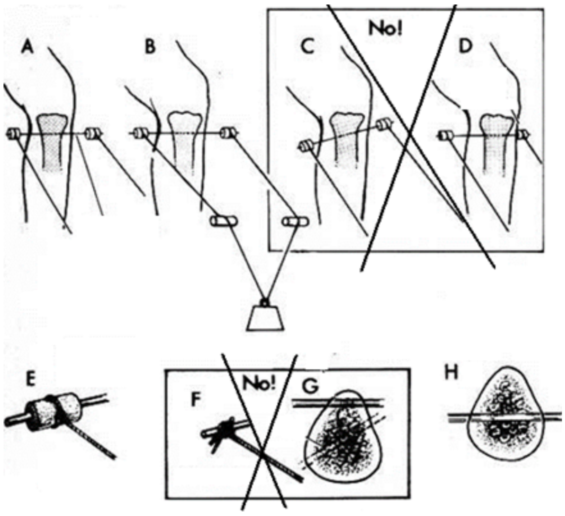

Fig. 59-15 TIBIAL TRACTION RIGHT & WRONG. A,B, at all sites the pin must be at 90^0 to the axis of the limb and in a horizontal plane. The pin must be clear of the skin, and protrude the same length of pin either side. C,D, If the pin is skew, or asymmetrical, the cord will slide along it and rub against the skin. E, if you don't have a Thomas swivel, tie the cord to a cork, F, *not to the pin directly.* G, pin too anterior, or skew. H, correct position of the pin. *Kindly contributed by John Stewart.*

Get 2 assistants, and use ketamine. Apply antiseptic to the pin-points on the skin, and introduce LA at these sites down to the periosteum of both sides, making sure it goes under the periosteum.

Make a generous longitudinal incision (5-10mm) in the skin with the point of a sharp scalpel. The main reason pin tracts become inefected is because the skin closes over the pin and prevents secretions from draining.

Insert the pin at the distal end of the incision, as the skin will glide over it when you reduce the fracture with some traction. *Check that there is no pressure on the skin.* If so, extend the incision.

Have an assistant apply counter-pressure and stabilize the limb. Advance the pin bluntly until you reach the bone. You can 'walk' the pin on the bone to identify its anterior & posterior borders, and aim for the middle.

With the toes pointing upward, the pin should be parallel to the floor and perpendicular to the long axis of the bone. Putting it in is hard work!

As the pin comes out of the bone on the other side of the limb, its point will raise the skin, so nick this with a scalpel, and push the pin through.

When the threads of a Denham pin reach the bone, screw them in about 6 turns, so that some of them enter its cortex. Ideally, the threads should bite both cortices *otherwise they will wear loose.*
Finally, secure the pin in a Böhler's stirrup or, preferably, with Thomas pin mounts. If the sharp point might injure the other leg, put a cork or a cap (*e.g.* an empty medicine vial) on it. Remember to mark your Denham pin and record it in the operative note!

PARTICULAR SITES FOR PIN FIXATION

THE LOWER FEMUR is used mostly for 90-90 traction, or if the knee or leg are also injured.
Insert the pin at the level of the flare of the condyles, opposite the upper pole of the patella, slightly anterior to the midline of the leg.

THE UPPER TIBIA is much the most important site, and is used for most femoral fractures, and many fractures around the knee. There are 2 alternative sites.

If you are using a chuck, put a 4 or 5mm pin through firm cortical bone 3cm distal to the tibial tuberosity. Push from the lateral to the medial side. Feel the fibular neck with your thumb: the common peroneal nerve will be winding round here, so insert the pin anterior to that point.

If you have no chuck and you have to hammer a pin in, do so from the lateral to the medial side 1cm distal to the tibial tuberosity through the junction of cortical & cancellous bone, that is, through the flare of the condyles. Make sure the tip is sharp. The pin will be less firmly held here but the bone is less likely to split.
N.B. On either site, don't insert the pin too far anteriorly, because there will not be enough bone to hold it. Insert it in the midline of the shaft, *taking care not to damage the peroneal nerve.*

THE LOWER TIBIA is used for some rare upper tibial fractures (69.5). Insert the pin from the lateral side 4-6cm above the medial malleolus immediately in front of the fibula. This makes sure it is well clear of the ankle joint, and avoids injuring the superficial peroneal nerve. Align it carefully so that it is at right angles to the long axis of the limb and is in the coronal plane.

THE CALCANEUS is used for some fractures of the tibia (70.7). Insert a 4-5mm pin, preferably of the Denham type, from the medial side, to avoid injury to the posterior tibialis bundle, through the posterior part of the calcaneus, (59-15,59-17). Put the pin approximately 2cm below and 2cm posterior to the tip of the medial maleolus.

N.B. If you put the pin in too far posteriorly, you will dorsiflex the foot.

SETTING UP CALCANEAL TRACTION

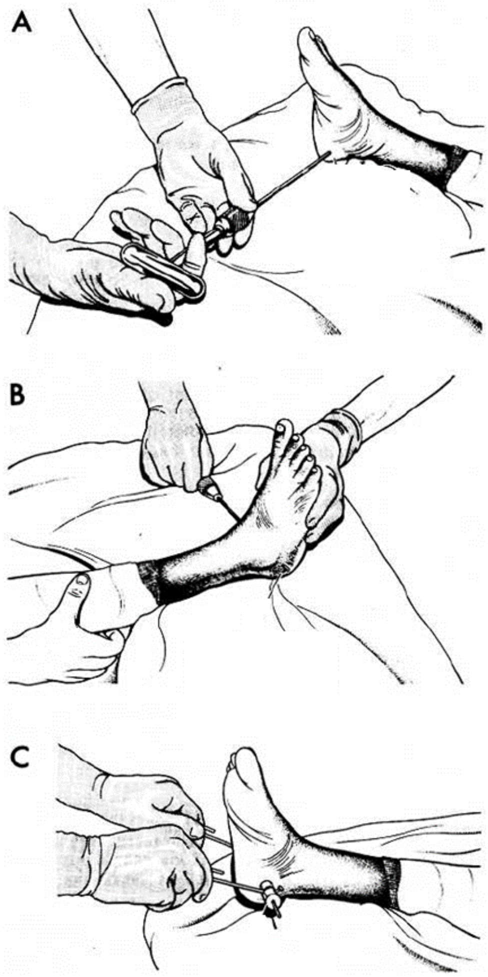

Fig. 59-16 INSERTING A STEINMANN PIN THROUGH THE CALCANEUS. A, put LA down under the periosteum before introducing the pin. B, incise the skin on the opposite side before the pin pierces the skin. C, attach the Thomas pin mounts so that they rotate freely. *N.B. If you leave it in for >15days you will increase the risk of osteomyelitis.* *Kindly contributed by Peter Bewes.*

N.B. K-wire traction is an alternative to a Steinmann pin.

THE OLECRANON is used for some distal humeral fractures. Use a thin 2-3mm Steinmann pin, or, better, a K-wire, and insert it from the medial side laterally, avoiding the ulnar nerve in the ulnar gutter below the medial epicondyle.

If there is frank purulent discharge or loosening of the pin, it needs to be removed and the tract and bone curetted to avoid the formation of a ring sequestrum. If you still need skeletal traction, put in a new pin at an alternative site.

REMOVING A PIN
Use an antiseptic to clean the projecting point of the pin to be drawn through the tissues. Pull it out with the chuck.

IF A PIN TRACK BECOMES INFECTED, REMOVE THE PIN

USING K-WIRES
K-wires are thin and flexible, and need to be tensioned to apply traction. Unlike a Steinmann or Denham pin, where movement takes place between the pin and the pin mount, movement with K-wire traction takes place between the wire and the tissues. This limits the amount of exercise that is practical.

DISTRACTION IS ONE OF THE GREAT ENEMIES OF UNION

Use traction with K-wires mostly in the calcaneus and proximal tibia, but occasionally in the olecranon and metacarpals.
K-wire fixation is also useful for internal fixation of some fractures of the hand, foot, patella and olecranon, with or without added cerclage wiring for tension banding.
To fix 2 K-wires in place, twist both ends in the *same direction* giving equal tension to both wires, but *avoid excessive twisting.*
As a general rule, *avoid circumferential cerclaging of long bones*: it kills the periosteal blood supply, and since the endosteal supply is also disrupted by the fracture, this leads to bone necrosis.

N.B. Don't leave K-wire sticking out of the skin, because this increases the chances of infection.

REMOVAL If a K-wire is causing no trouble, leave it. If the ends of the wire are painful under the skin, or if there is infection, or a sinus, remove it. Feel for the end of the wire under the skin; introduce LA, make a nick in the skin and remove it with pliers or with any convenient instrument.
If you cannot find the end of the wire, you may have to use a tourniquet under ketamine.

59.5 External Fixation

EXTERNAL FIXATION
You can efficiently stabilize open bony limb injuries with a device which holds healthy bone away from the fracture site using screws from outside, and fixes them using connecting rods.
This **external fixator** (X-fix) allows stabilization of a fracture while permitting easy access to the surrounding soft tissues.

ADVANTAGES
(1) External fixation provides *rigid fixation* of bones where other methods are inappropriate, *e.g.* severe open fractures, or in damage control.
(2) It also allows compression or fixed distraction of fracture fragments as required, and this can then be varied to allow a little movement for callus to form.
(3) You can easily monitor a wound for sepsis, ischaemia, viability of skin flaps or muscle compartment tension.
(4) You can perform procedures around the fracture site, such as skin or bone grafting, without disturbing bone alignment or reduction.
(5) It is useful especially in polytrauma patients: early mobilization is possible, especially for tibial injuries, without fear of loss of fracture alignment.
N.B. Even if reduction is far from perfect, you can correct the position easily later when the patient is more stable.
(6) You can elevate a limb without pressure on the posterior soft tissues. You can suspend the pins and frames by ropes from overhead frames. This will also help oedema to resolve
(7) You can insert pins under LA, if necessary.
(8) It is ideal for temporary fixation of a fracture adjacent to a dislocation.
(9) It is ideal in treatment of infected fractures or non-union, fractures in burn patients, and to achieve arthrodesis.
(10) It is much lighter than a cast.
(11) It is useful for temporary stabilisation method in patients awaiting referral, or when awaiting necessary supplies or a helping surgeon to arrive.
(12) It is useful as temporary treatment in patients unfit for invasive surgery (*e.g.* in polytrauma, or where haematological or biochemical correction is necessary) or as definitive treatment in patients who are chronically unfit.

Its greatest benefit is in the management of the soft tissues *not the management of the bone*.
However, a correctly applied external fixator is ideal for low-resource settings.

DISADVANTAGES
The equipment is expensive, although 'home-made' *(e.g.* wood, K-wires or plastic) devices will suffice, especially on the fingers. The X-fix is cumbersome, and a patient may fiddle with the apparatus, or (if confused) injure himself or another with it.

COMPLICATIONS
(1) Pin tract infection.
(2) Re-fracture after X-fix removal.
(3) Adjacent joint stiffness.
(4) Nerve, vessel or tendon damage.
(5) Non-union.
(6) Compartment syndrome (this risk is always present, although it is lessened by use of an X-fix)

Applying an X-fix may be difficult and needs experience; so, if simpler fracture fixation is adequate, and you are not very familiar with the X-fix, practice on some animal bones first : *don't experiment on humans with it!*

SPECIFIC INDICATIONS
(1) Any open fracture needing stabilization.
(2) 'Open book' pelvic fracture.
(3) Complex peri-articular injury (*e.g. elbow, wrist, knee, ankle, midfoot.*)
(4) Distal forearm fracture (definitive treatment), where the fracture is too unstable for a plaster.
(5) Unstable ankle fracture/dislocation.
(6) Finger fracture.
(7) Floating knee injury (distal femoral fracture with ipsilateral proximal tibial fracture).

TYPES OF EXTERNAL FIXATOR
There are basically 2 types of external fixators: a circular frame with K-wires, or rods connecting pins or screws. *Don't use the former unless you are familiar with it & its indications.* The latter relies on non-transfixing pins connected to rods to achieve a rigid construction. You can also incorporate transfixing pins used for skeletal traction in such frames.

There are dozens of X-fix kits available around the world. They all share the following basic components: pins, rods, pin to rod connectors and rod to rod connectors & clamps. They all come in different lengths, widths, and materials. Some sets are compatible with others, *most unfortunately are not*. The usual X-fix box available is a hodge-podge mix of all the above!

Part of your pre-operative planning is to visualize the type of frame you want to construct. Make sure *before* you start anesthesia that what you need (or an appropriate alternative) is available and in working order.

We describe here how to make your own X-fix with locally available materials.

For the 'rods', use hardwood timber of diameter 1-2cm of various lengths. A broom stick serves as a useful robust example.

For the 'pins', use sterilized autoclaved bicycle spokes: these have an ideal flexibility & strength.

EQUIPMENT FOR HOME-MADE X-FIX

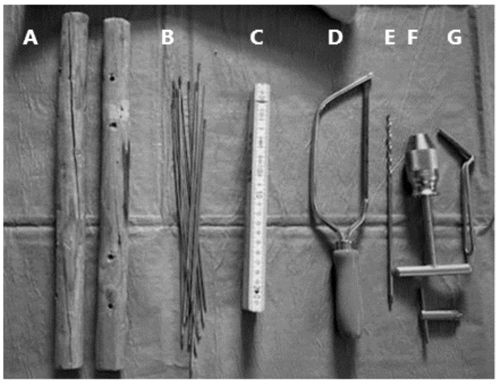

Fig. 59-17 EQUIPMENT TO MAKE YOUR OWN X-FIX. You'll need: A, wooden bars. B, bicycle spokes. C, stiff cm measure. D, handsaw. E, 4.5mm drill bit. F, hand drill with chuck. G, tissue guard. *After Bullmann T, Akim K, Domres B. The wooden external fixator.*

Basic elements of any X-fix set contain:
(1) external bars, rods, tubes of various lengths,
(2) spokes, pins or screws, either self-drilling or needing insertion through a slightly smaller hole drilled beforehand,
(3) cm measure
(4) handsaw (if you are making your own set)
(5) hand drill with chuck and bits
(6) pin inserter & soft-tissue guard,
(7) clamps
(8) pin-to-rod & rod-to-rod connectors

EQUIPMENT FOR EXTERNAL FIXATION

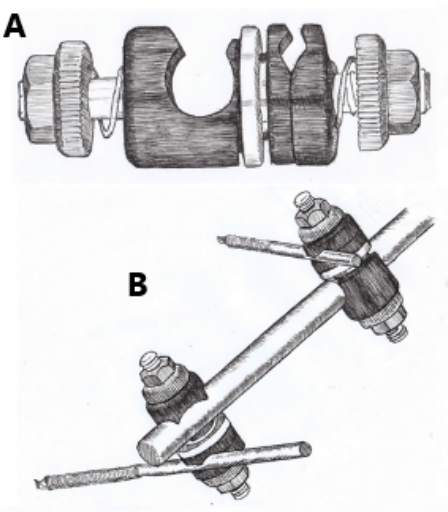

Fig.59-18 EQUIPMENT FOR EXTERNAL FIXATION A, connecting clamp. B, rod connected to 2 pins by clamps.

There are 3 basic types of frames: uniplanar, biplanar & modular. They are all simple but differ slightly in their fundamental principles, and whatever hardware is available to you may dictate your choice.

TYPES OF X-FIX FRAMES

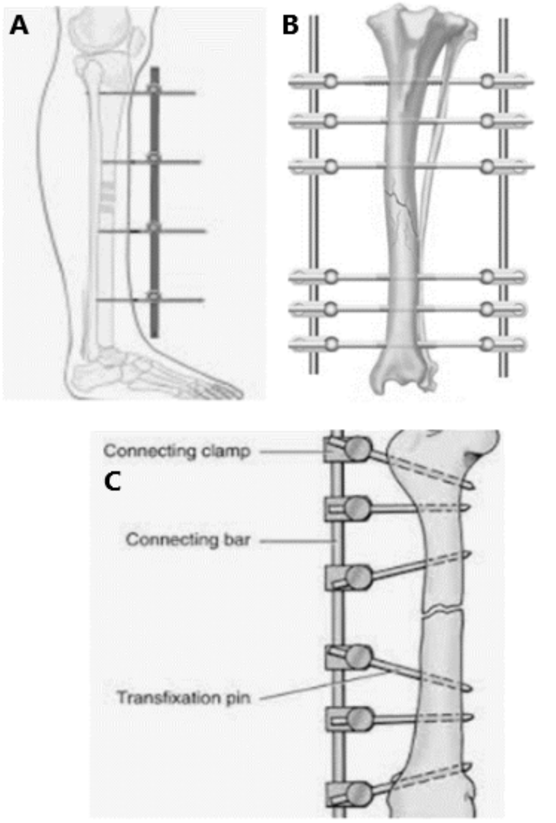

Fig. 59-19 X-FIX TYPES. A, uniplanar. B, biplanar. C, modular.

The unilateral and the segmental types, are both biomechanically inferior to the modular frame. So try to stick to the modular, if possible.

PUTTING AN X-FIX IN PLACE

Using the X-fix requires pre-operative planning, a knowledge of anatomy, understanding of basic biomechanical principles regarding pin insertion, and continuous post-operative monitoring for complications.

Remember 2 simple, but important, rules to follow when constructing an external fixator:
(1) Put the rods and the pins as close as possible to the fracture.
(2) Always use 2 rods when fixing the X-fix, in order to create a stronger frame.

Every bone and joint has designated 'safe zones' for pin insertion. Look them up before you scrub up. It is helpful to mark these safe zones with a permanent marker on the skin before surgery.

Once you have located the best areas for pin insertion, make a 1cm incision with a blade.

Dissect the soft tissues under direct vision until you reach the bone.

To protect the surrounding soft tissues when inserting the pin, either use a pin inserter and soft tissue guard or a mosquito forceps to guide your pin to the bone.

When drilling the pin with the hand drill, hold your non-dominant hand on top of the drill. With this hand, apply a constant, axial pressure on the pin. With your dominant hand, turn the drill, without applying any pressure, so that the pin stays perpendicular to the bone and so that it does not slip. You need an assistant to exert counter-pressure.

However self-drilling pins can produce thermal necrosis of both skin and bone, especially in the dense bone of the tibial diaphysis. It is therefore, advisable to pre-drill there for the external fixator pins, using a sharp drill bit that is slightly smaller than the chosen pin. A soft tissue sleeve, very limited blunt dissection to bone after incising the skin, irrigation, and a 'stop-and-cool' technique, all help to avoid tibial pin track complications.

If drilling is at all hard, remove the bit and clean off any bone chips. They should be white, not brown or black, which signify burning. If you encounter evidence of thermal necrosis, you should prepare and use another pin site, because pin site infection and associated loosening is a common complication.

In order to create the best stability, the 2nd (and sometimes 3rd) pin you wish to connect to the same clamp should be parallel to the 1st one.

Take the clamp and make the screws as loose as possible, but without detaching the 2 parts of the clamp. Put it over the 1st pin in the position you want to fix it later on. The clamp will indicate where the 2nd incision should go. Make your incision, using the same process as described above. Keep the clamp in place over both the pins when drilling the second one, to give the best indication of direction.

Attach the clamps to the pins on both sides of the fracture. Reduce the fracture in the best possible position using the clamps as joysticks. A 2nd person should now connect the rods to the posts and fix these as strongly as possible.

Elevate the limb. Get a repeat radiograph in 2 directions to check the fracture reduction. If the reduction is unsatisfactory, you can simply loosen the device and try again. ***Don't accept malalignment***: it defeats the object of using the X-fix!

If the reduction is acceptable and stable, add a 2nd rod for additional stability.

If you do not have rods available of the correct length, or no rods at all, connect the clamps by plaster cast bridging instead. You will need one person holding the reduction for 15mins (the time the plaster hardens), and 2nd person to take a piece of wood or cardboard to use as a rod of the correct length. Connect this provisional rod to the clamps with the plaster cast and strengthen the provisional rod itself with a few layers of plaster cast as well.

N.B. This principle is similar to the use of an anti-rotation bar or support bar in a hip spica.

Make sure that you:
(1) *avoid inserting pins through the wound*,
(2) use a hand drill, *not a power drill* as this produces excess heat & burns the bone cortex, resulting in a ring sequestrum,
(3) *don't insert pins too close to the fracture site* or in the fracture,
(4) *don't insert pins too far from the fracture site: you risk making the fixation unstable,*
N.B. 2-3cm on either side is safe.
(5) insert at least 2 pins in each part of the fracture you wish to stabilize,
(6) put pins as far apart as possible in the clamps, to use to a maximum the strength of frame,
(7) place the rod as close as possible (2cm) to the skin to use to a maximum strength of frame,
(8) always use a soft tissue protector to avoid iatrogenic soft tissue injury,
(9) *don't drill a hole a bigger size than the pin width:* it will be loose!
(10) *never attach the rods to your clamps before reducing the fracture*. This will complicate the reduction,
(11) attach the rod-to-rod or rod-to-pin connectors in the right direction, *i.e.* with the screw facing away from the fracture, so you can easily tighten it later on,
(12) tighten all screws on your construction to the fullest before leaving the operating theatre,
(13) test the stability of bone reduction on the operating table, as you may need to make some modifications,
(14) check pin position and fracture reduction with fluoroscopy or a portable x-ray machine in the operating theatre, if available.
(15) *take care if the bone is osteoporotic.*

A similarly constructed external fixator can span a joint if necessary.
Once you have assembled the frame and reduced the fracture, you should check the pin sites again. Occasionally skin tension that tents the skin may occur after reduction.
In this case, use a small pointed scalpel to incise the skin and release all tension.

GENERAL POST-OPERATIVE ADVICE

Clean the pin-skin interface twice daily, and apply antiseptic dressings.

The most important factor preventing pin tract infection is to mobilize the skin around the pin regularly to prevent the skin sides sticking to the pin, which traps the exudates inside. Pin sites need to drain, until they dry out on their own.

If a pin becomes painful with red, swollen skin, ***but is not loose,*** a course of oral antibiotics is all that is needed.

If there is purulent drainage or loosening of the pin, remove it and curette the track. Try to put in another pin elsewhere through normal skin, if it is still necessary.

N.B. You may have to reapply a completely new X-fix!

As soon as the wound is covered and stable (usually by 6wks for the leg), replace the X-fix with a cast or a brace until bony union is achieved.

N.B. Don't immediately allow mobilization until the bone can take the stress.

N.B. Don't leave an X-fix in place too long, as non-union may result.

Once you allow some fracture movement, the pins will become loose, and this may result in infection or new fracture. So, it is usually best to replace the X-fix by a cast or brace.

Details of specific X-fix insertions are mentioned in different chapters:

(1) Humerus (61-18)
(2) Elbow (62-8)
(3) Forearm (63-13)
(4) Wrist (64-9)
(4) Hip (66-9)
(5) Femur (67-10)
(6) Knee (69.5)
(7) Tibia (70-11,12)
(8) Ankle (71-13,14)

The amount of stiffness that provides the most favorable environment for fracture healing in an external fixator is unknown. More rigid frames are preferable at the start of treatment during the phase of soft-tissue healing and have usually fewer pin site problems. Fractures with more inherent instability require stiffer frames than more stable fracture patterns.

Gradually destabilizing the frame, to permit more weight bearing on the bone, stimulates fracture healing. Destabilization usually includes converting the frame from a static to a dynamic construct by loosening the pin-to-rod clamps on one side of the fracture.

Axial compression is allowed while maintaining angular and rotational alignment.

You can also make frames less rigid by increasing the distance between the rod and the bone and removing the outer rod in a double-rod frame. The fracture should be stable enough to resist excessive shortening or angulation before fracture destabilization.

REMOVING AN EXTERNAL FIXATOR

Don't hesitate to remove an external fixator when there is good callus formation & wounds are closed; do this as an out-patient under sedation. All necessary tools including a hand drill or t-handled chuck should be available.

Remove the external fixator pins, scrub the pin site with betadine solution and apply a fairly bulky sterile dressing to accommodate the usual brief bleeding. Then check for stability by manually stressing the fracture and either apply a walking cast or even allow pain-adapted partial weight up to full weight bearing without protection, if you estimate that the fracture has healed.

Most pin sites should heal after a few days and need little further care, if any at all. Occasionally, a tibial pin site may become infected, which may cause loosening, persistent purulent drainage, or a ring-sequestrum.

Don't try to clean the pin-tract with a curette, but use a hand drill with bits large enough to debride the affected bone. Do this under GA in theatre.

60 Amptations

N.B. For amputation in general and specific techniques in different antatomical regions: 35.3-7

60.1 Amputation in trauma

INTRODUCTION

You may have to decide whether you can save a severely injured limb or not. Your surgical judgement is very important and will not always be correct. You may need to balance the prospect of an amputation against prolonged hospital stay, sepsis, repeated and complicated operations and maybe fatal complications.

Remember, an amputee is a patient for life: "it is the beginning and not the end of treatment". Not only must artificial limbs be replaced on a regular basis, but a high percentage of patients develop anatomic complications in the stump and psychological problems.

Most amputations following road traffic accidents and during armed conflict affect young and healthy adults in the prime of their productive life. The resulting impairment may remove 2 or more people from independent living: the victim and the carer. Physical rehabilitation, socio-economic integration programmes and vocational training are sorely lacking in many poor resource countries.

Get a 2nd opinion! This may be easier than you think, using a photo and electronic communication.

It is the most severe soft-tissue injury, not the bone injury, which dictates the amputation level. Aim to preserve as much length as possible, compatible with good and durable prosthetic fitting. *Don't gain length, though, at the expense of poor stump healing and coverage. A common error is to amputate in the distal ⅓ of the lower leg.* Fashion a disarticulation in preference to a bony amputation close to a joint.

A fracture proximal to the amputation level is *not* an indication for a more proximal amputation, especially not in children and healthy adults. Immobilize the fracture and carry out an amputation at the level of soft-tissue injury.

Do not greatly delay performing a distal amputation for severe injuries; otherwise you may need to perform a more proximal amputation later!
Get consent & fully inform the family. Whenever possible, get consent for a more proximal amputation, especially for war wounds, as the soft tissue injury may be much worse than you expect from an initial evaluation (*e.g.* 'Umbrella effect', 60.10).

Get good cover of the stump with muscle (*the Syme's amputation is an exception)*; if there is viable soft tissue covering the stump, you will be able to put a skin graft on it later, if necessary, but *not straight on bone!*

However, if you are in doubt, preserve as much of the limb as you can. If the patient is haemodynamically stable you will be able to re-amputate more proximally later.

INDICATIONS
(1) Pre-existing traumatic amputation.
(2) Irretrievable damage (60.3).
(3) Ischaemic tissue damage, usually from unrelieved vascular damage, crush injury or compartment syndrome.
N.B. For muscle damage of one group, an extensive debridement & fasciotomy may be adequate.
(4) Haemorrhage (when other efforts fail).
(5) Overwheming sepsis.
(6) Chronic continuing sepsis.
(7) A finger or toe where function is more important than loss of a part.

N.B. All war and most road accident wounds are contaminated, and many are 'mangled', but not all require amputation. Anti-personnel mine injuries are an exception (60.6). Assume all traumatic amputations are potentially or actually infected.

Your decision to amputate must take into account your actual working circumstances (*e.g.* conflict scenario, mass casualty event) including the availability of blood transfusion, the level of post-operative and physiotherapy care, as well as the accessibility of prostheses and physiotherapy.

A patient may request amputation for a useless limb. But up to 50% of victims can regenerate sensation (*e.g.* in the sole) over 2yrs after trauma.
N.B. Nerve transfer may make a limb useful again!

A good amputation wound presents a healthy, bleeding muscle surface that contracts as the last compress is removed.

The aim is not merely to close the wound but also, and especially, to fashion a suitable stump with a sufficient padding of muscular soft tissue for later fitting of a suitable prosthes.

If there are other serious injuries, proceed according to ABC (41.1). You might, rarely, have to decide rather to perform a quick amputation or disarticulation if required.

In damage control, *remember 'life before limb'.* This might also apply in a mass casualty situation.

The initial aim is to excise all dead and contaminated tissue in preparation for delayed primary closure (DPC).

Drain the vessels by elevating the limb before the operation! Use a tourniquet, but keep in mind that the muscle retracts back in relation to the skin and bone after removal of the tourniquet. *Release it prior to the end of the operation for proper haemostasis*.

CONSIDERATIONS FOR TRAUMA AMPUTATIONS

(1) Unlike standard amputation flaps, you must usually resort to 'flaps of opportunity' as determined by the injury. *Do not attempt to fashion definitive flaps at the first operation*.

(2) Excise all damaged soft tissue first and then plan the bone section as distal as feasible. To allow as much leeway as possible to accomplish DPC and fashion a sturdy and painless stump fit for a prosthesis, save all viable skin and muscle distal to the bone section, however irregular the remaining tissue. You can always excise excess bone and soft tissue at DPC.

(3) When you raise the flaps, *do not dissect the skin from the underlying fascia*. Excise all non-viable soft tissue & skin distal to the bone section. Plan this to be as distal as possible. So, cut the flaps long; they will naturally retract.

(4) Cut back muscle obliquely across its fibres, *not transversely*. Try to retain a specific muscle in its entirety if you can. It is often possible to 'save' the entire *gastrocnemius*.

N.B. If you cut a muscle across its fibres, *it swells considerably* in the first few days post-operatively, owing to simple inflammatory oedema, especially in young men with bulky muscle.

Flaps which approximate at the primary operation may only do so under tension at DPC.

(5) Divide the bone as distally as possible *after you have removed damaged tissues.* However, you should nonetheless be able to cover the bone end with muscle without tension. *Don't amputate in the distal $^1/_3$ of the tibia* (60.5). Be sure to bevel the front edge of the tibia, & cut the fibula 2cm shorter.

N.B. Don't leave behind any splintered or loose bone.

(6) Treat blood vessels, nerves, and the wound as in non-trauma amputations (35.3).

(7) Obliterate any dead space (although this may be difficult if extensive tissue is lost). *Put suction drains where there is dead space!*

N.B. Never suture structures under tension!

At the end of the initial operation, the skin and muscle should approximate easily, without tension, over the bone end. *Don't put in any skin sutures.*

Remove the tourniquet and assure haemostasis. Irrigate the wound with copious amounts of normal saline or potable water (up to 8-10L) using simple pressure by squeezing an IV infusion bag, or by gravity flow through hanging up the bag.

Then dress the stump with a bulky absorbent dressing made of dry fluffed-up gauze reinforced with a layer of absorbent cotton wool. Hold it in place with a loose crepe bandage or non-circumferential adhesive tape.

N.B. A tight bandage wrapped around the limb and soaked with drying exudate will have a tourniquet effect and cause extreme pain.

Don't pack the gauze compresses too tightly in the wound. This will only impede drainage. The aim is to draw inflammatory exudate out of the wound and into the dressing. Exposed tendons and joint capsules may be covered with saline-soaked compresses.

Don't remove the dressing until you take the patient to the operating theatre for DPC. *Dressings put on in the ward are an invitation to nosocomial infection.*

N.B. Resist the temptation to change the wound dressing to 'have a look at how it is doing'.

Each dressing change constitutes trauma to the healing granulation tissue and exposes it to cross-infection. Instead, a good look at the patient will suffice: the wound is doing quite well if the patient is smiling, eating, and sitting comfortably in bed.

If the dressing and bandage have become soaked with exudate, either overdress with more absorbent cotton, or take down the bandage and wet cotton and replace it *without disturbing the gauze compress in direct contact with the wound*.

N.B. The state of the dressing is never a reliable indication of the state of the wound.

DON'T CHANGE DRESSINGS OF WOUNDS AWAITING DPC UNTIL FORMAL CLOSURE.

If there is continuing haemorrhage or signs and symptoms of severe infection (fever, toxicity, excessive pain and tenderness, warmth, redness or a shiny surface of dark skin, oedema and induration, or a moist wound dressing with an offensive smell), the patient needs further surgical excision which you must perform in the operating theatre, *not by changing the dressing in the ward*.

If the wound is infected or parts are necrotic, debride it. You may need to shorten the bone and leave the flaps open for 1-2wks, and close it only when it is clean.

If the soft-tissue wound breaks down, it will leave the bone end exposed and require further bone shortening.

POSTOPERATIVE CARE
Keep the limb elevated in bed to reduce oedema and keep the stump in a position to prevent joint contractures. A PoP posterior slab worn at night is effective. Pay great attention to post-operative pain and administer adequate analgesia. This helps initiate appropriate physiotherapy to maintain muscle tone and keep remaining joints mobile.

Start physiotherapy immediately, even before DPC, to get a good range of movement at the joint proximal to bone section. This must continue long after the wound has healed & include vocational training.

DELAYED PRIMARY CLOSURE
You should employ this routinely, but it is mandatory:
(1) if the limb is already infected or may soon be so.
(2) if the blood supply of the stump is uncertain.
(3) if there is much soft tissue injury.
(4) in all war wounds.

A good amputation wound is healthy-looking with, a bleeding muscle surface that contracts as the last compress, which is stuck to the granulations, is removed.

The dressings may give off a sour ammoniacal odour. This is due to the breakdown products of serum proteins, and *is normal. It is not a sign of infection*. It is a 'good-bad smell'.

N.B. An infected stump has a 'bad-bad smell' and the last compress slides off the layer of pus without any resistance.

The aim of DPC is not merely to close the wound but also, and especially, to fashion a suitable stump with a sufficient padding of muscular soft tissue. Although whatever soft tissues remain may limit you and have to make do with 'flaps of opportunity', long posterior flaps give the best possible stumps.

If your judgement was good during the initial operation and infection has been avoided, you usually don't have to shorten the bone. Otherwise, divide it until you can be sure of tension-free soft-tissue cover.

If you have achieved tension-free DPC, place a suction drain deep to the muscle layers to evacuate any ooze of blood. Remove this after 24h.
In a young and healthy patient, especially if you can save a joint, it is worth fighting for a longer extremity with repetitive debridements. To avoid shortening the bone and having to fit a poor prosthesis, you may have to put a skin graft over exposed bone *(provided it still has a periosteum)* if the remaining skin is insufficient or retracts after the initial operation.

In an old, weak or critically ill patient, in whom you want to avoid further surgery, it may be better to amputate at a safer, more proximal level.

If there is still infected soft tissue or even bone, you *must* amputate higher up and leave the stump open again for another attempt at DPC.

Quite apart from the physical loss, and the functional disability, an amputee often suffers psychological trauma, unemployment & social ostracism (resulting in family expulsion, marriage breakdown, and loss of self-image). *An amputee may 'feel' that the (phantom) limb is still there*! Loss of the right hand in some cultures may mean all these results!
Mentoring and support for other amputees may be extremely therapeutic from an amputee.

LATE COMPLICATIONS
Make a systematic examination of a stump, including a radiograph. Check:
(1) The status of the stump
- length, shape, joint mobility, contracture,
(2) The skin
- irritation, infection, blistering, ulceration,
- callosity, epidermal cysts,
- venous engorgement (prosthesis too tight)
(3) The scar
- suppleness, adherent, sensitive,
- pressure points, 'dog ears'
(4) The soft tissue
- excessive or not enough
- neuroma, heterotopic ossification
(5) The bone
- length, bevelled edges, bony extruberances
- osteomyelitis, osteophytes.

N.B. A neuroma gives sharp 'electric shocks' on palpation; it feels like a hard lump up to 2cm in size. Cut this out and divide the nerve (using a fresh blade) more proximally, burying it under fascia.

N.B. Before diagnosing 'phantom limb pain' you must exclude other causes as listed above!

60.2 The mangled limb

INTRODUCTION
The mangled extremity is defined as massive anatomic disruption of the bone, muscle, tendon, nerve, vasculature, and/or soft tissue that threatens limb viability and functionality.

Obviously, other life-threatening injuries may take precedence. *Always apply the ABC rule* (41.1).

Therefore, the only critical aspect of the mangled extremity management during the primary survey is control of bleeding.

If direct pressure on the wound or a proximal tourniquet does not control hawemorrhage, other options are (1) direct vascular clamping, (2) shunting or (3) emergency amputation as damage control. *Don't try to refer a bleeding patient elsewhere!*

REMEMBER: **LIFE BEFORE LIMB !**

The decision to amputate may be very difficult, especially as these patients are usually young working people.

A MANGLED LIMB

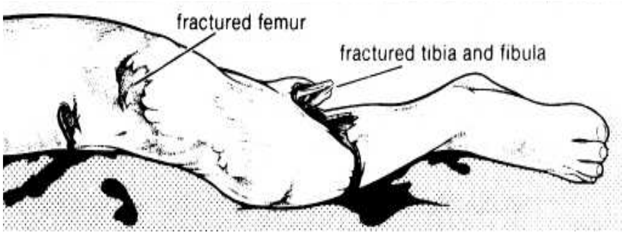

Fig 60-1 A MANGLED LIMB. One that needs amputation is defined as having massive anatomic disruption of the bone, muscle, tendon, nerve, vasculature, and/or soft tissue that threatens limb viability and functionality. Unless there is uncontrollable hemorrhage or major nerve damage, *this case is not an indication for amputation.* Reducing the fractures would be the 1st priority here.

Ask yourself:
(1) Is an attempt to save the limb possible?
(2) Is an attempt to save the limb reasonable?
(3) Will limb salvage get a better final result than amputation & prosthetic limb fitting?

This calamity most often involves the lower leg; for the arm, you should lean more towards salvage. You must also take cultural constraints into consideration.
For some the integrity of the body may seem more important than life itself, but counselling can help.

Your major focus is on restoring the victim's ability to resume a normal lifestyle. Keep in mind that both amputation & limb salvage are associated with risks of long-term disability. Your goal should be the best possible functional result, avoiding complications.

So how will you define a good outcome, and assess the risks? Is it better to save a useless insensitive foot with a couple of operative procedures, with whom the patient won´t be able to walk? Or is a primary amputation and a quick rehabilitation with a good prosthesis the better solution? Will the patient´s functional independence following reconstruction be better, or will it be worse than after amputation and prosthetic limb fitting?

The answer will vary according to age, vocation, medical health, social status, the demands of the patient's chosen occupation and the cultural context.
It also depends on the availability of a prosthesis, especially in resource-poor environments.

Does the patient have the means to afford a prosthesis? Is one available at all? If you try to save a limb, keep in mind that a long-lasting, burdensome, multiple-step treatment programme might overstretch the patient's financial & physiological capacity and so might be even life-threatening.

The result of salvage is sadly (even in sophisticated centres) often not as satisfactory as primary amputation. An early decision for amputation may often reduce a victim's suffering. Try to view an amputation as reconstructive rather than destructive surgery.

Remember:
(a) Tourniquet
(b) Vascular shunting
(c) Fasciotomy
(d) External skeletal fixation
(e) Multiple wound assessments

TREATMENT PRINCIPLES FOR MANGLED LIMBS
Document your neurovascular examination early on. Take photographs if at all possible.

Keep a low threshold for fasciotomy (49.6) in patients at high risk of the compartment syndrome: it is best to react prophylactically than lose a leg!

As a general rule, *don't amputate as a primary measure* if at all avoidable. You will only be able to make a definitive assessment of the soft tissue damage in the operating theatre during the initial debridement. This you should plan as early as possible, especially if you suspect a major vascular injury.

AVOID PRIMARY AMPUTATION

Carefully debride all non-viable tissue. Because of the high risk of post-traumatic infection, the quality of your initial debridement is central. *Meticulously remove all foreign material as well.* If this is likely to take you >2h, an amputation may be the better option, if you have many other patients to see to.

However, in polytraumatized patients, the criteria for limb salvage must be stricter than with isolated limb injury as limb salvage procedures are an additional physiological burden ('2nd hit').

In unstable polytrauma patients, stick to damage control surgery and concentrate only decontamination and controlling haemorrhage.

All else is unwise as the duration of procedures in such patients is critical to outcome. You can always re-assess the situation over next 48h and make a decision then. So, initially just debride, control bleeding and immobilise the limb(s) in slabs over fluffy dressings.

Leave definitive immobilisation till whenthe patient is stabilized, during a 're-look'; then decide whether or not to salvage a limb.

N.B. this applies only to UNSTABLE polytrauma patients.

Anticipate the definitive bony and soft tissue treatment from the beginning. Leave any contaminated soft tissue wounds open.

N.B. You'll get a better functional outcome with an amputation *with s*evere soft tissue injury around the ankle & foot.

Finally stabilize the bone, *e.g.* by using external fixators or splints. These should allow you access to all open wounds.

In the presence of combined major vascular injury and long bone fractures, vascular shunting (49.3), followed by external fixators are expedient damage control options.

After initial debridement and stabilization of the limb, discuss further intervention, risks and perspectives with the patient and the family. Make sure that these discussions are timely, transparent, non-coercive, and you clearly **document everything**.
Take into account any comorbidity such as diabetes, peripheral arterial disease and nicotine abuse, as well as available personnel and resources.

You may need to make several assessments of the soft tissue injury, before coming to a final decision.

SCORING SYSTEMS
Multiple scoring systems exist to classify the severity of mangled extremity to help establish guidelines regarding the decision to amputate or not.
These include the following: Extremity severity score (MESS). Predictive salvage index (PSI), Limb salvage index (LSI), NISSA score, Hannover fracture scale (HFS), Mangled extremity severity index (MESI) & Ganga hospital open injury severity score.

None of these systems have been shown to be useful in prospective clinical decision-making for amputation versus limb salvage, *especially not for the inexperienced*. In particular, *they are not predictive of the functional recovery after successful limb reconstruction*. In general they could be considered only as a help deciding to amputate or not a mangled limb.

Furthermore these scores are relevant only for the lower extremity in adults and *not for upper extremities* and *not for mangled extremities in children*.

Here are some guidelines which may help in the decision-making process. Not all mangled wounds with vessel damage warrant amputation. In these situations of vascular injury & severe tissue damage, an amputation is advisable.

(a) Haemorrhage with extensively comminuted fracture & bone defect, 2-finger sized wound cavity, and the sum of entry & exit wounds >10cm diameter.
(b) Transection of major nerves.
(c) Other life-threatening injuries.

If vascular repair by shunt & fasciotomy, & fracture immobilization is possible, limb salvage is worth trying. *Close observation over 48h is mandatory!*
However, if soft tissue damage is so severe that closure is impossible, limb salvage will probably fail.

If revascularization has failed, or severe sepsis ensues, amputation is necessary.

N.B. Insensitivity of the sole of the foot is not a criterion for amputation, as >50% recover over 2yrs.

60.3 Guillotine amputation

INTRODUCTION
Don't perform a Guillotine amputation as a routine procedure. It is only indicated in extreme situations such as the extraction of a victim under rubble or in a vehicle wreck. You might use it as a rapid damage-control procedure in a critically ill *e.g. with gas gangrene, neglected tourniquet application* (46.11)*, gross sepsis with diabetes* when later definitive amputation will take place at a different & more proximal level.

Guillotine amputation is quick, and the flaps are less likely to necrose if the blood supply is poor. This is important in the forearm, fingers or toes, because if you do a formal operation and it becomes septic, you lose more length.
However, if you don't have clear demarcation between healthy and septic or irreparably damaged tissue, you may also lose more length.

GUILLOTINE AMPUTATION (GRADE 2.2)
Cut the skin, fascia and muscle in one straight cut; the amputation knife is made for this purpose.
Saw through the bone at a slightly more proximal level. Tie vessels and cut nerves as in other amputations (35.3), but at the level of the amputation. The muscles should retract proximal to the skin edge, but remain distal to the bone. The final stump resembles an inverted cone.

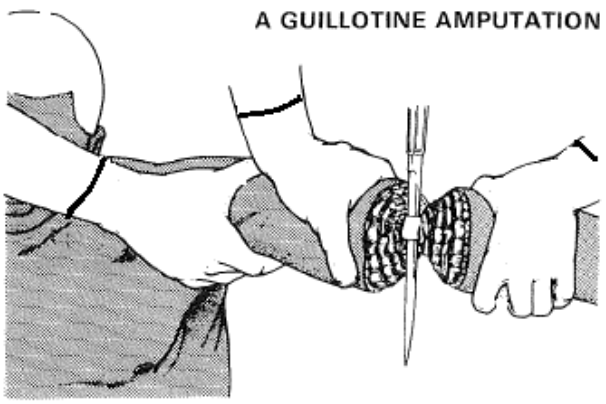

Fig. 60-2 A GUILLOTINE AMPUTATION. This is a quick procedure only indicated in extreme situations. *A revision is almost always necessary later. Beware injury to your or your assistant's fingers from the knife!* Use a saw for the bone!

If you perform the amputation too distally, you may miss dead muscle; if too proximally, you remove more length than necessary. Retraction of the blood vessels makes control of bleeding more difficult.

In addition, wound closure is made more complicated because of retraction of the skin, particularly if the amputation is at mid-calf or mid-thigh level.
The resultant significant oedematous muscle swelling always requires stump revision in order to fit a prosthesis.

MANAGEMENT OF AN OPEN STUMP
You may occasionally see a guillotine stump from a machete injury. The further management of a traumatic or surgical amputation depends on how clean and how fresh it is. Simple skin grafting the stump wound rarely gives a good result.

If the guillotine amputation stump is infected, take the patient to theatre for a debridement to remove any remaining necrotic tissue. You may have to repeat this several times.
Leave the wound open. In the process, try to create flaps for closure, so that you can achieve this when the wound is clean.

If the guillotine stump is on the leg or upper arm, is <48h old and is clean, re-amputate the clean stump at the correct level, salvaging all viable soft tissue. Leave the stump open, and perform a delayed primary closure 5days later.

If the guillotine stump is on the leg or upper arm, is >48h old and is clean, dress it every 2–3days and keep the limb elevated. Perform a secondary amputation after 2wks when the inflammatory oedema has subsided. Again, leave the stump open and perform delayed primary closure another 5days later.

If the guillotine stump is on the forearm, finger or toe, dress it every 2–3days and keep the limb elevated. *Don't try any V-Y or similar flaps, as their results are no better and often worse than letting the wound granulate on its own.*

MTHULISI (45yrs) was an ambulance driver at a Mission Hospital. One night he leant out of his cab to open a rusty gate to drive into someone's homestead. Unfortunately, he cut his hand deeply, but continued his work to bring a patient to hospital. He put a rough cloth round the wound to stop the bleeding and went to sleep as it was already late & dark.
His daughter, a trainee nurse at the hospital found him comatose in his bed 48h later. His right forearm was discoloured in its distal ⅓, he had a temperature of 39°C and was severely hypotensive.
The gravity of the situation was explained to the nurse, who was uncertain about giving her consent as she was under 21 years old. Her mother lived over 20km away, accessible only on foot. It was agreed that the nurse come to theatre to witness the status of the tissues on incision of the forearm, and then to give her consent if she agreed the soft tissue damage was irremediable. The greenish discolouration and smell of gas gangrene were undeniable (and unforgettable).
A damage control guillotine amputation was performed just below mid-forearm level. The wound healed on its own, and the patient recovered fully. He was then employed in the hospital garden, a job he always coveted!
LESSON: Acting quickly in an emergency may be life-saving.

60.4 Amputation of lips, nose, ears, breast & genitalia

INTRODUCTION
Traumatic amputation of lips, nose, ears, breasts and genitals are very mutilating injuries, but in themselves not usually life-threatening. They may either occur as isolated injuries or as multiple mutilation.

The 1° goal is always to save the patient's life, especially in a severely injured patient, by following the ABC algorithm (41.1).
This is particularly important in patients with trauma to their face, as this may compromise the airways.

Patients with severe injuries to their genitals may also suffer from severe bleeding.

Mutilation of lips, nose, breasts, and genitalia are not only cosmetic issues, but may also affect speech, breathing, breast-feeding and sexual function. This may have drastic psychological consequences.

Try to save and reconstruct whatever you can in order to allow your patient the best possible quality of life. If you can, once you have stabilized such patient, try to get specialist help.

If the injury was caused by an animal (or human) bite, or dirty knife, infection is almost inevitable. Primary repair may end disastrously, especially if an elaborate flap breaks down. A delayed primary repair is best. Dress the wound and plan this after 3-5days. Administer broad spectrum prophylactic antibiotics.

LIP AMPUTATION

The face is an exquisitely complex anatomic area, with distinct characteristics for each individual person. Deformity, therefore, is a fundamental issue. Even more important than aesthetic concerns are, however, the essential functions of breathing, chewing, swallowing, and talking.

TREATMENT

Inspect the mouth and pharynx for any loose or broken teeth or bone fragments, or continuing bleeding. This is necessary even in a conscious patient.
Avulsion of a lip segment can involve epidermis, dermis, underlying perioral facial musculature, and labial mucosa.

N.B. Pay attention to a possible delayed oedema formation that may block the airway.

Check the teeth occlusion in case you need to immobilize the mandible or maxilla.

There are 5 general methods of managing avulsed tissue:
(1) Debridement alone,
(2) Debridement and excision of the avulsed tissue with 1° or 2° closure of the wound, directly or with V-Y plasty, or rotation flaps (53.2)
(3) Debridement and excision of the avulsed tissue & free grafting of the excised portion,
(4) Debridement and excision of the avulsed tissue and split- or full-thickness skin grafting to close the wound,
(5) Debridement and excision of the avulsed tissue and a pedicle flap to close the wound.

For a partial or full-thickness avulsion of the lips, a primary re-approximation may be successful but is unpredictable. This depends on whether the patient is young and fit, and has no co-morbidity. It depends also on your dexterity and experience, and on your having fine instruments.

N.B. Skin grafting does not give very good aesthetic results.

Often, it is best to perform plastic procedures in a staged fashion. Sometimes even more sophisticated reconstructive surgery is necessary.

NOSE & EAR AMPUTATION

Traumatic auricular defects, especially partial defects, are relatively frequent, because of the prominent position of the ear on the side of the head and the delicate skin cover of the complex cartilaginous framework.

The loss or partial loss of an ear does not usually result in loss of hearing. Likewise, the loss of all or part of the nose does not result in significant loss of smell. Therefore, its reconstruction is necessary only for aesthetic reasons. However, this is very important for the nose as this contributes a central element to individual facial appearance.

TREATMENT

The reconstruction of a traumatic deformity of a nose or an ear is a challenging procedure. It differs in every case and requires tailor-made reconstruction. You can try replantation for amputations of the external ear and some full-thickness-skin avulsions of the nose, but success is unpredictable.
Repair is possible by skin grafts, Z-plasty, V-Y-plasty or local rotation flaps (53.9). You can replace a small defect of the nasal *ala* with a segment from the pinna.

BREAST AMPUTATION

Traumatic amputations to the breast are rare. The loss of a breast is hugely traumatizing for the victim, especially if she is of reproductive age. However, breastfeeding from the unaffected breast should be possible and is usually sufficient.
Very occasionally, the wrong breast is removed surgically!

TREATMENT

Unless a simple repair is possible, you will need to treat this as any other large wound by either skin grafting or local flaps (46.2). Breast reconstruction needs specialized techniques.

GENITAL AMPUTATION

The penis or scrotum may be amputated by a circular saw, or in motorcycle crashes or by animal (or human) bites. It is occasionally self-inflicted or the result of a punishment.

In males, penoscrotal injury may be associated with other abdominal or pelvic injuries and these take precedence. There may be brisk bleeding.

An isolated injury to the external genitals is usually not life threatening.

If scrotal skin is lost in a degloving injury, close the scrotum (and so cover the testes) using the remaining scrotal skin. A minimum of 20% of the original scrotal skin gives enough cover for the scrotal contents. *Make sure your debridement is adequate*. Irrigate the wound thoroughly before primary closure.

If the amount of remaining scrotal skin is insufficient, use local flaps, or bury the testes (temporarily) in each thigh.

If one or both testes are hopelessly crushed, document the injury by a photo and obtain consent for orchidectomy from the patient or the family. Try to avoid a bilateral testicular amputation whenever possible. Remember to tie off the vas deferens, as well as the vessels.

If the penis is partially amputated, try a primary reapproximation by meticulous repair of the urethra and the fascia, followed by stabilization with a Foley´s catheter. Strap the penis to the lower abdominal wall, and keep the patient on bed rest for 10days. *Don't allow any traction on the catheter;* it may be best to leave the drainage bag on the patient's bed (57.2).

In females, by far most amputations are carried out through forced social convention. In many countries, this practice is illegal, but is still carried out clandestinely. Sadly, there are >200 million girls and women alive today in 30 countries mainly in Africa, the Middle East and Asia who have sustained female genital mutilation (FGM, 57.6).

60.5 Prosthetic fitting

INTRODUCTION
An amputee is a patient for life. Your major focus is on restoring ability to resume a similar lifestyle to before. This is very important, as most of your patients will usually be young working people.
Although social support will usually depend on the family, there are in every country or at least in the capital or provincial capital, a rehabilitation centre, which offers a prosthetic service of some kind.

Whether the patient can obtain a prosthesis or not may well depend also on the family's financial means.

It is very important that you consult with your nearest physical rehabilitation centre. Its available technology and skills are fundamental in considering the sort of amputations which would be suitable for your patients. You should have a mutually agreed 'amputation policy' at your hospital to guide you.

If there is any uncertainty, perform a standard leg or foot amputation (35.3), and for the arm, always aim instead for the longest possible stump.

But even if your patient has received a well-functioning prosthesis, this needs replacing on a regular basis. Also a high percentage of patients will develop anatomic complications in the stump and additional psychological problems that must be dealt with.

GENERAL CONSIDERATIONS
Not every patient is suitable for a prosthesis. Assess each case on its individual merits, asking yourself about the possibility, usefulness and dangers of fitting a prosthesis. Many people are unaware of the extra physiological demands of walking or working with a limb prosthesis. The more proximal the amputation, the heavier the prosthesis and the greater the energy expenditure will be.

Take this into consideration in the elderly and in those with neurological deficits.

The quality of the amputation procedure itself and a lack of proper postoperative care may lead to problems that delay or even rule out the fitting of a prosthesis. The earlier the patient gets the prosthesis, the more he will benefit from it both physically and psychologically.

N.B. The quality of the stump is more important than its length.

Fitting of a prosthesis also needs careful observation and *is not just a one-off event.* Firm bandaging helps decrease oedema and maintain the stump in good shape.

If you can obtain a temporary or interim prosthesis, fit it immediately after the sutures have been removed. If the wound is healing primarily without any problems, you can even start using an interim prosthesis even a few days before suture removal.

Usually a temporary prosthesis is not manufactured from expensive material because it does not last very long (approximately 2months).
It permits amputees to leave hospital walking even before the stump has acquired its final shape, and is ready for permanent prosthesis fitting. The interim prosthesis should be worn for only short periods daily. The aim is to enhance the resilience of the stump gradually. An interim prosthesis may also be worn in case of delayed wound healing in a below-knee amputation with a long posterior flap, as the load then compresses the anterior wound, and also helps to reduce oedema.

N.B. Delayed wound healing should not delay mobilization of the patient, as long-time immobility impedes the rehabilitation process in the long run.

An ideal stump should be free of oedema, wounds or infection, contractures and muscle weakness; it should have no redundant muscle mass, no projecting spur of bone, be free from any tenderness, a fully mobile scar, neither adherent nor infolded, not exposed to pressure, without a stump neuroma.
Its length should not be too long or too short, with a good range of movement at the proximal joint.
These are the results of good wound aftercare and good physiotherapy. *Get patients to take care of their own bandaging!*

A 'permanent' prosthesis is not really permanent. It needs a regular follow-up and prosthetic maintenance. Child prostheses are expected to last up to 6months (depending on the child's growth). Adult prostheses are expected to last up to 3yrs (depending on the adult's activities).

BILATERAL AMPUTATION
Everyone with bilateral lower limb amputations needs a wheelchair but most bilateral below-knee amputees should become reasonably mobile if well fitted with prostheses.

You can fit bilateral above-knee amputees with shortened prostheses called 'stumpies' or 'stubbies' (60-3) They have a regular socket, no knee joint and no shank. These prostheses are most effective for amputees with short stumps. They are useful till the amputee gains confidence before managing 'normal length' prostheses.
They allow some degree of independence in the initial phase. Shortened prosthesis are much easier to make, they do not have jointed knees and only need sockets with simple boots on. You can keep them in place with cords over the shoulder.

'STUMPIES' FOR BILATERAL ABOVE-KNEE AMPUTATIONS

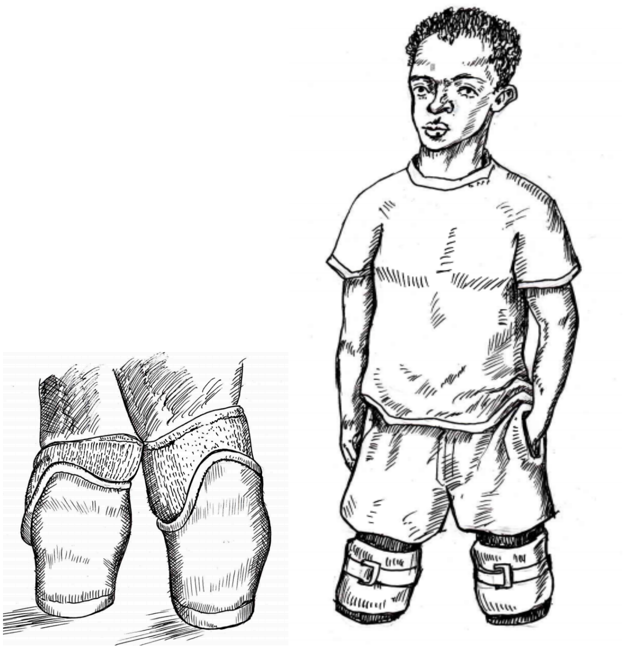

Fig. 60-3: 'STUMPIES' FOR BILATERAL ABOVE-KNEE AMPUTEES. These may be for temporary or permanent use

PRINCIPLES OF PROSTHETIC TECHNOLOGY
An important distinction is between the interim & the permanent prosthesis.

Prostheses are of 2 designs: shell & modular. In the former, the wall of the prosthesis assumes both load-bearing and shaping functions. It is made with thick-walled fittings made of wood or hard foam. Its disadvantage exists in this hard outer surface and the lack of adjustment possible in axis, length and fit.

N.B. The best prostheses are made by amputees themselves!

In the past 30yrs, the modular design has become standard. It imitates the physics of the human skeleton in its tubular skeletal construction. Its interchangeable load-bearing elements can be assembled easily and quickly. This allows axis and length corrections without much effort. It is possible to mould the foam shell also for better cosmesis.

In LMICs, the modular polypropylene system developed by the Red Cross is readily available. Polypropylene waste residues produced during production can be recycled and used again, which makes this system very economical.

But there are also other, simpler modern prosthesis costing about US$30, such as those developed by BMVSS Jaipur foot (35-23), which a mechanic can mend (www.jaipurfoot.org).

In addition, there are the traditional prosthesis, such as a pylon, a peg leg, or elephant boot. When well made these last longer than any of the others, and are better than a modern prosthesis for working in paddy fields.

THE VARIOUS TYPES OF PROSTHESES FOR LOWER LIMB AMPUTATION

HIP DISARTICULATION PROSTHESES
It is rare to be able to get any hip disarticulation prosthesis. Discuss this with your local orthopaedic technician or regional centre.

ABOVE-KNEE PROSTHESIS
N.B. If possible, perform a knee disarticulation rather than an above-knee amputation, especially in children.
There are also different types of prostheses: most are held in place by suction or auxiliary suspension such as a pelvic or Silesian belt.

PELVIC & SILESIAN BELTS

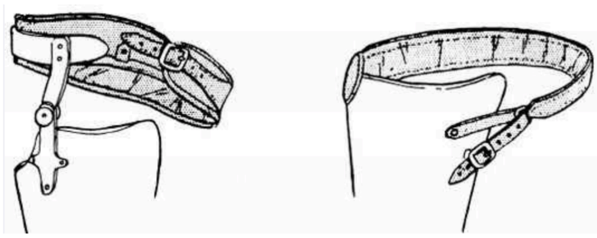

Fig. 60-4 PELVIC & SILESIAN BELTS to hold above-knee prostheses. *After Wilson AB Jr: Limb Prosthetics, New York, Demos, 6th ed, 1989*

These are made of leather, cotton or nylon webbing. The belt is worn around the waist above the iliac crest and is attached to the lateral and anterior surfaces of the prosthesis (60-4). Amputees must learn to tighten the belt sufficiently to prevent the stump moving up & down inside the prosthesis.

However, excessive tightening, especially if done with inadequate weight-bearing through the prosthesis, can rotate the socket internally and produce uncomfortable pressure on the groin or the anterior superior iliac spine. A permanent prosthesis may use Silesian suspension alone or in combination with suction to improve suspension and limit rotation (60-4).

A suction socket achieves adhesion by creating a vacuum between the stump and the prosthesis. As the amputee puts on the prosthesis, air is expelled from the socket through a one-way valve.

The negative pressure around the stump holds the prosthesis in place until the user releases it by opening the valve. With this type of adhesion, control of the prosthesis is very efficient.

Therefore, and whenever the stump conditions allow (*e.g.* distal end contact), technicians should advocate the use of adhesion devices. For initial fittings and when the stump volume alters, it is best that you secure the socket adhesion with a pelvic belt.

ABOVE_KNEE PROSTHESIS

Fig. 60-5 ABOVE-KNEE PROSTHESIS. This is held in place by suction & an auxiliary suspension Silesian belt.
After https://musculoskeletalkey.com/transfemoral-prostheses/

AMPUTATION ACCORDING TO GOTTSCHALK (GRADE 3.3)

For very short transfemoral amputations, when the adductor longus loses its attachment and the adductor brevis cannot resist the tension and forces of the abductors, the stump tends to turn into abduction, flexion and external rotation.
If you can, fix the *adductor magnus* laterally to the femoral shaft and the *quadriceps* to the dorsal end of the femur with strong transosseous sutures. This prevents abduction and flexion of the stump.

EFFECTS OF FEMORAL STUMP LENGTH

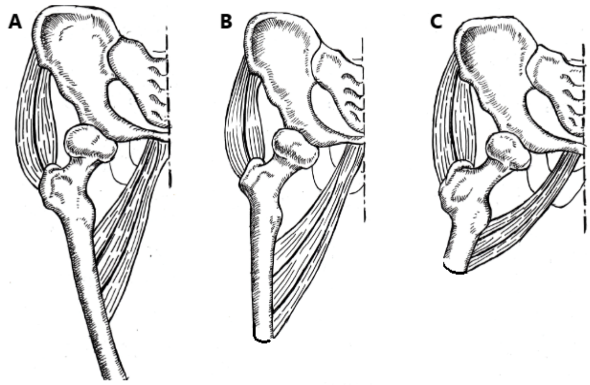

Fig. 60-6 EFFECTS OF FEMORAL STUMP LENGTH. A, the longer the femoral stump (distal $^1/_3$), the less energy consumption, as the leverage is best, with better muscular balance & preservation of adductor strength. B, medium-length stump (middle $^1/_3$) gives adductors reduced strength, with increased flexion & abduction. C, a short stump (proximal $^1/_3$) causes severe imbalance with the stump flexed & abducted and needs great energy expenditure; also prosthetic fitting is very difficult.

KNEE DISARTICULATION PROSTHESES
The features of a stump after knee disarticulation are a long, very stable, strong lever arm with end load capacity and with a much lower muscle imbalance than classic thigh stumps. Knee disarticulation gives a full end-bearing stump.

Knee disarticulation prostheses are relatively simple but efficient devices. The full weight is borne on the intercondylar fossa and provides almost ideal proprioception. The long lever arm provides excellent control of the prosthesis. It is usually worn with a soft socket (inner liner), which adheres to the stump through supracondylar suspension. To make the prosthesis easier to put on, the socket is usually fitted with an opening panel. Depending on the knee component used, the functionality and cosmetic appearance of the knee disarticulation is often poor. The position of the disarticulated knee usually does not match the unamputated knee. Though this may seem a big difficulty, in practice, it is not so. However, the proximal segment of the prosthetic leg may be too long when sitting, leaving the distal part dangling off a chair.

BELOW-KNEE PROSTHESES
Various types of below knee prostheses in both shell or modular design exist. The socket is held in place by (1) suspension or thigh corset, or (2) adhesion with a silicone liner or knee sleeves, or suction with a valve.

The most common types of sockets in LMICs are:
(1) patellar-tendon-bearing,
(2) supracondylar,
(3) supracondylar-suprapatellar.
Some of these prostheses may be re-inforced by a fork strap and cuff or a thigh corset.

EFFECTS OF TIBIAL STUMP LENGTH

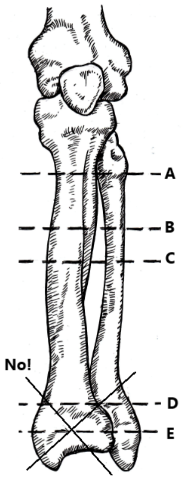

Fig 60-7 EFFECTS OF BELOW-KNEE AMPUTATION LENGTHS. The ideal site is 2-14cm distal to the tibial tuberosity. In very tall patients it might be ≤18cm. The longer the stump, the better the lever. A, a very short stump (the level of the tibial tubercle). B,C the most adequate length with the best muscle action. D, a common error is to amputate in the lower ⅓. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

The lower leg stump is not completely end- bearing. This means that most of the load needs to be absorbed by the complete stump surface and only partially by the end of the stump. The prosthesis shaft must therefore encompass the entire stump with the best possible fitting.

The minimum length for a tibial stump is 5cm, the ideal length is 15cm. A very short below-knee amputation (*e.g.* at the level of the tibial tubercle) should have the fibula removed (35.7), otherwise this will swing out and cause pain. A very short stump does not give adequate control or mobility.

FOOT PROSTHESES
There are many beneficial aspects of a Chopart or Syme´s amputation over a lower leg amputation, such as the long lever, the lower energy consumption, and the full distal end contact and full weight-bearing which give an ideal floor proprioception. For short distances (such as in and around the house), the patient can even walk without a prosthesis.

However, because of the unique aspects of the ankle-joint disarticulation, Symes prostheses are challenging to manufacture. So before planning such, it is wise to consult your local orthopaedic technician.

To relieve pressure on sensitive stump ends and because of the short distance to the ground, a special foot has to be used. Prosthetic adhesion occurs through supramaleolar suspension.

PARTIAL FOOT PROSTHESIS
Not everyone needs a prosthesis after partial foot amputation. But the shorter a foot stump is, the more will be the benefit. The main function of partial foot prostheses is the restoration of ground support surface as well as the forefoot lever.
For hindfoot amputations, use prostheses with soft sockets having an inner liner.

Fitting options may include: (1) orthopaedic shoes, (2) custom-made insoles with a toe filler, (3) custom-made or prefabricated ankle-foot orthoses with a toe filler, (4) free ankle-foot prosthesis and (5) cross-ankle foot prosthesis.

ARM PROSTHESES
An arm prosthesis is rarely available, and may be of little use. Unlike lower limb prostheses, which are remarkably efficient at enabling an amputee to walk, even the most sophisticated upper limb prosthesis is a very poor substitute for the human hand and can at best serve as a basic holding device. So, you should discuss this issue with the patient in order to avoid disappointment or even irritation. *N.B. Every cm in the arm counts!*

Bilateral upper limb amputees are of course completely reliant on their prostheses, and this will pose a great challenge.
A unilateral upper limb amputee will normally be able to carry out most daily activities with only one hand. Most will only tolerate a prosthesis if it gives an advantage over not wearing one. This advantage may be functional, *e.g.* using tools or driving a vehicle, or it may be cosmetic.

They generally have a PVC or silicone cover which is usually available in many different color shadings.
Functional prostheses are usually powered by the patient's own body movements. Thus, for example, moving the shoulder in a certain way will pull on a cable and cause it to open, close, or bend (60-8). These prostheses are usually unsuitable for fine precision activities or writing. Most prostheses work with a single hook, some even have a mechanical hand. But you should be able to attach any kind of tool to the prosthesis, such as a sickle.

FUNCTIONAL ARM PROSTHESES

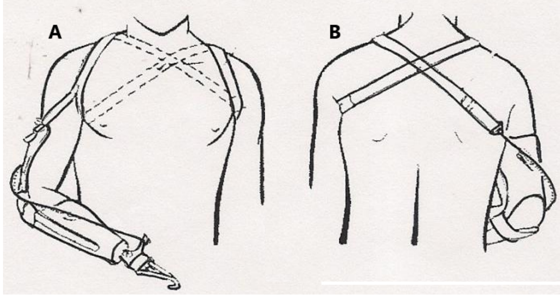

Fig**. 60-8 FUNCTIONAL ARM PROSTHESES. These are difficult to get, maintain and control. This type shows control by movements of the opposite shoulder using cables.** *After http://www.upperlimbprosthetics.info/index.php?*

Other devices may help a unilateral upper limb amputee. With a simple opposition plate (60-9), a patient with an amputated thumb may hold objects. It consistS of a metal plate attached to a leather or plastic socket over the hand or, in the case of a weakened wrist, over the wrist joint. This simple prosthesis is worn when needed.

THUMB OPPOSITION PLATE

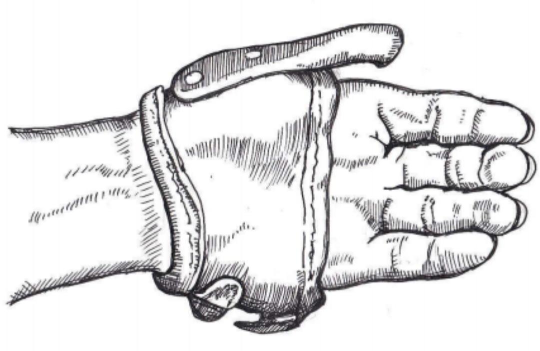

Fig 60-9 SIMPLE OPPOSITION PLATE. This allows a patient to hold objects. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

60.6 Anti-personnel landmine amputation

INTRODUCTION

Anti-personnel mines (APM) are a specific type of explosive device with special clinical effects. There are 2 types of APM: blast and fragmentation mines. Fragmentation mines cause wounds the same as described in 46.15 and are set off by a person hitting a tripwire. A blast mine detonates when someone steps on it (pressure mine) or handles one and constitutes a very localised explosion, causing massive destruction of soft tissue and bones. Stepping on an APM causes a traumatic amputation, whose level depends on the amount of explosive material and the size of the body of the victim, child or adult. Handling a mine will cause amputation of the fingers or hand and injuries to the face and chest in survivors. Infection is the great danger in all survivors of APM! *Apply the rules of septic surgery!*

It is a common mistake to underestimate the soft tissue damage. A blast mine creates an 'umbrella effect', propelling the tissues upwards and outwards. and then downwards. The deeper muscle layers (*soleus*) suffer more damage than the more superficial ones (*gastrocnemius*). There is a much bigger soft tissue injury than you would expect from an initial evaluation. In addition, the explosion pushes dirt, grass and leaves, and stones up into the injured tissues. To get a good idea of the level for surgical amputation, grab hold of the edges of the wound and pull them up to look into the depths of the amputated limb.

Your objective is to change a dirty and contaminated traumatic amputation into a clean surgical one that will heal as quickly as possible without becoming infected.

UMBRELLA EFFECT OF A LANDMINE

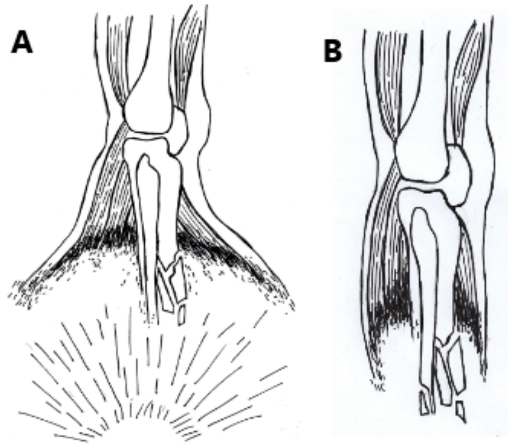

Fig 60-10: UMBRELLA EFFECT: A, note the skin and muscles being pushed up and out, & then collapse inwards (B). The deeper tissue planes suffer greater damage than the more superficial ones. *After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013*

SEPSIS IS THE GREAT DANGER IN SURVIVORS

Remember that a victim often has multiple injuries; fragments even from a blast mine can penetrate the perineum or abdomen, and the blast effect can thrombose vessels high up the limb or cause lung injury. Always examine the complete patient according to the standard ABCDE algorithm (41.1).

Make sure you have counselled the patient or the decision-makers properly (*e.g.* the military chief) if the patient is unconscious and obtained consent for the amputation. Always try to get consent also for a higher amputation, as the soft tissue injury in war wounds is often worse than you first think.

TWO-STEP SURGICAL PROCEDURE

Never close an amputation stump in war wounded in the initial operation! The risk of infection and septicaemia is very high. Leave the stump open, cover it with a bulky absorbent dressing and leave it untouched until DPC after approximately 4-5 days (60.1).

61 Shoulder & upper arm injury

61.1 Introduction

Most shoulder injuries are caused by falling on the point of the shoulder, or on the outstretched hand. Dislocation can occur at either end of the clavicle, and at the shoulder; the humerus, clavicle or scapula can fracture. The brachial plexus may be damaged, and axillary vessels ruptured.

SHOULDER EXAMINATION
As in the elbow, first check the radial pulse, and the sensory territories of the median nerve (flexor surface of thumb, index & middle fingers), ulnar nerve (flexor side of little finger) & radial nerve (extensor side of thumb, index & middle fingers). Check the distal pulses, and especially in clavicular injuries, exclude a pneumothorax (43.1)

LOOK
Check that the ends of the clavicle are in similar position on both sides: (abnormal prominence suggests a dislocation). Check for signs of an anterior shoulder dislocation (or circumflex nerve injury causing wasting of the *deltoid*:
(1) the shoulder outline is flattened,
(2) the normal roundness of the *deltoid* is lost,
(3) the anterior axillary fold is lowered,
(4) the delto-pectoral groove is swollen,
(5) the elbow is displaced away from the body, or
(6) the humeral axis points towards the middle of the clavicle (61-4).
Check if the shoulder is grossly swollen, implying a humeral neck fracture, perhaps with dislocation of its head. You may then not see the flattening of the shoulder outline. Check for swelling of the subacromial bursa.

FEEL
Stand behind the patient and feel the spine of the scapula, and the entire subcutaneous surface of the clavicle, and the joints at either end. Feel for any swelling for tenderness. Palpate the axilla to feel a dislocated humeral head in its abnormal position, and feel for the presence of free fluid. Check if the tips of the acromion & coracoid, and the greater tuberosity of the humerus are in their normal places.

MOVE
Check for any abnormal movement between the clavicle and the acromion.
Flex the arm to 90° and rest it on your forearm. Gently move the whole arm up and down. Provided the clavicle is intact, abnormal mobility or crepitus in the shoulder suggests that there is a fracture of the scapular neck.
Now stand behind the patient. Put one hand round in front and hold the outer end of the clavicle firmly. With your other hand hold the tip of the scapula still, so you can be sure that any movements made are those of the shoulder, not of the scapula moving over the chest.
The shoulder should be able to abduct to 90° before the scapula starts to move.
Holding the scapula, with the forearm flexed, note how far will the elbow come across to the midline in front of the chest.
Check external rotation with the forearm flexed, so that it reaches the coronal plane. Rotate it internally to scratch the small of the back.
If placing the hand onto the opposite shoulder is possible, there is no serious shoulder injury.

UPPER ARM EXAMINATION
Palpate the lower half of the humerus for signs of a fracture. This is more difficult in its upper half, which is hidden by muscles.
Support the forearm and gently abduct the arm. Pain, tenderness, angulation, or crepitus, indicate a fracture of the shaft.
On both sides, measure the distance from the tip of the acromion to the lateral epicondyle. Shortening indicates a fracture. This test is particularly useful if you suspect it is impacted.

RADIOGRAPHS
N.B. The clavicle rarely itself needs imaging but without a radiograph, these fractures are difficult to distinguish from subluxation of the acromio-clavicular joint (61.6).

For an acromio-clavicular joint injury, ask for an AP distracted view in which the patient carries a weight.

For the shoulder & humeral shaft, get an AP & lateral view, but if you suspect a posterior dislocation, try to get for an axillary view, which may be difficult, if the arm is held close to the side.

ELBOW AND FINGER EXERCISES MUST START IMMEDIATELY

61.2 Brachial plexus injury

This severe injury can result from a high fall, or typically by avulsion in a motorcycle collision, or in prone ventilation of patients. Total avulsion of all 3 cords results in a completely paralysed insensitive arm**,** but the injury may be partial. Injury to the long thoracic nerve causes paralysis of *serratus anterior* and ‘winging’ of the scapula.

If the nerve roots are stretched rather than torn, the function of the rhomboids (which have a nerve supply straight from C5) will be preserved. So test these by seeing if the patient can pull the shoulder blades together.

If the rhomboids are intact, support the arm in a sling, protect it from injury, such as cuts, bruises, and burns, until its sensation returns. Make sure that passive exercises of the shoulder, elbow, and hand continue for 6-12 months or longer, because sensation & strength may take long to recover.

If the injury is extensive, recovery is unlikely unless the nerves can be repaired.

N.B. A serious brachial plexus avulsion may be associated with an axillary artery injury! (49.4c)

61.3 Casts & slings

SLINGS FOR AN INJURED ARM OR HAND

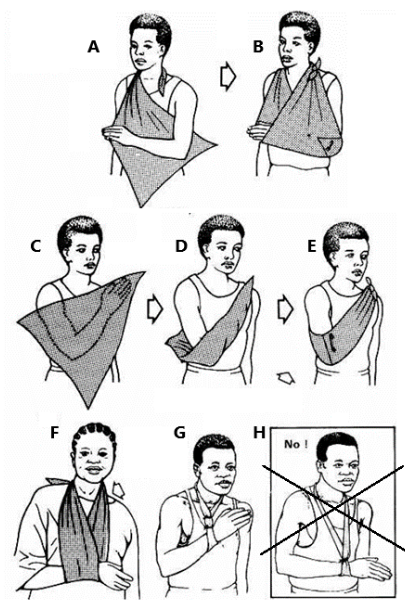

Fig. 61-1 SLINGS FOR AN INJURED ARM OR HAND. A, tie cloth as shown. B, fold it in a triangular shape to make a sling. C, make a St John sling. D, fold it around the forearm- E, raise the hand with it. F, in this sling, the elbow hangs free, allowing weight of the upper to distract humeral shaft fragments. G, a collar & cuff for a supracondylar fracture. H, a narrow bandage sling will cause a sore at the wrist.

Casts are seldom needed for elbow injuries and almost never for shoulder & upper arm injuries. The slings (61-1) are important for ambulant patients with injured arms. An injured or infected arm which hangs down is painful, and any sling makes it much more comfortable and allows it to be exercised when necessary.

Many hospitals supply plaster casts and sell or hire out crutches. They should do the same for slings. *An important principle in all shoulder injuries is for the patient to start exercising the elbow and fingers as soon as possible*. Even in a sling or with a brace, it is possible to move all the non-injured joints. Encourage regular isometric muscle strengthening symmetrically on the injured and the sound body side 6 times per day for 10sec. Also encourage pendulum exercises for the shoulder to prevent it stiffening (61-2).

INDICATIONS
(1) All clavicular fractures
(2) Most sterno-clavicular and acromio-clavicular dislocations.
(3) Scapular fractures.
(4) Reduced shoulder dislocation.
(5) Axillary nerve injury.
(6) Minimally displaced humeral head fractures

N.B. There is a fundamental difference between a sling and a collar & cuff, needed for a supracondylar fracture (62.4).

A loop of bandage (61-1E) *is not suitable* because it is uncomfortable and constricting on wrist, forearm and neck.

METHOD
A sling will relieve pain. Make it with a triangular bandage, and rest the arm in it for 2-3wks, or until the fracture site is no longer tender. Start elbow and finger exercises immediately. Begin shoulder exercises in 2-3days. If the clavicle is fractured, bracing the shoulders back will help to hold it to length. Encourage movements of the arm as soon as possible.

Shoulder exercises are in 2 groups; perform early passive exercises smoothly and rhythmically with gradually increasing amplitude. Give the instructions (61-2A-E). Perform late active exercises more vigorously with these instructions: (61-2F-I).

Don't leave a sling on too long. Remove it at a set time, as some patients develop a 'sling neurosis' and are unwilling to part with it.

SHOULDER EXERCISES

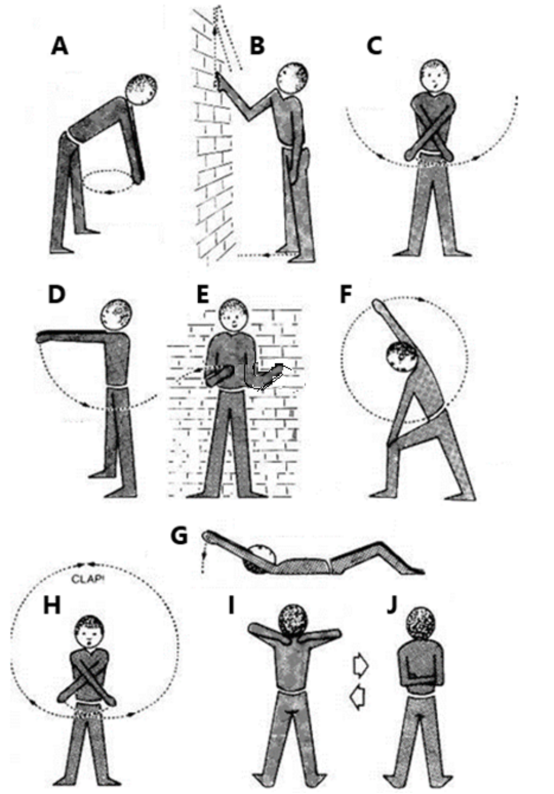

Fig. 61-2 SHOULDER EXERCISES in 2 groups. Early passive exercises: A, stoop forwards and dangle your arm in a circle (pendulum movements). B, put your arm against a wall. With the arm straight, move steadily closer to the wall. C, stand astride with your arms crossed and swing them sideways and upwards. D, stand astride and swing your arms forwards and upwards. E, lean against a wall with your arms bent, turn your arms to touch the backs of your hands against the wall (shown in left arm). Later active exercises: F, put one leg in front of the other, put your hand on your knee, and swing your arm. G, lie on your back with your arm stretched and press downwards to touch the floor. H, stand astride with your arms crossed, swing your arms sideways and upwards, and clap them above your head. I,J stand astride; alternately touch the back of your neck and fold your hands behind your back. *Kindly contributed by Michael Wood.*

61.4 Clavicular (collarbone) fracture

If an adult breaks the clavicular middle $^1/_3$, the *sternomastoid* muscle pulls the medial fragment up, while the weight of the arm pulls the lateral part down. Often there is a 3rd middle fragment. If the fracture is lateral to the coraco-clavicular ligament, the medial end of the clavicle is little displaced, because these ligaments hold it. If it breaks medial to the ligaments, its outer end may appear to be displaced backwards and upwards, so that it forms a lump under the skin.

CLAVICULAR MIDDLE $^1/_3$ FRACTURE

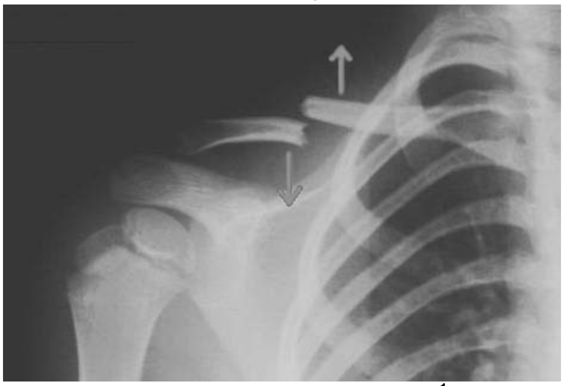

Fig. 61-3 FRACTURE OF THE MIDDLE $^1/_3$ OF THE CLAVICLE. If an adult breaks the middle $^1/_3$ of the clavicle, the *sternomastoid* muscle pulls the medial fragment upwards, while the weight of the arm pulls the lateral part down.

Treat all fractures of the clavicle with a sling and active movements (61.3). For very medial fractures, use a 'rucksack' brace. *N.B. Some say this is of no benefit! Don't forget to wash under the armpits!*

RUCKSACK BRACE

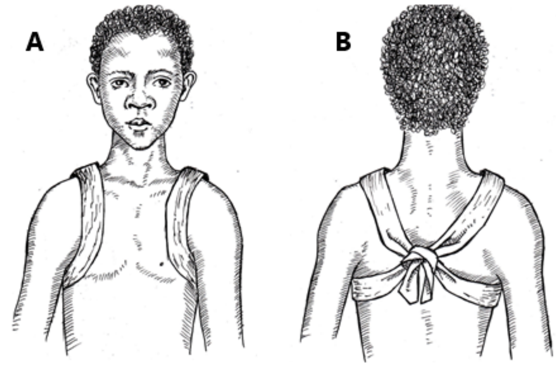

Fig. 61-4 THE RUCKSACK BRACE for a very lateral clavicle fracture. A, anterior view. B, posterior view. Tie the *straps tightly, but not too tight!. N.B. This may cause skin ulceration, so beware!*

The clavicle almost always unites with no loss of function, and if there is a lump, this will usually remould and disappear in an adult.

Rarely there may be a pneumothorax (43.1) associated; this may present with subcutaneous emphysema and is often asymptomatic. Take follow-up chest radiographs if you suspect this.

If the skin is severely tented, and at risk of perforation, administer a GA and press on the clavicle to reduce the fracture whilst an assistant distracts the shoulder.

If the skin is broken over the fracture, clean the skin & exposed bone with antiseptic, administer prophylactic antibiotics, and reduce the fracture as before. *Don't be tempted to fix the fracture internally.*

61.5 Sterno-clavicular dislocation

(a) An anterior dislocation makes the sterno-clavicular joint swollen and tender. This distinguishes it from a fracture of the medial end of the clavicle, where tenderness is immediately lateral to the joint. Reduction is usually unnecessary, so encourage use of the arm (61.1).

(b) A posterior dislocation is rare and is usually associated with a severe chest injury, in which several ribs may be broken.
The dislocated end of the clavicle obstructs superior mediastinal structures, causing severe pain, a tight feeling in the throat, difficulty in swallowing, and distended neck veins.

Place a sandbag between the scapulae, and press the shoulders back. If this fails to reduce the dislocation, clamp the proximal end of the clavicle with padded bone forceps, and, whilst an assistant abducts & pulls on the upper arm, twist the clavicle forwards and upwards. If this still fails to relieve pressure on the superior mediastinum, proceed to open reduction.

REDUCTION OF A POSTERIOR STERNO-CLAVICULAR DISLOCATION

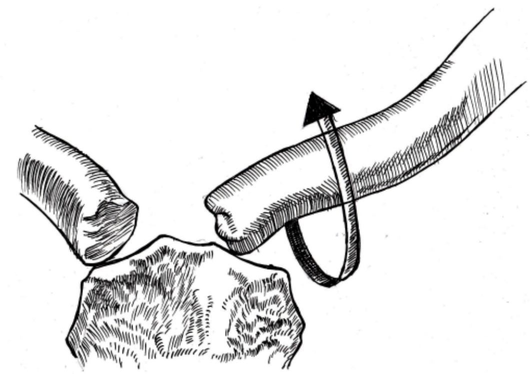

Fig. 61-5 REDUCING A POSTERIOR STERNO-CLAVICULAR DISLOCATION. While as assistant abducts the arm, grasp the medial end of the clavicle with bone forceps and twist it forwards & upwards. *After Iwai T, Tanaka K, Okubo M. Closed reduction of a posterior sternoclavicular joint dislocation. Trauma Case Rep 2018; 17:1-4.*

FIXATION OF A POSTERIOR STERNO-CLAVICULAR DISLICATION (GRADE 3.3)
Put a solid roll or sandbag between the scapulae so that the shoulders and the clavicles fall backwards.

Remember that the internal thoracic arteries & veins run along the lateral sternal rim posteriorly 2mm from the bone.
Make a 5cm horizontal incision over the sterno-clavicular joint and dissect sharply to expose the antero-medial surface of the clavicle and lateral upper border of the sternum.

Dissect bluntly with your finger on the posterior of clavicle & sternum, protect the underlying structures behind with a blunt-edged solid flat instrument (such as a bone spreader). Drill a hole through the distal clavicle and pass the wire on a needle through the manubrium from posterior to anterior. Tie the wire in a figure of 8 to reduce and fix the dislocation (61-6).

FIXATION OF A POSTERIOR STERNO-CLAVICULAR DISLOCATION

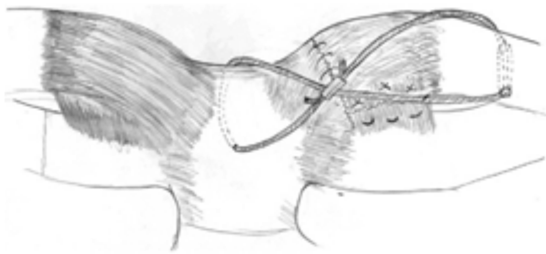

Fig. 61-6 FIXING A POSTERIOR STERNO-CLAVICULAR DISLOCATION. Pass a steel wire on a needle through the manubrium from behind to forward, and drill a hole in the medial $^1/_3$ of the clavicle. Pass the wire through this and tie a figure of 8 loop. ***Beware of the vessels behind the sternum, which are likely to be and so be very careful when using sharp instruments!!*** *After Janson JT, Rossouw GJ. A New Technique for Repair of a Dislocated Sternoclavicular Joint Using a Sternal Tension Cable System. Ann Thorac Surg 2013;95 (2):e53-5.*

61.6 Acromio-clavicular dislocation

There are 2 varieties of this injury, depending on whether the ligaments joining the clavicle to the scapula are partly or completely torn.

ACROMIO-CLAVICULAR DISLOCATION

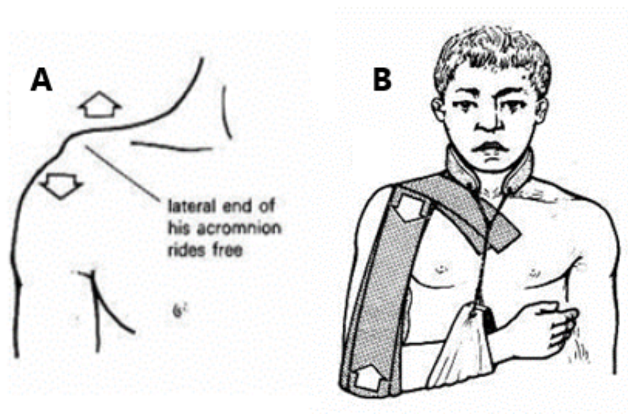

Fig. 61-7 ACROMIO-CLAVICULAR DISLOCATION. A, shows the characteristic deformity of the shoulder. B, shows the method of strapping it.

If only the ligaments between the clavicle & acromion are torn, those joining the clavicle to the coracoid can prevent severe displacement. The clavicle is stable and you cannot move it backwards or forwards.

If all the ligaments joining the clavicle to the scapula are torn, the weight of the arm pulls the shoulder downwards, while the *sternomastoid* muscle pulls the clavicle upwards (61-3A), as in a middle $^{1}/_{3}$ clavicular fracture (61.4).

The joint is so wildly unstable that the lateral end of the clavicle rides free, high above the acromion, and you can easily move it backwards and forwards. Get a radiograph standing. Holding a 2kg weight to distract the acromio-clavicular joint may reduce it spontaneously.

Treat a mild dislocation with a sling and active movements (61.3). For a major dislocation, stick pads to the acromion and the elbow, and reduce the dislocation by binding them together with adhesive strapping; then put the arm in a sling, (61-7B).
Don't refer these injuries for surgical repair.

61.7 Scapular fracture

The scapula can break in several ways. Direct blows occasionally break it into several pieces; its coracoid process can fracture, either with no displacement, or with downward displacement. Its neck can fracture, so that its glenoid articulation breaks off and is displaced. This is the most common scapular injury, and provided it does not involve the joint surface, it needs only symptomatic treatment. The acromion may fracture with only a crack, or with severe fragmentation and displacement. These fractures cause much pain and bleeding and are difficult to diagnose without sophisticated radiographs. The clavicle, the ribs, or the spine may be broken at the same time.
The scapula is splinted on both sides by muscle, so treatment is easy. Use a sling and encourage movements of the shoulder, elbow, and fingers actively and early.

61.8 Anterior shoulder dislocation

Dislocation is the most common shoulder injury. It is usually anterior and only occasionally posterior. In an anterior dislocation the humeral head passes forwards and downwards to lie in front of the scapula. In the common subcoracoid variety, the normal smooth curved outline of the shoulder is made angular (61-8). There is usually great pain, unless the dislocation is recurrent.

ANTERIOR SHOULDER DISLOCATION

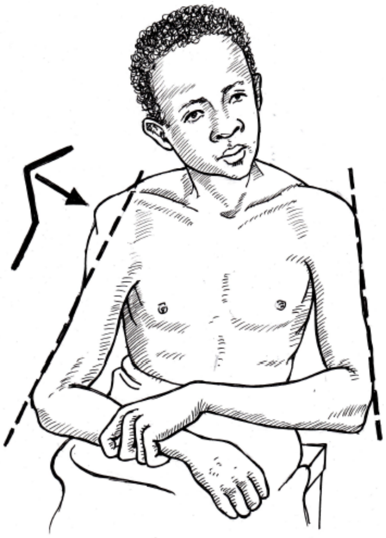

Fig. 61-8 ANTERIOR SHOULDER DISLOCATION SIGNS. Note the characteristic double angle profile of the shoulder, and the interrupted line of the upper arm...

RADIOGRAPHS OF AN ANTERIOR SHOULDER DISLOCATION

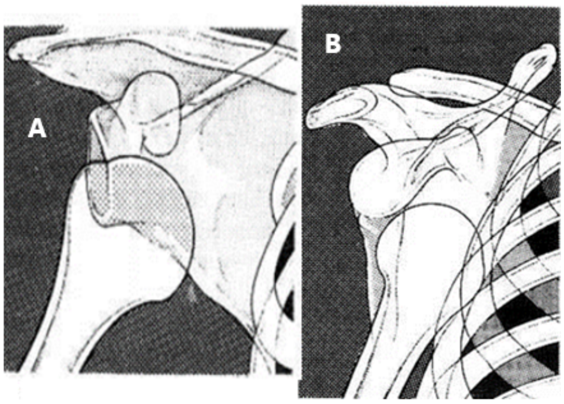

Fig. 61-9 RADIOGRAPHS OF AN ANTERIOR SHOULDER DISLOCATION. A. *always take an AP and* B, *an oblique view* before you try to reduce what might seem to be an ordinary dislocation. If you do this routinely, you will not miss a rare posterior dislocation. *N.B.* 25% of all acute dislocations are associated with a fracture, most commonly a fracture of the greater tuberosity.

This dislocation is often missed if loss of movement is not checked. Look for typical (61.1) signs. Although you can make the scapula move over the chest, you cannot make the humerus move on the scapula.

If the shoulder is not too swollen, you may be able to feel the displaced head of the humerus below the coracoid process.

You must differentiate a simple dislocation from a humeral neck fracture or a combination of the two. Both are less common (seen in 25%) but their treatment differs, and if you miss a fracture (61.12), the results may be disastrous.

So *always get AP and oblique radiographs* before trying to reduce what might seem to be an ordinary dislocation.

REDUCING A DISLOCATED SHOULDER

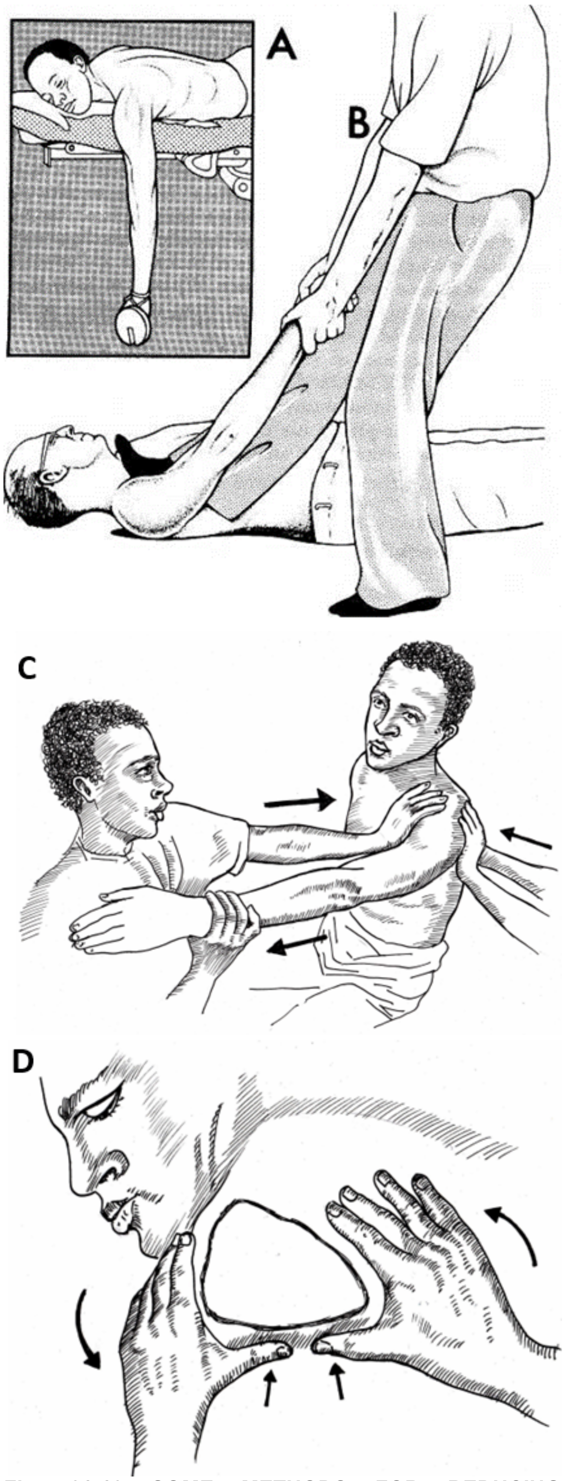

Fig. 61-10 SOME METHODS FOR REDUCING A DISLOCATED SHOULDER. A, Stimson method. B, Hippocratic method. C, scapular manipulation: pushing against the clavicle whilst. D, the scapula is rotated.

N.B. A, kindly contributed by Gerald Hankins. ***B,*** *The editor of the first edition is depicted lying on the floor; the foot belonged to co-author Peter Bewes!*

N.B. If you take an oblique view routinely, you will not miss a rare posterior dislocation (61.9). Although an oblique view is more difficult to take, it is easier to interpret than a lateral view.

Danger signs suggesting a humeral head fracture are:
(1) The elbow can touch the side.
(2) The humerus moves on the scapula.
(3) There is much swelling.

LACK OF SHOULDER MOVEMENT & AN ABNORMAL CONTOUR ARE CRITICAL SIGNS OF A DISLOCATED SHOULDER

Reduce the dislocation immediately if there is a neurological deficit. If the injury is recent, reduction is usually easy, and may only need mild sedation or analgesia.

Make sure you have seen the radiograph yourself and have excluded a fracture. Check for nerve injury (48.1), and feel for the radial pulse.

ANAESTHESIA
If the injury is recent, no anaesthetic may be necessary. Good relaxation is required later, or if the patient is anxious, very tense or muscular. Try simple methods first, especially if the dislocation is very recent, with analgesia.

METHODS FOR A RECENT ANTERIOR DISLOCATION (GRADE 1.3)

(a) Stimson method
With the patient prone and the arm hanging over the edge of the bed, tie a 2kg weight to the wrist (61-10B). Leave him like this for 20-30mins whereupon you may find the dislocation has reduced spontaneously. If it has not, flex the elbow and externally rotate the arm, whilst pulling on it.

(b) Scapular manipulation
Face the seated patient, hold the wrist with the arm extended forwards and push against the clavicle, whilst an assistant grasps the scapula with 2 hands (61-10C) and rotates it anticlockwise (on the left) or clockwise (on the right). Some external rotation (holding the elbow at 90°) may help.

(c) Spaso technique
With the patient supine, hold the wrist & distal forearm and lift it vertically. Apply gentle traction and external rotation.

(d) Milch technique
With the patient supine, gently abduct the arm straight, holding the elbow, till you reach above the head.
Then gently add external rotation whilst pressing on the humeral head with your thumb or fingers.

(e) Hippocratic method
Lie the patient on the floor. Place stockinged foot in the axilla, lean backwards, and pull on the abducted arm (61-10D). Pull gently and steadily for 5mins.
CAUTION ! *Don't exert excessive force:* you may injure the brachial plexus.

N.B. We don't recommend Kocher's method for reducing a dislocated shoulder because if you use it and are inexperienced, you may fracture the humeral neck.

If these don't reduce the dislocation, try again using GA.

POSTOPERATIVE CARE (both methods)
As soon as the patient is awake ask if abducting the arm gently is possible. Check that you have not injured the axillary or musculocutaneous nerves during reduction. Examine to make sure that you have reduced the dislocation, and take a check radiograph.
Put the arm in a sling for 3wks, and start pendulum exercises in the sling immediately. Then start most of the other early exercises. *Avoid abduction and external rotation exercises*, because they may re-dislocate the shoulder.

DIFFICULTIES WITH DISLOCATED SHOULDERS
If you suspect that there is a dislocation but you have no radiographs, under GA, move the shoulder *very gently*: a dislocation may reduce spontaneously, and you are unlikely to cause harm.

If part of the greater tuberosity has broken off, it will probably return to its bed as you reduce the dislocation. If it fails to do so, and prevents abduction of the arm, see 61.10. You can easily see this on a shoulder radiograph: the external rotator muscles of the shoulder pull a fragment of bone away from the head of the humerus as the shoulder dislocates.

If the dislocation recurs >6wks, especially in a young person, it will probably continue to recur subsequently; an operative repair is necessary, because the *labrum* has separated from the glenoid ring. Repeated dislocation makes the shoulder ever more unstable, so it may even dislocate on sneezing or turning over in bed.

If the humeral head drops out of the glenoid because the axillary nerve is damaged, support the arm in a sling for several months until the nerve recovers.
Tighten the sling regularly so as to keep the contour of the shoulder normal, and show a companion how to do the same. *This is not the same as recurrent dislocation of the shoulder*. Suspect it if there is no sensation over the *deltoid*, and is abduction of the arm is totally impossible.

If the shoulder remains stiff after a dislocation, explain that movements will eventually return. Active exercises are safer and more effective than passive ones. Avoid excessive force, because this will only make the stiffness worse. The shoulder is more likely to become stiff if early movements are missed out.

If the brachial plexus is injured, it may take a year to recover. Meanwhile, put the shoulder through a safe range of movements to prevent contractures. Some nerve injury is common after a dislocation, and may involve any of the three cords of the brachial plexus. The axillary and musculocutaneous nerves are most commonly involved.

If the axilla rapidly swells after a shoulder injury, the axillary artery has been torn. This rare event may follow a fracture dislocation, and can occur when you are reducing a fracture dislocation, particularly an old one in an aged patient with calcified arteries, or if you use greater force than the original injury.
The torn artery bleeds and forms a large haematoma round the shoulder, which can cause exsanguination. Apply firm axillary pressure and prepare to ligate (or repair) the torn artery (49-8) or the subclavian (49-7).

If the circulation in the arm is occluded after a reduction, the blood supply was probably impaired beforehand. Check the distal blood supply with a Doppler ultrasound. This may need surgery or anticoagulation.

If a patient with a dislocated shoulder presents late, reduction becomes increasingly difficult and dangerous as time passes. Initially, every hour is important, but after 6wks, reduction may be impossible. *Using force may break the humeral neck, or tear the axillary vessels or nerves*. Especially if pressure on the structures in the axilla causes symptoms, an open procedure is indicated. Try to find an expert, as otherwise the result may not be good.

REDUCE ALL DISLOCATIONS
IMMEDIATELY

NO MOVEMENT OF THE SHOULDER AFTER AN INJURY MEANS A DISLOCATION

61.9 Posterior shoulder dislocation

If a patient has pain, swelling, and reduced movement after a shoulder injury, together with an apparently normal AP radiograph, suspect that there is a posterior dislocation, not just a contusion. Typically, the arm cannot move, and is locked in adduction and internal rotation.

POSTERIOR SHOULDER DISLOCATION

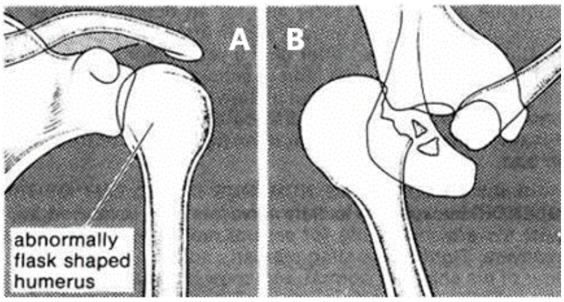

Fig. 61-11 POSTERIOR SHOULDER DISLOCATION ***This is often missed*** **because the AP view looks almost normal. A, the closeness of the head to the film does however make it look abnormally small and flask shaped. You will not miss a posterior dislocation if you always get an oblique or a lateral view of the shoulder. B, an axillary view, however, (if you can abduct the arm far enough from the side to get the tube into the axilla) shows the dislocation best.**

On an AP radiograph, the humeral head appears smaller and flask-shaped (61-11A).

METHODS FOR A RECENT POSTERIOR DISLOCATION (GRADE 1.4)

(1) Use GA. Try to put the shoulder through a normal range of movements, while pulling upwards on the humerus, with the arm above the head, and the elbow flexed to relax the biceps tendon. The dislocation will usually reduce promptly.
(2) Alternatively, flex the elbow, and exert traction in the long axis of the arm (61-12A). Ask an assistant to press downwards on the humeral head with the thumb (61-12B). Adduct the arm while still maintaining traction (61-2C). When the head reaches the glenoid cavity, rotate the arm externally (61-2D), and then gently rotate it internally (61-2E).
If this also fails, try to refer the patient.
If reduction is successful, put the arm in a sling for 3wks and encourage exercises as before.

DIFFICULTIES WITH A POSTERIOR SHOULDER DISLOCATION
If the dislocation is not painful, leave it as a partial arthrodesis. *Forceful reduction might well fracture the humerus!* Anterior open reduction is difficult, and needs an expert.

AN ALTERNATIVE METHOD FOR REDUCING A POSTERIOR DISLOCATION

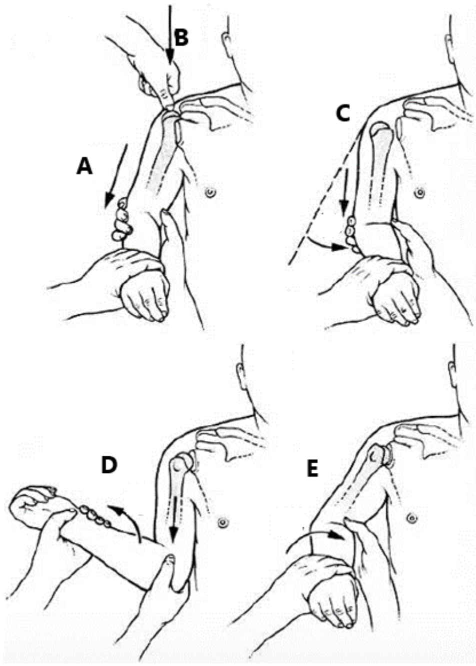

Fig- 61-12 AN ALTERNATIVE METHOD FOR REDUCING A POSTERIOR DISLOCATION. A-E follow instructions in the text. The axillary nerve may be injured, so support the arm in a sling to prevent the humerus dropping out of the glenoid. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

POSTERIOR SHOULDER DISLOCATIONS ARE OFTEN MISSED

61.10 Greater tuberosity fracture

The greater tuberosity of the humerus may be fractured by a direct blow, or it can be torn off at dislocation. Treatment depends on how far displaced the fragment is.

MINIMAL DISPLACEMENT Begin active shoulder, elbow, and finger movements immediately.

SIGNIFICANT DISPLACEMENT
REDUCTION (GRADE 1.4)
First try abducting the arm. This will cause the fragment to press against the underside of the acromion and may push it into place. Alternatively, press on it firmly whilst you lower the arm (61-13). If this fails, repeat it again after 2wks, when the fragments will have become 'sticky'.

GREATER TUBEROSITY FRACTURE.

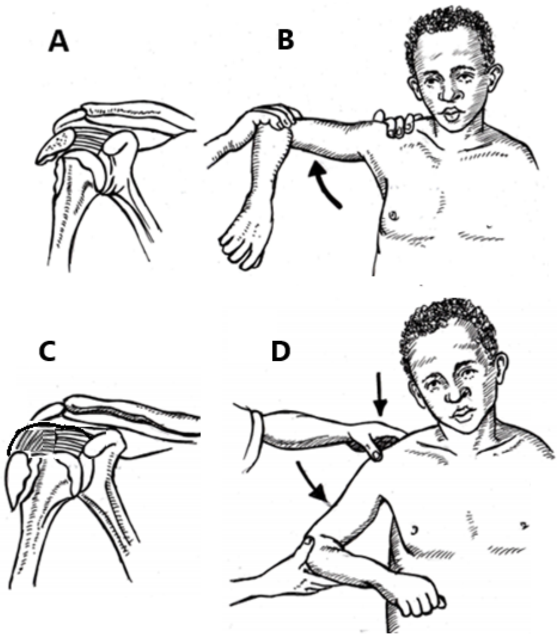

Fig. 61-13 GREATER TUBEROSITY FRACTURE. Infiltrate the fracture site with LA. A, the tuberosity detached. B, abducting the arm. C the tuberosity repositioned by D, pressing firmly on the fragment with your thumb while lowering the arm. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

If reduction fails, especially if there is >5mm dislocation, this is indication for an internal fixation.

FIXATION OF THE GREATER TUBEROSITY (GRADE 3.2)
Make a 5cm incision from the edge of the acromion down over the *deltoid* on the lateral aspect of the shoulder. Separate the muscle fibres by sharp and blunt dissection.
N.B. The axillary nerve lies >5cm distal to the acromion and is not at risk.

Dissect down directly onto the fracture site near the anatomical neck of the humerus. Palpate the dislocated fragment of the tuberosity and reduce manually or by means of a hook or forceps. Reduction may be easier if you move the arm into a half-abducted position. Press the fragment into its proper position and fix the *supraspinatus* insertion with a K-wire which you drive into the head 4cm deep and which you lead through the open wound. Bring a 2nd K-wire parallel to the 1st through the *infraspinatius*. Then close the wound.

Keep the arm in a sling and the K-wires *in situ* c.3wks. Continue pendulum exercises with the shoulder, & active exercises with forearm and hand

61.11 Humeral neck fracture

The surgical humeral neck is the region between the tuberosities, and is the site of the insertions of *pectoralis* & *teres major*. When it breaks the soft tissues hold the fragments together very satisfactorily, and provided there is some contact between them, they always unite. There is such a wide range of movement in the shoulder joint that the exact position of the fragments is unimportant. Even if the joint surfaces don't fit together perfectly, good function is still possible, *but only if the patient starts to move the shoulder early.* Most of these fractures need not be reduced. The only ones which you should reduce are those in which there is no contact between the broken surface of the neck & shaft.

The patient, who is typically an older woman, falls on her outstretched arm and injures her shoulder. Her osteoporotic humerus breaks across its neck. Sometimes, its head is comminuted.

HUMERAL NECK FRACTURE

Fig. 61-14 HUMERAL NECK FRACTURE. There is considerable displacement of the shaft. There is such a wide range of movement in the shoulder joint that the exact position of the fragments is unimportant.

In spite of her pain, she may be able to use her swollen, tender shoulder, so the diagnosis is often missed. Soon, she has severe bruising extending to her elbow. If the humeral head is impacted on the shaft, the fracture is more likely to heal with reasonable function. These fractures are less common in young adults, but when they do occur, they usually heal well.

Check the radial pulse and the axillary nerve function.

REDUCING A HUMERAL NECK FRACTURE

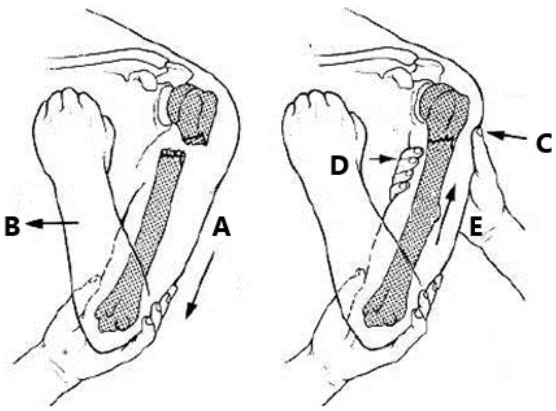

Fig. 61-15 REDUCING A HUMERAL NECK FRACTURE with wide separation or severe angulation. A, while still pulling, adduct the elbow across the chest and flex it in the frontal plane of the body. B, the combination of these movements will restore the humeral length. C, place your other hand in the axilla and press on the head with your thumb. D, pull the shaft outwards. E, after the fragments are aligned, release traction gradually, so that the fragments engaged. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

RADIOGRAPHS
Take 2 views at right angles. The fragments may be widely separated, but overlie one another in a single view.

IMPACTED FRACTURES
If you can move the arm through a reasonable range without causing severe pain, it is impacted. Begin active and assisted shoulder movements immediately.
Between these exercises, put the patient's arm in a sling for 4-6wks. Make sure that it supports the elbow, and so prevents disimpaction. *Avoid lifting heavy objects for 3months*.

UNIMPACTED FRACTURES
If there is no separation and angulation <90°, put the arm in a sling and use strong analgesia. Wait for 3wks before starting active shoulder exercises.

REDUCTION OF DISPLACED HUMERAL NECK FRACTURE (GRADE 1.5)

If there is wide separation or angulation >90°, under GA flex the elbow and manipulate the humerus so that fragments are in close contact, but *not necessarily in perfect position* (61-15A-E).

If the fracture is stable after reduction, put the arm in a collar and cuff. Keep it to the side for 3wks, then gradually begin progressive movements as pain lessens, starting with pendulum exercises and continuing with wall crawling exercises.

If the fracture is unstable after reduction, use forearm traction (62-4) for 2wks, then use a sling and arm dangling exercises.

If there is gross separation with the humeral shaft in the axilla, the axillary artery is in danger, so check the distal pulse first. *Reduction of the fracture may pull a spicule of bone out of the axillary artery and cause massive bleeding!* So, it is wise to reduce this fracture by an open method, which includes exposing the axillary artery (49.4c).

REDUCING A FRACTURE DISLOCATION OF THE HUMERAL NECK

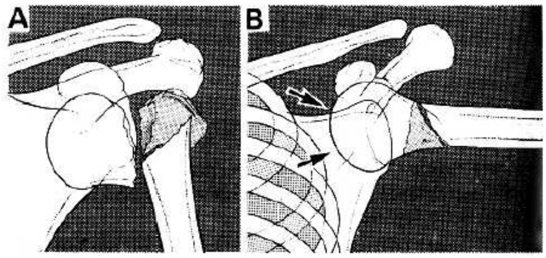

Fig. 61-16 REDUCING A FRACTURE DISLOCATION OF THE HUMERAL NECK. A, before reduction. B, during reduction. The arrows show where to push with your thumbs to return the humeral head back into the glenoid.

CONSCIENTIOUS EXERCISES WILL OFTEN RESTORE MOVEMENTS TO A STIFF SHOULDER

61.12 Shoulder dislocation with humeral neck fracture

In 25% of cases, a shoulder dislocation is associated with a humeral neck fracture. *If you try to reduce the dislocation (especially without GA), you may worsen the fracture and endanger the brachial plexus & axillary vessels.*

Unless the dislocation reduces without the least force under GA, internal fixation is indicated. Sometimes the fractured and dislocated fragment will resist any attempt at closed reduction.

OPEN REDUCTION OF A SHOULDER DISLOCATION (GRADE 3.3)
Obtain anterior access through the delto-pectoral sulcus, keeping the cephalic vein medially or laterally and thus reaching the upper end of the humeral shaft where the fracture is situated. The humeral head is somewhere under the *subscapularis* muscle.
To approach it, it may be necessary to dissect the conjoint tendon in a Z-shaped manner 1cm below the top of the coracoid process, leaving a tendon seam for later suture.

Occasionally it is necessary to dissect the *subscapularis* tendon in its upper $^{1}/_{2}$ to find and get hold of the head. Try to keep some soft tissue attached to the head, and reduce it into the glenoid fossa with the shaft fragments reduced into satisfactory position distally.
If this reduction as well as the manipulation of fragments remains unstable, proceed to intramedullary wiring by means of one, or better, two 2mm diameter K-wires, whose tip must be blunt (or filed blunt)

Make an incision 8-10cm above the olecranon on the back of the upper arm. Split the *triceps* tendon and muscle fibres and reach the distal humeral shaft above the olecranon fossa.

Retracting the soft tissue, using a 4.5cm drill, make an oval-shaped hole in the cortex (by slanting the drill bit side to side). Bend the K-wire 2cm from its end by c.10°, and its other end by 90° in the opposite sense.

Introduce the K-wire by rotating it to avoid it becoming stuck in the medullary canal. Once it reaches the fracture site, push it into the femoral head, and hammer it softly in place.
Check, if the head is now fixed to the shaft. If possible, insert a 2nd K-Wire of the same length alongside the 1st.

Repair the *subscapularis* tendon as well as the conjoint tendon and close the wound in layers. Place the arm in a sling, encourage exercises as below.

61.13 Humeral shaft fracture

Adult humeral shaft fractures are not common until adult life. They are many kinds, but their treatment is the same. Union is the first priority, then elbow movement. Moderate angulation is no disability.

Put the arm in a narrow sling (61-18B), so that $^{1}/_{2}$ the weight of the forearm acts on the lower fragment to reduce overlap and angulation. Put the arm across the chest to correct rotation. The muscles attached to the humerus will hold the fragments in place. Overlap and shortening are unimportant.
Tell the patient that he may hear and feel crepitus for the 1st 2wks, but that this is a good sign.

RADIOGRAPHS are not essential, unless there are signs which suggest that the shoulder may be dislocated also, or unless the fracture is so low in the shaft as to be supracondylar (62.6).

HUMERAL SHAFT FRACTURES

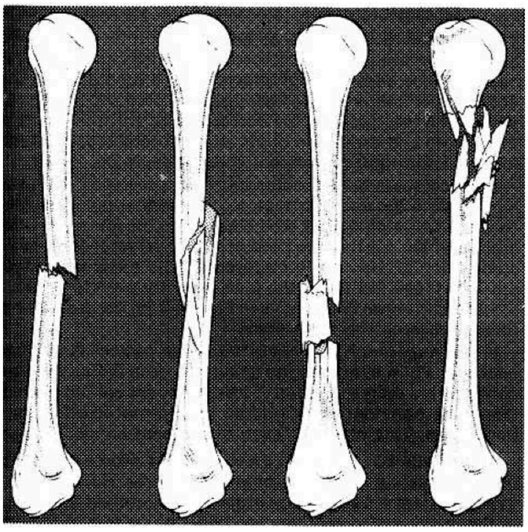

Fig. 61-17 FRACTURES OF THE SHAFT OF THE HUMERUS. A, transverse. B, oblique, C, segmented. D, comminuted. All these can be treated the same way.

TREATMENT
Check the peripheral pulses, and the function of the radial nerve and record these (65-3).

TREATING A HUMERAL SHAFT FRACTURE

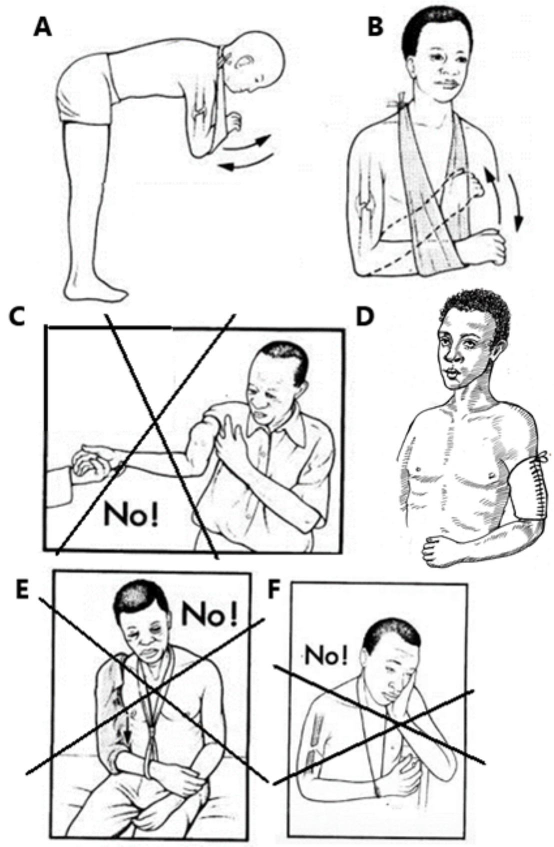

Fig. 61-18 TREATING A HUMERAL SHAFT FRACTURE A, a properly treated patient exercising the shoulder. B, the same patient exercising the elbow. C, mal-union after a fracture 30yrs. However, this patient had surprisingly little disability. D, a perfectly satisfactory traditional splint. E, this heavy cast caused non-union. F, a sore at the wrist. *Kindly contributed by Peter Bewes*

REDUCTION OF AN ANGULATED HUMERAL SHAFT FRACTURE (GRADE 1.4)
If the fracture is grossly angulated, reduce it under GA, or LA into the fracture haematoma. Manipulate it carefully, as the radial nerve is close to the fracture site.

If the fracture is very mobile & painful, putting a light splint is more comfortable and will protect the fracture in case of another fall; otherwise a wide sling will suffice.

Make the patient a sling 10cm wide which supports only the distal part of the forearm; *it must not include the elbow,* which must be at 90°. Make it by folding a triangular bandage several times (61-18B).

CAUTION! The width of the sling is critical. Use a narrow wrist sling which supports only the distal half of the patient's forearm.

Don't use: (1) an elbow sling which raises and supports the elbow, or (2) a collar and cuff, or (3) a bootlace or piece of bandage

N.B. If the elbow is supported in a full sling, the *weight of the forearm cannot reduce the overlap*. A collar and cuff will draw the lower fragment forwards and angulate the fracture. A bootlace or a single turn of bandage will be acutely uncomfortable and may well lead to a chronic wound (61-18F)

Once the fracture is 'sticky', after 1wk, apply a Sarmiento brace. Around a tube of cotton wool from above the acromion to below the olecranon and from 3cm below the axillary crest to 3cm above the elbow fold, apply a light plaster. While the plaster is hardening, model the brace to correct any axial displacement. Cut out a 2cm wide section anteriorly from the plaster cylinder, and wrap an elastic bandage (or better, velcro fastenings) round it, to fit it nicely to the arm.

Repeatedly readjust the binding to maintain circular compression on the arm, thus stabilizing the fracture site as the swelling, reduces.

The ideal splint is a stiff, *light* cuff with 'velcro' fastenings, which will allow active shoulder and elbow movement. A *light* bamboo or plaster. U-slab is an admirable alternative (61-18D).

Encourage isometric muscle strengthening, pendulum exercises of the shoulder (61-2A, 61-18A), active movements of forearm and hand and assisted flexion-extension of the elbow (61-18B). Keep the arm in a sling for 4wks more. Then remove the sling but keep the brace and encourage active movements in the shoulder and arm till 10wks after the injury, by which time the fracture has usually united.

Slight shortening or moderate axial bowing, usually *varus*, is acceptable in the upper, non-weight bearing limb.

N.B. Alternatives to cotton is crepe paper, stripes of cotton cloth, or even toilet paper in layers of 10.

Consolidation usually takes 2months in spiral & 3months in transverse fractures; it normally takes twice as long as clinical union.

DIFFICULTIES WITH HUMERAL SHAFT FRACTURES
If the arm is pulseless and cold, apply gentle traction. If this does not restore the circulation, explore the axillary artery (49.4c). If its circulation is not restored, the arm may need amputating (35.4).

If the shoulder or elbow is stiff, a stiff shoulder is a serious disability, but loss of movement is less serious in the elbow. Encourage increasing movements of the shoulder but no forced activity at the elbow.

If delayed union results, the causes are likely to be:
(1) Removing the brace too early, so causing posterior angulation of the fracture.
(2) Using a hanging cast (61-18E).
(3) Inadequate traction or fixation when the patient is confined to bed because of other injuries,
(4) Applying a heavy cast which distracts the fragments.
(5) Unskilled internal fixation (58-4)
(6) Excessive traction.
(7) Soft tissue between the bone ends.

If there is non-union, if there is no pain, it is probably best to accept the disability and continue daily activities; bone grafting is the alternative, but this may fail, even in the best hands.

If there is a wrist drop, the radial nerve is injured. It may have been present before the injury, because of the injury or because of the treatment. *So documentation on presentation is important!*

When new & noticed early, and relieved by reduction of an angulated fracture, or removal of a tight splint, passive extension exercises of the fingers several times a day, using the other hand, is usually sufficient to recover function, though this may take 3months.

Exploration of the radial nerve is indicated if paralysis develops some weeks after the injury, or if there is no recovery after 6months.

Meanwhile, use a cock-up splint to support the wrist in dorsiflexion and prevent a contracture, (69-2).

If the humeral head is fractured & dislocated, it will be almost impossible to reduce, because traction on the arm will not shift the humeral head. This requires internal fixation.

If there are other injuries which prevent sitting or standing, apply skeletal traction with a K-wire through the thick part of the olecranon, hold the arm in a Gissane stirrup (59.4). Pass a cord from the stirrup over the foot of the bed. Suspend the forearm with the elbow flexed at 90° and the humerus slightly abducted.

CAUTION! Start with 2kg in an adult, and check reduction with radiographs once or twice during the 1st wk.
Adjust the weight so as not to distract the fragments. Once sitting, the patient should use a sling.

DON'T LET THE PATIENT TAKE THE ARM OUT OF the SLING TOO SOON!
HEAVY CASTS ENCOURAGE NON-UNION

61.14 Rotator cuff injury

Injury or degeneration with age (probably from repeated minor insults) sometimes with calcification is common. Typically there is pain between 60^0 and 120^0 of abduction. Steroid & LA injection into the *supraspinatus* tendon may help.

The 'frozen' shoulder, occurring after relatively trivial injury, is an adhesive capsulitis, which responds to NSAIDs.

61.15 Multiple fractures in the arm

When there are simultaneous fractures of humerus, radius & ulna, concentrate on the forearm; the humerus will probably heal itself. This is a classic indication for an X-fix. Management depends on the type of humeral fracture.

If the humeral fracture is spiral, distraction is less of a problem and it will probably unite, so reduce the forearm fracture and apply a thin long arm cast with the elbow at 90° and the forearm in mid-pronation, so that if rotation is reduced subsequently, the hand will be in the best position.
Support the cast in a sling so that its weight does not distract the humeral fracture.

HUMERAL SHAFT EXTERNAL FIXATION (GRADE 3.2).
If the humeral fracture is transverse, a long arm cast will probably cause serious distraction. This is an indication for an X-fix

The X-fix is also useful where a sling or brace is impractical, *e.g.* in chest injury, and for open fractures.

For the X-fix you need two solid insertion points above and below the fracture site, so this is not possible for head and subcapital fractures. Make sure you avoid the radial nerve (61-19).

EXTERNAL FIXATION OF THE HUMERUS

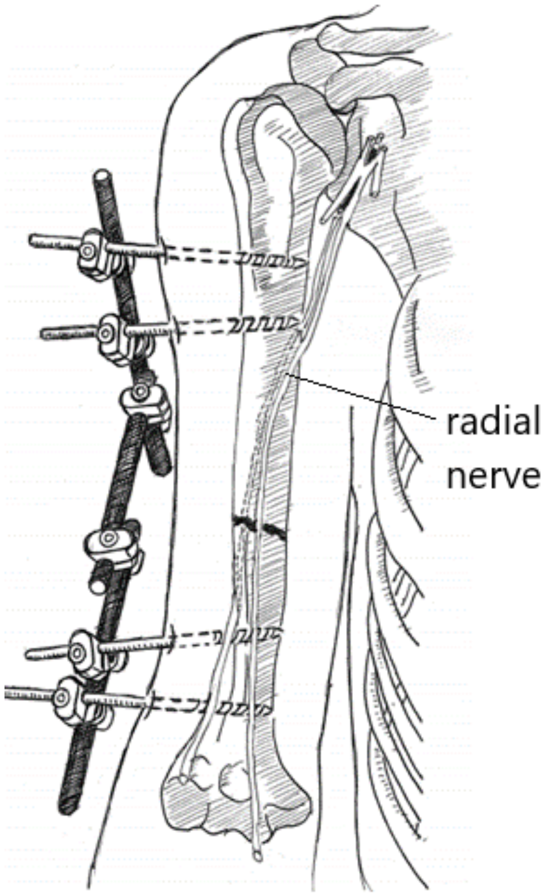

Fig.61-19 EXTERNAL FIXATION FOR A TRANSVERSE HUMERAL FRACTURE. ***Avoid the radial nerve*** **which runs from the axilla, crosses the upper humerus posteriorly, and then the lower humerus anteriorly towards the radial head.** ***See how close it comes!***

62 Elbow injury

62.1 Introduction

A normal function of the elbow joint is essential for the daily use of the whole arm. Mismanagement of displaced fractures, dislocations or ligament instability often leads to a stiff or painful, dysfunctional joint.

Injuries can occur to ligaments, bones or both. Severe complications may include nerve or vessel damage.

N.B. The typical elbow injuries of adults are quite different from those of children (73.7).

EXAMINATION
First check the radial pulse, and the sensory territories of the median nerve (flexor surface of thumb, index & middle fingers), ulnar nerve (flexor side of little finger) & radial nerve (extensor side of thumb, index & middle fingers).

LOOK
Check the contour of the posterior of the elbow. If is abnormal, a supracondylar fracture or dislocation is likely.

FEEL
Feel the 3 bony points, the medial & lateral epicondyles & the olecranon tip (62-1A). If the elbow is very swollen, they will not be palpable.
If the 3 bony points are displaced in relation to one another there may be a dislocation. If the olecranon is displaced, has it moved medially or laterally in relation to an imaginary line down the back of the arm? (You will need to know this when you come to reduce a supracondylar fracture or a dislocation).
Is there a gap in the olecranon?
Check where there is the greatest tenderness: above the elbow, over the medial or lateral epicondyle, the head of the radius, or the olecranon.

MOVE
Normal painless elbow movement excludes any severe injury; any limitation or pain suggests some pathology. If very little movement is possible, there is a dislocation, supracondylar fracture, or a T-shaped fracture. If the elbow is fixed in 45° of flexion with almost no movement, there is almost certainly a dislocation.
Check movement of the radial head. Bend the elbow to 90°; if the forearm can rotate, the head and radial neck are probably normal. Place your middle finger on the lateral epicondyle, and your index beside it over the radial head.
Pronate and supinate the forearm. If the radial head is intact, you will feel it moving under your index finger. Does the olecranon move in relation to the ulnar shaft?
Steady the arm with your other hand. Then very gently try to move the lower end of the humerus sideways, backwards & forwards on the shaft. Use your finger and thumb to feel the bony ridges running up from the medial and lateral epicondyles. This is very painful, so only do it if you have no Xray machine.
If the elbow is obviously swollen, try to move one condyle in relation to the other, & check for crepitus.
If the patient can extend the elbow, its extensor mechanism is intact (62-23).

RADIOGRAPHS
Always get an AP & lateral radiograph of an injured elbow. Minor fractures such as small chips off the capitulum are difficult to diagnose without a radiograph.

In a severe elbow injury, the medial epicondyle is easily detached, so it is the 1st thing to look for. If you are still in doubt, X-ray the elbow again after 7days. The fracture, if there is one, will then be easier to see.

THE 3 BONY POINTS AT THE ELBOW

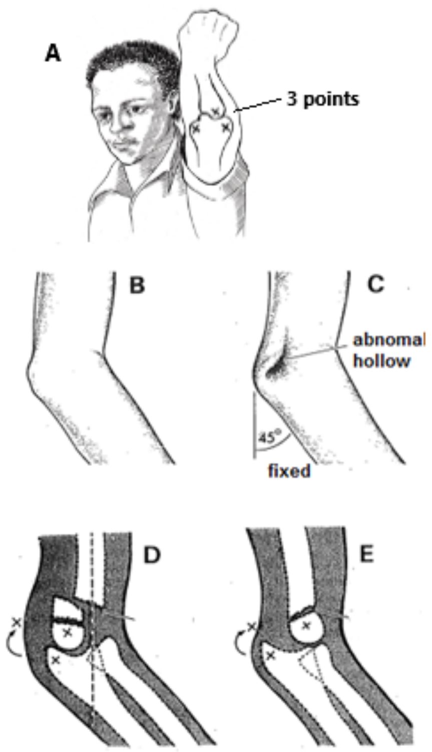

Fig. 62-1 THE 3 BONY POINTS AT THE BACK OF THE ELBOW. A, the medial & lateral humeral epicondyles & the olecranon tip of the ulna. B, normal contour of the elbow. C, contour of a dislocation. D, in a supracondylar fracture, the 3 bony points are correctly related to one another, but are posteriorly displaced in relation to the humeral shaft. E, in a dislocation the relationship of the 3 bony points to one another is disturbed. *Kindly contributed by John Stewart.*

SUMMARY OF MAJOR ELBOW INJURIES

FRACTURE	C	Sw	MOVEMENT	BONY POINTS	OTHER
Dislocation	N	++	fixed 45^0	mal-aligned	
Supra-condylar	Ab	++	some	displaced relative to humerus	crepitus
T-shaped	Ab	++	some	mobile	crepitus
Medial epicondyle	N	+	some	tender medially	normal rotation
Capitulum	N	+	v. little flexion	N	
Radial head	N	+	little or no rotation	N	tender radial head
Olecranon	N	+	?some active extension	abnormal	tender olecranon

Ab = abnormal, C = Contour, N = normal, Sw = swelling

62.2 Elbow aspiration

ASPIRATING THE ELBOW (GRADE 1.2)
Clean the skin carefully with betadine, and taking the most careful aseptic precautions, aspirate at the summit of the swelling between the 3 bony points on the outer side of the elbow (62-2B)

An injured elbow rapidly swells, and makes reduction of a fracture difficult, especially comminuted supracondylar fractures in adults (62.4) and fractures of the head of the radius (62.7). As with the knee, aspirating the blood from a tensely distended elbow joint relieves pain, and allows the patient to move the elbow much earlier. Also, you can inject LA at the same time. This is however an invasive action, and you must only do it under aseptic conditions. Consider if the risk outweighs the advantage.

ELBOW ASPIRATION

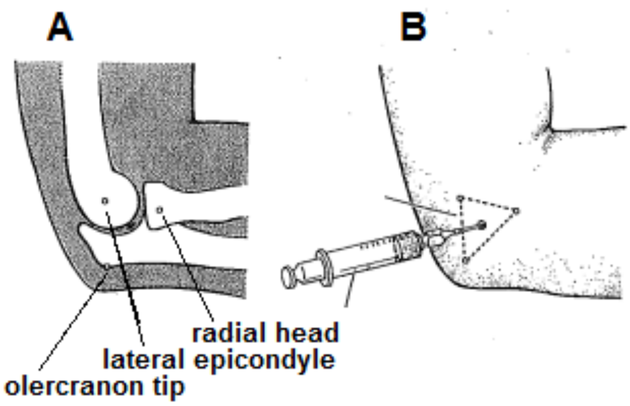

Fig. 62-2 ELBOW ASPIRATION. Strict aseptic technique is mandatory. ***N.B. These 3 bony landmarks are not the same as 62-1.***

ELBOW DISLOCATION

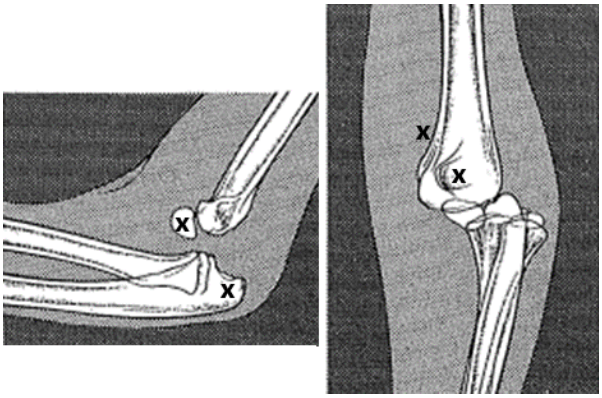

Fig. 62-3 RADIOGRAPHS OF ELBOW DISLOCATION showing mal-alignment of the 3 bony points.

62.3 Elbow dislocation

A fall on the outstretched hand may cause an elbow dislocation. In this common injury, the force travels up the forearm and pushes the radius and ulna posteriorly, or the humerus posteriorly and laterally. The elbow is immobile and held at c.45°. The posterior outline of the arm, instead of being normally rounded, or showing a slight prominence over the olecranon, bends abruptly backwards (62-1C,E). The 3 bony points of the elbow are not in their normal places.

N.B. There may also be a lateral condyle fracture, and severe soft tissue injuries. Occasionally the circulation of the forearm is obstructed, with development of a compartment syndrome (49.6).

REDUCE A DISLOCATED ELBOW IMMEDIATELY

ELBOW DISLOCATION REDUCTION
(GRADE 1.3)
The sooner you do this, the easier it will be, and the fewer the complications. If it is very recent, the alternative method described below may work. If it is fractured and too swollen to reduce immediately, elevate the arm (63-11).

Good relaxation is essential.
Lie the patient on the back with the upper arm vertical, and the forearm flexed across the chest. Get an assistant to exert traction on the hand from the other side of the table (62-4A), and at the same time, to flex the elbow gradually (62-4B).
While this is being done, grasp the elbow in both hands, with your fingers round the front of the humerus, and your thumbs behind the olecranon, then push it forwards (62-4C).
The olecranon should lie in the centre of the arm midway between the two epicondyles (62-1A).

If it has shifted sideways, first move it into the midline with your thumbs as you reduce it, then push it forwards over the lower end of the humerus. The dislocation will reduce with a crunch.
When you are satisfied, move the elbow through its normal range. *Unless you can get full flexion, you have not reduced the dislocation, and the olecranon will not be properly in the trochlear groove*.
When you have achieved full flexion, slowly return to 30° of extension whilst supinating the forearm. If you feel the elbow wants to re-dislocate before reaching 30°, it is unstable.

REDUCING A DISLOCATED ELBOW

Fig. 62-4 REDUCING A DISLOCATED ELBOW A, the assistant pulls on the wrist; B, flexes the elbow gradually; C, whilst you push the olecranon forwards. *Kindly contributed by John Stewart.*

CHECK RADIOGRAPHS
Make sure that: (1) reduction is satisfactory, and (2) there is no bony fragment trapped in the joint. If there is, it needs removal by opening the joint.

CAUTION! If you fail to get a post-manipulation radiograph, you may miss an incomplete reduction. Reduction will then be possible only at open operation.

POST-OPERATIVE CARE
Check the radial pulse, and function of the median, ulnar, and radial nerves to make sure that they have not been injured during reduction.

If reduction is stable, rest the arm in a collar & cuff I flexion >90° for 3wks. After 1wk, gently exercise the elbow, starting with pronation-supination in 90° of flexion. Then continue with extension-flexion with the thumb in line with humerus (*i.e.* the forearm in neutral). Exercise also with the arm vertical over the head.

CAUTION! Never perform passive stretching exercises: these encourage post-traumatic ossification (*myositis ossificans*).

N.B. The only safe movements are those that are possible using the injured elbow's own muscles, without the help of the normal hand or an assistant.

COMPLICATED ELBOW DISLOCATIONS

Fig. 62-5 COMPLEX ELBOW DISLOCATIIONS. A, with an olecranon fracture. B, the 'side-swipe' fracture-dislocation when a car driver's elbow protruding through the car window is hit by another car. *After Apley AG, Solomon L. Apley's System of Orthopaedics and Fractures. Butterworth, 6th ed.1982 with kind permission.*

If reduction is very unstable in all directions:
(1) there is a fracture of the radial head or olecranon, or there is a grossly comminuted fracture with an anterior dislocation (62-5),
(2) the medial epicondyle is trapped inside the elbow joint, or
(3) all the ligaments are torn.
Apply a temporary plaster backslab and organize an open/closed reduction.

Attempt fixing an elbow only if you are sure you have what it needs to achieve a joint stable enough for active mobilization on the 2nd day post op. *In desperate situations*, bridging with an ex fix on the lateral side may provide stability, *but at the expense of range of movement.*

DIFFICULTIES WITH A DISLOCATED ELBOW
If the patient presents >2wks late, but <6wks, try to reduce it by manipulation under GA, *but only once*. If you fail, arrange open reduction.

OPEN REDUCTION FOR CHRONICALLY DISLOCATED ELBOW (GRADE 3.2)

Use the Soddo method (after the hospital of this name in Ethiopia); apply a proximal tourniquet. Do this if you have the skills: *it is not for the occasional surgeon!*

Expose the elbow joint through separate lateral & medial incisions, avoiding the *triceps* extensor mechanism. On the lateral side, cut along the supracondylar ridge to the lateral epicondyle, and over the radial head (62-6A), identified by pronation & supination of the forearm.
Deepen this incision to make separate sleeves of anterior muscles (*brachialis, brachioradialis & extensor carpi radialis longus & brevis)* & posterior muscles (*triceps & anconeus).* Identify the ulnar nerve.

PROCEDURE FOR CHRONIC ELBOW DISLOCATION

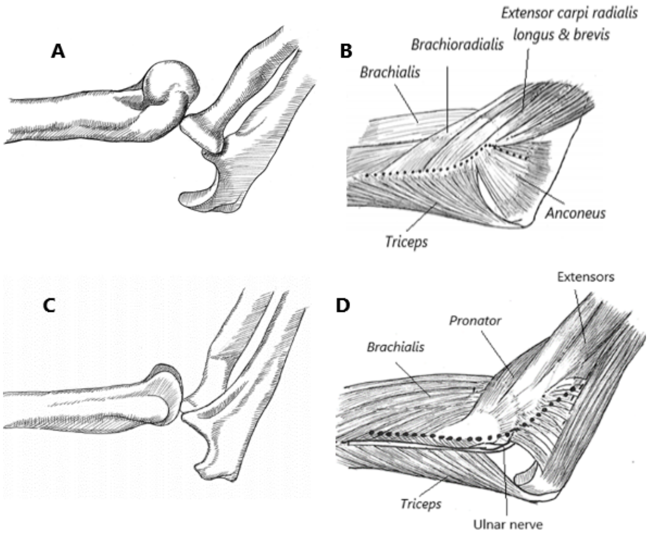

Fig. 62-6 SODDO PROCEDURE FOR NEGLECTED ELBOW DISLOCATION. A,B, the line of the lateral incision. C,D, that of the medial incision, taking care to dissect out the ulnar nerve. *After Anderson DR, Haller JM, Anderson LA, Hailu S, Chala A, O'Driscoll SW. Surgical Treatment of Chronic Elbow Dislocation, J Ortho Trauma, Wolters Kluwer Health 2017.*

Don't go posteriorly beyond the radial neck, and go around any heterotopic calcification to expose the capitellum posteriorly.
Now turn the elbow over, and cut on the medial side along the medial supracondylar ridge to the medial epicondyle, and distally 2cm. Then very carefully dissect out the ulnar nerve, which may be buried in scar tissue (62-6B).

Then mobilze *brachialis* anteriorly off the distal humerus extraperiosteally; *scar tissue is often very thick here*. Make sure the anterior muscle sleeve contains all the flexor pronators' insertion and the medial collateral ligament. The posterior sleeve should include the *triceps* expansion & most of the scar tissue.

Continue dissection anteriorly into the joint, taking care to stay close to the bone, till the trochlea. Use a finger or blade to release all the capsule and scar at the articular margin anteriorly from both medial epicondyle and condyle.

You should then see the articular surface of the anterior humerus.

Now start the posteromedial dissection, which is more difficult; flex and extend the elbow to delineate the contour of the dislocated olecranon in order to identify its articular surface.
Then mobilize the triceps off the posterior supracondylar ridge for 4–5 cm, and exend dissection to the tip of the olecranon, freeing it from the posterior humerus medially.

Flexing and extending the elbow allows you to feel the olecranon; cut the soft tissues in the contour of the olecranon, taking care not to injure its articular surface

Now turn the elbow over again; carry on the dissection anterior to the radial head towards the lateral olecranon. Repeatedly flex & extend the elbow in order to palpate the olecranon. Now carefully dissect the scar between it and the posterior humerus, till it separates completely. Now dislocate the 'naked' distal humerus out of the medial or lateral wound, aiming to disrupt the periosteum At this stage, the radial head should also be free.

Now gently dissect scar tissue off. The olecranon articular cartilage; this should come off *en bloc,* so it makes a nice fit with the trochlea.

Make sure that there is adequate space between the anterior and posterior sleeves distally to allow full reduction of the humerus. This usually means further deep dissection into the flexor pronator mass in line with the ulnar nerve until its first motor branch becomes visible.

Beware of catching the ulnar nerve when you reduce the elbow! Check for impinging soft tissue around the olecranon so that the elbow remains well reduced in near-full extension. Check that the *triceps* is nicely taut with flexion of the reduced elbow; *avoid forceful manipulation!*
N.B. You may be able to stretch the *triceps* tendon by piercing it in a few (not too many) places with a Ch18 needle.

Finally, transpose the ulnar nerve anteriorly submuscularly.

Starting on the lateral side, fix the soft tissue sleeves with no.1 long-acting absorbable sutures through 2mm holes drilled anterior to posterior through both medial & lateral epicondyles.
Test stability again after reduction and close the wound.

Post-operatively, if reduction is stable intra-operatively, a sling is all that is needed. If there is some laxity, keep the elbow in a backslab with the forearm in neutral and elbow at 90°. After 2 days, take the cast off for exercises described above, & at 2wks, abandon the cast and start lifting gradually heavier bottles of water.

If the elbow remains incompletely reduced, there is probably soft tissue between the joint surfaces which needs removal.

If the elbow re-dislocates easily and is very unstable, make sure there are no fractures. Try to refer for ligament reconstruction, but if this is impossible, immobilize the elbow with a backslab for 3wks in 90° flexion and the forearm in neutral. Right after applying the cast, get a radiograph within the cast, and if it is still dislocated, apply an external fixator (62-8).

If the medial epicondyle is trapped inside the elbow, arrange an arthrotomy: a trapped medial epicondyle is easy to find because the flexor muscles are attached to it.

If there are other fractures, there may be a flake off the capitulum, a fracture of the coronoid, or a fracture of the radial head. First reduce the dislocation, and then treat the fracture as if the dislocation had never existed, but if you cannot fix the fragment securely, remove it.

If a nerve has been injured, it needs to be explored if it does not recover spontaneously in 3 months.

If 2-3wks after an injury the movement of the elbow diminishes, a firm mass forms near the joint, and the soft tissue starts to calcify, this is post-traumatic ossification. The periosteum is torn off the back of the humerus and *brachialis* is torn off the front. These injured tissues may calcify and ossify, particularly in children.

The same complication can follow a supracondylar fracture, and is made worse by:
(1) repeated reduction attempts, or
(2) subsequent forceful movements.

Don't try to remove any bony lumps. Don't intervene until at least a year after the injury.

Sometimes, in spite of everything, the elbow becomes permanently stiff. If this seems unavoidable, keep it in its most useful position, according to the patient's needs.
This is usually flexed to 45-60°, with the forearm in mid-pronation (63-1).

AVOID ANY FORCED ELBOW MOVEMENTS!

N.B. An elbow arthrodesis is only indicated in case of untreatable pain or to obtain stability demanded by the patient!

62.4 Humeral supracondylar fracture

The swollen and deformed elbow is impossible to move. The swelling obscures the bony landmarks but you may be able to feel crepitus.

These fractures are usually T-shaped or comminuted. Rarely, they are transverse as in children. The fragments cannot be reduced by closed manipulation, and they are difficult to fix at open operation. Even with accurate internal fixation, the late results are often disappointing, so better to institute *early* active movements. Much less osteoarthritis occurs than you might expect. Ultimately, function will depend on a good position of the 2 condyles. If they are widely apart or shifted onto one another, movement will be poor. If they are parallel, movement will be better. Displacement of the fragments at the transverse fracture is less important. Combine active movements with traction (62-7).

OLECRANON TRACTION
If the olecranon is intact, pass a K- wire through it from the ulnar to the radial side, and tension the wire with a Gissane stirrup (62-7A), or, less satisfactorily, use a thin (<4mm) Steinmann pin. *The direction matters to avoid damage to the ulnar nerve.* If the fragments are displaced, ask an assistant to exert traction on the stirrup while you press them back into place (62-7B). You may need anaesthesia to achieve this.

Apply enough traction to keep the upper arm under tension (62-7C) but not enough to lift the shoulder off the mattress. Apply a sling (62-7D) to keep the elbow at 90° and the wrist half-way between pronation and supination, with the hand over the opposite shoulder.

Apply 0.5-1kg of backward traction on the upper arm (62-7E), if necessary.
Feel the epicondyles and adjust the direction of traction so that their positions are at right angles to pull of the traction (62-7F). For this, you may have to adjust the pull of the stirrup (62-7G).

CAUTION! Check the radial pulse often. *Don't apply too much traction*, or you may obstruct the circulation to the arm, injure the nerves, or distract the fragments and so prevent union.

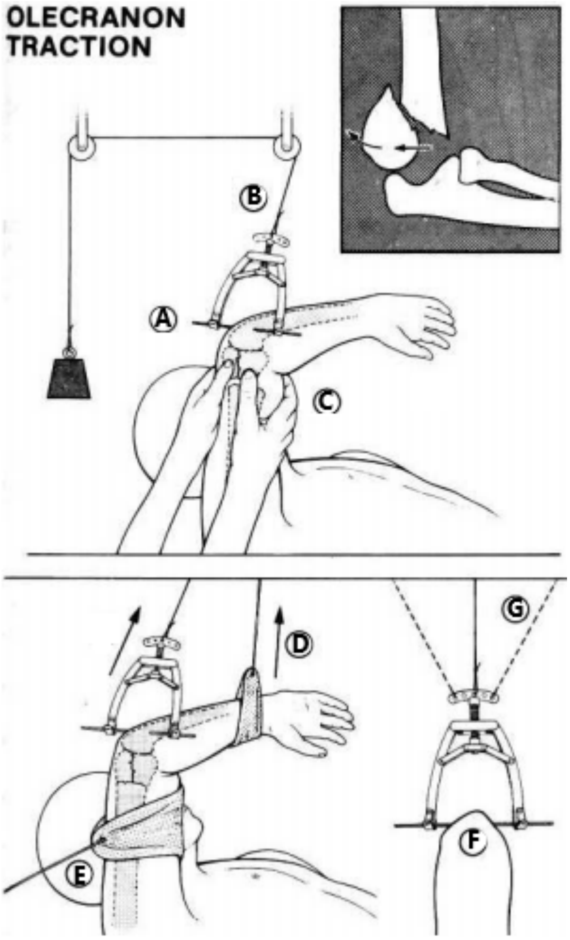

Fig. 62-7 OLECRANON TRACTION FOR A COMMINUTED SUPRACONDYLAR FRACTURE. A, if the olecranon is intact, pass a K- wire through it. B, tension the wire with a Gissane stirrup with 2-4kg, or, less satisfactorily, use a thin (<4mm) Steinmann pin. C, get an assistant to exert traction whilst you push any displaced fragments into place. D, apply a cuff to keep the elbow at 90^0 and the arm in neutral rotation. E, apply backward traction of 0.5-1kg if necessary. F, adjust the line of traction so that the epicondyles are at right angles. G, you may need a V-shaped pull to achieve this correction. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

Obtain a radiograph. Slight backward displacement is acceptable, *but there should be no angulation or lateral displacement*.

While in traction, encourage elbow movements. Let the patient take hold of the traction cord and assist in these movements.

Remove the traction at 2-3wks, put the arm in a sling with the elbow at 90° and the forearm in 45° of pronation. Start carefully graded active movements without using force. Recovery will take several months.

EARLY ACTIVE MOVEMENTS
If necessary, anaesthetize the patient and try to get the fragments into a better position. Try to start active movements as soon as possible. If the arm is very swollen keep it raised for a few days in straight traction (as for a child, 73-7).

Put the arm in a collar & cuff for ≤7days. During this time take it out several times a day and encourage movements.

CAUTION! Flexion & extension are subsequently likely to be limited, so make sure they are in the most useful range (62-7). For the same reason the forearm should be in mid-pronation.

Start pendulum exercises for the shoulder, and exercises for the wrist and fingers immediately after the injury.

Put the arm in a sling only if this relieves pain, and for as long as it is needed for analgesia. Encourage using the hand and moving the elbow as much as possible. No recovery of elbow movement will occur without severe determination.

INDICATIONS FOR REFERRAL
(1) If you can refer to an experienced surgeon, especially if the patient is young.
(2) Injuries to the median or ulnar nerves.
(3) Open injuries.

TRANSVERSE SUPRACONDYLAR FRACTURE
If the lower fragment is in one piece, reduce it as in a child (73.7).

DIFFICULTIES WITH SUPRACONDYLAR FRACTURES IN ADULTS

If there is a complex open fracture, toilet the wound. If the elbow is dislocated, reduce it. Suspend the arm in the position of function, and get it moving. Dress it, but *don't close it by primary suture*. Look at it in 4-5 days, and either close it or graft it. Hang it up with metacarpal K-wire or use skin traction on the fingers *while watching the circulation carefully.* Hang the hand up in the same position as for forearm traction.
This is a good indication for an X-fix crossing the joint (62-8). Pay attention to a functional joint position (45-60° flexion). The external fixator has to remain for 4-8wks depending on fracture healing.

EXTERNAL FIXATION OF THE ELBOW (GRADE 3.2)

Make sure you avoid the radial nerve when placing the humeral pins (61-18). Dissect soft tissues bluntly, using small Langenbeck retractors to prevent damage to muscles, vessels and nerves to prepare a channel for pin insertion. If you have any doubt, drill at the insertion of the *deltoid,* or make the incision big enough so that the drill sleeve will have direct contact with the bone.

For more rigidity add a rod between the most proximal to the most distal pin.

EXTERNAL FIXATION OF THE ELBOW

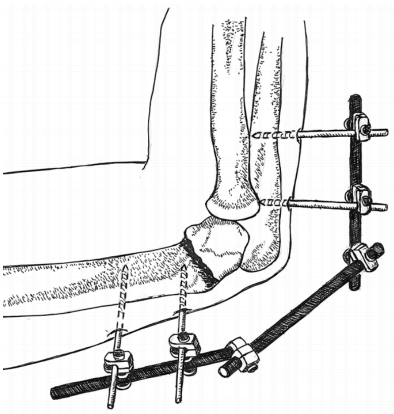

Fig. 62-8 EXTERNAL FIXATION OF THE ELBOW. Beware of the radial nerve which crosses from laterally across the cubital fossa.

62.5 Humeral medial epicondyle fracture

Up to the age 20yrs, the centre of ossification of the medial epicondyle may be a separate piece of bone, and may be pulled off by the flexor muscles of the forearm. The detached fragment may remain outside the elbow joint or enter it and lock it. Treatment is as for a child (73.7)

62.6 Capitulum fracture

A fall on the hand with the elbow straight may rarely cause a piece of the capitulum to break off, tilt, and shift anteriorly. The fragment may be small or include the whole of the anterior capitulum and part of the trochlea. The head of the radius may also be fractured.

The victim holds the elbow at 90°, the contour of the arm is normal, but fuller anteriorly, and tenderness is difficult to locate.
Some rotation is possible, but very little flexion. Small fragments consisting only of cartilage are difficult to see on a radiograph, so suspect this if there is intermittent locking of the joint.

REDUCTION OF CAPITULUM FRACTURE (GRADE 1.5)
If the fragment is large, & you have no opportunity for referral, ask an assistant to exert traction on the extended forearm, while you press the fragment down firmly with your thumbs. Then when the fragment is reduced, flex the elbow >90°. Check the distal circulation, and reduce the flexion if it is impaired. Apply a collar & cuff or a backslab for 4wks and start shoulder and finger exercises immediately.

If radiographs show that reduction has failed, try external fixation of the fragment.

CAPITULUM FRACTURE

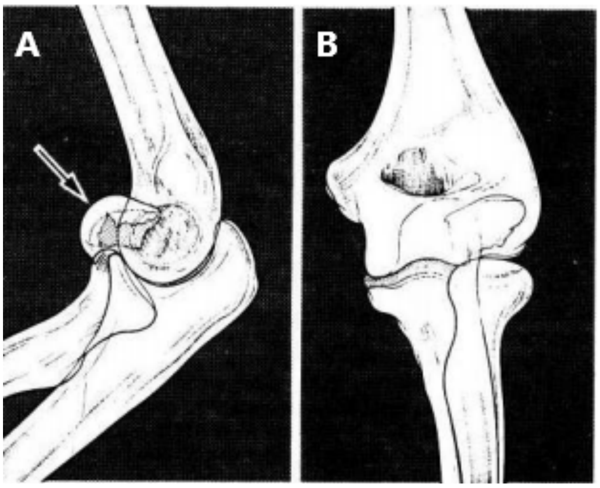

Fig. 62-9 FRACTURE OF THE CAPITULUM. A, lateral view showing a large piece of the capitulum displaced anteriorly. B, diagnosis on an AP view is much harder.

If the fragment is small and has entered the joint, it needs removal. Use the same approach as for a radial head fracture (62.7).

62.7 Radial head fracture

A fall on the outstretched hand forces the elbow into valgus and cracking the radial head against the capitulum. The important feature is the resultant incongruity of the articular surface.

RADIAL HEAD FRACTURE TYPES

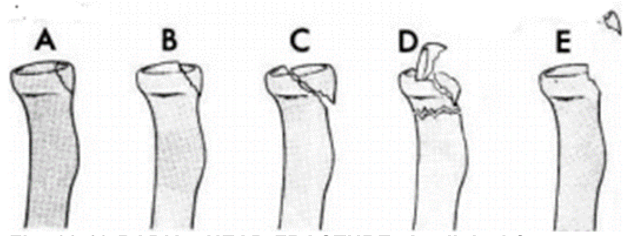

Fig. 62-10 RADIAL HEAD FRACTURE. A, clinical features and the radiograph may look normal. B, conservative treatment may be adequate. C, the more displacement, the more the joint will be affected later. D, with gross displacement of the fragment, fixation is necessary. E, a separated fragment may cause little trouble. ***Think of the radial head as the base of a spinning top: as long as it can continue spinning, it won't get stiff!***
Kindly contributed by Peter Bewes.

Typically, the contour of the elbow is normal, and not greatly swollen. Flexion & extension is possible but rotation difficult. The radial head is tender.

The elbow and the radiograph may look so normal that you can easily miss this. If you are not sure, and rotation remains painful, get a radial head view (62-11).

RADIAL HEAD VIEW

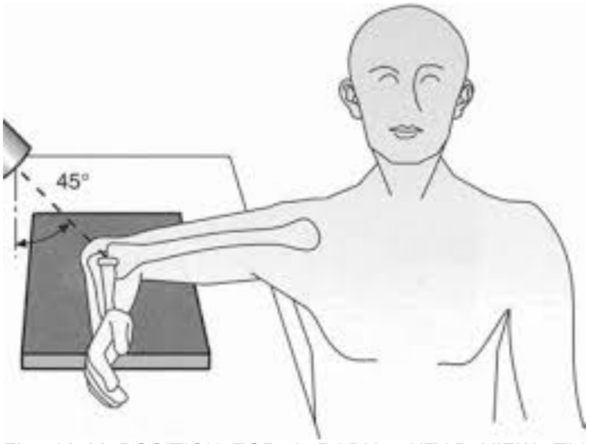

Fig. 62-11 POSITION FOR A RADIAL HEAD VIEW. This shows up all elbow fractures.

N.B. Any fractures that only show up after 2wks will be undisplaced and you can treat them conservatively.

CONSERVATIVE TREATMENT
Where there is insignificant displacement of the radial head (62-10A,B), conservative treatment will give as good results as fixation. There is no need to operate on a loose widely displaced fragment (62-10E), unless it locks the joint.

Reduce a dislocation (62.3) first, if present. If the elbow is very tense, aspirate the haematoma (62-2), and inject LA. Encourage active & easy movements, *especially rotation.* Apply a collar & cuff. *Don't apply PoP*.

If you can get accurate fixation done for 62-10C,D fractures, refer the patient. If not, do your best to rehabilitate the patient. For a non-union or malunion, excise the radial head.

EXCISION OF THE RADIAL HEAD (GRADE 3.4)
Never remove the head of the radius in a child, because this will interfere with growth.
Although the operation itself is not difficult, you can easily cut the deep branch of the radial nerve (posterior interosseous nerve); so refer if possible.

Exsanguinate the arm with an Esmarch bandage, and place a tourniquet (3.8) round the upper arm.
Position the arm over the front of the chest, so that the posterior surface of the elbow is uppermost. Use an arm table if available. Leave the hand free so that you can rotate the wrist, pronate the forearm initially, and so turn the head of the radius.

Make a 5cm incision (62-12A) surface of the elbow staying anterior to a line connecting the most lateral point of the radial head to the radial epicondyle, extending downwards between the *extensor carpi ulnaris* and *anconeus* muscles (62-12B).
Deepen the incision through the fascia to expose the joint capsule (62-12C). If there is much bruising, and you cannot define these muscles, remove them subperiostially from the anterior surface of the radial column of the humerus (the 'over the top' approach).

RADIAL HEAD EXCISION

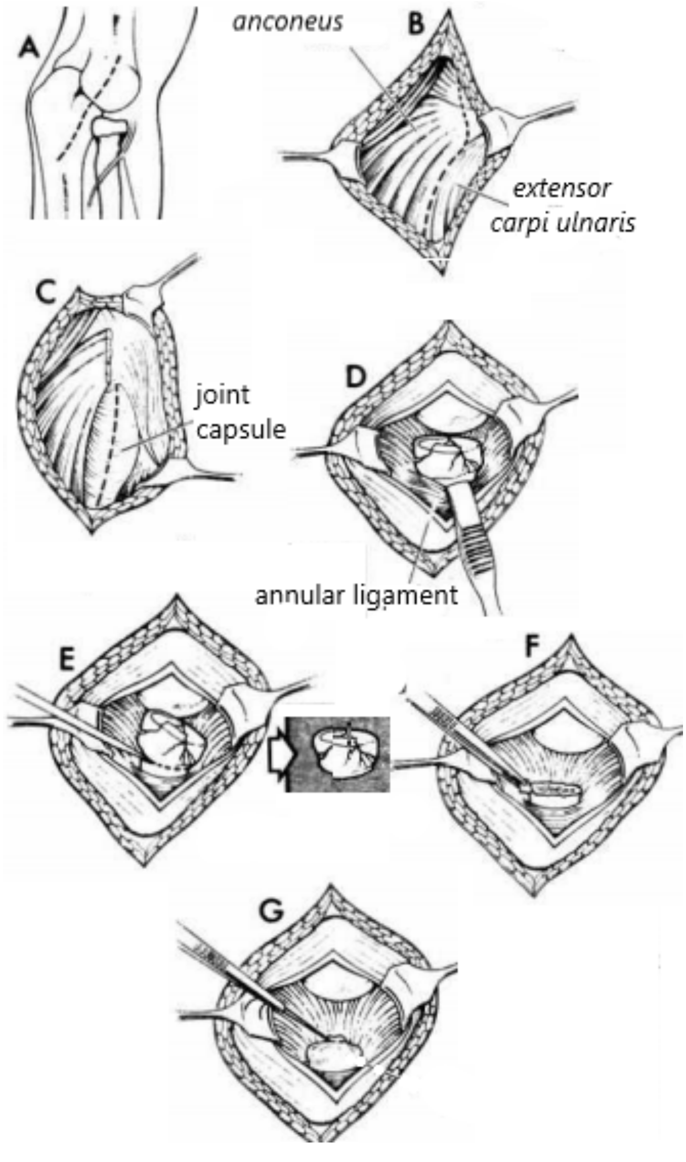

Fig. 62-12 RADIAL HEAD EXCISION. A, incision over the posterolateral surface of the elbow. B, extend the incision deeply. C, open the joint capsule. D, expose the broken radial head. E, lever the head off above the annular ligament. F, leave no loose pieces behind. G, cover the stump with soft tissue. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

CAUTION! The posterior interosseus nerve, a deep branch of the radial nerve, arises from it 2-3cm below the elbow. It winds round the lateral side of the radial neck, 1cm below its head, between the two planes of the *supinator*.

Don't dissect deeply in front of the radius, or distal to the annular ligament posteriorly. Unfortunately, the course of the nerve may vary considerably. Rather, create the space you need by mobilizing muscles subperiostially from the anterior surface of the radial side of humerus as described.
Make a longitudinal incision in the capsule to expose the radial head & the capitulum (62-12D) Wash out blood clot from the joint.

Find the annular ligament and divide it, but *don't go much further distally* as you might damage the posterior interosseous nerve, the deep branch of the radial nerve.

Cut away the head of the radius with nibblers immediately proximal to the annular ligament (62-12E). Remove all loose fragments: you may need to check this with X-ray. Smooth the bone edges with a small rongeur. Then repair the annular ligament with non-absorbable sutures.

If the elbow has been dislocated, re-dislocate it to remove any loose fragments of the radial head that may be lying in other parts of the joint. Fragments are sometimes driven through the capsule and lie outside it. Inspect the capitulum for injury.

Rinse the wound forcibly. Close the capsule and the muscle with absorbable sutures. Release the tourniquet and control any bleeding.

POST-OPERATIVE CARE
Flex the elbow to 45-60°. Apply a pressure dressing to the wound and apply a backslab. Encourage exercising the fingers and shoulders from the 1st day. After 1wk, encourage use of the elbow, but *avoid vigorous exercise or forced passive movement.*

If there is a stiff elbow, check for loose fragments left behind. *Don't force movements.*

62.8 Olecranon fracture

A direct blow to the point of the elbow or a fall on the outstretched hand whilst the *triceps* is contracted may break the olecranon. In both cases the elbow is acutely tender and swollen. Sometimes the radial head is also injured.

If extension of the forearm against gravity is possible, the extensor mechanism of the elbow is intact.

If no extension of the forearm against gravity is possible*,* the extensor mechanism needs repair.

If the extensor mechanism is intact, place the arm in a sling and encourage movements, regardless what the radiograph shows.

OLECRANON FIXATION

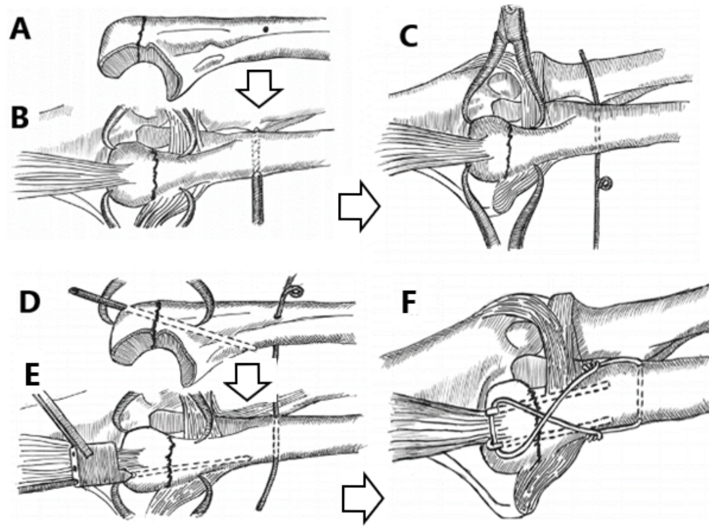

Fig. 62-13 OLECRANON FIXATION. **A, hold the olecranon fragment onto the ulnar shaft, and B, drill this transversely 4cm distally. C, thread a tension wire through this drill hole. D, introduce a K-wire medially through the olecranon fragment, and E, another laterally. F, pass K-wires beneath the *triceps* to join the other distal wire in a figure-of-8 loop. The stiff K-wires maintain alignment, while the figure of 8 of soft wire holds the fragments together.**

OLECRANON INTERNAL FIXATION
(GRADE 3.1)

If the extensor mechanism is ruptured, to enable elbow function to return, you must repair it.

Exsanguinate the arm with an Esmarch bandage, and place a tourniquet (3.8) round the upper arm.

Make an 8cm midline posterior longitudinal incision just lateral to the elbow joint. *Take care to visualize the ulnar nerve to avoid it.* Incise and expose the olecranon fragment: it may be in smaller pieces than you expect from the radiographs.

Open the joint and rinse away any blood clot. Hold the fragments together with 1 or 2 bone hooks or towel clips to reduce the fracture carefully and approximate the joint line (62-13A). There is almost always a small spike on one side that fits exactly into a gap on the opposite fragment. Hold the hook so that it presses in the long axis of the ulna.

N.B. The fracture line will be easier to see if you strip away some periosteum from around it.

Drill the ulnar shaft transversely 4cm distal to the fracture line for the insertion of the tension band (62-13B). Thread the tension wire through the drill holes from the medial side (62-13C).

Introduce 2 K-wires parallel medially & laterally through the proximal olecranon into the ulna towards its anterior cortex (62-13D,E).
Pass the tension wire in a figure-of-8 loop beneath the *triceps* tendon around the protruding K-wires.
Twist both ends of the wire together and then cut the olecranon ends of the K-wires & bend them to hold the tension wires (62-13F)

EXCISION OF THE DISTAL OLECRANON (GRADE 3.3)

If <½ the olecranon is broken off, and internal fixation is not possible, you can excise the distal part and suture the *triceps* to the distal ulna & fascia.

Remove the distal bone fragments, and cut them away from the *triceps* tendon. Drill 2 holes in the ulnar shaft, and pass strong non-absorbable sutures through these holes, and then through the *triceps* tendon (62-14).
CAUTION! Find the ulnar nerve and gently retract it.

EXCISION OF THE DISTAL OLECRANON FRAGMENT

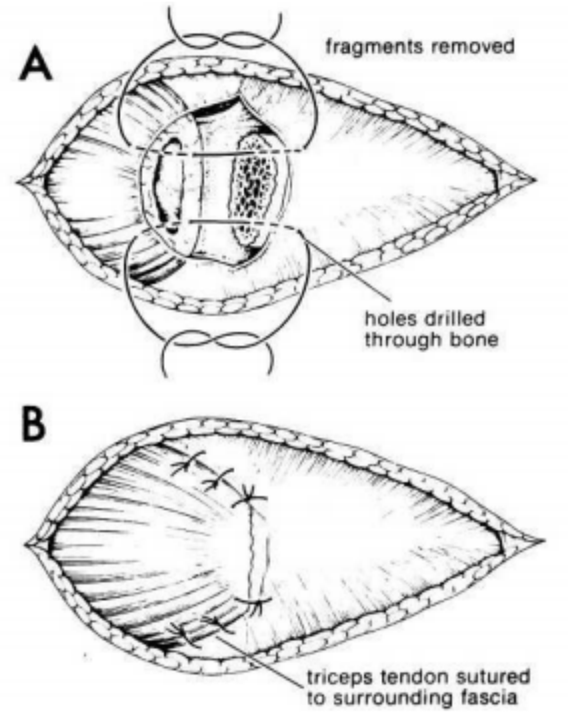

Fig. 62-14 FIXATION OR EXCISION OF THE OLECRANON FRAGMENTS. A, **after exposing the fracture site, remove the olecranon fragments, and drill holes through the ulna to fix the *triceps*.** B, **fix the tendon to the fascia for extra stability.** *After Bentley G, Greer RB, Rob and Smith's Operative Surgery: Orthopaedics, Butterworth 4th ed, 1998 with kind permission.*

POST-OPERATIVE CARE
Encourage early return to light work.
CAUTION! Don't splint the elbow, especially not in extension.

63 Forearm injury

63.1 Introduction

The conservative treatment of forearm fractures of adults is difficult, because the reduction is often unstable and leads therefore to re-displacement with bad results. Fractures of the forearm are mostly the result of a direct blow. If the forearm bones are broken, the muscles attached to the fragments displace them.

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(1) Either forearm bone can fracture alone.
(2) Both can fracture simultaneously, usually in their middle ⅓.
(3) Either bone can fracture, and the upper or lower joint between them may dislocate simultaneously.

If the radius fractures & is displaced, the lower radio–ulnar joint will sublux (Galeazzi fracture).

If the proximal ⅓ of the ulna fractures & is displaced, the head of the radius will dislocate anteriorly (Monteggia fracture).

These dislocations are easy to miss, *so always include the wrist & elbow in a forearm film*, particularly if the fragments are overlapped or angulated.

EXAMINING THE FOREARM
Palpate the whole of the subcutaneous border of the ulna & the lower ⅔ of the radius. Squeeze the radius and ulna together in the lower part of the forearm. If this hurts, there is probably a fracture.
Examine the radial head (62.1) (Monteggia fracture and the inferior radio-ulnar joint (Galeazzi fracture) to make sure they are not dislocated.

PRONATION AND SUPINATION

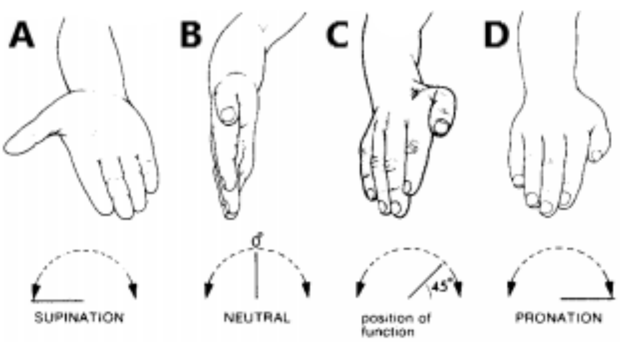


Fig. 63-1 FOREARM ROTATION. A, full supination. B, neutral position. C, position of function where the hand will be most useful if the forearm is in mid-pronation. D, full pronation. *Kindly contributed by John Stewart.*

Examine the elbow & the wrist. Test pronation & supination, as well as radial & ulnar deviation, flexion & extension. Test the circulation and sensation distally.

RADIOGRAPHS should include the wrist and a lateral view of the elbow. A line through the long axis of the radius should pass through the capitulum in both views (63-4).

X–RAY THE WRIST & THE ELBOW

It is best to treat most radial fractures and all fractures of both bones by open methods when skills and facilities are good. But if you are not a skilled surgeon, and your facilities are not perfect, closed methods are more likely to get a better functional result. External fixation is an alternative. Isolated ulnar fractures are easier to treat than radial fractures, because the muscles attached to the ulna are much less likely to displace its fragments.

LONG ARM CASTS
Use a long arm cast modified by varying the position of the wrist to suit the needs of particular fractures. If both bones are broken, gently squeeze the cast from front to back to correct the angulation of the fragments towards one another. A forearm cast is heavy, so hang it from the neck. otherwise its weight may re-displace the fragments or damage the radial nerve by pressing on it. Extend most forearm casts to above the elbow.

The 1st cast on a forearm fracture should always be a long arm cast. Apply a single layer of cotton wool to the arm, then put cotton pads over the bony points around the elbow, and in the antecubital fossa. Apply the cast from just below the shoulder to just proximal to the mcp joints. Hold the elbow at 90° and the thumb and fingers free. *The thumb must be free enough to touch the little finger.*

If the thumb is in abduction, it will be so stiff when you remove the cast as to be temporarily useless.

Apply the cast to the base of the thumb & knuckles and to the distal palmar crease. *If you apply it beyond this point, finger movement will be impossible.*

Adjust the rotation of the forearm as is best for each particular fracture (63.5). Take a narrow plaster bandage, mould a plaster eye over the centre of gravity of the cast, and tie it with a comfortable collar around the neck.

CAUTION! Always split the cast. Only when the swelling has gone (mostly >1wk) add a circular plaster bandage.

N.B. Instead, you can apply anterior & posterior slabs *but never overlap them!*

A LONG ARM CAST

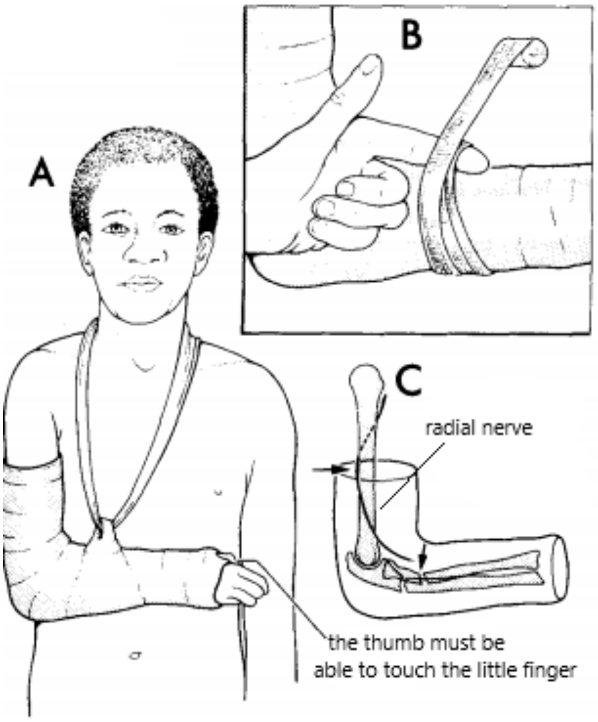


Fig. 63-2 A LONG ARM CAST. A, put a ring to suspend the cast. B, allow one finger breadth under the bandage so it is not too tight. C, avoid pressure on the radial nerve. *Make sure that the thumb is free and able to touch the little finger*. *Kindly contributed by Peter Bewes.*

63.2 Isolated ulnar shaft fracture

The fracture is usually complete and transverse, with minimal displacement. There may be slight angulation and bowing, but mostly there is neither shift, overlap nor rotation. The subcutaneous border of the ulna is tender and swollen over the fracture. These fractures are common and easy to miss. If tenderness over the bone persists after a few days, repeat the radiograph. Because the intact radius makes a good splint, it sometimes hinders displaced fracture healing, resulting in non-union.

TREATMENT
Make sure that the radial head is not dislocated (Monteggia fracture, 63.3) by including the elbow in a lateral radiograph.

ISOLATED ULNAR SHAFT FRACTURE

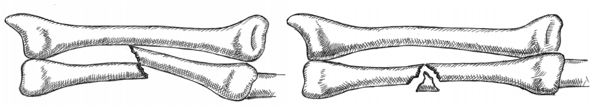


Fig. 63-4 ISOLATED ULNAR SHAFT FRACTURE. *Make sure that the head of the radius is not dislocated by including the elbow in a lateral radiograph*.

Apply a long arm cast & a sling to carry the forearm for 6wks. Then test for union by squeezing the radius and ulna together. **If there is tenderness,** the fragments have not yet united, so continue with a forearm circular plaster for another 4-6wks.
Don't use a collar & cuff as this will cause bowing of the ulna (63-3).

THE EFFECT OF A COLLAR & CUFF

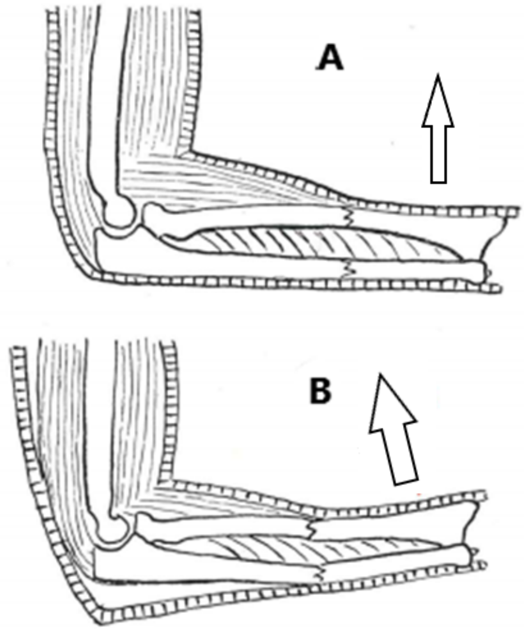


Fig. 63-3 USING A COLLAR & CUFF will cause the elbow to drop, whilst the wrist is held firmly in the cast. Ulnar bowing will result and limit rotation. *After Charnley J, The Closed Treatment of Common Fractures. 3rd ed. E&S Livingstone, Edinburgh 1961*

63.3 Monteggia fracture

Direct personal violence may result in this nasty adult fracture (it is otherwise a children's fracture, (73.7). The raised arm, protecting the head from a blow, receives its full force breaking the upper ⅓ of the ulna and dislocating the radial head. The important element is the latter. Rarely, the ulna does not break, or it may be overlapping (63-5).

If you suspect a dislocated radial head, take an AP & lateral view, because the dislocation may only be evident in the latter.

N.B. A line through the centre of the radius should pass through the centre of the capitulum in both views.

N.B. **If the ulnar fragments overlap**, either the radius is also fractured, or its head is dislocated.

Unless you reduce the dislocation of the radial head, the elbow will never be able to flex again.
Closed reduction is not always possible in adults.
The longer the delay, the more difficult is the reduction.

MONTEGGIA FRACTURE

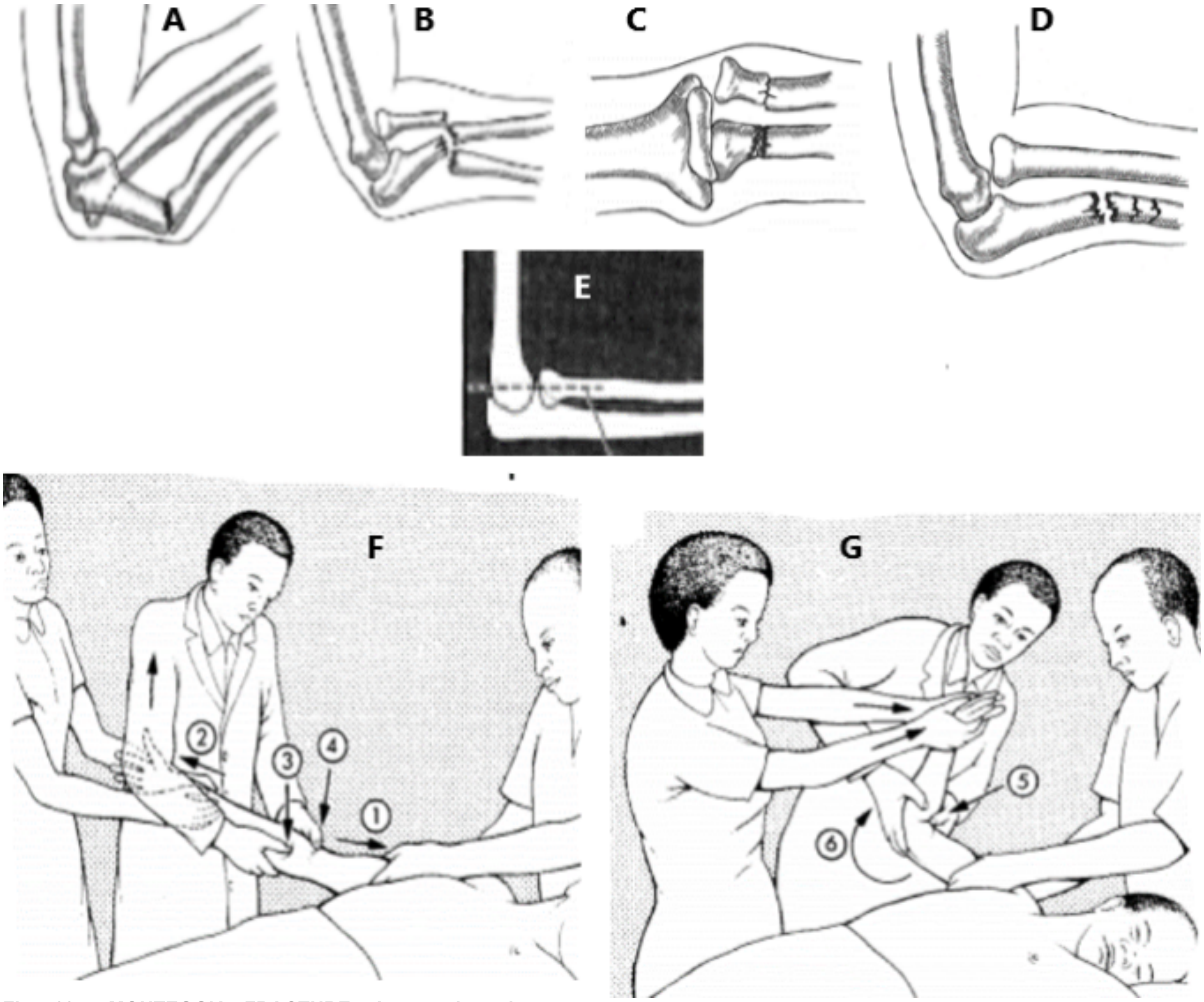


Fig. 63-5 MONTEGGIA FRACTURE. A, anterior ulnar displacement & anterior dislocation of the radial head. B, posterior ulnar displacement & posterior dislocation of the radial head. C, transverse ulnar fracture & lateral dislocation of the radial head. D, anterior displacement of ulna & radius, with anterior dislocation of the radial head. E, in a normal arm, a line through the radial head passes through the capitulum. F, while one assistant pulls on the supinated wrist (1), & another on the extended upper arm (2). Press the distal end of the proximal ulnar fragment (3), and the radial head into place (4). G, while still pressing the radial head (5), flex the supinated forearm (6). The radial head should reduce with a 'clunk' and the ulna should finally straighten completely as it does so. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

TREATMENT
Test sensation in the little finger.
Elevate the arm from a drip stand (63-10). Under anaesthesia bend the radius back into place. This reduces the fracture and the distal radio–ulnar dislocation. *N.B. If the distal ulna is also fractured, the radial overlap will usually remain.*

Under GA, whether or not the ulna is fractured, with 2 assistants, manipulate & reduce the fracture-dislocation (63-5F).

Apply a long arm cast with the elbow at 90^0, the arm in mid–supination, and the wrist in the functional position. Mould this to give a flat contour (63-9), and keep it on for 6wks

Then, remove it to test the stability of radius and distal radio-ulnar joint. If there is tenderness re-apply a cast for another 4wks.

Start finger and shoulder exercises immediately.
CAUTION! The head of the radius is unstable after this injury and can re-displace readily, so check radiographs at weekly intervals.
Hang the slabs from the neck for 6wks, then remove them and start active & passive joint movement. don't *force this,* it may take months.

If reduction of the ulna or radial head fails or the presentation is late, open reduction is necessary.

If a Monteggia fracture is open, perform a careful wound toilet, and reduce the fragments into the best position you can. Apply an elbow crossing external fixator (59.5) or a backslab with a window for wound treatment. Provide skin cover by delayed primary closure or grafting.

63.4 Galeazzi fracture

These are rare, difficult fractures in adults, usually from falls onto the hand. The radius is completely fractured and the distal fragment tilts, shifts anteriorly, overlaps, and inclines towards the ulna. The distal end of the ulna dislocates from both radius and carpus and displaces dorsally to create an ugly bulge on the dorsum of the wrist. The fracture is often open, with the radius penetrating the skin on one side of the forearm. An ulnar nerve injury is common.

If reduction is not adequate, reduce the fracture with an external fixator (59.5) for 4-6wks and apply a percutaneous K-wire through the distal radio-ulnar joint to fix it.

GALEAZZI FRACTURE

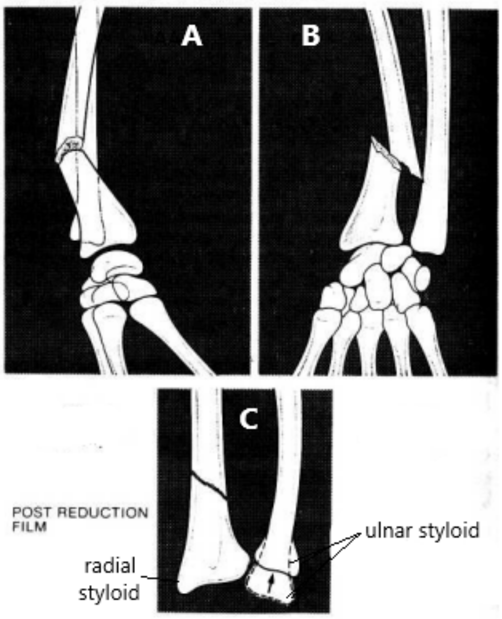


Fig. 63-6 GALEAZZI FRACTURE. A, radial fragments bow anteriorly. B, fragments overlap. C, after manipulation, if the ulnar styloid is distal to the radial styloid, *reduction is inadequate.*

If the fracture was missed, and both bones have united solidly, with the lower end of the ulna sticking out as a lump on the back of a stiff painful wrist, excision of the lower end of the ulna is necessary.

63.5 Isolated midshaft radial fracture

The fact that the radius rotates makes its fractures much more difficult to treat than those of the ulna. If there is no overlap, no reduction is necessary, and treatment with a long arm cast for 4wks, & another 2-4 weeks with a forearm cast is all that is needed. Mould this to give a flat contour (63-9).

ISOLATED RADIAL SHAFT FRACTURE

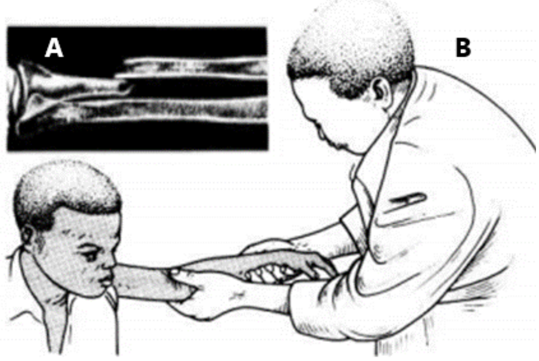


Fig. 63-7 ISOLATED RADIAL SHAFT FRACTURE. A, displaced fracture. B, technique of distraction. *N.B.* More than minimal angulation at the centre of the bone is unacceptable and needs fixation.

If the fragments overlap, reduction is difficult because the intact ulna prevents distraction and angulation of the broken radius, which usually breaks at its proximal ⅓. More distal fractures are even more difficult to reduce except with an external fixator.

ROTATION OF RADIAL FRAGMENTS

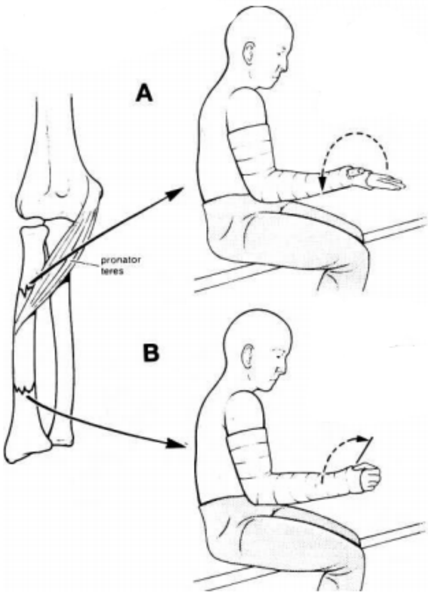


Fig. 63-8 ROTATION OF THE RADIAL FRAGMENTS. A, in fractures above the insertion of *pronator teres*, *biceps* supinates the proximal fragment, so for good alignment of the bones, supinate the distal fragment also. B, in fractures just below the insertion of *pronator teres*, this muscle, it pulls the proximal fragment into mid-pronation, so pronate the distal fragment likewise. *Kindly contributed by John Stewart.*

TREATMENT
Rotation of the distal fragment in more distal fractures may be variable, so it is best to obtain an AP radiograph of the proximal radius. The supinating muscles, *biceps* & *supinator* are attached to the proximal radius, and the pronating muscles, *pronator teres* & *pronator quadratus* are attached to its distal end. Use the position of the radial tuberosity as a guide to how far the proximal fragment has rotated.
Closed reduction is difficult, try elevating the arm and maintaining the position appropriately in a long arm cast. It is likely, though, you will need fixation.

JUDGING THE ROTATION OF THE PROXIMAL RADIAL FRAGMENT

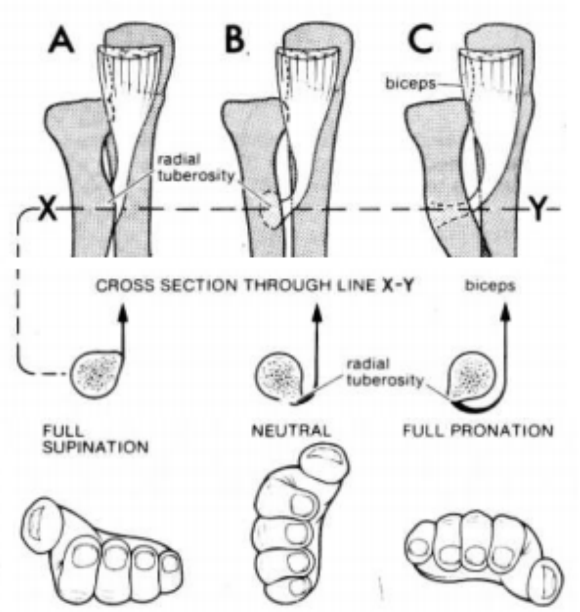


Fig. 63-9 HOW FAR HAS THE PROXIMAL FRAGMENT ROTATED? On an AP view of the proximal radius and check the position of the radial tuberosity, match it with supination/pronation positions A, B, or C, and apply the cast accordingly. *Kindly contributed by John Stewart.*

63.6 Midshaft radius & ulna fracture

These are common and difficult fractures as the fragments are difficult to align, and displace readily, and cross-union may occur, preventing rotation of the forearm. Internal fixation can be delayed up to 10days, provided you correct overlap by applying traction meanwhile. If rotation will later be limited, make sure it is set in the position of function (63-1). Fixation in any other position is a completely unnecessary tragedy.

TREATMENT
If both bones are broken at the same level, the forearm is free to bend in the middle. You can easily correct this angulation; but you must separate the fragments of the ulna from the radius. Suspend the arm vertically (63-11) and wait till swelling subsides.
While applying a cast, gently squeeze it antero-posteriorly *while it sets*. This flattens its cross-section, compresses the muscles of the forearm, and pushes the two bones apart. However, *this is a potentially dangerous cast*, so remember to split it correctly, so as not to lose reduction. *Never use an ordinary backslab*, which is quite ineffective in complete fractures. Encourage the patient to use the fingers actively as their muscles are attached to the broken bones, and so will promote osteogenesis & union.

DISTRACTING THE FOREARM BONES

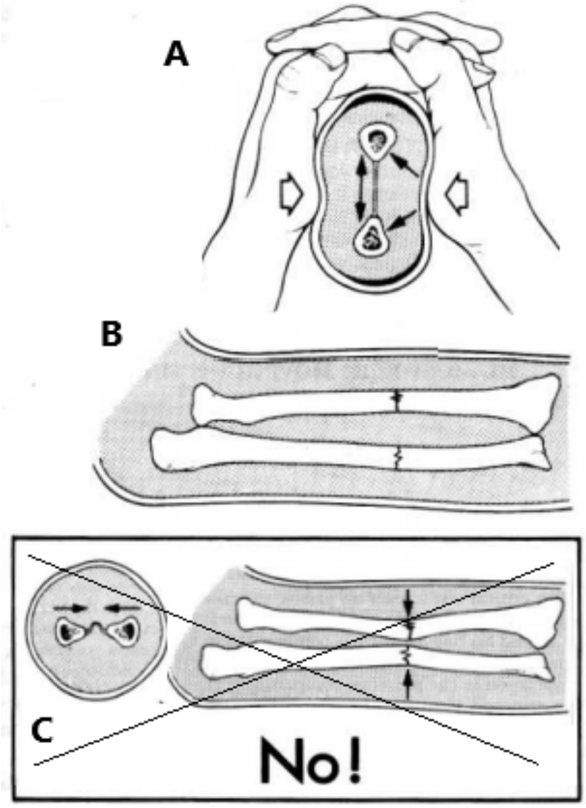


Fig. 63-10 DISTRACTING THE FOREARM BONES. A, exert gentle pressure on the forearm through a soft cast, as this will separate the radius & ulna (B) and help to prevent cross-union (C). *Kindly contributed by Peter Bewes.*

Occasionally you need to exacerbate a fracture to disengage the fragments. Be patient! When the displacement is reduced, apply the cast using cool water (so that it will not set too quickly), starting with the forearm part whilst 5Kg counterweight remains hanging from the upper arm.

ELEVATING A FOREARM FRACTURE

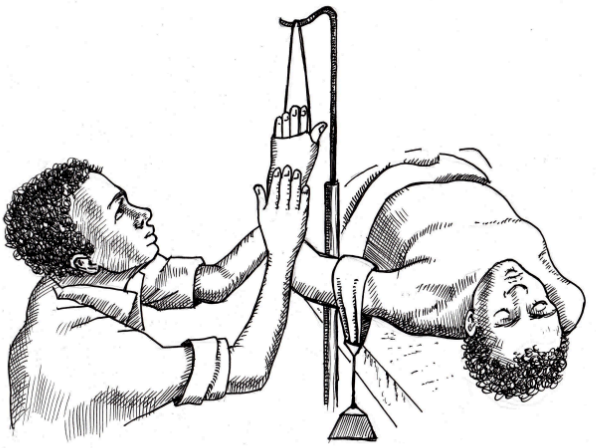


Fig. 63-11 ELEVATING A FOREARM FRACTURE. Anaesthetize the patient & elevate the forearm vertically with Chinese finger traps (63-12), so that the upper arm is horizontal, the elbow at 90°, by holding the fingers up. Apply the forearm part of the cast while 5kg counterweight applies the traction.

CHINESE FINGER TRAPS

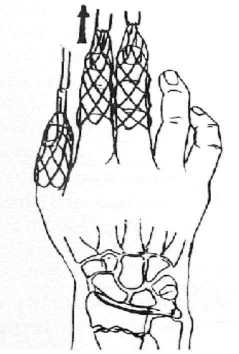


Fig. 63-12 CHINESE FINGER TRAPS. These ancient 'girl catchers' work on the principle that pulling the braid narrows the mesh, and so tightens its grip. *After Lao Tzu, China 650BC.*

Keep the forearm in mid-pronation. Extend the cast as far as the ip joint of the thumb & the mid-palmar crease. *The cast must allow free movements of the fingers, and the thumb should be able to touch the fingers*.
As the cast sets, squeeze it *lightly* between your hands to flatten it and separate the radius and ulna (63-9). Remove the sling and continue the cast to the upper arm.

CAUTION! *Always split the cast!* Do this while it is still soft, by making a single cut along its ulna side, from the hand to the upper arm.

Obtain a post-reduction radiograph straight away.
If reduction is unsatisfactory, apply an external fixator (63-13).

POSTOPERATIVE CARE
Watch the circulation in the fingers carefully. The compartment syndrome (49.6) is a serious danger in this particular injury.

Check frequently whether the fingers move easily and if passive extension is painful.

Start shoulder and finger exercises immediately. Practise putting the hand as far behind the head as possible. This will also exercise the shoulder. Encourage movement of the hands.

Take radiographs at 2wks, and again at 4wks, to make sure that rotation remains in the position of function. If necessary, correct any angulation, with a new cast. *After 4wks the bones will have united and it will be too late to make any correction*.
Keep the cast intact for 6-8wks. Gently spring the forearm bones. If these angulate or are tender, reapply the cast.

If the cast needs to be changed for any reason, suspend the arm by the fingers to prevent the fracture angulating while you apply a new cast.

DIFFICULTIES WITH FOREARM FRACTURES
If pain or loss of finger movement develops, split the cast and treat as a compartment syndrome (49.6). Soft tissue swelling is much more serious than loss of position, which you can correct this later by applying another cast.

If a spike of ulna is piercing the skin, clean it & reduce the fracture. If it still protrudes, nibble it off and toilet the wound. Suspend the forearm till the wound has begun to heal, and then treat as for a closed fracture.

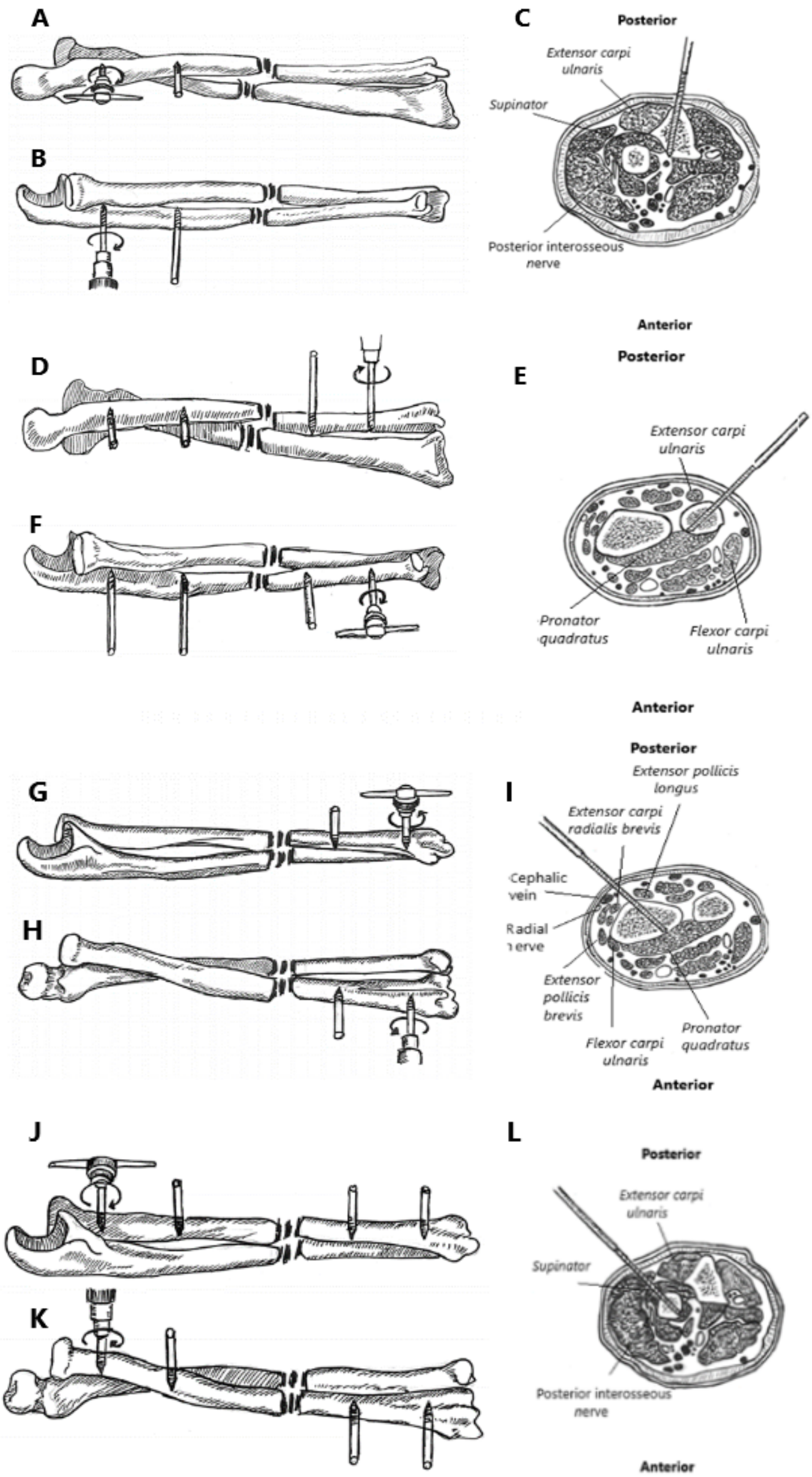
WATCH THE CIRCULATION IN THE HAND CAREFULLY!

KEEP THE FINGERS MOVING!

63.7 External fixation of forearm fracture

A good alternative, especially if you cannot properly reduce & hold displaced fractures of the forearm, is external fixation (63-13). Conservative treatment often gets bad results, unless done with fine attention to detail.

EXTERNAL FOREARM FIXATION (GRADE 3.2)
Insert the proximal ulnar pins at its subcutaneous posterior border. Avoid the pin tip protruding the opposite cortex in order to avoid nerve damage (63-13A,B). Supinate the forearm fully and insert the distal ulnar pins through its posteromedial cortex. Make sure you insert the pins down to bone to avoid the superficial branch of the radial nerve (63-13D,E)



EXTERNAL FIXATION OF THE FOREARM

Fig. 63-13 EXTERNAL FIXATION OF THE FOREARM. A-C proximal ulnar pins, D-F distal radial pins, G-I proximal ulnar pins, J-L proximal radial pins. C,E,I,L cross-sections.

Insert the distal radial pins between the *extensor pollicis longus* & the radial wrist extensors (63-13G,H). *Take great care with the proximal radial pins*, which have to penetrate the *supinator* muscle through which the posterior interosseous nerve passes (63-13J,K). Make 1cm *(not stab)* incisions, so you can dissect bluntly carefully down to bone.

You must put the pins distal to the radial neck of the radius and passes between the *extensor carpi ulnaris* muscle and the mobile wad. It will penetrate the *supinator* muscle, and pass anterior to the *extensor carpi ulnaris.*

64 Wrist injury

64.1 Introduction

There is rarely any indication to intervene surgically for wrist injuries. Even without perfect reduction, many fractures heal with excellent functional result if you pay attention to detail. Most injuries to the wrist result from a fall onto an outstretched hand.

There distal radius can fracture in 2 ways, by hyperextension (which is common) or hyperflexion (which is unusual). These are most easily distinguished on a lateral radiograph.

(a) Hyperextension fractures:
(1) Usually a transverse fracture <2.5cm from the wrist joint with the distal fragment displaced dorsally (Colles fracture), often with fracture of the ulnar styloid.
(2) The distal radial fragment is comminuted or T-shaped.
(3) The fracture line enters the joint, often with fracture of the radial styloid.

(b) Hyperflexion fractures:
(1) A transverse fracture <2.5cm from the wrist joint with the distal fragment displaced forwards (Smith's or reversed Colles fracture).
(2) The fracture line enters the joint, with the palmar fragment dislocating proximally (Barton's fracture).
(3) Comminuted fractures may include a flexion component.

FLEXION & EXTENSION WRIST FRACTURES

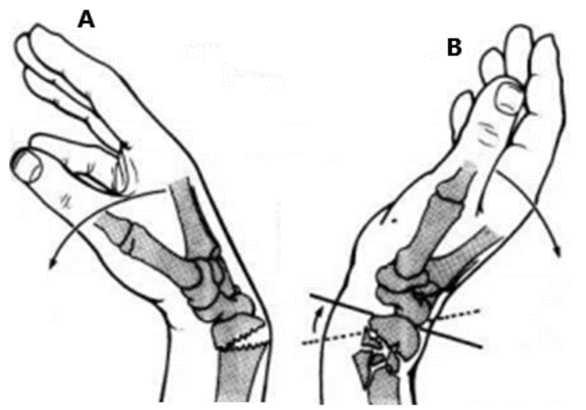


Fig. 64-1 FLEXION AND EXTENSION FRACTURES. A, in the lateral view, the flexion fracture has the distal radial joint surface tilted in flexion more than the norm (10°). B, in an extension fracture it is tilted less to volar, most often even to dorsal.

(c) Scaphoid fracture, across its middle, when the wrist is hyperextended & radially deviated. This may result in avascular necrosis of its proximal half (58-8B).

(d) Various types of carpal ligament rupture. Alone or in combination with scaphoid fracture, this leads to carpal instability. If disarrangement of carpal bones is visible on radiographs, it is called *static carpal instability.* If the deformity becomes only visible under arthroscopy or stress radiographs, it is called *pre-dynamic* or *dynamic carpal instability* respectively This can cause pain, a limited range of motion and osteoarthrosis in the long run.
(1) The lunate may separate from the scaphoid (scaphoid subluxation). This or a scaphoid fracture may cause avascular necrosis of the lunate (58-8C).
(2) Dorsal displacement of the carpus may leave only the lunate in contact with the radius (perilunate dislocation), and be associated with a radial styloid fracture of fracture of any carpal bone.
(3) When the hand snaps forward again, the lunate may be dislocated anteriorly (lunate dislocation).
(4) The 2 rows of carpal bones may dislocate in relation to each other (mid-carpal dislocation)
Small fractures of the triquetrum imply a ligament injury, but are of no consequence.

EXAMINING THE WRIST

Observe the wrist for swelling and deformity, and feel for warmth and tenderness.
Check for movements of ulnar & radial deviation.
Ask the patient to put both palms together, as in a position of prayer, and then to raise the elbows. Then compare the dorsiflexion in both wrists.
Then ask to put the backs of the hands together with the elbows at right angles. Compare palmar flexion in both wrists.
Then with the elbows in this position, check pronation & supination (63-1). If pronation and supination against resistance is pain free, the wrist and carpus are stable, if not, there may be an undetected problem.

CAUTION! Always examine the elbow. There may also be a fracture of the radial head.

If the radial styloid is no longer distal to the ulnar styloid, this implies a radial facture. Its replacement is a useful sign of adequate reduction.
Is the normal concavity in front of the injured radius filled by a tender hematoma?
Is there dorsal (a 'dinner fork' deformity), or palmar swelling?

SCAPHOID FRACTURE SPECIAL FEATURES:
(1) Place a finger tip in the 'anatomical snuffbox' with the hand in full ulnar deviation and press (64-2A). Wincing suggests a fractured scaphoid. The radial nerve passes over the 'snuffbox', and pressing on this pressed may be painful, so compare both sides carefully. Occasionally, there is mild swelling in the 'snuffbox'.

(2) Elicit pain only at the extreme ranges of palmar- & dorsi-flexion (64-2B)
(3) Deviate the clenched fist radially, and percuss the middle metacarpal head to elicit pain. There may also be tenderness over the knuckles of the index and middle fingers, but none over those of the ring and little fingers (64-2C).
(4) Pain on pronation & supination against resistance.

FOUR SIGNS OF SCAPHOID FRACTURE

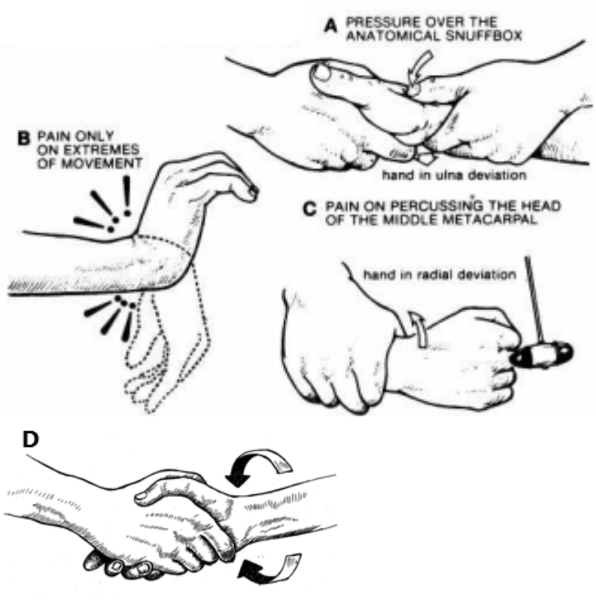


Fig. 64-2 FOUR SIGNS OF A SCAPHOID FRACTURE. A, tenderness at the bottom of anatomical snuff box over the scaphoid. B, pain only at the extremes of wrist extension & flexion. C, painful percussion with a patellar hammer over the head of the middle metacarpal. D, pain on pronation / supination against resistance.

The clinical appearance of carpal dislocations is not much different from that of wrist fractures. Rarely, there may be a gap palpable at the dorsum of the carpus or bony resistance in the ball of thumb region that is not there on a normal hand indicating a dislocated lunate.

Always test for circulation & sensation distally. A heamatoma in the carpal tunnel or dislocated carpal bones may compress the median nerve, and cause paraesthesia or sensory loss on the palmar side of the thumb, index, & middle fingers, especially if you hold the wrist palmarflexed for 1min. In this case, swift fracture reduction and/or carpal tunnel release (32.17) are necessary to avoid persistent nerve damage.

Analyse the carpal bones by bone in both views. Compare it to images of normal wrists in books, online or from other patients. As a last resort, x-ray the patient's opposite wrist.

CAUTION! If you suspect a fracture, but the radiograph is normal, repeat it in 7-10days.

NORMAL WRIST ANATOMY & RADIOGRAPH

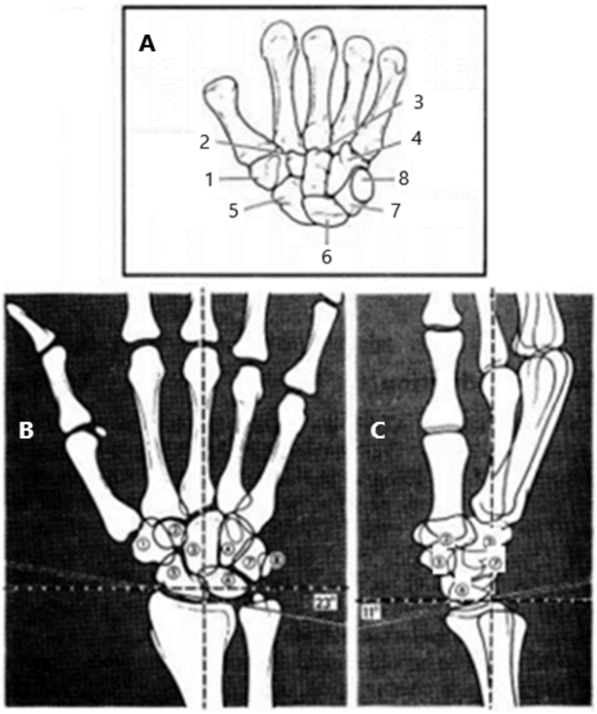


Fig. 64-3 WRIST ANATOMY A, the 4 distal carpal bones (trapezium 1, trapezoid 2, capitate 3, hamate 4) are tightly bound together, but the 4 proximal bones (scaphoid 5, lunate 6, triquetrum 7, pisiform 8) show considerable mobility. The pisiform is in effect a sesamoid bone for the *flexor carpi ulnaris* and plays no role in wrist stability. B, the a-p view and C, the lateral view with the wrist in a neutral position. show the articular surface of the radius to be angled medially c.23° and anteriorly c.11°. The radial styloid tip should be 2mm distal to the ulnar styloid tip.

64.2 Extension (Colles) wrist fracture

These are the most common human fractures. On hyperextension of the wrist, the distal end of the radius, and the tip of the ulnar styloid hits the triquetrum, either of which may break. In all cases, there will be a painful swollen wrist with reduced range of movement.

Radiographs are highly desirable, but if they are unavailable, rely: (1) on the nature of the injury (flexion or extension) and remember that, (2) if there is any displacement, the distal fragment will be displaced dorsally in extension, and anteriorly in flexion.

TREATMENT
Aim to restore as good an anatomical position as possible and maintain it until the fracture has healed well enough not to slip out of position after you remove the cast.

Make sure the fingers are always exercised!

COMMINUTED COLLES FRACTURE

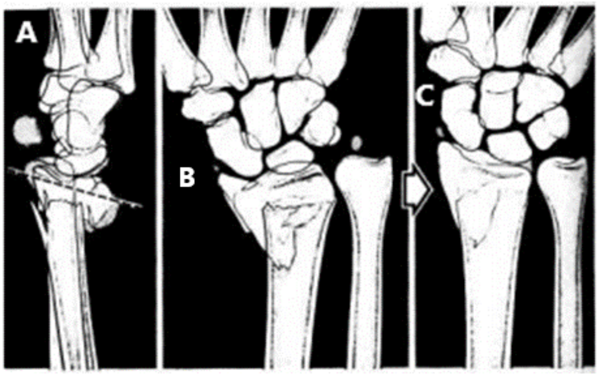


Fig. 64-4 A DISPLACED COMMINUTED WRIST EXTENSION FRACTURE. A, lateral view with dorsal angulation of the distal radial fragment. B, a-p view before reduction: *N.B. the ulnar styloid is distal to the radial styloid.* C, after reduction.

A satisfactory position (before manipulation or after) is if angulation of the distal radial joint surface is 20-30° medially & 0-10° anteriorly, the ulnar side of the radius is distal or adjacent to the ulna, and there are neither steps nor gaps >2 mm in the articular surface in any view.

A fracture will remain unstable in a cast if >3 of these criteria exist:
(1) dorsal angulation of the distal fragment >20°
(2) any element of a flexion
(3) comminuted metaphyseal fracture
(4) radio-carpal joint involvement
(5) radio-ulnar joint involvement
(6) ulnar fracture as well as radial
(7) radial shortening >2cm

Stable fractures (<3 criteria apply) you can treat satisfactorily by closed reduction and cast with good expectation of success. Even without perfect reduction, a good functional result is often achievable with exercises *even if a deformity remains.*
However, even a small crack involving the radio-ulnar joint may displace significantly on supination & pronation, and then give severe pain with this essential function of the wrist.

If a fracture is impacted in a reasonably good position with only moderate shift, and less than 15° of dorsal angulation, *don't try to reduce it*. It is stable enough to enable active movements to start at 4wks and thus reduce stiffness. Until then apply a slab to palmar surface of the arm and wrist suffices.

If the patient is >60yrs, do the same regardless of the fracture position. Osteoporosis will soon spoil your reduction and *function for eating and personal hygiene is what matters foremost*. At 3wks hold the cast in place with crepe bandages, and remove them for exercise. To regain pain-free function is all that matters.

N.B. Disregard fractures of the ulnar styloid.

Reducing a more severely displaced fracture is usually easy, but you must apply the cast properly to minimize the likelihood of the fragments slipping. *A poor end result is more often due to poor cast technique than incorrect fracture manipulation.* Radial instead of ulnar deviation of the distal fragment is the common mistake. Prevent this by making sure the patient's hand is in moderate ulnar deviation when you apply the cast.

If there is gross wrist swelling, it is better to elevate the wrist and wait (up to 48h) till the swelling has reduced, before attempting reduction. If you use Chinese finger splints, though, the fracture may even reduce on its own (59-13)!

ANAESTHESIA
(1) Local anesthesia of the fracture haematoma is very effective if the fracture is recent. Its disadvantages are: (a) risk of infection, and (b) it does not relax the muscles. Using careful aseptic precaution, insert the needle on the back of the forearm well above the wrist. Aim the needle a little proximal to the fracture, and advance it obliquely (64-5), so that it enters the fracture cavity; if you aspirate 'oil', this is emulsified fat; make sure you are then inside the haematoma, and inject 10ml, not more, of 2% lignocaine without adrenaline and wait 15 mins.
(2) Regional (supraclavicular or axillary) blocks
(3) Bier's block
(4) Ketamine.

N.B. Nitrous oxide is rarely adequate.

WRIST FRACTURE REDUCTION (GRADE 1.3)
Lie the patient down. Elevate the forearm (63-11) Put a strap round the upper arm & apply 5 kg counterweight. Wait 10mins while the traction corrects the impaction. Alternatively use Chinese finger traps (59-13). At the end of this time the distal fragment will usually be free, enabling you to move it into position with minimum of effort.

If disimpaction has not occurred, ask an assistant to hold the upper arm and give counter-traction with the elbow flexed 90°.

For a *left* Colles fracture, hold the distal fragment with your *right* thumb on its dorsal surface, whilst gripping the forearm in full pronation with your *left* hand. Apply traction with your right hand, moving it to just distal to the fracture line, and further *increase* the deformity by dorsiflexing the distal fragment in order to free it (64-5A). Use the edge of a table as a fulcrum holding against the external side of forearm just proximal to the fracture. When the fracture is disimpacted, pull the wrist into maximum flexion and ulnar abduction (64-5B) so that the thumb that you are pulling on points to the floor.

If there is still a ‘bump’ palpable on the dorsal side of the wrist, try to mould it away from proximal to distal with your right thenar eminence (64-5C).

You should now have fully reduced the fracture, *but its position will slip if you release the traction, or the forces applying pressure & counter-pressure to the distal fragment are relaxed.*

N.B. Pronation will then usually maintain the reduction without traction.

Keep your left hand stationary whilst anchoring the reduction in full pronation. Maintain this position and slide your right hand from the position in 64-6C to holding the 1st 3 fingers (64-5D), in moderate ulnar deviation and slight palmarflexion; then get an assistant to apply the cast.

N.B. For a *right* Colles fracture, swop hands.

DISIMPACTION OF A COLLES FRACTURE

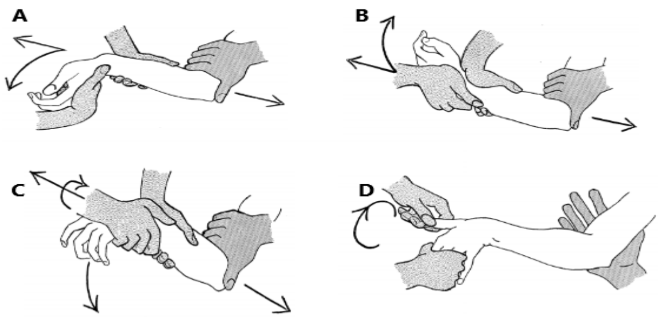


Fig. 64-5 DISIMPACTION OF A LEFT COLLES FRACTURE. A, with countertraction, hold the distal radial fragment with your right thenar eminence whilst holding the forearm with your left hand. Then increase the deformity by dorsiflexion. B, press the distal fragment in a palmar direction & flex the wrist. C, fully pronate the forearm whilst maintain traction & counter-pressure. D, hold the forearm in strong pronation by pulling on the thumb & the *1st three fingers only.* *After Charnley J, The Closed Treatment of Common Fractures. E&S Livingstone, Edinburgh 3rd ed.1961*

IMMOBILIZATION POSITION FOR A COLLES FRACTURE

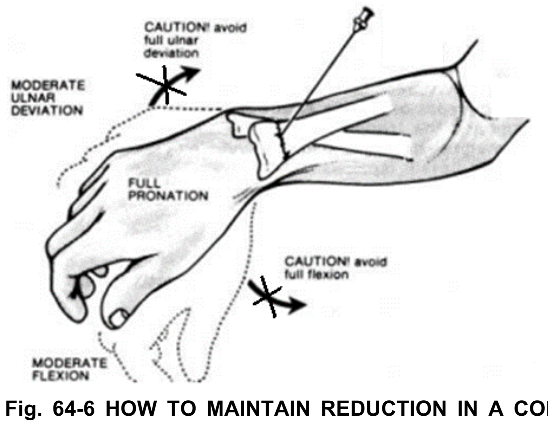


Fig. 64-6 HOW TO MAINTAIN REDUCTION IN A COLLES FRACTURE. Apply the cast in full pronation, in moderate flexion and in moderate ulnar deviation. In this position the extensor tendons passing over the back of the distal fragment hold it reduced. Extreme flexion or extreme ulnar deviation will cause a stiff wrist. (The needle shows the position for entering the haematoma for LA).

CAST TECHNIQUE

Follow the steps carefully and you will have less likelihood of the position slipping. *Remember that the cast should not just be dorsal, but radial*. The cast should reach most way along the forearm in order to achieve three-point action. *On its palmar aspect, the cast should be thick enough to take a permanent impression of your thenar eminence!*

Don't let the cast reach further than the distal palmar crease. Make sure the mcp joints are free, and the tip of the thumb can touch the index finger.

Hold the cast in place with a crepe bandage. *Make sure the plaster is not completely circular initially;* you can complete the plaster when the swelling has subsided, usually after 1wk.

If the fracture is unstable, continue the cast up the upper arm with the elbow at 90° in a young person. Alternatively, augment stability with external fixation:

FOLLOW-UP CARE

Check the cast!

(1) Make sure the wrist is fully pronated, moderately palmarflexed & moderately ulnar deviated in the cast.

(2) The mp joints must be free. If the cast extends too far distally, it will splint them in extension, and produce a stiff useless claw-like hand.

(3) Make sure the fingers are pink and not numb.

(4) Never put on a complete circular cast without splitting it through *all* its layers! Even if the swelling is not significant at first, *it will recur after your manipulation*. If the cast does not allow for the swelling, a compartment syndrome (49.6) may result.

CAST FOR A COLLES FRACTURE

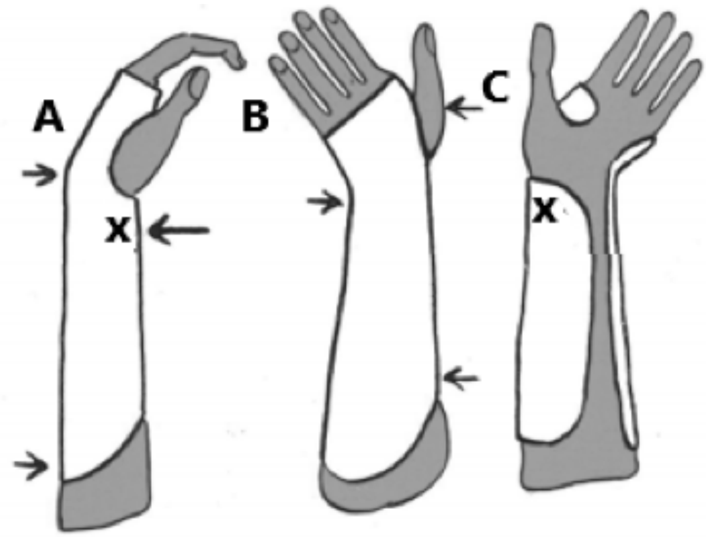


Fig. 64-7 CAST FOR A COLLES FRACTURE. A, make a *radial* cast, with thickening to allow pressure at point X. B, ensure the mcp joints are free. C, keep the cast open initially. *After Charnley J, The Closed Treatment of Common Fracture, E&S Livingstone, Edinburgh 3rd ed. 1961*

CHECK RADIOGRAPHS
Compare your result to the acceptable anatomical position criteria described before.

If reduction is unsatisfactory, have one further attempt at manipulation. *More attempts will only make the clinical result only worse*.

FINGER EXERCISES

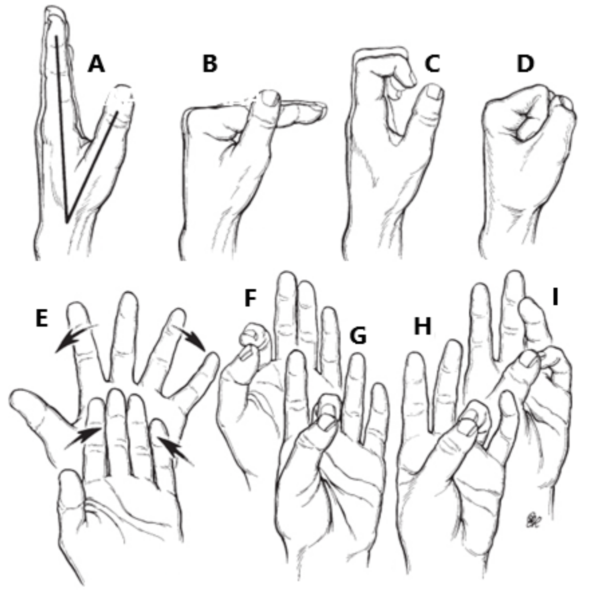


Fig. 64-8 FINGER EXERCISES. The '6-pack' of exercises to keep finger joints mobile and the intrinsic muscle pump active: A, arrow. B, table-top. C, claw. D, fist, E, in & out. F-I, thumb to finger tips. *After Elsevier Science*

Keep the cast in place for 3wks or up to 6wks for more unstable fractures.
Encourage active finger movements (64-8): this activates the muscle pump and reduces swelling. Also insist on elbow & shoulder exercises.

Where possible, repeat radiographs after 7-10days, to check for re-displacement.

CAUTION! Tell the patient to return immediately if the fingers become painful or numb or the cast feels too tight. Otherwise give instructions how to split the cast with firm scissors or tools.

N.B. The approach to unstable fractures will depend on the facilities available. If you can refer to expert help in a well-equipped resource, which offers a good service, do so before the fracture stiffens at 2wks.

WRIST EXTERNAL FIXATION (GRADE 3.2)
Otherwise stabilize the fracture with an X-fix (64-9)

N.B. it is easy to damage nerves using K-wires at the wrist!

EXTERNAL FIXATION OF THE WRIST

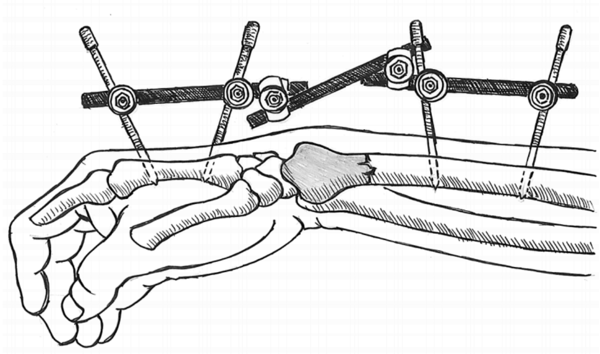


Fig.64-9 EXTERNAL FIXATION OF THE WRIST. Use this to position unstable fractures, especially if you have fluoroscopy.

DIFFICULTIES WITH EXTENSION FRACTURES

If the distal radio-ulnar joint remains subluxed & painful, and rotation at the wrist limited, there is probably persistent radial deviation and a protruding distal ulnar deformity. You can get good results by resecting part of the distal ulna (Darrach operation). Remove only enough bone so that the distal portion of the ulna lies adjacent to the sigmoid notch of the radius. Remove the bone subperiosteally to encourage anatomical and physiological regeneration of its distal end and leave the ulnar styloid and its ulnar collateral ligament attached *in situ*.

If there is sudden inability to extend the thumb weeks or months afterwards, the tendon of *extensor pollicis longus* has ruptured. You can usually repair this.

If pain will not settle or even increases, and there is no other explanation, especially if there are ≥2 of these features:
(1) glove distribution of pain affecting the whole hand distal to the fracture,
(2) hypersensitivity to touch or minimal painful stimuli,
(3) skin color and temperature different to the collateral hand,
(4) oedema and abnormal sweating,
(5) stiffness of finger joints,
(6) altered hair and nail growth, and a fusiform appearance of the fingers, this may be the Complex Reflex Dystrophy Syndrome.
Use hydrocortisone 100mg od and reduce the dose over 2-3 weeks

64.3 Flexion wrist fracture

This rare injury arises from a fall onto a flexed wrist, and produces a characteristic deformity on lateral views (64-10).

You may be able to achieve reduction by disimpacting the distal fragment anteriorly and then pressing it dorsally into position, and anchoring it in full supination with dorsiflexion. An above elbow cast is necessary, but this fracture usually needs internal fixation for a good result.

FLEXION WRIST FRACTURES

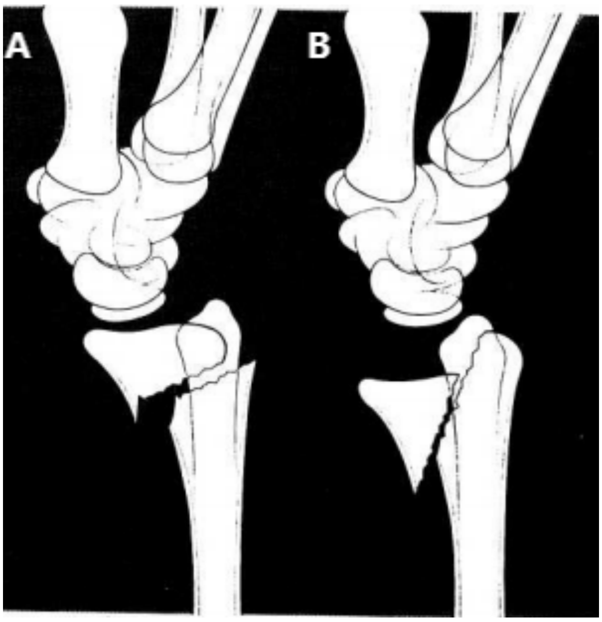


Fig.64-10 FLEXION WRIST FRACTURES. A, Smith's extra-articular fracture. B. Barton's intra-articular fracture. Both are unstable.

64.4 Scaphoid fracture

This can occur at any age, even in children (73.9), but is particularly common in young men. A fall on the hand forcibly dorsiflexes the carpus. Instead of, or in addition to, the distal radius breaking, the scaphoid and/or intra-carpal ligaments (64.5) may rupture.

A scaphoid fractures often results in non- or mal-union, because most of this little bone is covered by cartilage and its blood supply enters through the distal pole and the dorsal crest. Furthermore, this little bone articulates with 5 others and is located deep in the carpus, and so is difficult to immobilize to allow fracture healing.

A scaphoid fracture is too often missed. You need a special view to get a good look at the scaphoid bone.

Get an oblique dorsopalmar view in ulnar abduction with a strongly clenched fist (which stresses the ligaments and may make unusual gaps appear, *e.g.* between lunate & scaphoid. Always check the 4 signs suggesting a scaphoid fracture (64-2).

SCAPHOID FRACTURES

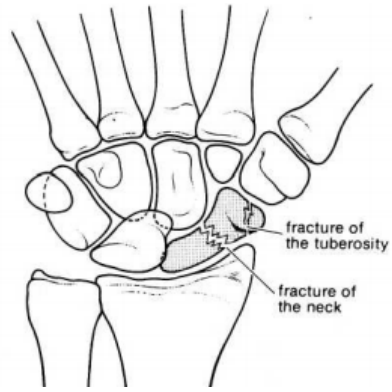


Fig. 64-11 SCAPHOID FRACTURES. The more distal & the less displaced, the less likelihood of avascular necrosis. The fracture of the tuberosity is insignificant, but that of the neck important.

The fracture line may only be a fine crack in the neck of the scaphoid which you can easily miss. Look for it on a good light with a magnifying glass or zoom. If there is clinical evidence but you cannot see a fracture, apply a scaphoid cast and obtain another radiograph after removing the cast 7-10days later. The fracture line will then be much more obvious.

If clinical signs remain strongly suggestive, but the radiograph is still unhelpful, assume there is a scaphoid fracture, and treat it as such. Avascular necrosis of the proximal part (58-8B) often results if the fracture is not kept well immobilized.

TREATMENT

FRACTURE OF THE DISTAL POLE
Strong ligaments help to stabilize the fragments. Therefore this is a benign injury. Apply a dorsal cast until pain subsides (≤3 weeks) and arrange for early active movements.

UNDISPLACED FRACTURE
No reduction is necessary, but rigid splinting is. Apply a radio-dorsal cast from below the elbow to the include the mcp joint of the thumb, with the wrist in slight dorsiflexion and the thumb in mild opposition as if holding a glass (64-12).
If swelling reduces and the cast becomes loose, it should be replaced by one fitting snugly.

OTHER DISPLACED FRACTURES
Displaced scaphoid fracture of the middle and proximal third are likely to end in non- or mal-union. Both have great potential to limit wrist motion, cause chronic pain and osteoarthritis within a few years.

Immobilize in circular above elbow cast in supination and ulnar deviation of the wrist. While the cast is hardening, mould it by pressing the distal scaphoid pole upwards from the palmar side and at the same time apply counter pressure dorsally over the capitate. Try to refer such a fracture.

A SCAPHOID CAST

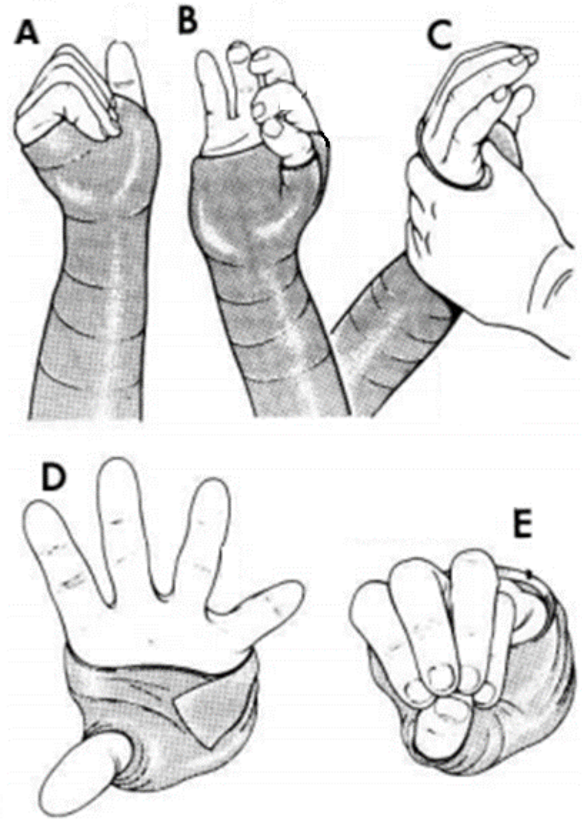


Fig. 64-12 A SCAPHOID CAST. A, the cast includes the mcp joint of the thumb. B, make sure the thumb is in mild opposition, and able to touch the index tip. C, a grip must be possible. D, full spreading of fingers and thumb also. E, all fingers should be able to touch the thumb. Clenching a fist should be possible. *Adapted from Perkins G, Fractures & Dislocations, Athlone, London 1958 with kind permission.*

FOLLOW-UP CARE
Encourage use of all the joints outside the cast. This will soon make it soft, so renew it as necessary Remove the cast at 6wks for undisplaced fractures and at 10wks for displaced, and obtain more radiographs.

If the fracture has not united, remove the cast, encourage active motion. Your hopes rest with a fibrous non-union or a false joint. There may be none or few symptoms, but if later there is severe disability, try to refer to a specialist hand surgeon who may still find options for repair or a salvage procedure.

64.5 Carpal dislocation

During a fall on an outstretched hand violent dorsiflexion of wrist can cause intra-carpal ligaments to rupture together with an extension fracture of the distal radius or a scaphoid fracture.
Many patterns of injury are possible. The most important ones are (1) scaphoid subluxation, (2) perilunate dislocation, (3) lunate dislocation, & (4) mid-carpal dislocation.

(a) Scaphoid subluxation.
Owing to rupture of the 3 scapho-lunate ligaments, an abnormally wide gap between the two bones will appear on AP radiographs (64-13B). The ligaments between the distal pole of scaphoid on one side, and trapezium and trapezoid on the other side, rupture and the lunate rotates into extension and the scaphoid into flexion. On a lateral radiograph, the half-moon of the lunate faces dorsally and the distal scaphoid points anteriorly. *Always compare with the radiograph with the unaffected wrist*, since there is great anatomical variety. If the injury is confirmed try to refer for ligament repair and temporary carpal transfixion. Otherwise treat this like a displaced scaphoid fracture (64.4)

(b) Perilunate dislocation.
When the intra-carpal ligaments on both sides of the lunate give way, the carpus may dislocate dorsally, but the lunate remains in its normal place in relation to the radius. If the injury stays like this, there is a perilunate dislocation.

(c) Lunate dislocation.
This is the 2nd stage of a perilunate dislocation: the displaced carpus springs back and rotates the lunate forwards. As it does so, the weak posterior radio-lunate ligament ruptures, but the strong anterior one remains intact. The displaced lunate presses on the median nerve, and if the fracture is not reduced, permanent neurological deficit may ensue. (Rarely, the lunate dislocates posteriorly.)

(d) Midcarpal dislocation.
If the ligaments between the proximal carpal row (scaphoid, lunate & triquetrum) and the distal row (trapezium, trapezoid, capitate & hamate) are torn, the 2 rows my dislocate from each other. The most obvious sign on a lateral radiograph is the incongruence of the lunate-capitate joint.
These dislocations are important, because you can usually reduce them. If the dislocation is neglected, severe disability follows, and the greater the delay, the worse it becomes. Exactly the same kind of injury fractures the scaphoid, *so always look for a fractured scaphoid too*.

SIGNS
Clinically, all carpal dislocations make the wrist swell. The fingers remain partly flexed, and will not straighten. Wrist movements are impossible, and its antero-posterior diameter is increased. The styloid processes are in their normal places. The radial pulse and the concavity of the lower end of the radius are normal. There may be sensory loss in the thumb & 1st 3 fingers if the median nerve is involved.

RADIOGRAPHS
These are difficult to interpret. Take a lateral view and compare it with one of the normal wrist.

In a perilunate dislocation*,* the lunate is more or less in its normal place in relation to the radius, and is facing in its proper direction, but its distal cup-shaped articular surface is not in contact with the dome-shaped surface of the capitate. Instead, the hand and the carpus lie in a plane posterior to the radius. So, the radio-scaphoid joint is incongruent. *This dislocation is less easy to see in an AP view*. A useful sign is an increase in the normal space between the lunate and the scaphoid, as in scaphoid subluxation (64-13B), because torn scapho-lunate ligaments are a prerequisite for such a dislocation.

In a lunate dislocation, the proximal dome-shaped surface of the lunate faces posteriorly, and is no longer in contact with the radius (64-14A). Its distal cup-shaped surface faces anteriorly, and is no longer in contact with the capitate. The capitate and the carpus are in the same plane as the radius.
Signs in the AP view are characteristic, but are often missed. The normal lunate appears to have 4 sides in an AP view, but when it is dislocated, it seems only to have 3. So, look for a 'triangular lunate'. Look also for a widened space between the scaphoid and the lunate. Normally they touch. *Dislocations of the lunate are so easily missed that the lunate is always the first bone to look at in any radiograph of the wrist.*

In a midcarpal dislocation, the radiocarpal joint is in place but the dome of the capitate is out of its socket at the distal side of the lunate.

A 'SEVERELY SPRAINED WRIST' IS A FRACTURED SCAPHOID UNTIL PROVED OTHERWISE

LOOK CAREFULLY AT THE LATERAL RADIOGRAPH

TREATMENT
Try to reduce a carpal dislocation immediately; your chances of success will never be better and decrease by the hour. *The median nerve may otherwise be permanently damaged!* After 2wks, closed manipulation is impossible.

2 CARPAL DISLOCATIONS

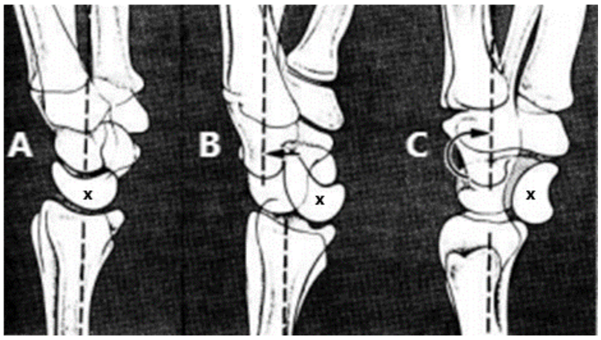


Fig. 64-13 PERILUINATE & LUNATE DISLOCATIONS. A, the normal wrist. B, in the perilunate dislocation, the carpus is pushed backwards leaving the lunate in its normal position in relation to the radius. C, in the lunate dislocation, the carpus has sprung back into its place and has displaced the lunate anteriorly. The lunate is marked 'x'

LUNATE DISLOCATION

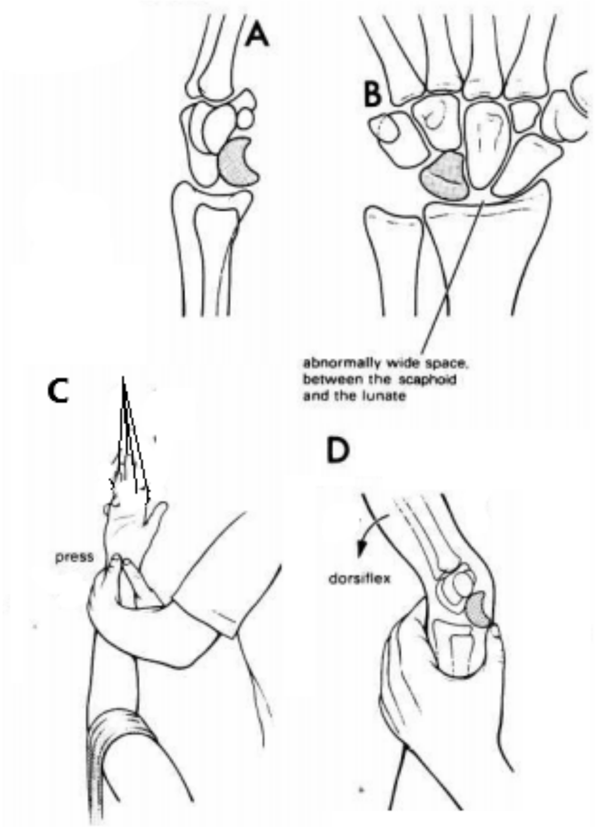


Fig. 64-14 LUNATE DISLOCATION. A, Lateral view of the wrist, showing a 'crescent' shaped lunate, not in contact with the radius, facing posteriorly. B, the lunate takes on a 'triangular' appearance, and the space between it & the scaphoid is enlarged. C, press with both thumbs on the back of the wrist. D, while continuing to press hard, dorsiflex the wrist. then palmarflex the wrist. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

Reduction of the latter 3 dislocations is similar:
(1) Use a GA, since this alone will provide enough muscle relaxation.
(2) Elevate the hand with Chinese finger traps as before (63-11) for ≥10mins.
(3) Supinate the forearm.
(4) While your assistant is maintaining very strong traction, you reduce the dislocation:
(5) For a *perilunate dislocation*, place both your thumbs against the back of the wrist, push forwards, while slowly palmarflexing the wrist.
(6) For a *lunate dislocation,* place both your thumbs against the front of the wrist over the lunate, and press hard dorsally while dorsiflexing the wrist (64-14D). Then palmarflex the wrist while maintaining traction and pressure.
(7) For a *midcarpal dislocation* the direction of pressure depends on the direction of displacement of the distal row. If the displacement is dorsal, press anteriorly or *vice versa*.

If your reduction attempt has failed and you cannot refer within a few days, try open reduction yourself: Open the carpal tunnel as for carpal tunnel release and extend the incision proximally into the forearm.
Hold the tendons aside and repeat the reduction maneuver described above but pressing now directly on the lunate, which you should be able to see. *Make sure it is not tilted when attempting to press it into place*.

If the carpus is dislocated dorsally, try again but with the appropriate reduction manoeuvre for perilunate dislocation, applying counter pressure with your thumb to the lunate and the anterior edge of the distal radius.

OPEN CARPAL REDUCTION (GRADE 3.2)
If all this fails as well, make a straight dorsal midline incision centered over Listers' tubercle. Open the 4th extensor compartment, hold the tendons aside and push against the carpus now visibly sitting dorsal to the radius.
Before closing your incision, look at the wrist capsule. Close tears in it with a few interrupted sutures of absorbable 3/0, but *don't overlap it* as this will hinder dorsiflexion later on.

If the diagnosis was missed, this may be because no fracture was spotted on the radiograph despite the patient's complaint that something was wrong with the hand. If nothing is done, permanent disability is inevitable.

EXAMINE THE LUNATE FIRST WHEN YOU LOOK AT A WRIST RADIOGRAPH

POSTOPERATIVE CARE
Apply a cast if the scaphoid is fractured.
Obtain a post-manipulation radiograph to make sure the lunate is not dislocated.
Deficit of the median nerve function should improve quickly after reduction. If it does not, decompress the carpal tunnel (32.17).

If you can, refer the patient for ligament repair and internal fixation even after successful reduction and splinting. If not, maintain a splint for *6wks* to allow some healing of the ligaments by scar formation, & then encourage active movements immediately.

65 Hand injury

65.1 Introduction

Different people use their hands in very different ways. Some need nimble agile fingers, while others need a powerful grip. So, find out which functions you most need to preserve. Violinists and labourers have quite different expectations of their hands, and yet, provided their injuries are correctly treated, it is possible ultimately for each hardly to notice what might seem to have been a severe mutilation.

Hand injuries are often worse than they look, but there are many opportunities for disaster:
(1) You can easily miss cut nerves or tendons, so assume they are injured, until you have proved otherwise.
(2) If you neglect proper management especially about splinting, movement, and amputation (65.18), a patient may easily end up with a stiff hand, or a stiff useless finger.

The outcome of a hand injury mostly depends on how you care for it during the 1st few days. Injuries to the flexor tendons will cause difficulty. Most patients are unlikely to return for simple physiotherapy, so try to get the hand back into action as quickly as you can.

Don't forget the general principles of wound care (46.1). Grafting raw surfaces as soon as is practicable is particularly important, because this minimizes infection and the stiffness which otherwise follow.
Hand injuries are often multiple with several types of unjury in the same hand, so be prepared to modify the methods for single injuries described.

N.B. Hand operations are not easy, and only careful, dedicated, painstaking, delicate work is good enough! Although a hand injury may look minor, it is *never trivial*: a fractured phalanx can disable a patient and prevet work just as easily as a fractured femur!

Equipment:
FINGER SPLINTS, aluminium, padded. These are strips of aluminium with foam rubber on one side. Cut them and bend them to suit the need (65-9). If you cannot get them, try to make them.

ASSUME NERVE & TENDON INJURIES IN A HAND WOUND UNTIL PROVED OTHERWISE

ELEVATING THE INJURED HAND

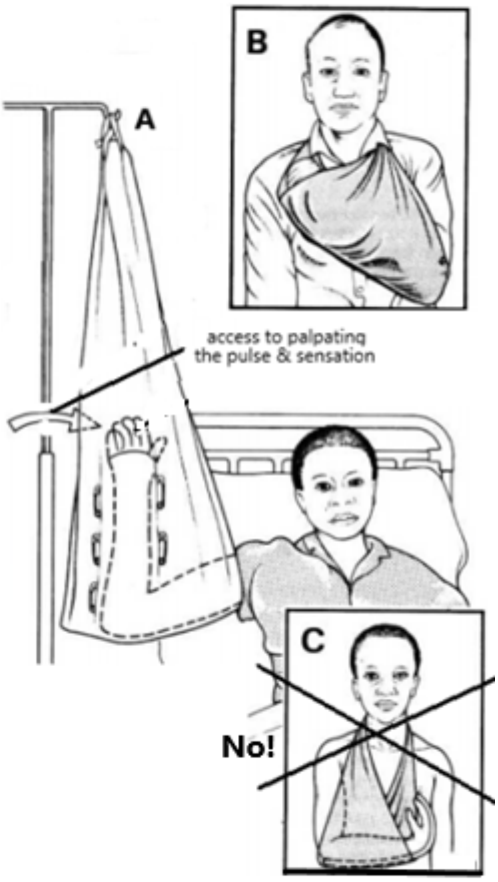


Fig. 65-1 RAISING AN INJURED ARM AND HAND will reduce traumatic or infectious oedema and minimize stiffness. A, if the hand is injured or infected, pin it in a towel, & suspend it with the upper arm horizontal. B, for an ambulant patient, raise the hand in a St John's sling, C, *don't keep it horizontal.* *Kindly contributed by Peter Bewes, Richard Batten & John Stewart.*

HAND POSITIONS IN TENDON INJURIES

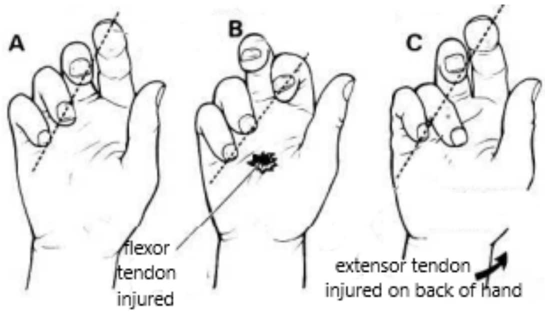


Fig. 65-2 HAND POSITIONS IN TENDON INJURIES. A, in a normal hand the fingers are approximately in line. B, in a flexor tendon injury the injured finger is extended. C, in an extensor tendon injury it is flexed. *Kindly contributed by Peter Bewes*

N.B. There is a special position for flexor injuries (65.16).

HISTORY
Find out:
(1) the cause of injury: clean or dirty object *(e.g. a bite)*?
(2) the normal use of the hand? Left or right-handed?
(3) the injury mechanism: crushing, end-on force, injection, penetration, fire, heat, hyperextension, or angulation?

EXAMINATION
Answer 5 questions:
(1) Is the hand or finger viable?
(2) Is the hand skeleton stable?
(3) Is there actual or impending skin loss?
(4) Are the nerves intact?
(5) Are the tendons intact?

Do your testing first on the uninjured hand. This allows you to be sure the patient understands what movements you want to test & also reassures him the testing won't hurt.

LOOK
If the fingers are not in their normal position of rest, suspect a fracture, dislocation, or tendon injury because an unopposed uninjured tendon has pulled the injured finger into an abnormal position (65-2).

FEEL
CHECK THE CIRCULATION
Test revascularization after pressure on the nailbeds & fingertip sensitivity.
Test the digital arteries: raise the hand, compress the digital arteries at the base of the injured finger until it becomes pale. Still compressing them, lower the hand. Release one artery. If the finger becomes pink, that artery is patent. Repeat the process with the other artery (modified Allen's test).
Perform the same test with radial & ulnar arteries to check the palmar arch (Allen's test).

CHECK THE NERVES
Test the motor & sensory functions of the median, ulnar, and radial nerves (65-3) *before you use any LA.*

(a) Median nerve:
(1) Test opposition.
(2) Test sensation at the index fingertip.
(b) Ulnar nerve (deep branch)**:**
(1) Lay the hand flat; test abduction of the index finger towards the thumb.
(2) Test sensation at the little fingertip.
(c) Radial nerve (distal):
(1) Test extension of the straight index with the wrist dorsiflexed. Or, keeping the palm flat on a table, test extension of the fingers.
(d) Radial nerve (proximal & distal)**:**
(2) Test the area on the dorsum outlined (65-3Dx)

TESTING THE NERVES

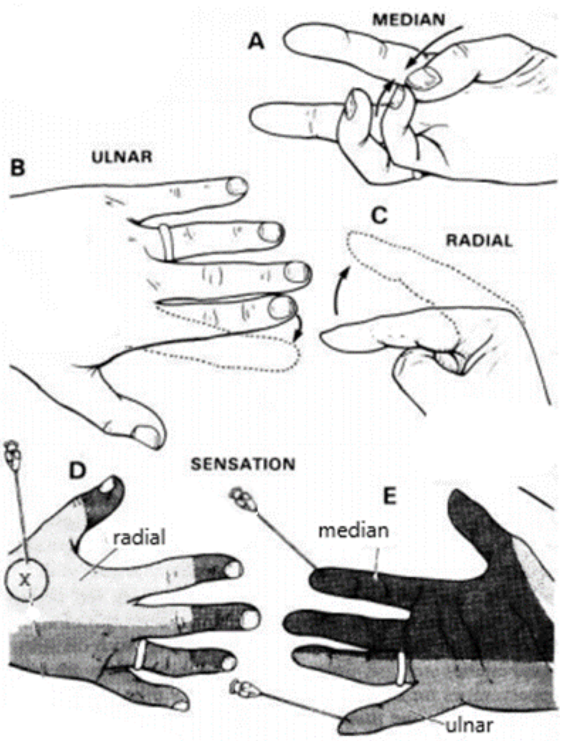


Fig. 65-3 TESTING THE NERVES OF THE HAND. A, median nerve: check opposition of thumb & little finger. B, ulnar nerve: check abduction of the index towards the thumb. C, radial nerve: check extension of the straight index with the mcp joint flexed. D,E, check pin-point sensation over the palm & on a specific zone 'x' on the dorsum.

MOVE (CHECK TENDON FUNCTION)
Test the superficial, deep finger & wrist flexors, & the extensor tendons.
(a) *Profundus* tendons:
Test each finger in turn. Hold the proximal ip joint extended (65-4A): if flexion even to only 15° of the distal phalanx is possible, the tendon is intact.
(b) *Superficialis* tendons:
Hold all the fingers, except the one you are testing, fully extended (65-4B). If flexion of the proximal ip joint is possible, the tendon is intact.
(c) Wrist flexors:
Feel the tendons on the anterior of the wrist tightening with flexion against resistance (65-4C).
(d) Extensor tendons:
Test extension of the fingers against resistance (65-4D).

CHECK STABILITY
Look for swelling, and feel for tenderness over the injured joint; hold the bone proximal to the joint and move the bone distal from side to side. Check for laxity with an ip joint extended, and a mcp joint flexed. This is the position in which the ligaments are taut (65-8A).

TESTING THE TENDONS

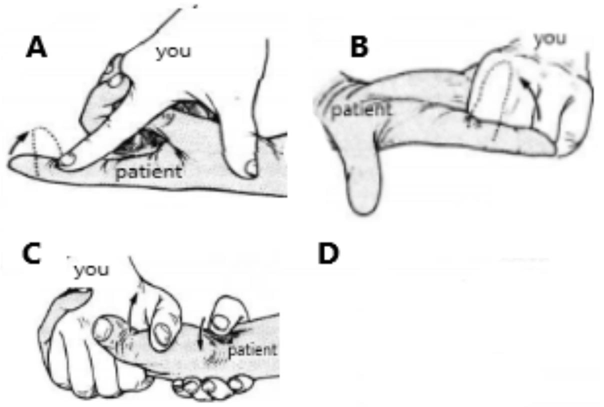


Fig. 65-4 TESTING THE FLEXOR TENDONS. A, keeping the proximal ip joints extended, test flexion of the distal ip joints. B, keeping the fingers extended, except the one tested, test flexion of the proximal ip joint. C, feel wrist flexors at the wrist when acting against resistance.

RADIOGRAPHS
If you suspect fractures or foreign bodies, including glass, take AP & lateral views. If you suspect an avulsion fracture at the base of a phalanx, make sure that the radiograph is centred correctly. To locate foreign bodies, cross 2 pieces of wire and put them over the entry hole, and a 3rd wire in a plane at 90°.

CAUTION! Don't confuse a fracture with:
(1) A nutrient artery which passes obliquely through the cortex of a phalanx, usually at the junction of its middle and distal ⅓.
(2) The shadow of soft tissues. These may look like fracture lines but pass across a bone and are not confined to it.
(3) Epiphyses.

IMMEDIATE TREATMENT
Bleeding is seldom severe. Pressure with gauze, and raising the injured hand, will usually stop the haemorrhage. If it persists, apply a tourniquet, identify the bleeding vessel & ligate it. *Don't use diathermy. Don't clamp blindly.*

TREATMENT FOR SEVERE HAND INJURIES (65.19)
Record which nerves and tendons have been damaged before you use anaesthesia! Peeking and poking in a wound will achieve little afterwards.

LOCAL ANAESTHESIA FOR THE HAND

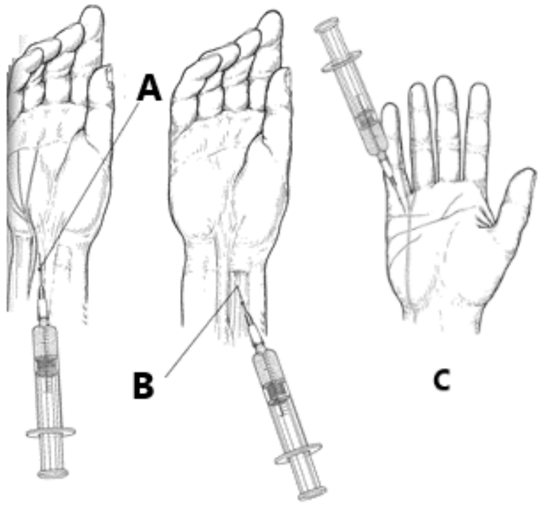


Fig. 65-5 LA FOR HAND SURGERY. A, for an ulnar block, inject LA just lateral to the *flexor carpi ulnaris* tendon. B, for a median block, inject LA just lateral to the *flexor carpi radialis* tendon. C, for a digital block, inject LA between the metacarpal heads. *After Champion HR, Robbs JV, Trunkey DD, Trauma Surgery Part 2, Butterworth, 4th ed 1989.*

Anaesthesia must be adequate, so that you are not fighting with a moving hand. Relaxation is unnecessary. There are several possibilities:
(1) Ketamine.
(2) An axillary block.
(3) An intravenous forearm block.
(4) Median, ulnar, or radial nerve blocks.
(5) Finger blocks (for the 2 distal segments only), or a combination of these.

CAUTION! Never use adrenaline in an intravenous forearm block, or in any block in the fingers or hand.

Admit all but the most minor injuries and operate on them in the main theatre. Put yourself in a comfortable position, seated with the patient's hand on a table in front of you.

A 'lead hand' which you can bend to hold the patient's fingers how you want is very useful. *Don't use the big instruments of a general set.*

Use fine forceps and needle holders. Cut the bones with a bone nibbler, a Gigli saw, or a fine finger saw. Remove as little bone as you can. *Don't use a big amputation saw.*

INCISIONS FOR HAND EXPLORATION

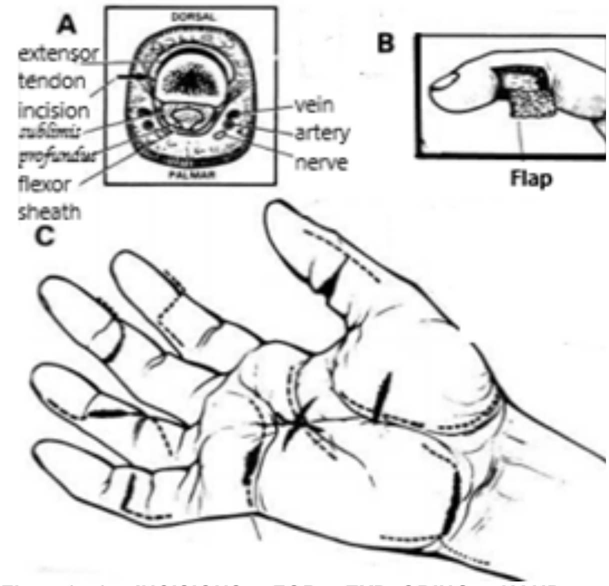


Fig. 65-6 INCISIONS FOR EXPLORING HAND INJURIES. A, anatomy of the finger. B, base a flap towards the palmar surface. C, incise a finger in its mid-lateral line (Bunnell's incision); ***avoid extending an incision across a flexor crease.*** **If this is inevitable, make a 'snake' the incision across the hand, or extend it each way from the ends of the wound in the form of a 'Z' (Bruner's incision).** *Kindly contributed by Peter Weston.*

TRACTION is of little value. It may be briefly necessary to reduce dislocations, or multiple displaced metacarpal fractures. Apply adhesive strapping along the sides of the fingers and watch the circulation in them carefully or use specially made finger traps if available. *Don't simply wrap strapping around them.*

TOURNIQUETS

Start by exsanguinating the hand with an Esmarch bandage and place a tourniquet on the forearm (3.8). Then scrub up yourself and paint and drape the hand. For most wounds, leave the tourniquet on throughout the operation, *but don't exceed 1½h.* If there is much tissue damage, remove it to determine which tissue is non-viable.

N.B. It is dangerous to wind a thin rubber round the base of a finger and hold it with a haemostat.

CAUTION! Wherever you apply a tourniquet, record its time of application.

RINGS can seriously impede the circulation in an injured hand. So remove them either with soap and water. If this fails, wind a fine string closely round the finger from its tip towards the ring. Thread the string under the ring, and use it to help pull the ring off (65-7A-E). If this also fails, cut the ring off, protecting the finger.

REMOVING A RING

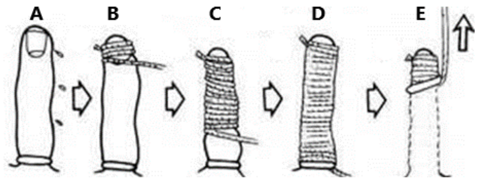


Fig. 65-7 A-E, how to remove a ring by lubricating a finger with soap and then using a piece of string, or suture. *Kindly contributed by Peter Bewes.*

WOUND TOILET

Get patients to put their hands under running water. Wound toilet must be thorough (54.1). Use plenty of soap and water. The skin of the hand is very precious, so excise only what you have to. Remove any prolapsed fatty tissue from the palm of the hand. If a wound is badly contaminated, take time to extract all foreign material, remove necrotic tissue, and wash it thoroughly.

INCISIONS

To extend a wound, use incisions along creases as much as possible (65-6). If a wound crosses a crease, make a 'Z'; if you need to extend an incision on a finger, cut on the side of the finger in the mid-axial line, obliquely across it, or along a crease line.

CAUTION! Avoid cutting at right angles to a crease, because a contracture may follow.

Reflect a flap on the side of a finger with its base on the palmar surface (65-5B).

NERVE AND TENDON INJURIES

Do your utmost to repair cut nerves & tendons primarily (48.1).

COVERING AN OPEN HAND INJURY

Wait until there it is clean before closing a wound. Useful solutions, if there is a defect, are skin grafts from the anterior forearm or an abdominal flap (46.5). For fingertip injuries, dressings are better than flaps or skin grafts (65.18).

EXTERNAL OR INTERNAL FIXATION ?

In some fractures, and especially in severe hand injuries, external fixation is useful, but it isn't simple. Internal fixation with K-wires 0.8-1.2mm in diameter is usually better; it needs some basic skills and hygienic OT conditions (65.21). *We don't advise screws and plates!*

CLOSING A HAND INJURY

Use monofilament sutures (4/0 or 5/0) on fine needles and *don't tie them too tight. Don't close wound edges unnecessarily.* Allow space for drainage. *Wounds along the creases don't need suturing.*

DELAYED PRIMARY SUTURE is always safer in all but the cleanest and most recent wounds, especially if the wounds overlie joints or fractures. It is also best in 'untidy', burst, or severely bruised wounds.

ANALGESICS are necessary because hand injuries are painful, so make sure the patient is given enough analgesics; opioids might be necessary.

ANTIBIOTICS are not nearly as important as a careful would toilet. Delayed primary suture gets better results than immediate primary suture & antibiotics.

TETANUS TOXOID: Don't forget this (46.7).

BANDAGES
(a) Thumb.
Ensure the thumb is held well anteriorly and in abduction. Place a roll of bandage between it & the palm, so that the thumb opposes the fingers and *does not lie in the plane of the palm*.
(b) Severe Injuries (65.19)

Try to obtain uniform, firm compression. Pack plenty of dry gauze around a severely injured hand. If adjacent fingers are injured, pack plenty of gauze between them to prevent them sticking together. *Don't bind them to one another.*

CAUTION! If possible, keep the fingertips showing, so that you can check their perfusion.

SPLINTS
When necessary, always splint the hand in the position of safety (65-8), except when the tendons are injured. Leave the splint on until the wound has healed. Splint ip joints extended. Splint mcp joints flexed, unless it is absolutely necessary to splint them extended, as in an extensor tendon injury. Splint the thumb in opposition.

CAUTION! Don't forget to elevate the hand!

For someone ambulatory, raise the arm across the chest with a St John's sling (65-1B).

POSTOPERATIVE CARE
Watch the circulation in the fingers, check the temperature, and palpate the regional lymph nodes. If there are no signs of infection, leave the dressing and the splint for 7days. Remove the sutures after 10days.

NEVER IMMOBILIZE A mcp JOINT IN EXTENSION

EXERCISES
In a serious injury, exercises are absolutely critical if normal use of the hand is to return! Start as soon as the traumatic oedema has subsided. Explain that exercises are essential to prevent the hand becoming stiff: *make sure this is understood!* Movements must begin even if painful. Demonstrate these movements, and then get the patient to do them, actively, or, gently, passively many times a day.

The range of movement should slowly increase until each joint has a full range. This means:
(1) Flexion and extension of all the fingers and the thumb.
(2) Adduction and abduction of all the fingers to and from the midline.
(3) Abduction, adduction, and circumduction of the thumb, and its opposition to each of the fingers.

Most adults can do these exercises on their own. Children usually recover so quickly that they hardly need them.
Provided patients do their exercises, they need not come for physiotherapy, but if they are reluctant, you need to persuade them somehow.

CAUTION! Explaining to a patient the value of exercises may be the most valuable thing you can do.

65.2 Stiffness in hand injury

Stiffness is *the* great enemy in hand injuries. The bones in an injured hand almost always unite, but in adults, the finger joints easily become stiff as the result of oedema, infection, and immobility.
Minimize stiffness by:
(1) Elevating an acutely injured hand (65-1B). A firm compression dressing with plenty of cotton wool will also help.
(2) Pay particular attention to the principles of wound management, and *never suture an injured hand or any of its fingers tightly*.
(3) *Never unnecessarily immobilize fingers*
(4) *Never immobilize >3wks*.
Then start exercises immediately, whatever the condition of the finger. If you break this rule, a stiff finger may remain forever.
Many finger fractures don't need immobilisation, and will unite better without.
(4) *Don't immobilize any neighbouring normal fingers*, because they too will become stiff.
(5) Dress an injured hand in the position of safety (65-8).

(6) Start movements early. From the very beginning, exercise all joints that have not been splinted, including the wrist, the elbow, and the shoulder. This will prevent the being left with a good hand, but a stiff shoulder.

NEVER TRY TO BEND FINGERS FORCIBLY, OR TO STRETCH THEM PASSIVELY.

Start active movements early, and if the injury is severe, make sure the patient has some occupational therapy. Encouraging doing or making something is better than merely encouraging movements.

CONTROL TRAUMATIC OEDEMA BY ELEVATION

65.3 Positions of safety & function

When the ligaments of a finger joint that is not being used lie slack, they shorten, and then the joint becomes stiff. The mcp joints stiffen if they are left in the extended position, and ip joints if they are left flexed. So leave injured fingers so that their ligaments are stretched. This is the position of safety (65-8). It is the position from which a patient is most easily rehabilitated.

THE POSITION OF SAFETY

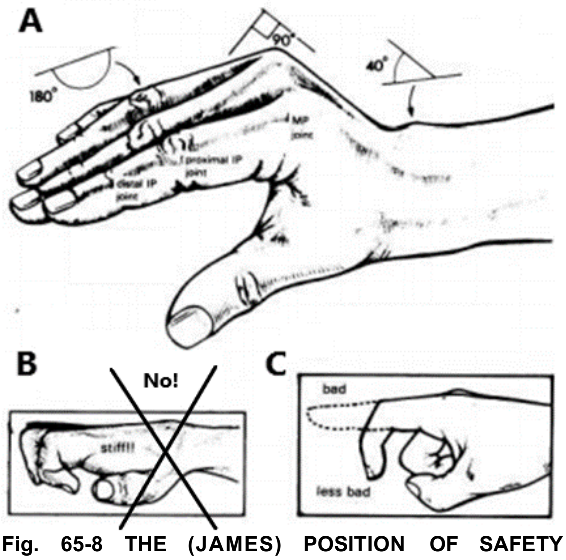


Fig. 65-8 THE (JAMES) POSITION OF SAFETY A, note that the mcp joints of the fingers are flexed, as near 90° as possible, but that the ip joints are in full extension. Both the joints of the thumb are extended, and the thumb is forward of the palm. B, the results of malpositioning: the mcp joints will extend, and the ip joints will flex. C, the least unsatisfactory position for a stiff finger. *Kindly contributed by Peter Bewes.*

(a) The position of safety in the fingers *is not easy to maintain*.

Always splint an injured hand in the position of safety (65-8):

(1) Flex the finger mcp joints 70-90°, or as near to 90° as possible.

(2) Keep the finger ip joints in full extension.

(3) Keep the thumb mcp & ip joint extended, abducted and opposed (well forward of the plane of the palm, so that it can be used for grasping). *A stiff thumb in the plane of the palm will be useless.*

(4) Dorsiflex (extend) the wrist to 30-40°.

The only exceptions are nerve and tendon injuries in which the positions for relaxing injured tendons take precedence over the position of safety.

Adapt whatever method you choose to the needs of the injury. *The only part which needs to be in the position of safety is the injured part.* The rest of the hand can be in any position provided it is allowed to move.

The wrist is the key. Keep it moderately dorsiflexed with a plaster cock-up splint (58-4), and the rest of the hand will fall into the position of safety.

(b) The position of function is the most useful position for a finger or hand that will not move, and *is different from the position of safety*. *The worst position for a permanently stiff or ankylosed finger is full extension.* It will be much less of a nuisance if it is partly flexed. It may be even less of a nuisance if it is amputated (65.24). If several fingers are stiff, they should be partly flexed, as if the hand were grasping something.

SPLINTS FOR FINGER INJURIES

Bend the aluminium splint to 90°, and strap it to the palm with its angle just proximal to the proximal transverse palmar crease for the index and middle finger, or the distal palmar crease for the ring and little fingers. These are the positions of the mcp joints: (compare them with your own by looking at your own hand from the side).

After reduction of a fracture, lay the finger on the splint so that the mcp joint is flexed to 90°, and the ip joints are extended. The splint need not cross the wrist. *Don't double it back over the dorsum of the finger.*

FINGER SPLINTS

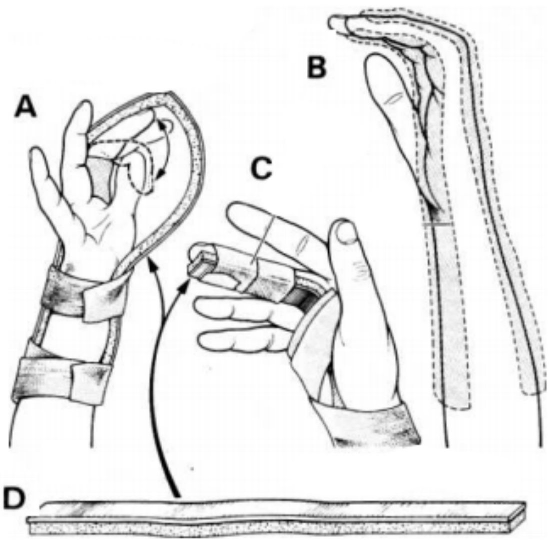


Fig. 65-9 SPLINTING AN INJURED HAND. A, a splint for a fracture of the anterior tip of the middle phalanx: it will allow the pip joint to flex but not extend. B, dorsal and palmar plaster cast in the position of function. C, a finger correctly splinted with its mcp joint flexed and its ip joint extended. D, you can use padded aluminium splints for many purposes *Partly after Watson-Jones R. Fractures & Joint Injuries, Churchill Livingstone 5th ed, 1974 with kind permission.*

CAUTION! Examine the fingertip to check for rotation, and warn the patient not to meddle with its position, or take it off. If this is a real problem, a plaster cast will be wiser.
If the injury is stable, you can usually use a garter splint (or "buddy tape". If the finger is still rotated (scissoring), fixation may be indicated.

As soon as the immediate swelling is reduced, bind the patient's injured finger to one of its neighbours with adhesive strapping (65-10). If there is the choice of 2 adjacent fingers, strap it to the finger which best corrects any deformity.

A garter splint is more comfortable if you put a little padding between the two fingers. If more than one phalanx is fractured, you may be able to apply more than one garter splint.

(1) *Make sure you correct any rotational deformity*.
(2) Be careful how tightly you apply a garter splint during the acute phase, or the strapping may obstruct the circulation of the injured finger.
(3) *Don't let the strapping cross a joint*.

Remove a garter splint at 3wks, except for fractures of the middle phalanx, for which you may need to leave it on longer. Rely on clinical union, and *don't wait for radiological union*.

A GARTER SPLINT FOR FINGER INJURIES

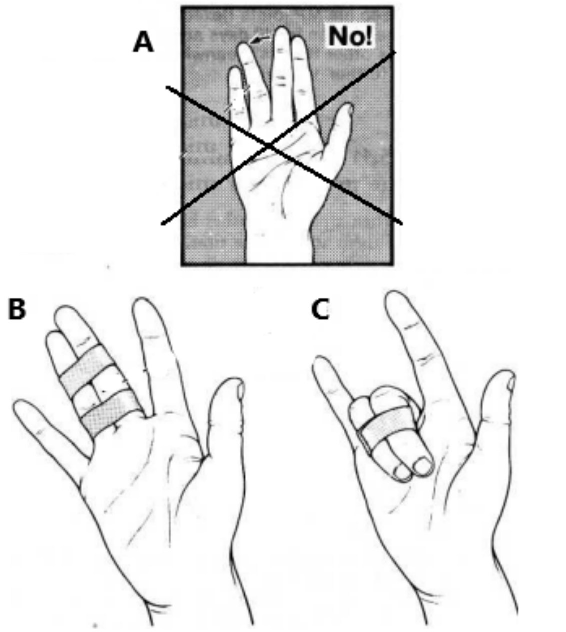


Fig. 65-10 A GARTER ("BUDDY") SPLINT. A, its great advantage is that it keeps an injured finger moving, and simultaneously corrects rotation. B, *never put strapping across a joint.* C, the splint is designed to achieve stability *with* movement. *Kindly contributed by Peter Bewes.*

If a garter splint fails to achieve good reduction of an oblique fracture, fixation is probably necessary.

CORRECT ANY ROTATIONAL DEFORMITY IN AN INJURED FINGER

PLASTER SPLINTING INDICATIONS
(1) Fractures of single fingers in uncooperative, uneducated patients who might interfere with an aluminium finger splint.
(2) Multiple fractures.
(3) Some fractures of the thumb.
(4) If necessary, you can use a volar slab for almost any fracture or wound of the hand.
(5) Burns (50.14).
(6) Infections involving joints or tendons.

Apply a volar slab with the wrist dorsiflexed, the mcp joints flexed, and the IP joints extended, as when using an aluminium splint. When the volar slab has set, add a dorsal one to maintain the position of the fingers against the volar slab. If necessary, add longitudinal ridges to the volar slab to give it greater strength.

CAUTION! (1) If possible, leave the thumb free. If you have to include it, bring it forward of the palm. (2) A hand which has been properly immobilized is bulky. *Don't try to make a tidy parcel out of it.* (3) *Don't immobilize normal fingers*: keep them moving.

DIFFICULTIES WITH SPLINTS FOR THE HAND

If you are in doubt as to when to remove a splint, err on the side of removing it a little too soon, especially if a finger is not in a position of safety. Remove all splints at 3 weeks or earlier (the mallet splint is an exception (65.7).

65.4 Nail injury

Considerable discomfort and disability may result from loss of the nail (not just in guitar players!).

ANATOMY OF THE NAILBED

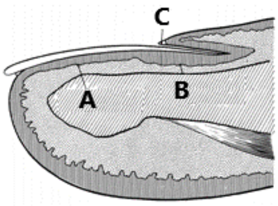


Fig. 65-11 DISTAL FINGER ANATOMY. A, the nail bed is a 'sterile' matrix. B, the germinal matrix (from which the nail grows) is more proximal. C, the eponychium is not attached to the nail, and leaves an opening where infection can enter. *After Champion HR, Robbs JV, Trunkey DD, Trauma Surgery Part 2, Butterworths, 4th ed 1989.*

(a) Severely lacerated nailbed & avulsed nail, usually with an underlying distal phalanx fracture, remove any foreign material & all loose bony fragments. Close nail bed lacerations with 6/0 absorbable so it is smooth enough to make a new nail adhere to it (65-12B).

NAILBED INJURIES

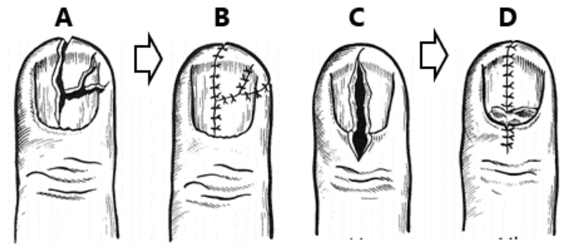


Fig. 65-12 NAILBED INJURIES. A, burst nailbed, usually associated with a distal phalanx fracture. B, sutured carefully to create a smooth surface. C, nailbed & eponychium laceration. D, separated closure. *After Champion HR, Robbs JV, Trunkey DD, Trauma Surgery Part 2, Butterworths, 4th ed 1989.*

A more severe injury to the fingertip may remove the nail, completely or partly. Clean the wound, remove the base of the nail, and replace the nail or the nail bed under the nail fold. Hold the nail in place with a mattress suture, and administer antibiotic prophylaxis.

SUBUNGUAL HAEMATOMA

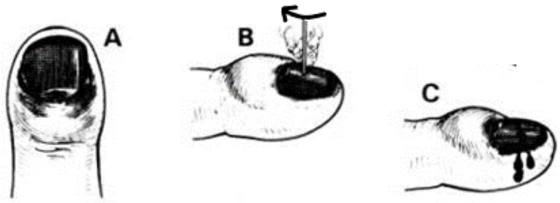


Fig. 65-13 NAIL INJURIES. A-C, trephining a subungual haematoma with a blunt needle. *Partly after Rutherford WH, Nelson PG, Weston PAM, Wilson DH. Accident and Emergency Medicine. Pitman 1980 with kind permission*

(b) Subungual haematoma. A blow on the end of a finger may cause blood to collect under the nail. You can easily relieve the severe pain that this causes. Use a large hypodermic needle, and twist this through the nail over the haematoma (65-13B). *This doesn't need LA.* Dress the wound to keep the finger dry for 24h.

REMOVING A SPLINTER UNDER THE NAIL

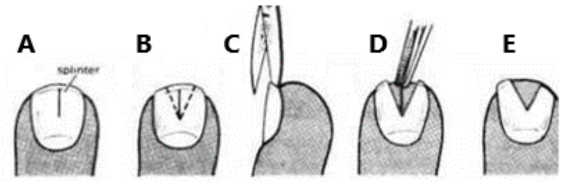


Fig.65-14 REMOVING A SUBUNGUAL SPLINTER. A-E Cutting the fingernail around the splinter to release it. You need a regional LA block to do this. *Partly after Rutherford WH, Nelson PG, Weston PAM, Wilson DH.Accident and Emergency Medicine. Pitman 1980. with kind permission*

(c) Splinters below the nail. If you cannot remove a splinter with forceps, use scissors to excise a V-shaped area of the nail under a LA ring block (65-14D-H), and then extract the foreign body.

65.5 Finger fracture

There are many possible fractures in the hand, seeing there are 23 bones in it. Some fractures, such as those entering joints, are serious, while others, such as undisplaced fractures of the phalanges need only exercises.

FINGER FRACTURE TYPES

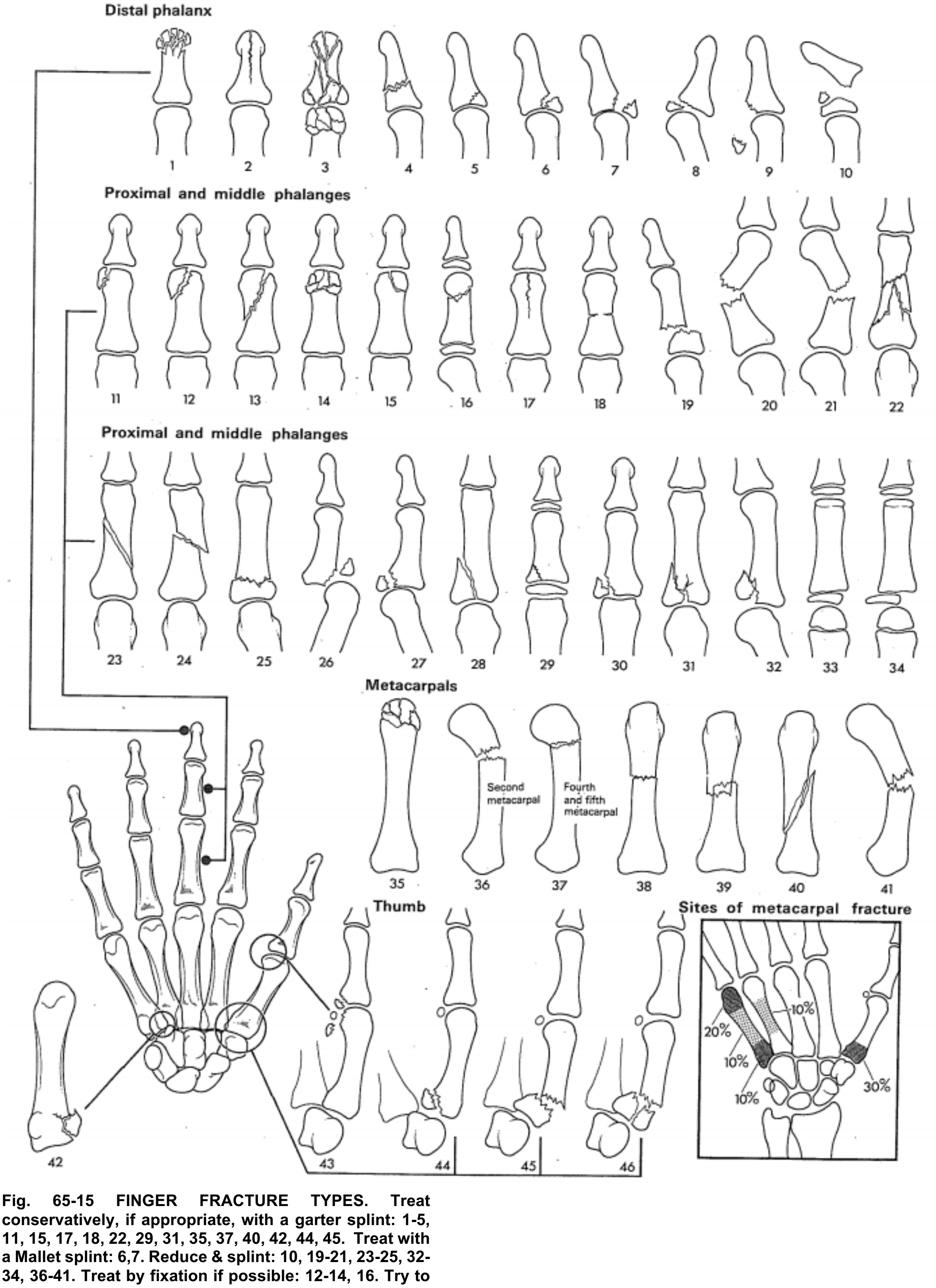


Fig. 65-15 FINGER FRACTURE TYPES. Treat conservatively, if appropriate, with a garter splint: 1-5, 11, 15, 17, 18, 22, 29, 31, 35, 37, 40, 42, 44, 45. Treat with a Mallet splint: 6,7. Reduce & splint: 10, 19-21, 23-25, 32-34, 36-41. Treat by fixation if possible: 12-14, 16. Try to obtain early surgery for: 8, 9, 26-28, 30, 43. Note the relative frequency of metacarpal fractures. *Adapted from Watson-Jones R. Fractures & Joint Injuries, Churchill Livingstone 5th ed, 1974 with kind permission.*

Appropriate treatment includes:
(1) Active movements.
(2) A garter splint (65-17).
(3) An aluminium splint.
(4) K-wire fixation
(5) Internal fixation
(6) External fixation.

By all means avoid stiffness! An unnecessary splint is much worse than no treatment! You can disregard many fractures; concentrate on helping the patient to regain movement.

A common error is to overtreat hand fractures; but phalangeal fragments often angulate, and any fracture which needs reduction also needs splinting, preferably with an aluminium splint.

Avoid rotation in finger fractures, because this will make an injured finger overlap its neighbour (65-15D). Prevent this serious disability by making sure that all fingers always point to the point (65-15Ax), which is slightly lateral to the wrist crease.

Fortunately, most fractures unite readily, so there is no point in checking for radiological union. If after 3wks, there is clinical union, you can assume that a fracture has united.

AVOID ROTATION IN FINGER FRACTURES

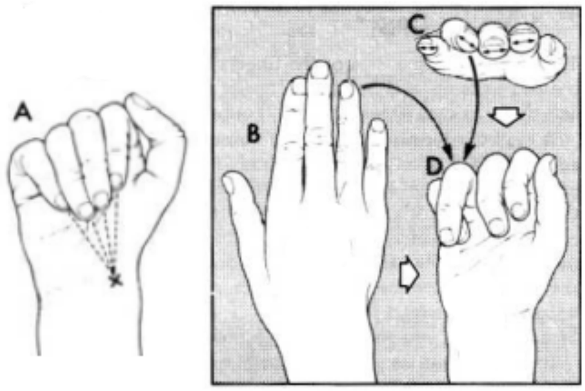


Fig. 65-16 THE PROBLEM OF MALROTATION. A, all fingers should point to 'x'. B, you can easily miss a rotation deformity. C, check the alignment of the nails by looking at them end on. D, look at the effect of malrotation with the fingers flexed.

65.6 Distal phalanx & ip joint injury

The tips of the 3 longest fingers are often crushed in a door, or hit with a hammer. Their distal phalanges may be small bones, but they are particularly important, especially for a typist or a guitarist.

In most injuries to a distal phalanx, ignore injuries to the bone and the nail, and treat the soft tissue injuries alone.

A combined angulating and crushing injury, such as crushing in a door (65-17A), can cause a mallet finger. Take a lateral radiograph to distinguish this from extensor tendon rupture, which is rare.

(a) Crush fracture (65-16:1,2).
Don't suture the wound. Mould the fragments together, apply a paraffin dressing, gauze & plenty of cotton wool, and a firm bandage round the distal phalanx only.
Don't include the terminal ip joint in the bandage. Keep it moving & flexing. *Don't splint the finger.*
Warn that the finger will remain tender for 6wks, but may continue to improve its shape over the next 6months.

Drain a subungual haematoma if present and painful (65-11B). Leave the nail in place, and dress it with Vaseline gauze. If it is loose, reconstitute the nail bed with a mattress suture which will draw it under the nail fold. It may regrow normally.

Don't amputate exposed bone of the terminal phalanx, *or remove any possibly viable bone*, because much of the fingertip may still be alive.

N.B. **If you remove the distal fragment**, *a useless floppy fingertip will remain*.
The distal phalanx has great capacity for repair.

(b) Crush fracture including the distal ip joint (65-16:3).
Amputate through the middle phalanx, leaving enough of its shaft to include the attachment of the *flexor superficialis* tendons.

(c) Transverse & basal distal phalanx fracture (65-15:4,5).
An undisplaced transverse or basal fracture needs no special treatment.

(d) Dorsally displaced basal distal phalanx fracture (65-15:6,7)
Treat this as a mallet finger (65.7) if it is displaced.

(e) Anteriorly displaced basal distal phalanx fracture (65-15:8,9).
This needs early surgery. Suture or fix the bone fragment in place with a pull out suture (65-29).

(f) Anteriorly displaced distal phalanx fracture (65-15:10).
The distal fragment is forced out through the nail bed; reduce it & insert the proximal end of the nail into the nail fold where it will act as a splint. Splint the distal ip joint in extension (as a mallet finger) for 2wks. A mallet deformity often follows.

65.7 Mallet finger

The extensor mechanism of the fingers is liable to two similar injuries: the distal ip joint to a 'mallet finger' (65-17D), and the proximal ip joint to the 'boutonnière injury' (65.18).

A mallet deformity is the distal ip joint which cannot be fully extended. One of the extensor tendons tears away from the base of the distal phalanx. In doing so it may remove a small fragment of bone. The distal phalanx cannot be extended actively, so that it remains permanently bent. If you apply a cast in the first fortnight, you may succeed in preventing a mallet deformity. However, if the cast is too tight, it will cause a pressure sore, and if it is too loose, it will be useless, so try to get it just right.

N.B. Check the fit after 3days when the swelling decreases.

If a patient has a mallet finger, disregard it if employed as a labourer, and encourage active movements. Many patients will accept the mild disability of a slightly bent fingertip. But, if a patient does fine work, apply a mallet splint or cast, especially if the index finger is involved

If a chip of bone is displaced and does not reduce with extension, fixation is needed. If this is impractical, do nothing, because a mallet cast will make things worse.

If there is no bony fragment, or there is one but it is not displaced (5), apply a special mallet splint (65-17E).

A MALLET CAST
Use it very sparingly, because the pip joint tends strongly to stiffen in the flexed position! The patient should keep moving the pip joint. Keep the splint or cast in place for 6wks for a non-bony injury.

TERMINAL PHALANX INJURIES

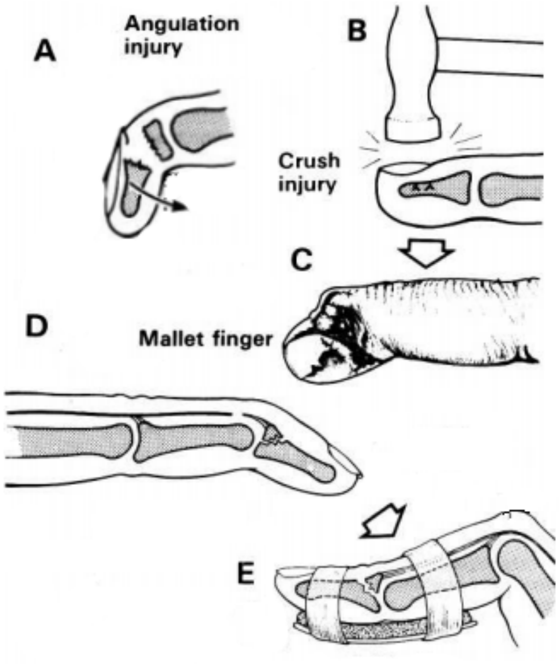


Fig. 65-17 DISTAL PHALANX INJURIES. A, an angulation injury fractures an adult's terminal phalanx, or displaces a child's epiphysis. B, a crush injury. C, results in D, the typical deformity of a mallet finger. E, correct splinting held with an aluminium splint. *Partly after Rutherford WH, Nelson PG, Weston PAM, Wilson DH. Accident and Emergency Medicine. Pitman 1980 with kind permission.*

65.8 Injuries common to middle & proximal phalanx

(a) Injury of the head or condyle of the proximal & middle phalanx
Stable injuries (65-15:11,15) need only a garter splint (65-17) but unstable injuries (with ruptures collateral ligaments or displaced fragments (65-15:12-14) need surgery. *The danger is a permanently swollen bent dip joint.*
In a comminuted or T-shaped fracture (65-15:14), the future function of the finger is likely to be poor. You may well get a better functional result with a distal phalangeal amputation.

(b) Phalangeal neck fracture (65-15:16).
Especially if the distal fragment is rotated**,** this needs fixation.

(c) Phalangeal shaft fracture.
An undisplaced fracture (65-15:17,18,22,23) needs only a garter splint.

Reduce displaced fractures (65-15:19-21,24) by pulling on the distal part, and correct any rotation especially for the spiral fracture (65-15:23).
Hold these in a garter splint but if they remain unstable, an aluminium splint or even K-wire fixation may be necessary.

(d) Phalangeal basal fracture (65-15:25-32).
The transverse basal fracture of a proximal phalanx (65-15:25), usually in an elderly patient, may well have marked angulation, which you may mistake it for hyperextension of the mcp joint. *Make sure the other fingers don't obscure it on a radiograph.* Reduce the angulation and splint the finger for 3wks in the position of safety 65-7).

Try to reduce dorsal (65-15:26,30), anterior (65-15:27) or lateral (65-15:28,31) fragments, pushing the fragment into alignment with the joint, and reducing any luxation. Hold these, as before, in a garter splint but if they remain unstable, an aluminium splint or even fixation may be necessary, but will not be feasible if the fracture is comminuted (65-15:31,32).

(e) Angulated phalangeal fractures
This is a common type of finger injury in which a transverse fracture angulates, either in a palmar (65-15:20) or dorsal (65-15:21) direction, pressing on the flexor or extensor tendons respectively. *If you don't correct this displacement, particularly in a fracture of the proximal phalanx, the tendons cannot function normally.*

Easy to reduce, this fracture readily displaces again, unless you hold the mcp joint firmly flexed until the fragments have united. This is fortunately also the position of safety (65-7) for this joint. *Be sure to correct any rotation*. Although closed methods are not perfect, *you are likely to get better results than with K-wiring.* A practical closed method to hold the position is to strap the fractured finger over a firm roll of bandage in the palm (65-18).

After traction, disimpact & reduce the fracture, making sure the injured finger points to the point 'x' (65-16A). Hold it there with adhesive strapping for 10days, *but not longer*. Finally, protect it for another 10days with a garter or aluminium splint.

Treat the fracture with dorsal angulation similarly; keep the mcp joints flexed, and the ip joints extended. Hold the position with aluminium splints both dorsally & on the palmar side of the finger.

ANGULATED PHALANGEAL FRACTURES

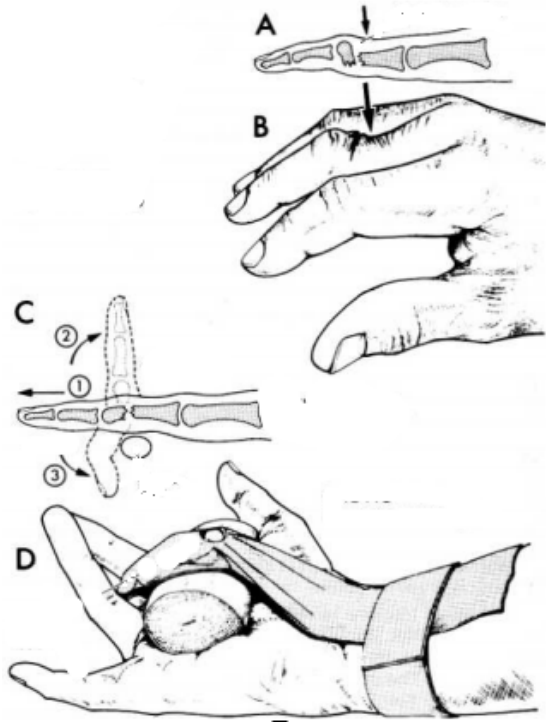


Fig. 65-18 PROXIMAL & MIDDLE PHALANX SHAFT FRACTURE WITH PALMAR ANGULATION. A, radiograph. B, appearance of a fractured proximal phalanx with palmar angulation. C, traction for disimpaction (1), posterior angulation for reduction (2), & flexion for holding (3). D, the completed splint with the finger flexed forwards in the palm over a roll of bandage.

65.9 Open proximal or middle phalanx fracture

A serious injury usually crushes several fingers at the same time. Both flexor (65.16) and extensor (65.15) tendons may be badly bruised.

If only 1 finger is severely injured, an amputation may be best to regain function quickly (65.24). But *preserve even a stump of an injured thumb.* Toilet the wound carefully. Remove detached fragments and any dead fatty tissue. Trim any grossly contaminated bone ends.

If the skin edges come together easily, suture them immediately with the minimum number of fine sutures. The hand is very vascular, so immediate primary closure is usually worth the risk. If the skin edges do not come together easily, or the wound is not clean, leave the wound open for delayed primary suture, or apply a split skin graft.

If the fracture is stable (65-15:22**) and the next finger is normal,** put it in a garter splint. If there are no adjacent normal fingers, find the position that best holds the fragments reduced, close the wound, and then devise an aluminium or plaster splint that will hold this position. Leave the normal fingers unsplinted and encourage movements. Elevate the hand.

If a severe open injury is unstable, you need some sort of fixation (65-32).

65.10 Metacarpal fracture

These common fractures usually follow a blow to the jaw in which the assailant breaks one or more metacarpals, usually the base of the 1st, the neck of the 5th, or the mid-shafts of the others. The fracture lines run either spirally, or transversely across the shafts or necks. If a fracture is transverse, the fragments are usually angulated dorsally; if it is spiral, fragments may overlap.

Typically, the back of the hand is painful and swollen. On clenching the fist, the normal contour of the knuckles is lost. *Radiographs are not essential,* and may fail to show the fractures, unless you take several views.

Reduction in the anteroposterior plane is much less important than with fractures of the phalanges. The bowing of a transverse fracture and the overlap of a spiral fracture usually cause little disability.

HOLDING REDUCTION OF A TRANSVERSE METACARPAL SHAFT FRACTURE

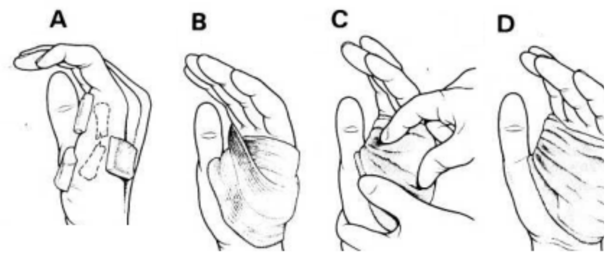


Fig. 65-19 MAINTAINING REDUCTION OF A TRANSVERSE FRACTURE OF A METACARPAL SHAFT. ***Don't use this for fractures of the neck.*** **A, apply padding (preferably orthopaedic felt) ready for 3-point pressure. B, apply adhesive strapping to the hand. C, apply an 8cm plaster bandage to the hand and mould it by firm pressure to provide 3-point fixation. D, the completed cast.** *After Watson-Jones R. Fractures & Joint Injuries, Churchill Livingstone 5th ed, 1974 with kind permission.*

You can leave many of these fractures unreduced. There may be no need to splint them, except temporarily for comfort. *The main danger is a stiff hand, so early movement is more important than accurate reduction of the fragments.*

EARLY RETURN OF FUNCTION TAKES PRECEDENCE OVER ACCURATE REDUCTION OF METACARPAL FRAGMENTS

(a) Metacarpal head fracture (65-15:35).

Ignore this and treat by active movements; if a twisting injury has torn a small chip off the metacarpal head, apply a garter splint for 3wks.

(b) Metacarpal neck fracture
Where the 2nd metarcapal neck is fractured (65-15:36), the head tends to angle palmarwards**,** reduce it by pushing the proximal fragment forwards. You may need to maintain reduction by fixation with a K-wire. Treat 3rd, 4th, 5th, metacarpal neck fractures, often from boxing injuries (65-15:37) conservatively.

CAUTION! Don't try to disimpact and splint these fractures because stiffness will result.

(c) Metacarpal shaft fractures
Treat undisplaced fractures (65-16:38) by rest and elevation for 10-14 days, with or without a protective bandage. Follow this with active finger and wrist movements.

Use of the hand should be fairly comfortable within 1wk. There may be crepitus for some days and a lump on the back of the hand permanently. A transverse fracture takes 5wks to unite, and a spiral fracture only 3wks.

A displaced fracture (65-15:39) needs traction and pressure to reduce it. Correct any rotational deformity. Apply a plaster cockup splint and mould it to the palm so as to maintain the metacarpal arch. Bandage the hand to the splint and leave the fingers free.

For a spiral fracture (65-15:40), correct any rotational deformity by manipulation, and apply a garter splint so that the correction is maintained.

A fracture of the 5th metacarpal shaft may displace dorsally (65-15:41); you can accept an angulaton <40°. Greater than this, reduction & fixation is advisable or apply 3-point fixation (65-19).

(d) Metacarpal base fracture

Posterior displacement of the bases of the 2nd, 3rd, 2nd & 4th metacarpals causes the line of the knuckles will be flat instead of tracing a normal curve. This is a rare, unstable and disabling injury, because dorsiflexion of the wrist becomes impossible, and so use of the fingers will be impaired. Reduce the fracture by asking an assistant to exert traction on the fingers. Press firmly with your thenar eminence on the back of the hand, while exerting counter-pressure on the front of the carpus.

A fracture of the base of the 5th metacarpal (65-15:42) is the equivalent to that of the 1st on the other side of the hand.

65.11 Thumb sprain

Although the 1st metacarpal is more mobile and more like a phalanx than the other metacarpals, stability is also important. Try to keep an injured thumb mobile and to maintain palmar abduction, and radial abduction, though the latter is less important. *Try, especially, to avoid a contracture in adduction.*

A violent lateral movement tears the medial mcp ligament, or pulls a bony fragment from the base of the proximal phalanx (65-15:43, 65-20). Hold the 1st metacarpal steady, and try to move the thumb from side to side. Compare the movement with that on the contralateral side.

Examine the radiograph carefully.
N.B. There is a sesamoid bone opposite the metacarpal head!
If you are in doubt about the diagnosis, inject LA into the site of the fracture and repeat the clinical examination by comparing with the contralateral thumb. If there is abnormal movement, assume rupture of the ligament.
Unless this injury is successfully treated, pinch grip is lost, and so will writing or opening a door.

If a fragment of bone is visible and can be reduced, the thumb may be successfully managed in a thumb spica cast (65-20).

If the ligament is fully torn and there is no piece of bone, the ligament must be repaired with sutures pulled through the bone or a specialized suture anchor. This type of procedure should only be done by a specialized hand surgeon.

SPRAINED THUMB

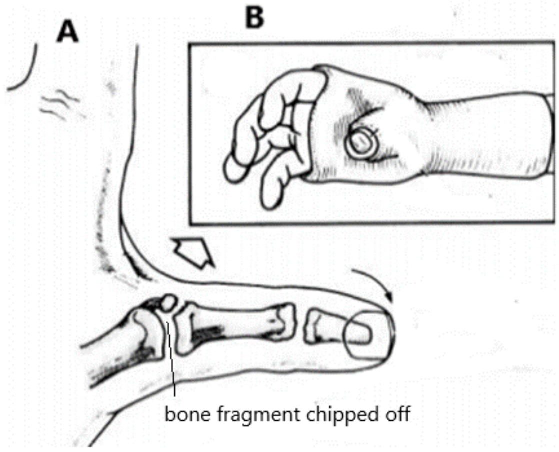


Fig. 65-20 SPRAINED THUMB. A, forceful abduction tears the medial ligament & may chip off a piece of bone. B, fit this cast from mid-forearm including the thumb ip joint. Just before it sets, try to move the shaft of the proximal phalanx into the reduced position. Keep the fingers free.

65.12 Thumb injury

CRUSH INJURIES
If the thumb has been crushed, immobilize it with a dorsal aluminium splint, or scaphoid cast (64-11), which leaves the fingers free and brings the thumb forward into a position in which it opposes the other fingers.

METACARPAL BASE FRACTURE
The base of the first metacarpal is often injured. If there is no abnormal movement between the thumb and the carpus, there is a sprain or an undisplaced fracture. Fit a cast as described below.

If there is abnormal movement, the base of the 1st metacarpal has broken in one of 3 ways (65-21).

(a) Bennett's fracture (65-15:44, 65-21C).
An oblique fracture line runs proximally into the joint from the ulnar border of the shaft of the 1st metacarpal, c. 1cm from its base. The proximal fragment remains attached to the trapezium, and the long distal fragment displaces radially and dorsally. The thumb looks shortened.

1ST METACARPAL BASE FRACTURES

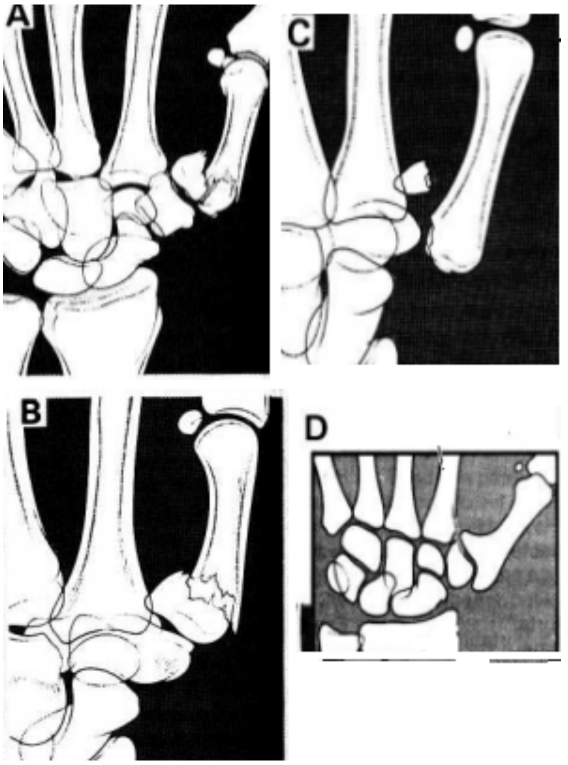


Fig. 65-21 1ST METACARPAL BASE FRACTURES. A, a T- or Y-shaped fracture. B, a transverse fracture. C, Bennett's fracture. If you don't treat this, it causes a characteristic deformity, D, which may, however, cause few symptoms. *Kindly contributed by Peter Bewes.*

The base of the thumb swells; moving it is painful, and the swelling obscures the displacement. This is one of the few fractures where you should examine for crepitus, so pull the thumb gently, if necessary under LA. It will elongate, and you will feel the two fragments grating together, after which the thumb will spring back. This distinguishes Bennett's fracture both from a dislocation (65.23), and from an impacted transverse fracture (65-15:38).

Reducing it is easy, but holding it reduced needs careful attention to detail. With LA in the fracture haematoma, extend the thumb while applying pressure to the palmar aspect of the 1st metacarpal head *(not the phalanx)*, and simultaneously pressing on the dorsal surface of the metacarpal base. *Don't exert traction & don't extend the thumb too much* which will force it out of joint. You should first be able to *see* the base of the 1st metacarpal slipping in & out of the carpo-metacarpal joint, & then feel it.

N.B. Now place felt or wool over the joint and rehearse the sensation of dislocation & reduction, so that you can place the thumb in its correct position in the cast.

BENNETT'S FRACTURE

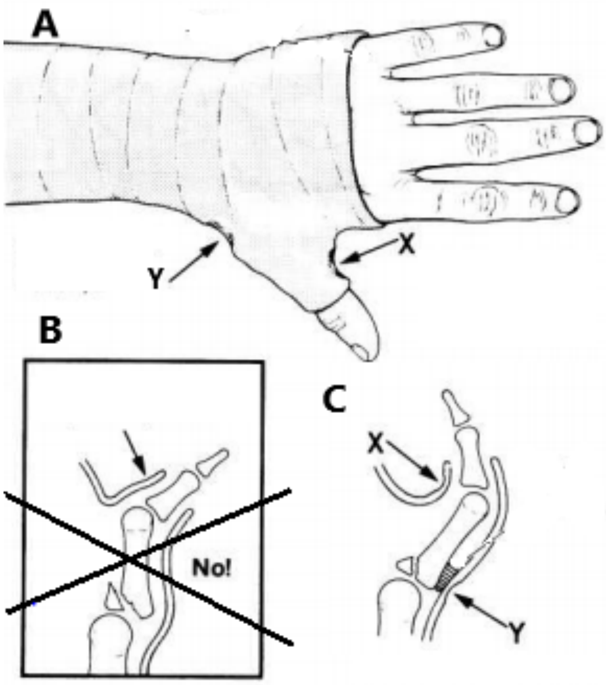


Fig. 65-22 BENNETT'S FRACTURE. A, pad the 1st metacarpal. While the cast is setting, apply pressure to its head ('X') and base ('Y'). Apply the cast with care so as to avoid a pressure *sore.* B, *don't press on the ip joint & extend the thumb, and not extend the mcp joint.* C, points X,Y shown radiologically*. *After Charnley J, The Closed Treatment of Common Fractures. E&S Livingstone, Edinburgh 3rd ed.1961 with permission.*

Apply a complete wet plaster from just below the elbow to half-way up the proximal phalanx of the thumb. Feel again for the sensation of reduction that you have already rehearsed. Recognize this through the wet plaster, and hold it while the plaster sets at points X,Y (65-22C), so that your finger pressure marks remain visible on the plaster. *You don't need much pressure*, just ensure extension at the carpo-metacarpal joint.

Immediately obtain a post-reduction radiograph to check the position. If this is unsatisfactory, try once more. If once again, you fail, the options are either fixation or encouraging early active motion. Leave the cast on for 4wks.

If the patient complains of severe pain, remove the cast. There may be a pressure sore on the skin, which can erode down to tendon.

If the reduction slips, remove the cast and start active motion. After 2yrs, most movement will have returned, despite the characteristic radiographic deformity (65-21D).

(b) Transverse & T- or Y-shaped fractures of the 1st metacarpal base (65-15:45,46)
The latter fracture line enters the joint, but treat all 3 types of fractures by early active motion, and warn that a lump will remain. Neglect of motion will result in a stiff hand.

65.13 Finger & thumb dislocation

These injuries are usually the result of severe hyperextension of the finger or thumb. The base of the dislocated phalanx comes to lie dorsal to the head of the bone proximal to it. Dislocations of ip joints are more common and more easily reduced than dislocated mcp joints.

REDUCTION OF AN MCP DISLOCATION

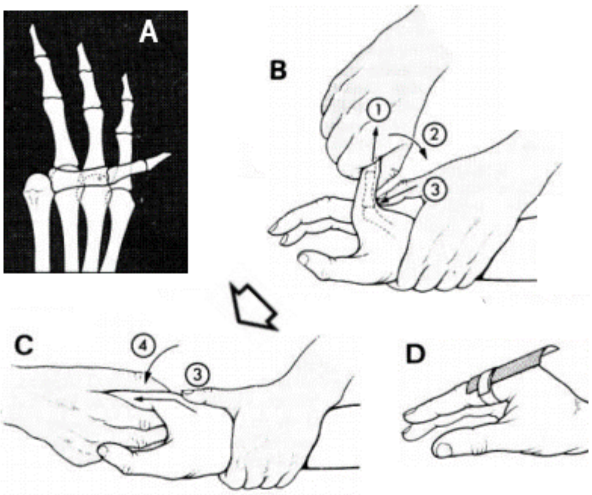


Fig. 65-23 REDUCING A DISLOCATED MCP JOINT. A, reduce dislocations of the ip joint in the same way. B, exert traction on the finger (1) & disimpact the dislocation by hyperextension (2), while sliding the base of the phalanx forward on the metacarpal (3). C, then flex the finger into a straight position. D, if the finger is unstable after reduction, fit a guard. *After de Palma AF, Management of Fractures and Dislocations, An Atlas.WB Saunders, 2nd ed. 1970 with kind permission*.

(1) Pull in the long axis of the dislocated phalanx (65-23B:1), *not the metacarpal,*
(2) Hyperextend an mcp joint first (65-23B:2), because this is the position in which the collateral ligaments are slack,
(3) Push the base of the dislocated phalanx forwards into place.
(4) Finally, flex the mcp joint and the finger will snap into position.
(5) Treat the injury as an acute emergency; the longer a finger is dislocated, the more difficult will it be to reduce.
After 4days, reduction may be impossible.

DISLOCATED FINGERS AND THUMBS ARE ACUTE EMERGENCIES

USING LONG GAUZE FOR REDUCTION

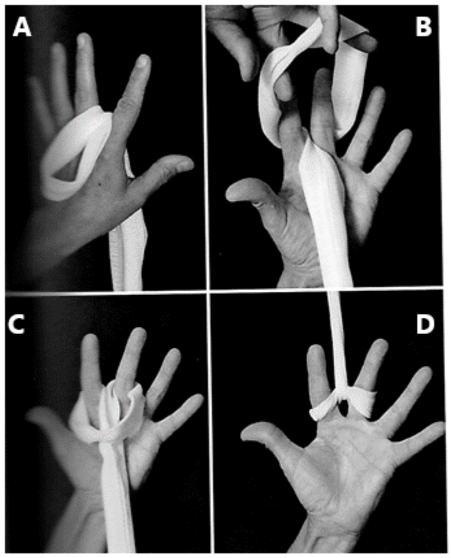


Fig. 65-24 USING A LONG GAUZE FOR REDUCTION. A, pass the looped bandage between 2 fingers. B,C slip the loop back from the dorsal to the palmar side. D, then hook the bandage upwards, so it pulls the loop tight. *After Gosselin RA, Spiegel DA, Foltz M. Global Orthopaedics. Springer 2nd ed 2019*

Test the finger for stability with the ip joint extended and the mcp joint flexed. Hold the proximal bone of the joint steady, and move the distal bone from side to side.

If the reduction is stable, flex the injured finger over a roll of crepe bandage for 7days (65-18), then apply a garter splint (65-10) & start exercises.

If reduction is unstable, immobilize the finger in the position of safety with a splint (65-9).

Reduction may fail if:
(1) the anterior ligament has detached and entered the joint.
(2) the phalangeal head has buttonholed through the anterior capsule, which becomes tighter the more you pull.
(3) there is an avulsion fracture of the phalangeal base.
N.B. Don't make >2 attempts at reduction, because you may damage the capsule and the collateral ligaments. Torn ligaments will cause the finger to deviate to one side and result in much disability.

N.B. In a severe extension injury, the fibrocartilaginous volar plate over the palmar surface of mcp & ip joints may tear. This may pull & avulse a chip of bone (65-15:27).
Immobilize the finger in flexion for 5days, then start active movements. The swelling may take weeks to resolve. A flexion contracture, or a hyperextension deformity sometimes follows.

65.14 Collateral ligament injury

A violent sideways movement may tear the collateral ligaments of the fingers. The ip joints have less sideways 'give' in them than the mcp joints. Examine the injured finger carefully to distinguish a strain from a tear.

Take a careful history to decide how force was applied to the finger: end-on, laterally, in crushing. Localize the tenderness and swelling exactly.
Check joint movements through their full ranges, from full flexion to full extension. If there is impairment, expect a significant injury.
Stress the collateral ligaments by holding the proximal bone still and angulating the distal bone.

If stressing the joint is merely painful, but there is no abnormal mobility, it is only sprained. If there is abnormal mobility compared with the normal side, but there is still a good end-point there is a partial tear. If the movement has no good end-point, however, it is completely torn. If you are in doubt, introduce a ring LA block and repeat the test.

SPRAINS
Apply a garter splint. Pain may persist for 6months and swelling for 2yrs.

TEARS
Reduce any displacement and get a radiograph, apply a garter splint for 6wks.
If reduction failed, the joint needs to be explored and any interposed soft tissues extracted.
Although complete ligament tears of the ip joints do recover with conservative treatment, tears of the mcp joints often remain unstable, especially the ulnar collateral ligament of the thumb.

65.15 Extensor tendon injury

Follow guidance on tendon repair in general (47.1)
Injuries to extensor tendons are easier to treat than those to the flexors because the extensor tendons have only short sheaths, so that adhesion to them is not the problem that it is with flexor tendons, and they are joined to one another so that their cut ends do not retract. Any suture method which will bring their cut ends securely together is likely to be adequate.

The boutonnière deformity is the result of a wound on the dorsum of the pip joint which destroys the central slip of the extensor tendon, so extension of the joint actively through its last 30° is no longer possible, although there is still a full range of passive movement. Such a wound may look minor, and the skin over it may only be bruised, but it is potentially serious. If you don't treat this adequately, the serious deformity of 65-26 may follow. The proximal ip joint is acutely flexed, and the distal ip extended.

The tear in the central slip of the extensor expansion prevents extension of the middle phalanx & enables the combined tendons of the *lumbricals* and *interossei* to slip forwards and flex the proximal ip joint, instead of extending it in the normal way.

EXTENSOR TENDON INJURIES

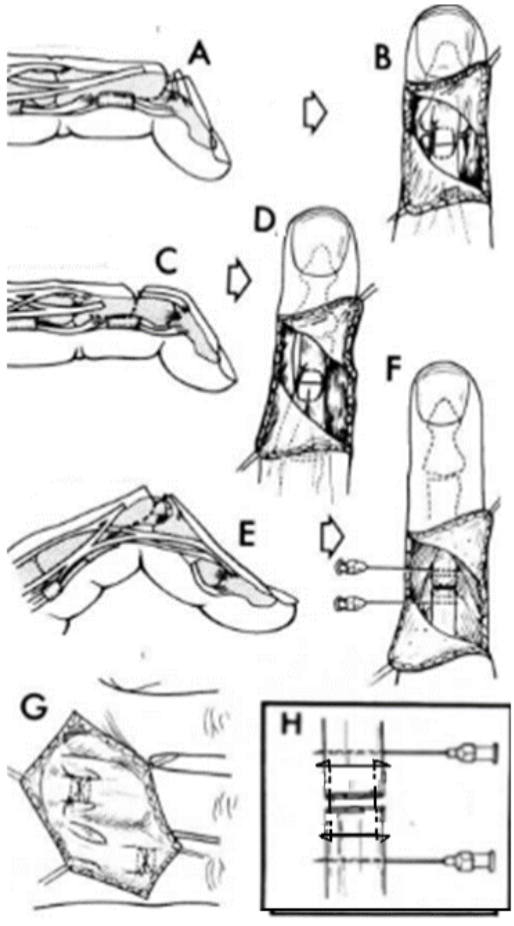


Fig. 65-25 EXTENSOR TENDON INJURIES. A, B, a tendon cut over the dip joint. The flaps to repair this injury have been cut along the extensor creases, *not across them*. C, D, a similar injury, this time over the middle phalanx. E,F, an injury over the proximal ip joint held with needles to make it easier to suture. It is often more convenient for these needles to go in through the skin on one side and out on the other. G, cut extensor tendons over the back of the hand. H, tendon fixed for suturing *From Heim U, Baltensweiler J. Checkliste Traumatologie, Thieme 1984, with kind permission.*

Treat a boutonnière injury like any other injury of the extensor tendons, but the results will not be as predictable.

INDICATIONS FOR PRIMARY SUTURE
(1) The injury occurred <24h before.
(2) There is no crushed or dead tissue.
(3) The wound is not badly contaminated.
In all other cases delayed primary suture of the skin and secondary repair is wiser.
If there is severe loss of the skin of the back of the hand, consider the flap coverage.

REPAIR
Apply a tourniquet and irrigate & debride the wound. Splint the hand and wrist in hyperextension while you operate. Clean the wound (54.1), excise the skin edges, and extend the wound if necessary to expose the tendon ends. Trim them.

Draw the proximal and the distal ends into the wound and hold them in place with needles which pass through the skin, the tendon, and then the skin again.

Hyperextend the finger to bring the distal tendon into view. Suture the flat ends with 3/0 or 4/0 non-absorbable monofilament suture (48.4). Splint the hand for 3wks with the wrist hyperextended (if possible), the mcp joints flexed 15°, and the ip joints extended.

CAUTION! Don't allow flexion of the injured hand until the period of splinting is complete.

THE BOUTONNIERE (BUTTON-HOLE) DEFORMITY

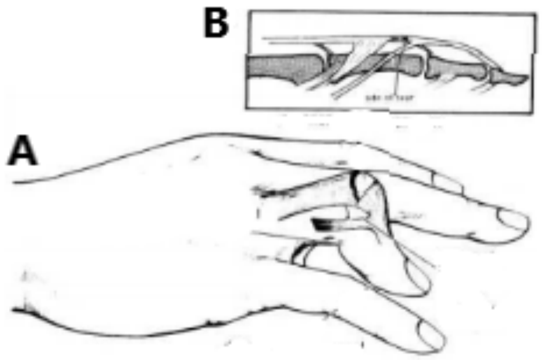


Fig. 65-26 THE BOUTONNIERE (BUTTON-HOLE) INJURY is a tear in the extensor expansion of the pip joint in which the combined tendon of the *lumbricals* & *interossei* slips forwards anterior to the axis of the joint, so that they flex the middle phalanx instead of extending it, as they do normally. The dip joint is extended. If not treated correctly, a disabling flexor deformity will result.

If after repair of a boutonnière injury, extension of the proximal ip joint is impossible when you take off the splint, you need to make a further attempt at open repair.

65.16 Flexor tendon injury

Flexor tendon lacerations are difficult injuries. On the volar (anterior) surface of the wrist there are 14 tendons, 2 main nerves, and 2 arteries, all of which can be cut. Exposing and finding them is not easy, thus repairing them takes a long time. Diagnosing that a flexor tendon is injured is usually easy.
However, if one of the fingers lies extended out of line with the others, it has probably been pulled by the unopposed action of its extensor tendon. This enables you to decide which of the flexor tendons is cut (65-2).

ANTERIOR WRIST STRUCTURES

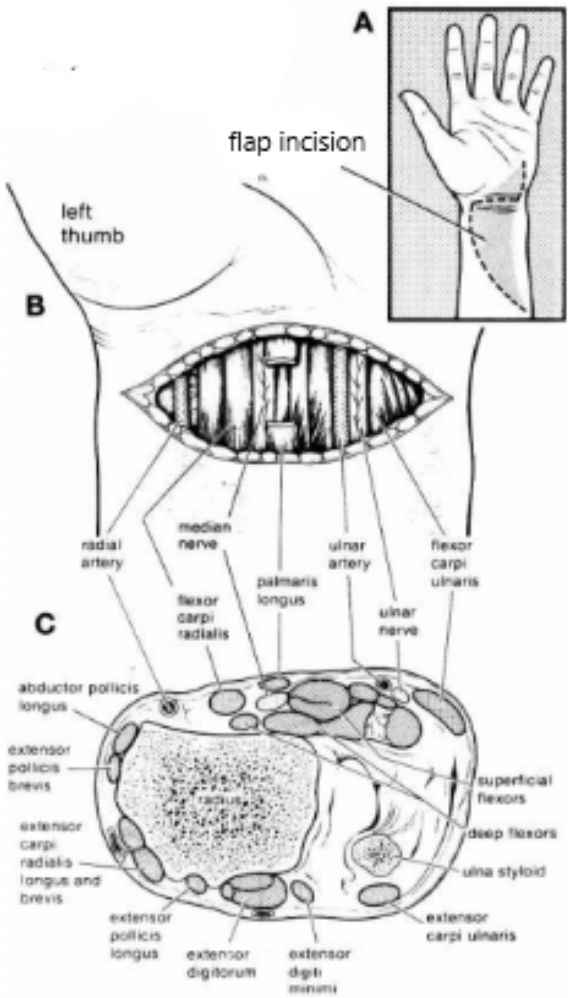


Fig. 65-27 STRUCTURES ON THE ANTERIOR WRIST SURFACE. A, cut flaps like this. B, the structures exposed through an incision in the flexor crease of the wrist. C, a cross-section of the wrist. Note the median nerve is under the *palmaris longus* tendon, between the *flexor carpi radialis* & the deep flexors.

One of the dangers in any flexor injury is that on clenching the fist, the proximal ends of the flexor tendons are pulled too far proximally in their sheaths, especially in Zones 1 & 2. If this happens, the blood vessels on the *vinculae* which nourish the sheath's cut end will be torn, and it becomes ischaemic, producing dense adhesions. The first principle in caring for such an injury is to keep the wrist flexed.

For repairing flexor tendon injuries, there are 5 zones:

Zone 1, distal to the pip crease and the insertion of the *superficialis* tendon, where repair is easier, because there is only the *profundus* tendon to be sutured. One difficulty is that the *profundus* tendon usually retracts. A flail dip joint is a nuisance, but a stiff dip joint after a repair is only a minor handicap.

Zone 2, an intermediate zone between the distal palmar crease and just distal to the pip crease, where repair is very difficult because the superficial and deep flexor tendons are so closely packed and run in the same sheath. This is a 'no man's land': even experienced surgeons have problems here.

ZONES FOR FLEXOR TENDON REPAIR

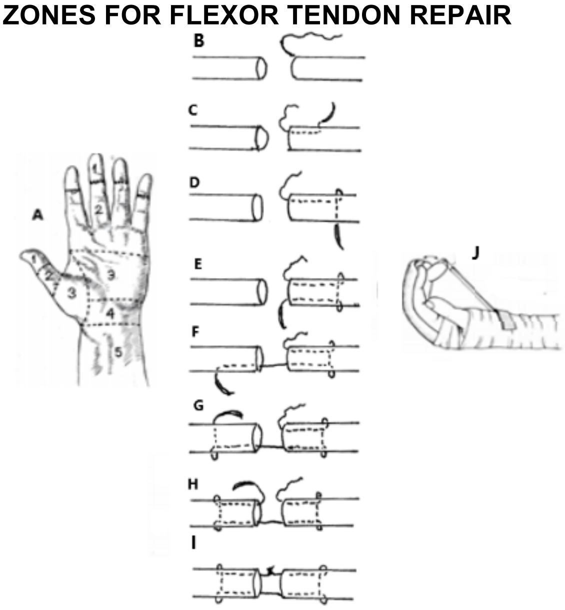


Fig. 65-28 ZONES FOR FLEXOR TENDON INJURIES. A, Flexor injuries in Zone 5, at the wrist, are not too difficult. Zones 4 & 3 are fairly difficult. Zone 2 is a *'no man's land' that even experts find difficult.* Zone 1 is is about as difficult as Zones 4 & 3.
B, the rough ends of a cut tendon. *In real life injured tendons never look as tidy as this!* Anchor the tendon with needles & trim its ends. B, oppose the clean ends. C-H, insert the needle as shown to bring the ends together. I, tie the suture ends together to bring the tendon ends into apposition. J, on completion, use a plaster backslab and curve it as shown. Pass a suture through the nail and tie a rubber band to a piece of strapping fixed proximally on the wrist.

For the unskilled, and the moderately skilled, the concept of 'no man's land' is still very relevant, because damage to normal fingers & their neurovasculature is a real risk.

So don't try! Instead, perform debridement and irrigation of the wound, and close the skin.
Also, *flexor pollicis longus* is difficult to repair with good results, even if it is the only flexor tendon.
Zone 3 extends from the end of the carpal tunnel to the A1 pulley.

Zone 4 is within the carpal tunnel.
Zones 3 & 4 include the palm between the wrist and the distal palmar crease where repair is not too difficult. If you are moderately skilled, try to repair the *profundus* tendon(s) and disregard or remove *superficialis*.

Zone 5 extends from the musculo-tendinous junction of the forearm to the tendons at the wrist at the entrance to the carpal tunnel. In this zone, repair the tendons immediately because they retract and scar rapidly.

DISTAL FLEXION TENDON INJURIES

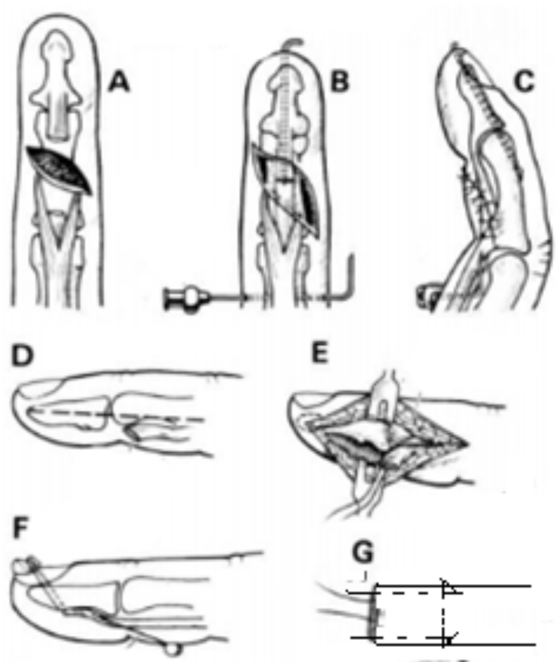


Fig. 65-29 FLEXOR TENDON INJURIES IN ZONE ONE. A, an injury over the middle phalanx. B, the terminal phalanx anchored with K-wire, and the *profundus* tendon brought into the wound and anchored with a needle. C, repair is complete. D, avulsion of the flexor tendon off the distal phalanx. E, open the finger from the side and place a suture in the end of the deep flexor tendon. F, with a withdrawal suture in place, anchor the tendon with sutures round the nail. G, how the withdrawal suture is anchored. *After Heim U, Baltensweiler J. Checkliste Traumatologie, Thieme 1984, with kind permission.*

EMERGENCY TREATMENT

Irrigate and debride the wound. Put the arm in a sling, with the wrist and fingers flexed so that they form a ‘C’ (65-1). This will keep the cut tendons in their sheaths with their blood supply intact. Clean the wound, suture the skin only.

AMPUTATION

Even when the flexor tendons to a single finger have been cut and you cannot refer the patient, there are good arguments for you to attempt a repair.

REPAIR

Indications & method are as for extensor tendons (65.15)

Retrieve the distal tendon stumps by flexing the digit. Bring the proximal tendon end down by flexing the wrist and by proximal-to-distal milking.

If this does not bring the cut end out, try *(only once)* to grasp it very gently using a fine haemostat and bring into the wound.

N.B. Repeated blind attempts to retrieve the tendon with a clamp will damage the surrounding sheath and lead to excessive scarring.

If these manoeuvres fail, extend the incision proximally to find the proximal end or make a separate incision just proximal to the A1 pulley in the palm. Once you find the proximal cut end, deliver the tendon end to the injury site through the flexor sheath using a fine PVC tube or silicone catheter. Then hold the tendon in place with a 25-G needle and repair it (65-21).

If you are not sure which finger a tendon belongs to, put a suture through the tendon and pull on this to see which finger moves.

If the *profundus* tendon is cut over the middle phalanx, repair it beyond the fibrous flexor sheath. Squeeze it to a button near the distal end of the finger. This will prevent the strong pull on the tendon tearing the repair apart.

If the *profundus* tendon becomes detached from its terminal phalanx, perhaps with a fragment of bone (65-15:8,9) this is the palmar equivalent of a mallet injury (65.7). Open the finger from the side (65-29E), and pass a suture through the torn end of the tendon. Pass the suture round the terminal phalanx and tie it, leaving a segment outside to allow its removal.

If the thumb tendons are injured, attempt primary repair.

POSTOPERATIVE CARE (ALL ZONES)

Immobilize the wrist in a splint in flexion for 3wks (65-28). This allows an injured tendon to move in its sheath, and in doing so to minimize adhesions. It also allows limited active extension, while the rubber band keeps the flexion without straining the suture.

The critical period for rupture of the suture line is immediately after removing the splint, so start movements gradually, and try to devise some form of check strap to prevent sudden movements which may rupture the repair. The hand will be stiff and painful after the injury, but with perseverance, it should improve steadily over several months.

If you are able to perform a 4- or 6-strand intra-tendinous repair, early movements are possible, starting from the 1st day with strictly passive movements of the injured fingers in flexion. Then from 2wks, passively placing the fingers into flexion and then trying to and actively hold the finger in place.

From 3wks advise active movements in stepwise fashion without loading or resistance over the next 8wks.

65.17 Repair of a digital nerve

Follow guidance on nerve repairs in general (48.1)

A finger with sensation will be much more useful than without, and since secondary suture is unsatisfactory, attempt a primary repair if you can. The digital nerves are quite large and are entirely sensory, so they recover well. Beyond the dip joint, the nerve is too small for repair.

After repair, immobilize the finger round a roll of bandage in the palm for 3wks. Injuries in the distal part of the hand will take 4months to recover, and those proximal to the wrist c.1yr.

65.18 Accidental amputation

The treatment of a pulp amputation depends on the completeness & the size of the piece lost. Treatment also depends on how clean the cut is: a butcher’s knife and a power saw cause very different injuries.

DISTAL PHALANX INJURIES

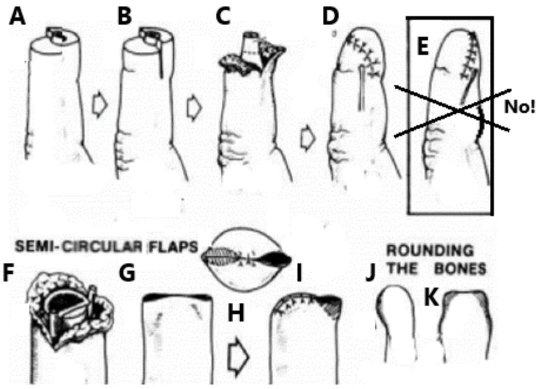


Fig. 65-30 DISTAL PHALANX INJURIES. A-D, transverse amputation of the distal phalanx (*rarely in reality as neat as this*). E, prepare unequal flaps, shorter on the dorsal side. F, trim the protruding bone, prepare the flaps. G, ensure the suture line is on the dorsum. H, *avoid a palmar scar & a neuroma.*

If there is some soft tissue covering the bone, even some periosteum, the finger can be left to granulate in with good result although this may take several weeks. However, in this case, the tip will be sensate and thus more functional. Skin grafting almost always results in an insensate tip, albeit with faster healing. *Don't perform a V-Y plasty except in cases of amputation at the ip joint:* this also results in an insensate tip & maybe scarring.

If the partly detached slice is still bleeding, showing that it is still alive, debride & suture it back on, even if it is quite large. Apply the minimum of dressings and elevate the hand.

If the partly detached piece is not bleeding, or if its tendons or nerves have been cut, it is probably better amputated completely.

If the piece is <1cm^2, it is not worth grafting. Apply vaseline gauze and let it granulate. This is possible in most of the cases with injuries in the finger tip!

If the piece is >1cm^2, shorten the bone so as to cover the stump with a good flap of palmar skin, either as fish mouth flaps (65-30D-G) or semicircular flaps (65-30J-L). A shortened finger is often best, so patients often say.

CHANG (36). an amateur guitarist, amputated the index finger through its middle phalanx, and severely injured the middle, ring, and little fingers in a machine at work. They were hanging on only by some crushed soft tissue and were cold and without sensation or movement. The possibility of microsurgery and the many months of rehabilitation it would require was discussed. He wished to be back at work quickly because there was much unemployment, so he opted for amputation. After intensive physiotherapy involving heavy metalwork, he was soon back at work, and still plays the guitar, but with a plectrum to pluck the strings.

KALIM (39) the wood chopper in Fig. 75-29, degloved the index, middle finger, and thumb in a machine at work. The ring and little fingers were less severely injured. But he could still move them all normally; their tendons were undamaged. The possibility of burying them in an abdominal skin pouch was discussed, but it was not considered practical to restore sensation with a neurovascular island transfer, since this would have required months of physiotherapy. He was in danger of losing his job, so he chose to have the thumb, index, and middle fingers amputated. A few weeks of physiotherapy restored movement to the ring and little fingers and he was soon back at work; he can even do up his own buttons. LESSONS (1) All the surviving parts of the hand were covered with good skin. (2) It was possible to preserve the whole of the 1st metacarpal. (3) Active physiotherapy started almost immediately. (4) Early amputation can leave a very functional hand.

CONSIDER THE NEEDS OF EACH PATIENT

65.19 Severely injured hand

Multiple injuries demand measures that may be quite different from single finger injuries. The soft tissues are likely to be severely injured, causing much swelling and stiffness. There may be other even more serious injuries elsewhere. One stiff finger is manageable, but a stiff hand is a serious disability. It is often difficult to know whether to splint or mobilize an injured hand.

METHOD

Carefully irrigate and debride the hand (65.1). *Don't suture the skin*. Apply a wet dressing with plenty of cotton wool. The hand will swell severely, so elevate it. Keep it in the position of safety with a plantar plaster cast. Administer an antibiotic and analgesics.

First find the median or ulnar nerves (48.1); it is seldom that both are involved. Then find the injured tendons: beware, *the median nerve looks very much like a tendon*! Suture the nerves (48.1) and tendons (47.1). If one artery is cut, repair it if possible, but *don't waste time on it*. If both arteries have been cut, the collateral circulation may be enough to keep the hand alive, but repair at least one artery (49.5), especially if the patient is old. Try to suture all tendons, *except palmaris longus*. If you have difficulty, the deep flexors are the most important.

If there are fractures of the middle and ring fingers, strap them to their normal neighbours. If this is impractical, support the injured fingers with aluminium splints.

If there are multiple phalangeal fractures, early active movements are likely to produce good function, though *not if the metacarpals are fractured*. Here K-wire fixation is more effective (65.20).

If a single finger is badly damaged, consider amputating it, especially if the other fingers are normal.

If several metacarpals are fractured and severely deviated, apply K-wire fixation (65-32). If convenient, incorporate it in a cast which is immobilizing the wrist.

If several of the fingers are badly damaged, conserve as much function based on the examples described below.

SOME SEVERE HAND INJURIES TREATED

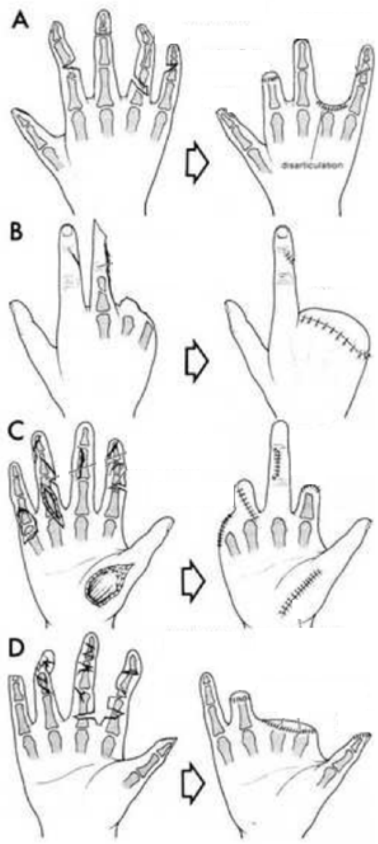


Fig. 65-31 SOME SEVERE HAND INJURIES. You may have to cope with any of these. One of your most difficult decisions will be whether to splint an injured hand or to mobilize it. *After London PS. Practical Guide to the care of the injured. E & S Livingstone 1967 with kind permission.*

Hand 65-31A. The tendons and the neurovascular bundles of the index and ring finger are so severely injured that amputation is the only reasonable option. Close the end of the index finger with a palmar flap, and the ring finger by removing the stump of its proximal phalanx.

Close the middle finger with a fish mouth flap (36.14), so as to save as much length as you can. The ulnar neurovascular bundle of the little finger is intact, so fix its middle phalanx. Graft the wound on the tip of the thumb with skin taken from the amputated tip of the index finger.

Hand 62-30B. Half the middle finger is intact, so fillet it by removing the bone to make a flap that will cover the stumps of the amputated 4^{th} & 5^{th} fingers. *Take care not to damage its blood supply, including its dorsal veins*. Remove the injured phalanges, pull the flexor and extensor tendons distally, cut them off cleanly, and allow them to retract.
Cut back the digital nerves of the amputated fingers so that their cut ends lie deep in the palm. Leave all the fat in the flap, suture it in place without tension, and evert the suture line. If there is any excess skin, remove it from the dorsal aspect rather than the palmar aspect of the flap, but *don't make it too narrow*.

Hand 65-31C. There is a soft tissue wound round the base of the thumb. Close it without tension by slightly increasing its length. Both the neurovascular bundles in the index finger are cut, so amputate it just proximal to the ip joint.
Suture the small flap on the middle finger into place. The ring finger is so severely injured that you can only save its proximal phalanx. The little finger is also severely damaged, so amputate it through the head of its metacarpal. A grip between thumb and index finger will still be possible, so there will still be a useful hand.

Hand 65-31D. Repair the thumb by simple suture. Both the index and the middle fingers are so severely damaged that amputation through the mcp joints is necessary. More of the index finger remains, so you can amputate it through its proximal ip joint, and turn up a flap. A powerful grip will remain.

A GROSSLY INJURED HAND

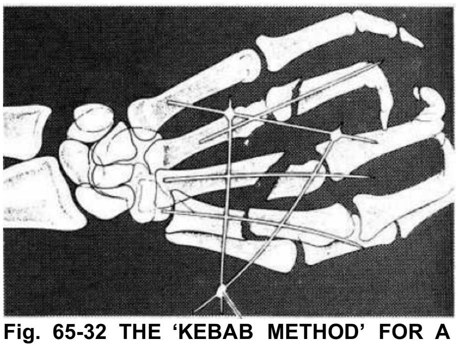


Fig. 65-32 THE 'KEBAB METHOD' FOR A GROSSLY INJURED HAND. This is the patient 'Yvonne' in the text, who was later able to return to typing, despite the severity of her injury. *Kindly contributed by Peter Bewes.*

Hand 65-32
If the hand is so severely injured that you cannot save any of the fingers, try to save as much of the metacarpals as you can. If the thumb remains, this will give something to grip against. Mould what remains of the hand into the best position (65.8). If necessary, insert K-wires longitudinally down the fractured bones and transversely across the hand to stabilize the metacarpals. Hold the ends of the rods or wires together with epoxy resin, plaster, or string. Leave the wound open for the first few days. Close it by secondary suture, or with skin grafts as appropriate. Remove all K-wires after 14-21 days.

YVONNE (26) and her husband had been driving all night when he veered into the fast lane on the motorway. She sustained multiple open dislocations of the mcp joints of the right hand, its dorsum was degloved, and several of its metacarpals and proximal phalanges were fractured, as in (65-32). Amputation was considered, but the circulation and sensation in her fingers was good, and she was, moreover, a typist. A tourniquet was applied and the wound was irrigated and debrided under GA. The metacarpals were repaired by threading K-wire down their marrow cavities, and further stabilized with transverse wires held with epoxy resin.
The wound was covered with split skin (fortunately most of the extensor tendons were still covered with paratenon), and the hand was bandaged in the position of safety (65-7). She later returned to typing.

65.20 External & internal fixation

INTRODUCTION
Open reduction and internal fixation (ORIF) by plating or screwing demands high standards of hygiene and resources. Therefore, where resources are limited, *it is usually impossible to perform and usually contra-indicated.*

FINGER FIXATION USING PLASTIC

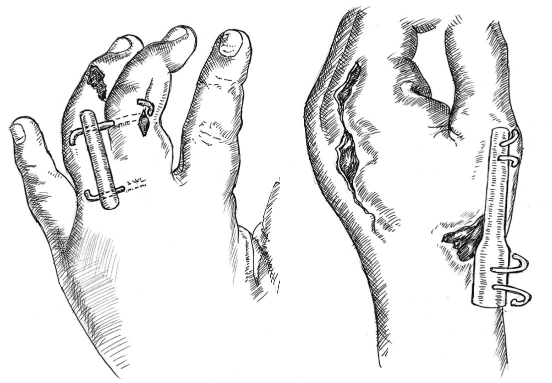


Fig.65-33 EXTERNAL FIXATION WITH A PLASTIC CANNULA SHEATH. Don't put it over the midline & avoid the extensor mechanism.

External fixation is a good option for the treatment of complex trauma of the wrist.

Bridging external fixation of the wrist *via* the radius and the 2nd metacarpal row is very helpful in dislocated wrist trauma with or without severe skin and soft tissue trauma.

Use external fiaxation for finger fractures severely comminuted or open & grossly contaminated (*e.g.* in gunshot injuries). You can use the plastic sheaths of cannulae as crossbars and needles or K-wires as pins. Reduce the fracture and measure the length of plastic you need. Avoid the extensor mechanism & the midline when placing the pins; make them diverge slightly to add to stability of the fixation.

K-wiring is however better and less complicated for simpler fractures. K-wiring can combine various aspects of external and internal fixation in severely injured fingers. It offers bone stabilization without further bone exposure, thereby protects skin and soft tissue, and can be easily removed. Bone infection due to K-wiring is very rare. So, even in the hands of the less experienced surgeon, it is a good option.
Use it in complicated finger and metacarpal, as well as in open fractures.

INDICATIONS:
(1) Displaced fractures of phalangeal shafts, where closed reduction has failed and there is a rotational deformity (scissoring).
(2) Displaced fractures close to or involving a joint.
(3) Major unstable injuries.

FIXING FRACTURES WITH K-WIRE

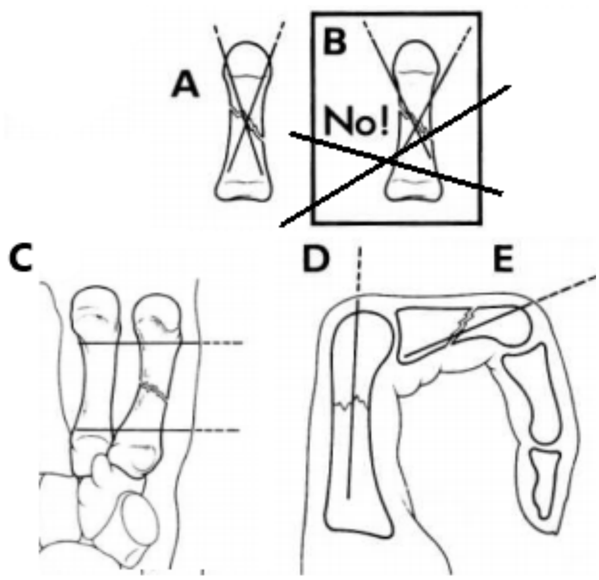


Fig. 65-34 FIXING FINGERS WITH K-WIRE. A, drill the wires through the sides of a condyle. B, *not through the side of the neck*. C, fixing the shaft of the 5th metacarpal with K-wire. D, longitudinal fixation of a metacarpal. E, is the same injury as in A, but viewed from the side. *Kindly contributed by James Cairns.*

A useful way of fixing some unstable fractures is to use K-wires. Insert 2 wires to cross one another in order to immobilize a fracture very satisfactorily (65-34).

EQUIPMENT
A bone drill,
A K-wire plier cutter,
Some 8 cm lengths of 0.75-1.2mm K-wire.

If you don't have a drill, you may be able to put the wire in with a Steinmann pin introducer, but this is technically very difficult.

K-wires are usually supplied with sharp points; to sharpen a cut end, do so with a wire cutter. If possible, use wire with a beveled end slightly wider than the rest of the wire.
This will overdrill the bone through which it passes and avoid distraction of the fragments.

METHOD (GRADE 2.3)
Drill the wire in with a hand drill or power drill. Cut the wires short just under the skin. Leave the wires in for 12-21days, or until the bone has united.
Bend the wire protruding outside the skin and cut it, so it makes a small hook c. 0.5cm long.

Make sure the cut end doesn't press into the skin. This can then easily be removed in clinic without LA.
Otherwise a buried wire needs a cut in the skin under LA to extract it with pliers, which may not be readily available.

For the shaft of a phalanx, enter the lateral aspect of a condyle, and drill through the shaft, into *but not through its base*. Drill from the dorsal aspect of the condyle, towards the volar aspect of the base. Going through the sides of a condyle will be easier than trying to go through the sides of the neck of the shaft. The bone is harder here and it is difficult for the drill to enter the bone obliquely.

For fractures of the neck of a metacarpal, enter the condyle in a similar manner.
N.B. Many of these fractures don't need K-wire (65.11).

For unstable open finger fractures, apply K-wires in the position of safety. Drill the wire through the head of a phalanx to one side of the midline (65-10A). Pass it down to, *but not through,* the base of the phalanx. Cut it off under the skin over the proximal ip joint. Supplement this with an external splint to protect the pins.

To hold the position of a metacarpal base & neck fracture (65.10) apply K-wire fixation if necessary.

65.21 Difficulties with finger injury

If the finger is degloved, the skin is stripped off the finger, by a ring, a rope or high-pressure liquid. An alternative to amputating the degloved finger is to cover it with an abdominal flap (46.5). *This is a method for the careful, caring operator.* It is easy to start this procedure, but difficult to see it through to a successful result. Too often the result is a stiff hand.

If there is a severe injury of the back of the hand, perhaps involving the extensor tendons, management will depend on whether or not the tendons still have a thin filmy pink sheath of *paratenon* over them. If they do, primary repair of the tendons and primary split thickness skin grafting is the best and allows you to put the hand into the position of safety (65-7). If there is no *paratenon* over the extensor tendons, a flap is needed.

THERE IS NO SUCH THING AS A TRIVIAL HAND WOUND

If the thenar muscles are severely crushed, pressure builds up within the firm thenar fascia causing severe pain and paralysis. Pain on passively stretching the muscles is a sign of impending ischaemic contracture, so make an urgent surgical decompression (49.6). Make an incision over the thenar eminence parallel to the skin crease at its base or obliquely. Cut the underlying fascia *taking care not to go too far medially or proximally*, or else you will injure the recurrent branch of the median nerve which supplies the thenar muscles.
N.B. If there is pressure on the median nerve with numbness, a carpal tunnel release is necessary as well.

If the hand has been bitten, the risk of infection, particularly after a human bite, is great. Osteomyelitis may follow. So, irrigate and debride the wound thoroughly and leave it open. Elevate the hand in a roller towel. Administer a broad spectrum antibiotic. *Don't forget anti-tetanus toxoid!*
N.B. Beware the bite injury of the knuckles: a seemingly innocuous wound easily results in spreading infection along the extensor tendons!

65.22 High pressure injection injury

Sticky liquid mixed with air from an industrial spray gun can penetrate very deep in the hand and spread along synovial sheaths to the bursae in the palm, or even the forearm. You may only see a small puncture wound initially, from which an oily frothy liquid exudes.

Where the substance has been injected may be grossly swollen. Such a wound needs radical debridement. A radiograph will show how far thick oil has extended into the tissues (65-35).

If an industrial gun or pump has injected grease, diesel oil, paint, compressed air, or abrasives into the hand, these materials enter the tissue planes of the hand under high pressure, and may reach even up into the forearm. *Although the skin wound may be small and the initial injury almost painless, the tissues underneath are grossly injured.* Soon the hand starts to swell and becomes very painful. This is an acute surgical emergency and an extensive wound debridement is essential. *Neglect may lead to amputation.*

HIGH PRESSURE GUN HAND INJURY

Fig.65-35 HIGH PRESSURE GUN INJURY TO THE HAND. Extensive spread of oil in the index finger. Explore the wound after applying a tourniquet; remove all foreign material, loose fragments of bone, & dead tissue. Note damage to nerves & tendons for later repair. N.B. You may need to release the tourniquet to see which tissue is viable. *After Verhoeven N, Hierner R, High pressureinjection injury of the hand. Strategies Trauma Limb Reconstr.* 2008; 3(1): 27–33.

MANAGEMENT (GRADE 2.4)
Elevate the hand for 5-10mins. Explore the injury under GA and a tourniquet. Consult an anatomy book to show you where the important structures are. Incisions recommended are not exactly the same as for sepsis (8-4B,6B).

Don't use an Esmarch bandage as this may spread the oil further.

Note damage to nerves, arteries, and tendons. *Leaving foreign material in the tissues is more dangerous than opening up the hand fully.*

When you have removed all the foreign material, apply a firm dressing and take the tourniquet off. After 5-10mins, remove the dressing and control bleeding.
Then dress the wound without suturing it. Finally, leave the hand in the position of safety, inspect it daily, and remove more foreign material if necessary. The hand will be stiff, but if you don't treat this radically an amputation will be inevitable. This is an acute surgical emergency and an extensive wound debridement is essential.

(a) Index, middle & ring fingers
Injection into the index, middle & ring fingers does not extend to the palm. If there is gross swelling, amputate the finger at the mcp joint. Otherwise make a radial or zigzag incision (8-6B) and clean out the oil conscientiously (65-36). You may well end up amputating the finger later because of stiffness.

EXPOSURE OF A FINGER

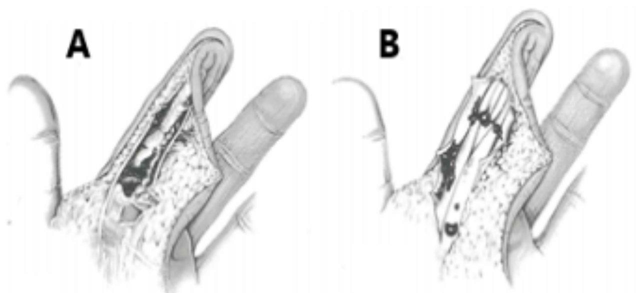


Fig. 65-36 EXPLORING A FINGER FOR INJECTION INJURY. A, initially the oil penetrates along the line of fire, B, but then reaches the transverse metacarpal ligament and spreads laterally. *After Champion HR, Robbs JV, Trunkey DD, Trauma Surgery Part 2, Butterworths, 4th ed 1989.*

(b) Little finger
Make a zigzag incision on the palmar surface and inspect the synovial sheath. If oil has penetrated this, open it fully proximally with a further zigzag, taking care not to damage nerves & vessels, clean the tissues and rinse out the bursa (65-37).

EXPOSURE OF THE LITTLE FINGER

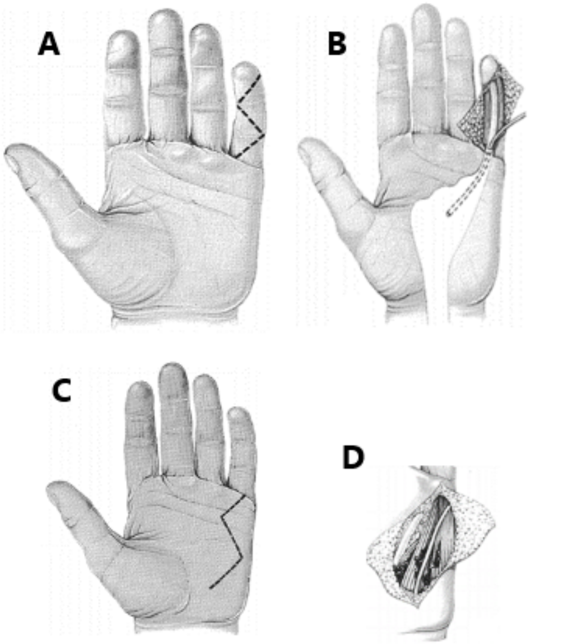


Fig. 65-37 EXPLORING THE LITTLE FINGER. A, make a zigzag incision to explore the little finger. B, extend this to open the ulnar bursa. *After Champion HR, Robbs JV, Trunkey DD, Trauma Surgery Part 2, Butterworths, 4th ed 1989.*

(c) Thumb & thenar eminence

Decompress the thumb itself by a zigzag incision, and if the oil has spread proximally, open the thenar eminence also (65-38) to explore the radial *bursa*.

EXPOSURE OF THE THUMB

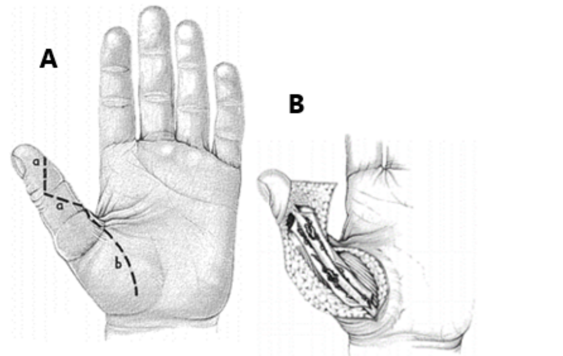


Fig. 65-38 EXPLORING THE THUMB. A, make a zigzag incision to explore the thumb. B, extend this to open the radial bursa. *After Champion HR, Robbs JV, Trunkey DD, Trauma Surgery Part 2, Butterworths, 4th ed 1989.*

(d) Mid-palm

Make an angular incision and undermine a large palmar V-flap with its fat. Remove the superficial palmar aponeurosis and clean the area superficial to the flexor tendons very carefully, taking care not to damage nerves & vessels. You may need to go deeper towards the septum attached to the 3rd metacarpal which divides off the thenar space (65-39).

EXPOSURE OF THE MID-PALM

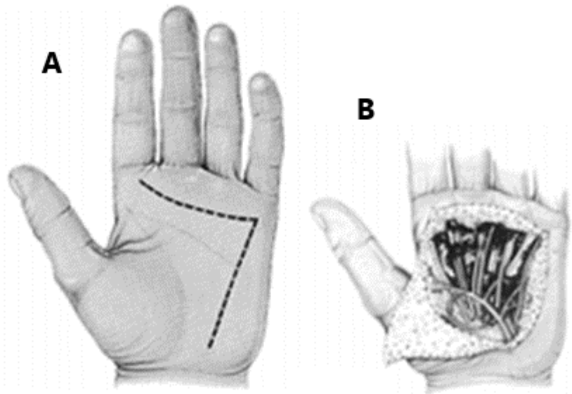


Fig. 65-39 EXPLORING THE MID-PALM. A, make an angular incision reflecting a V-flap with its fat. B, after removing the palmar aponeurosis, carefully remove the oil with saline & pledgets. *After Champion HR, Robbs JV, Trunkey DD, Trauma Surgery Part 2, Butterworths, 4th ed 1989.*

66 Hip injury

66.1 Rehabilitation with an injured lower limb

After any serious lower limb injury, your aim will be to regain walking *without* a limp. There are 3 stages to do this, usually initially with crutches:
(1) a non-weight bearing stage in where the foot is kept off the ground, (2) a stage of partial weight bearing,
(3) a stage of full weight bearing with no aid, except perhaps from a stick.

HELP WITH WALKING

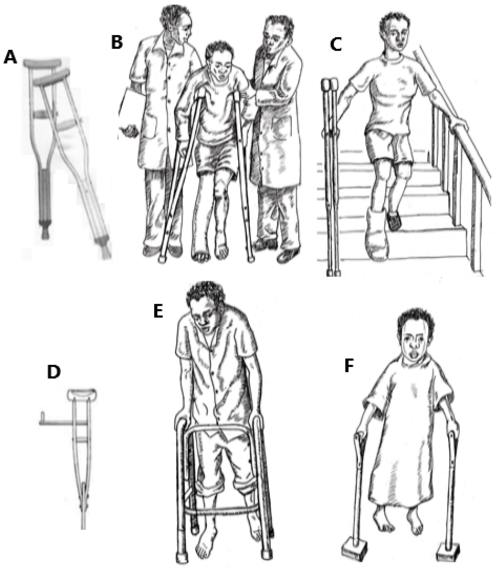


Fig. 66-1 HELP IN WALKING. A, crutches with well-padded shoulder supports. B, being taught to walk. C, coming down stairs. D, a crutch with an arm support. E, a walking frame. F, 'plonkers' for a child.

When an injured patient learns to walk normally, he uses all the muscles, and stabilizes the injured limb. If he limps, some of the muscles remain unused, with the result that he may limp permanently, and quite unnecessarily. So try to interest your ward staff in the way their patients walk, and turn them into active physiotherapists. The time indicated for no, partial or full weight bearing depends mostly on the kind of injury.

CRUTCHES FOR AN INJURED LEG
A plentiful supply of crutches is essential. Ask the hospital carpenter to make well-padded axillary crutches with rubber tips, adjustable for height, and also for the position of the hand grips, which should be c. ⅓ the way down the crutches. Fit crutches carefully so that the crutches are just short of the axilla on standing. When the hands are on the hand grips, the elbows should be slightly flexed. *A crutch which is slightly too short is better than one which is too long*. Weight bearing should be not only on the axilla but also on the forearm. Walking is easier if the good leg is slightly longer than the injured one; so use a shoe with a thicker sole.

CAUTION!
(1) Some weight bearing must occur on the hand rests, *not the axillae*, or a crutch paralysis may develop. Any nerve of the brachial plexus, particularly the radial, may be injured. This takes c.6 months to recover.
(2) A comfortable crutch will do much to reduce the burden of disability. Stand behind the patient and explain how to hold the crutches close to the side slightly in front of the feet, and to look straight ahead. Explain how to take the weight on the hands, to lean forwards, so that the weight is over the crutches, and then to transfer the weight to one crutch before moving the other.

NON-WEIGHT BEARING
Ask the patient to hop on the normal leg while steadying the trunk with the crutches.

PARTIAL WEIGHT BEARING
Ideally, you should use bathroom scales to measure how much weight is being put on the injured leg. Encourage as much weight bearing as possible without causing pain.

(a) Try first, '3-point walking': get the patient to bring the crutches & the injured leg forward together, taking some weight on each.

(b) Then try '4-point walking': get the patient to advance the right crutch followed by the left leg, and then the left crutch followed by the right leg. This is slow at first, but is much more like normal walking.

STICKS FOR LEARNING TO WALK

Two sticks are better than one, and less likely to cause a limp. Use the 4-point gait described above. For children, flat pieces of wood on the bottom of two sticks ('plonkers', 66-1F) will make them easier to use.

WALKING IN A CAST
If a patient is in a cast, explain how, if possible, to start walking normally erect and looking ahead, right from the start. Teach how to lift the heel, to transfer the weight to the forefoot, to bend the knee, to move the leg forward, to put the forefoot on the ground, to lower the heel, and to move the body forward.

Then practice repeating these movements with both legs until walking normally.

Once the cast has been removed, teach how to walk without a limp, using crutches at first to minimize the pain. Teach how to balance on both feet. Start by holding with both hands on to the foot of the bed, then teach how to balance on one foot. *This is the most important part of the training*. Stand in front and put both the patient's hands on your shoulders. Ask him to hold tight and lift the injured leg first, then the good one. To start with, he may be unable to balance the body over the injured leg, but he will soon learn to do so by abducting the hip on the injured side.

As soon as he can balance on one leg, ask him to bend the opposite knee to a right angle. This makes balancing more difficult.

Next, make him lift first one leg then the other, while standing in the same place. When he can do this, ask him to take short 'baby' steps, putting the good foot down 10 cm in front of the bad one, and then the bad foot the same distance in front of the good foot. Like this, he learns to put equal weight on both legs to avoid a limp.

TURN YOUR WARD STAFF INTO PHYSIOTHERAPISTS

66.2 Overview of hip & femoral neck injury

HIP DISLOCATION AND FEMORAL NECK FRACTURES are not easy to distinguish without a radiograph. These are the injuries of the hip & femur you may encounter (66-2).

(a) Dislocations are usually posterior (66-2A), and occasionally anterior (66-2B), or central through the fractured acetabulum (66-2C).

(b) Femoral neck fractures are of 2 kinds: (a) the common unstable (66-2D), where the fracture line gores right across the bone (complete), or only partially across (incomplete), and (b) the rarer stable impacted valgus fracture (66-2E). Fractures here unite badly, because the blood supply to the proximal femoral fragment is damaged.

Conservative treatment is usually unsatisfactory, and so most of these fractures need internal fixation, if possible.

Intertrochanteric fractures (66-2F) occur between the two trochanters. Fractures here unite well, so that conservative treatment is usually satisfactory.

INJURIES TO THE HIP & FEMORAL NECK

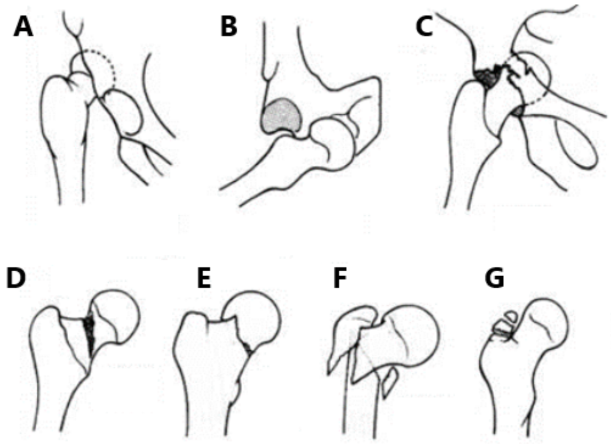


Fig. 66-2 INJURIES TO THE HIP AND FEMORAL NECK A posterior, B, anterior, C, central dislocations of the hip. D, unstable & E, impacted valgus femoral neck fractures. F, an inter-trochanteric fracture. G, fracture of part of the trochanter with an intact shaft.

Fractures of the greater trochanter are rare and not serious. A patient falls on the hip and breaks off the greater trochanter without breaking the neck of the femur (66-2G). Start walking on crutches until free from pain. *No other treatment is necessary*.

IF THE FEMUR IS FRACTURED, MAKE SURE THE HIP IS NOT DISLOCATED BY ALSO EXAMINING THE HIP

EXAMINATION
Remove all the clothes down to underwear. Observe the patient walking if possible. Is there a limp? If walking is possible, a serious leg injury is unlikely, but there may be an impacted femoral neck fracture.

Observe the patient standing on one leg. When a normal person does this, the pelvis tilts so that the opposite hip lifts up.

If it dips down, the hip mechanism of the weight-bearing leg is abnormal. The gait may be abnormal in a similar way (Trendelenburg sign and gait).

CHECK THE ATTITUDE OF THE HIP
When a normal patient lies supine, the legs rotate externally a little.

If the leg is abnormally externally rotated after an injury, there is probably a femoral neck fracture. If it is rotated 90°, the fracture is probably low in the neck, but if it is rotated only 45°, it is likely to be high in the neck, where it is partly retained by the capsule.

If the hip is flexed, adducted, and internally rotated after a violent injury, this is a posterior dislocation (66-2A).

If the hip is flexed, abducted and externally rotated, this is an anterior dislocation (66-2B).

CHECK THE HIP MOVEMENTS
Lie the patient flat with the pelvis level. With your hands on the thigh, gently rock the leg from side to side. Compare both sides.
Any painful limitation of movement indicates muscle spasm & possible fracture or dislocation.

N.B. With the patient prone, bend the knee, grasp the foot, and rotate the leg from side to side.

(a) Flexion. Put one hand palm upwards under the lumbar spine. With your other hand flex the normal hip. This will flatten the normal lumbar curve, and force the spine against the couch. If the other hip is able to extend normally, it will remain flat on the couch as you do this, but will flex otherwise.

(b) Rotation in flexion. While the hip and knee are flexed to 90°, rotate the hip externally and internally, and compare its range with the opposite side. Any 'crunchy feeling' in this or any other movement is a sign that the hip joint is abnormal.

(c) Abduction. Flex the normal knee and hook it over the edge of the couch. This will lock the pelvis and prevent it tilting. Now, keeping the other knee straight, grasp the ankle and then abduct the leg as far as it will go. Put one hand on the opposite anterior superior iliac spine to detect if the pelvis rotates.

(d) Adduction. Still steadying the pelvis, bring one thigh as far as possible over the other. It should be able to cross at its middle $^{1}/_{3}$.

CHECK THE GREATER TROCHANTERS
Standing over the patient, place your thumbs on the anterior superior iliac spines, and your middle fingers on the trochanters.
Compare both sides, and feel if the trochanter on the affected side is displaced upwards (posterior dislocation), or downwards (fractured femoral neck of femur, or anterior dislocation).

If the greater trochanter has moved medially this is a central hip dislocation.

N.B. The dislocated femoral head is only palpable in the perineum or groin in a very thin patient.

CHECK THE POINT OF MAXIMUM TENDERNESS

If this is anterior, suspect a femoral neck fracture
If this is lateral, suspect a greater trochanteric injury

CHECK FOR LEG SHORTENING
This may be obvious, with the patient supine (66-3A), or with both hips and knees flexed (66-3B-D). The measurement of true shortening is useful in many hip and leg conditions. Place the uninjured leg in exactly the same position as the injured side.

TEST THE SCIATIC NERVE
Check if foot dorsiflexion is possible.

RADIOGRAPHS
Always get radiographs of the hip if there is pain on weight-bearing after a fall. Get an AP film with the hip in as much internal rotation as possible, even if you have to hold the leg in this position yourself. *Don't take it in external rotation* which is the natural position of a resting injured hip.

Also get a horizontal lateral view (to see if the head of the femur has been displaced posteriorly), with the X-ray tube in the groin and the plate pressed in well above the iliac crest.

If the films are difficult to interpret, compare both sides.

CAUTION! You can easily miss a fracture of the neck, especially if it is subcapital (close to the head). In doubt, look carefully all around the cortex for small breaks in continuity, a step, or an angular deformity.

THE MAJOR FEATURES OF SOME COMMON INJURIES

(a) An unstable femoral neck fracture.
Severe pain and inability to walk or lift the foot off the bed. The leg is externally rotated with ≥1cm shortening.

(b) A stable impacted valgus femoral neck fracture. Little pain, ability to lift the foot off the bed and maybe walk. The leg is not rotated nor shortened.

(c) An intertrochanteric fracture.
Severe pain and inability to walk or lift the foot off the bed. The leg Is externally rotated with shortening. Maximum tenderness is over the greater trochanter.

MEASURING LEG SHORTENING

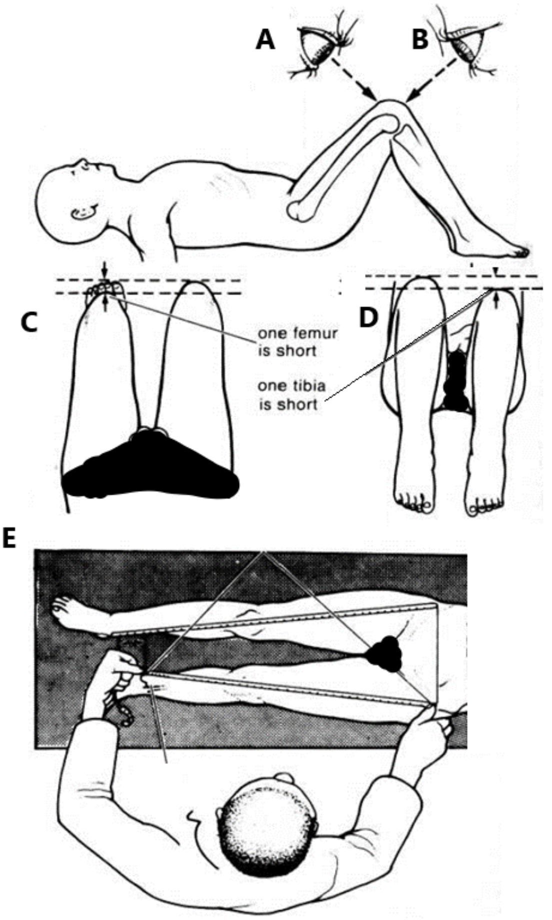


Fig. 66-3 MEASURING SHORTENING. A,B, with the patient's hips and knees flexed, look along the line of the tibia & femur. C,D, looking from above & below, check the position of the kneecap. E, measure from anterior superior iliac spine to medial malleolus.

Measure the distance between the inferior edge of the anterior superior iliac spine, and the tip of the medial malleolus (66-3E).

(d) Posterior hip dislocation.
The hip is flexed, adducted, and internally rotated, and the leg is shortened.

(e) Anterior hip dislocation.
The hip is flexed, abducted, and externally rotated, and the leg is shortened.

(f) Central hip dislocation.
The trochanter is displaced medially. There is no shortening.

66.3 Posterior hip dislocation

Posterior dislocation of the hip often occurs in a head-on car collision, where the knee hits the dashboard and the impact drives the femoral head at first behind, & then out of the acetabulum.
Typically, the hip is adducted & internally rotated. Soon, it rides up onto the dorsum of the ilium.

There are usually also other serious injuries, especially a fracture of the femoral shaft, or posterior cruciate ligament rupture in the knee, so that the dislocated hip is often missed.

N.B. Hip dislocation is relatively frequent after hip replacement and more so with revision arthroplasties. They can occur repeatedly if there is poor alignment or size discrepancy. They can be either posterior or anterior, but are usually relatively easy to reduce.
Patients should avoid internal rotation of the flexed hip, and bending too far forward.

HIP DISLOCATION REDUCTION (GRADE 1.3)
Resuscitate the patient if there are other serious injuries. However, don't delay long before reducing the hip, because it will become more difficult, and risks avascular necrosis of the femoral head.

Look for other fractures, especially a fracture of the posterior rim of the acetabulum. Check the function of the sciatic nerve before and after reduction (48.1), and examine the dorsalis pedis pulse.

Ketamine with diazepam is usually enough, if you use the method described.

REDUCING POSTERIOR HIP DISLOCATION

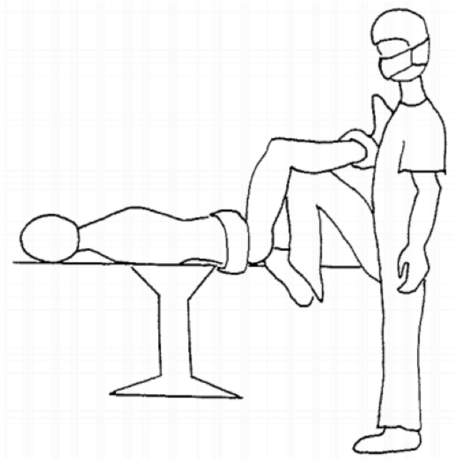


Fig. 66-4 REDUCING A POSTERIOR DISLOCATION OF THE HIP *After Bergman N, Reduction of posterior dislocation of the hip. Trop Doctor 1994; 24:134-5 with kind permission.*

'CAPTAIN MORGAN' REDUCTION
Place the dislocated hip close to the edge of the operating table. Tighten a broad leather belt tightly across both anterior superior iliac spines under the table. If possible, use a 2nd belt tightened over the inguinal ligament on the ipsilateral side. Lower the operating table so that you can comfortably put your forefoot on its edge, just distal to the dislocated hip. Flex the hip & knee to 90°. Keeping your forefoot in place, put your knee in the patient's popliteal fossa as snugly as possible. Grasp the ankle with one hand (66-4).
Now plantarflex your foot so that your knee pushes up against the patient's knee. Depress the foot with your hand and so reduce the dislocation.

While the patient is still anaesthetized, examine the knee for rupture of the posterior cruciate ligament (68.6).

TEST FOR STABILITY
While the patient is still anaesthetized, flex the hip to 90° and check to see if the femoral head easily slips out of the acetabulum posteriorly, or if it stays in place. If it slips out easily, suspect a fracture of the posterior rim of the acetabulum (66.5).

POSTOPERATIVE CARE
If the dislocation is stable and pain-free, there is no need for traction, so start active movements in bed, and after 10days get the patient up on crutches with partial weight bearing.

If reduction is unstable, and the femoral head slips out of the acetabulum, get a radiograph. If this shows a large chip broken off the rim of the acetabulum, try extension traction with a distal femoral or tibial pin. If this controls the reduction, continue to apply it for at least 6wks.

If this fails to control the unstable hip, it is probably because the posterior rim of the acetabulum has been shattered. Assemble '90-90 traction' (70-10), using skeletal traction with a tibial pin, as for an acetabular fracture (66.5). Get an AP and a lateral radiograph to make sure the reduction is satisfactory, while in traction. After you have held the hip like this for 6wks, there will be enough scar tissue in the posterior acetabulum to hold it. Provided the range of movement in the hip and the ability to control it increase each day, allow him to move it as he wishes. Explain that late complications may occur, and follow up for 2yrs.

DIFFICULTIES WITH DISLOCATED HIPS
If the hip is particularly painful immediately after reduction, consider aspirating it (7.17).

If dorsiflexion of the foot is impossible, and sensation on its dorsum is absent, there is a sciatic nerve palsy. This usually recovers. A fragment from the rim of the acetabulum may have impaled the sciatic nerve. Refer if possible so that the hip can be explored and the fragment fixed.

If the foot is cold, blue, and swollen, the femoral artery or vein has thrombosed, so reduce the dislocation urgently, and start anticoagulants.

If the foot is swollen, raise the leg. if the artery is thrombosed, keep the leg cool. Refer urgently for vascular surgery. If this is to be effective the operation must be done within 2h.

If there is a hip dislocation & a femoral head fracture, there may be a loose fragment inside the joint. Try to refer him as above.

If there is a hip dislocation & a femoral shaft fracture, reduce the dislocation using an external fixator (66-9).

If a posterior hip dislocation has been missed, try to reduce it by closed methods up to 2wks after the injury. If you fail, try to refer him. Older dislocations are usually impossible to reduce by closed methods.

If the hip becomes progressively more painful some months or years after a dislocation, it is probably due to avascular necrosis of the femoral head and consequent osteoarthritis. You will see an increased bone density of the femoral head on a radiograph. This may be visible at 6wks but usually much later. Try to arrange an arthroplasty.

REDUCE DISLOCATED HIPS IMMEDIATELY

66.4 Anterior hip dislocation

In this rare injury the patient falls from a height and displaces the head of the femur in front of the acetabulum. Typically the hip lies flexed, abducted & externally rotated.

STIMSON'S REDUCTION (GRADE 1.5)
Intubate the patient and lie him prone. Strap the pelvis to the table with a broad belt across the anterior superior iliac spines (66.3).

Hold the leg and bend the hip and the knee to 90°. Get an assistant to hold the foot. If the weight of the patient's own leg does not achieve reduction, gently insert your heel into the patient's popliteal fossa, and exert downward pressure. You may need some internal rotation at the hip by turning the foot to achieve reduction.

POST-OPERATIVE CARE
Keep the patient in bed until he has regained control of the hip. Then allow him up and let him bear weight. Monitor for avascular necrosis of the femoral head, as with a posterior dislocation.

66.5. Acetabular fracture

The outlook for a patient with an acetabular fracture depends mostly on whether or not the femoral head has destroyed the upper part of the acetabulum. This is the part which bears the weight, and if enough of it remains unbroken, the outlook is good. Otherwise severe degenerative arthritis is likely to follow.

Posterior rim acetabular fracture is one of the results of a car accident in which the patient's knee hits the dashboard. The head of the femur is driven backwards, and breaks off a piece of the rim of the acetabulum. At the same time, the hip may dislocate posteriorly, and the sciatic nerve may be injured. Provided the hip has not been dislocated, the attitude of the leg is normal, and there is no shortening. These fractures are often missed and their late effects are underestimated.

Acetabular floor fracture is the result of the patient falling from a height onto the greater trochanter and forcing the femoral head against the acetabular floor. Or, it may occur through direct injury in a car crash.

The head may remain in its socket (66-5A), or it may dislocate centrally through the broken floor of the acetabulum into the pelvis, so that he has a central dislocation of the hip (66-5B).

Movement of the leg or lifting the foot off the bed is impossible. If the foot is in its normal position, it shows that the hip is in its normal attitude. Unless displacement is gross, the leg is not shortened. Although the radiograph is characteristic, fractures of an acetabular floor are often overlooked. Traction combined with gentle movements gives surprisingly good results. *Don't treat in a Thomas splint.*

ACETABULAR FLOOR FRACTURE

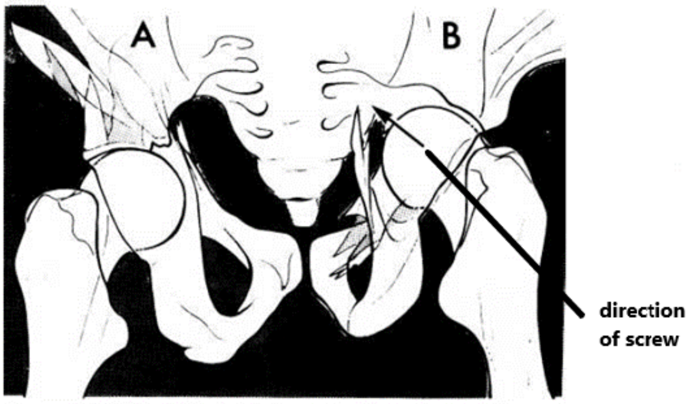


Fig. 66-5 ACETABULAR FLOOR FRACTURE. A, the femoral head is in its normal place. B, it is dislocated it centrally into the pelvis (B). Place the fixation screw in the direction shown.

POSTERIOR RIM FRACTURE
Check if this is associated with an unstable hip dislocation (66.3). If not, and the hip is stable, maintain bedrest for 1wk, and then allow partial weight bearing.

If the femoral head will not stay in the acetabulum, try to refer immediately to have the posterior lip of the acetabulum screwed back. The longer you delay the more difficult this will become. If you cannot refer, introduce '90-90 traction' for 6wks (67-3).

If a fragment of bone is trapped inside the joint, it must be removed at open operation, so try to refer for this.

ACETABULAR FLOOR FRACTURE WITHOUT CENTRAL DISLOCATION
Encourage active hip movement and then allow partial weight bearing on crutches as soon as pain allows.

ACETABULAR FLOOR FRACTURE WITH CENTRAL DISLOCATION (GRADE 3.4)
This is a severe injury and the patient is likely to need a blood transfusion. Under GA correct lateral rotation of the leg, by bringing the patella to face anteriorly. Flex the hip a little and feel for the greater trochanter. Insert a Schanz screw (or any strong long threaded pin) through the femoral neck into the femoral head under fluoroscopy if possible. Otherwise, make a small lateral incision well distal of the greater trochanter. Insert the screw in the anterior portion of the femur owing to the shape of the trochanter)

CAUTION! Don't put the pin too far medially or you may injure the sciatic nerve!

Insert another pin in the upper tibia, and apply 7-10kg longitudinal traction. Put a stirrup on the vertical pin and apply 15kg for 15mins. If this pulls the femoral head out, it will usually stay out. Then, remove the vertical pin and continue skeletal traction in extension with 5-10Kg applied to the tibial pin (67-3).

N.B. You might need to flex & abduct the thigh forcibly, or adduct it using your foot as a fulcrum.

Get radiographs to check reduction. Exert countertraction by raising the foot of the bed 25cm. This will make the patient more comfortable, but will not, by itself, reduce the dislocation.

Put a sling under the thigh and pass the cord from this over a pulley allow exercise of the hip. Maintain traction for at least 6wks. Encourage exercise as much as possible. Then allow gradually increasing weight bearing
with crutches (66-1A).
Remove the crutches as soon as standing normally is possible on the injured leg.

If reduction is still unsatisfactory, try to refer him for open reduction.

66.6 Femoral neck fracture

These are difficult fractures. The nearer they are to the femoral head, the less likely they are to unite (except in the case of a stable impacted valgus fracture), and the more likely the head is to undergo avascular necrosis.

The blood supply of the head of the femur is precarious, little callus is formed, and early rigid internal fixation provides the only hope of union.

Surprisingly, these fractures are often missed. For the purposes of management in a district hospital, there are 3 kinds:
(1) An incomplete unstable fracture (66-6A)
(2) A complete, unstable fracture (66-6B).
(3) A stable impacted valgus fracture (66-6C).

UNSTABLE FEMORAL NECK FRACTURE
Most fractures of the femoral neck are unstable and complete. The patient is either a young adult who has sustained a severe injury, or an old person who has fallen and injured the hip.
Standing or lifting the foot off the bed, or moving the hip gives great pain. The leg is externally rotated so that the foot points laterally, and the leg is shortened c.1cm.

3 TYPES OF FEMORAL NECK FRACTURES

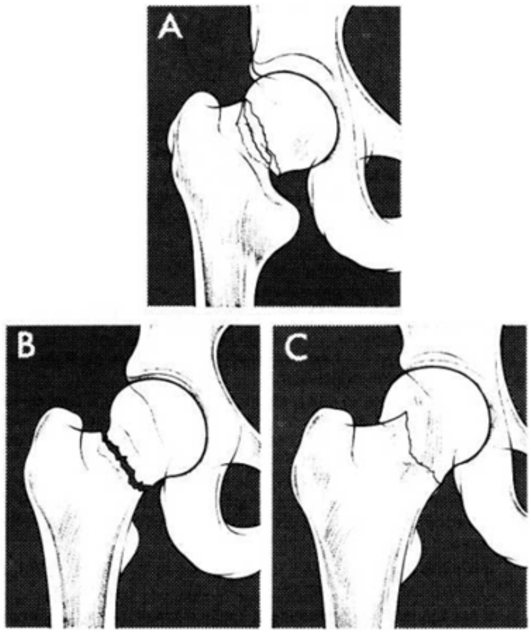


Fig. 66-6 TYPES OF FEMORAL NECK. A, the rare incomplete unstable fracture. Note that the fracture line has not gone completely through the neck. B, the common complete unstable fracture (66-2D). C, the uncommon impacted valgus fracture (66-2E). *Kindly contributed by John Stewart.*

There is less shortening than with intertrochanteric fractures. Sometimes, the injury may seem to be trivial. Occasionally, there is pain in the knee, rather than in the hip, so *any patient who cannot walk after a fall must have the hip X-rayed*, with the leg held in maximal internal rotation in order to get the best view of the femoral neck of the femur. External rotation makes the neck look foreshortened.

N.B. If you allow walking, you can easily convert an incomplete fracture into a complete one.

Try to refer all patients with incomplete fractures for internal fixation or for the fitting of a prosthesis. Transport him with the legs bandaged gently together with cotton wool between them.

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If referral is an impossibility, mobilize the patient as best you can. A false joint will develop, and the final result will resemble that after a Girdlestone's operation (7.19), except that it may be somewhat less satisfactory. There will probably be a limp and permanent need for crutches, or at the very least a walking stick, but the patient may do surprisingly well.

There is no indication for excising the head of the femur immediately, and traction is useless.
N.B. Don't use a hip spica in an old person; because immobility will certainly lead slowly but surely to fatal complications.

If there is an incomplete unstable fracture, it may become complete at any moment. As there is no way of testing for clinical union, apply Perkins traction or extension traction for at least 12wks, but without the vigorous exercises necessary for fractures of the femoral shaft.

STABLE IMPACTED VALGUS FEMORAL NECK FRACTURE

The fracture line runs across the proximal part of the femoral neck and the fragments are firmly impacted, with the head in valgus. This makes the fracture stable and is a useful point in recognizing this particular fracture.

The patient is usually an old person. Walking may be possible after the accident, and with a little encouragement can lifting the leg off the bed. There is no rotational deformity and no shortening.

Because the fracture line is mainly horizontal, there is little shearing stress across it, and a good chance that the head will not disimpact. Bearing a little weight on it is beneficial because it maintains the impaction. It is a useful rule that if a patient can walk into the hospital, the fracture is probably stable. If he is lucky it will remain so.

If there is any doubt about the stability of the impaction and you can refer the patient immediately for internal fixation, do so.
There is no case for the application of a hip spica.
CAUTION! Don't apply traction, because it will disimpact the fracture and make it unstable.

If walking is possible, let this continue, with partial weight bearing and crutches. The head is at its softest and most liable to displacement 10-14 days after the fracture. Supervise walking carefully for the first 2-3wks before discharge. Warn that care is needed not to trip or stumble.

If walking is not possible, advise bedrest, while doing vigorous *quadriceps* exercises, until the pain has subsided enough to allow mobilizing on crutches, with partial weight bearing while you carefully supervise walking for 3-4wks. As pain diminishes, allow progressively more weight-bearing on the injured leg.

DIFFICULTIES WITH IMPACTED FEMORAL NECK FRACTURES

If a patient has been walking satisfactorily on an impacted valgus fracture, and the leg suddenly becomes painful, prohibiting weight bearing, the fragments have probably disimpacted. Try to refer for internal fixation.

DISPLACING THE FEMORAL SHAFT FOR AN INTER-TROCHANTERIC FRACTURE

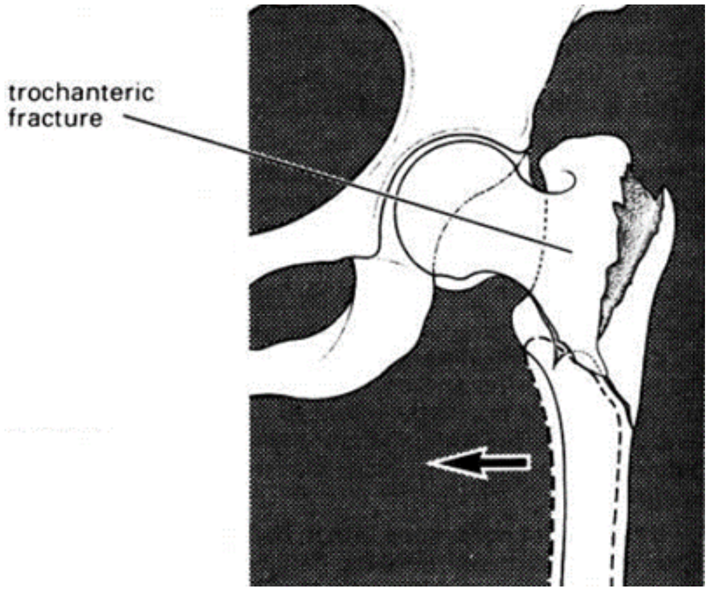


Fig. 66-7 DISPLACING THE FEMORAL SHAFT after a intertrochanteric fracture. By displacing the femoral shaft medially, it is better able to support the neck and head. *Kindly contributed by John Stewart.*

66.7 Inter-trochanteric femoral fracture

In these common fractures, the femur breaks between its 2 trochanters. The lesser trochanter sometimes separates as a 3rd fragment, or there may be multiple fragments. Muscular pull reduces the normal 145° *varus* angulation of the neck on the femoral shaft to 90°, and shortens the leg. Sometimes, there may be little displacement when viewed anteriorly, but considerable in a lateral view.

Although the patient is commonly an elderly person who trips and falls, a more severe injury can cause this fracture in a young person.

Typically, the elderly person cannot walk after a fall. She lies in bed unable to lift her leg, with her foot turned outwards, and her leg as much as 3cm shortened. The outer side of the thigh is painful, and moving the hip produces great pain. After a few days, bleeding from the fracture site spreads to cause a bruise in the posterior thigh.

Although internal fixation greatly shortens the time in bed and reduces morbidity, these fractures will usually unite with non-operative treatment. Use Perkins traction, because it allows the patient to sit up and exercise, and so reduces the incidence of pneumonia and bedsores.

The critical milestone (6-12wks) is the patient's ability to lift the leg off the bed. Most patients are partly weight bearing with two sticks or a walking frame by 12wks.

N.B. If a patient bears weight on the fractured femur too soon, it may angulate or refracture. This is much less likely to happen if you displace the lower fragment medially under the femoral head. This may occur spontaneously at the time of the injury, but if it does not, you can produce it.

If displacement is minimal, and the patient elderly, maintain bedrest for 3wks, then start partial weight bearing for another 2wks.

If the fracture is moderate but not comminuted, apply Perkins traction in abduction.

REDUCTION OF DISPLACED INTER-TROCHANTERIC FEMORAL FRACTURE (GRADE 2.1)

If the fracture is moderate and comminuted, (67-5B) displace the femoral shaft medially under the femoral head (66-6) and apply Perkins traction.

Under GA, lying the patient on the contralateral side, with an assistant abducting the leg a little, exert some traction. Put both your hands on the thigh just below the fracture site. With one good push using your full weight, move the lower fragment medially. You cannot push it too far or too hard!

Apply Perkins traction (67.4)

If, after 12wks, radiographs show that the distal fragment remains medially displaced, partial weight bearing in crutches can start immediately.

If you could not maintain medial displacement, or if the fragments have displaced into a *varus* position, allow very little weight-bearing, using only the heel and toe of the injured leg.

The fracture will have consolidated after 5-6 months of partial weight bearing. This is difficult to evaluate clinically, so check with a radiograph.

66.8 Girdlestone operation for ununited femoral neck

If an arthrodesis or a prosthesis is impractical, you can remove the femoral head so a pseudarhrosis forms (the Girdlestone procedure), either as the definitive operation, or as a temporary one before a prosthesis is fitted. This is not an easy operation, and is for more experienced operators only. Refer the patient if you can. Other indications are for sepsis (7.19).

INDICATIONS

Painful walking as the result of:

(1) An ununited femoral neck fracture.

(2) Osteoarthritis with a femoral neck which is too osteoporotic to allow a prosthesis to be fitted.

(3) Avascular necrosis following the insertion of a pin or plate in sickle cell disease.

METHOD (GRADE 3.5)

Make a posterolateral incision (66-8A), extending it upwards almost to the iliac crest and downwards in a vertical incision through skin and *fascia lata* to the bone on the outer surface of the femur (66-8B).

Use a periosteal elevator to detach the gluteal muscles from the femur so as to reflect an inferomedial flap of these muscles (66-8C) and expose the *obturator internus*, the 2 *gemelli*, & the upper fibres of *quadratus*. Divide these c.1cm from their insertion into the femur, and swing them medially where they will protect the sciatic nerve (66-8D).

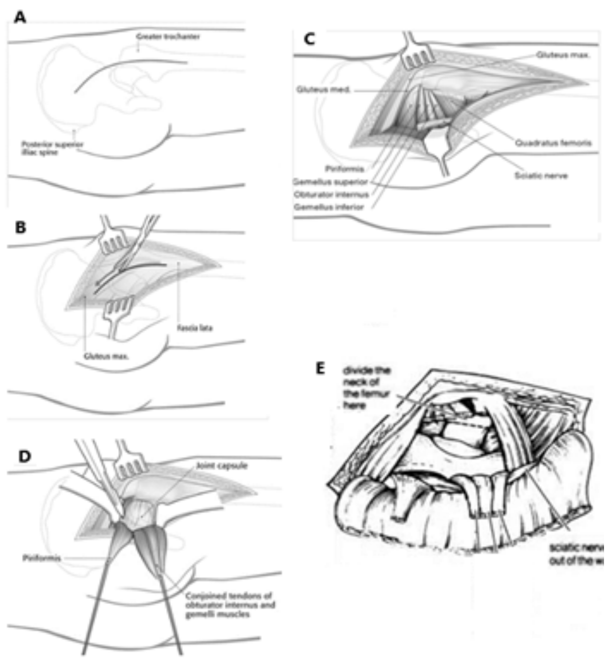
Approach the hip joint from behind. Open the capsule and check that it really is the hip joint by asking an assistant to move the patient's leg and seeing the head of the femur move too.

Dislocate the head of the femur from the acetabulum, by asking your assistant to adduct the leg and forcibly internally rotate it, while you divide the remaining fibres of the capsule and the *ligamentum teres*. If necessary, use a sharpened spoon to divide these.

Cut the neck of the femur flush with the shaft using an osteotome or Gigli saw (66-8E). Remove the head. If the neck is already fractured, trim it back with a rasp. Wash out the joint thoroughly to remove chips of bone.

Control bleeding. Close the wound without drainage, and apply skin traction as above.

If you have difficulty removing the head of the femur, try to get a Gigli saw under the neck of the femur. You may need help to do this. You can use an osteotome to insert the retractors, and remove the head and neck of the femur piece by piece. The lower border of its neck will be the hardest piece to cut.



GIRDLESTONE OPERATION

Fig. 66-8 GIRDLESTONE OPERATION FOR NON-INFECTIVE CONDITIONS. A, a long curved incision. B, divide the *fascia lata*. C, reflect the gluteal muscles. D, reflect *pyriformis, obturator internus,* & the *gemelli* to hide the sciatic nerve out of the way. E open the capsule of the hip joint & divide the femoral neck.
Kindly contributed by Peter Bewes.

67 Femoral shaft injury

67.1 Introduction

It takes considerable force to fracture an adult femur, unless it is affected by infection, osteoporosis or tumour. Therefore, you should look for other injuries, particularly of the pelvis & hip (66.2), as well: palpate the buttocks & the trochanters.

A broken femur is severely painful, and bleeds considerably: count on a loss of >1L. The thigh becomes swollen and may be obviously deformed; there may be an open injury (either from soft tissue wounds, or the bone penetrating the skin). A gunshot wound can obviously easily shatter the bone, and disrupt the soft tissues. Walking is obviously impossible.

In a fall, with the foot anchored, a twisting force may produce a spiral fracture; a direct force may produce a transverse fracture (particularly common in motorcycle injuries).

The leg is often rotated externally (especially in proximal fractures) & may be shortened & deformed. The fracture may be in any part of the femur, though the middle $^{1}/_{3}$ is the most common site. There may be a separate triangular ("butterfly") fragment on one side. If there are 2 transverse fractures, the central portion of the femur may become ischaemic.

Follow the ABC routine for major injuries (41.1); you often need to transfuse blood, particularly if the fracture is comminuted. Careful splinting of the leg, for example with a Thomas splint, will minimize blood loss.

Always check the peripheral pulses, and distal sensation.

Take AP and lateral radiographs of the thigh, and of the pelvis & hip.

67.2 Shortening, distraction & rotation in femoral fracture

When the femur fractures, the fragments sometimes overlap, so that the leg becomes shorter. The importance of this depends on the age of the patient, and the degree of shortening.

An adult may have a difference in leg length up to 1.5cm without noticing it. He compensates for a leg ≤4cm shorter by tilting the pelvis. So, if there is already a shortening of 2cm, after a femoral fracture, there may be a leg length discrepancy of 3.5-4 cm. Differences in length >2cm may lead to prolonged back pain.

For a difference ≤1cm, put an inlay-sole in the shoe. For larger discrepancies, especially **if the leg is ≥4cm short or if the patient is symptomatic**, make the adjustment in the shoe sole itself. *Always raise the whole shoe, and not just the heel* to avoid *equinus* in the raised foot.

Distraction is much more serious than shortening, and although a fractured femur may unite even if the ends of the fragments do not touch, it will unite more quickly if they do. Sometimes, even 2mm of distraction between the bone ends will prevent union, *so make sure that nobody adds extra weights to the traction apparatus by mistake!*

N.B. Avoid rotational deformity at all costs, irrespective of the age of the patient. Traction usually corrects shortening, and avoids rotational deformity.

67.3 Perkins traction

Your aim in treating an adult femoral fracture should be to make the bone unite in a good position without the knee becoming stiff.

The indications for internal fixation are outlined already (58.6). Here we describe the classical conservative method, which still gives by far the best results in many complicated situations.

PERKINS TRACTION
Put a Steinmann pin through the upper end of the tibia, and apply enough traction to it to keep the fragments in place, to pull the leg to its normal length, and to correct any angulation or rotation.

Meanwhile, sit the patient up in bed, and start knee exercises as actively as possible, because controlled movement and compression of the bone ends encourages union.

Other advantages are:
(1) the knee does not become stiff,
(2) maintaining the tone of the *quadriceps* muscle,
(3) doing exercises means keeping fit,
(4) avoiding thrombosis and hypostatic pneumonia.

Perkins traction differs from extension traction where the leg is held straight; the patient does not sit up and exercise it.

Perkins traction uses the same simple equipment for all sizes of patient, it prevents knee stiffness more effectively than other methods, and it gives a patient a wide range of knee movement, which is important in societies where people squat. Excessive shortening is rare, and as soon as you can drop the end of the patient's bed, and the knee is being flexed, malrotation of the lower fragment is impossible.

Physiotherapy and nursing care are easy, and after a few days the patient can lift himself onto a bedpan. Most patients spend 6-8wks in traction, followed by 2wks, exercising their legs over the end of the bed, and then 2wks more on partial weight-bearing. They are out of hospital in 8-10wks with at least 90° of knee movement, and without noticing that the injured leg is 1-2cm shorter.

Also, importantly, if there is also a tibial fracture (70.1,2), you can treat whilst the femur is in traction.

INDICATIONS FOR PERKINS TRACTION

(a) In the pelvic region: vertical fractures of the pelvis with upward displacement of one fragment.

(b) In the hip region: undisplaced, incomplete fractures of the neck of the femur (67-1A), all intertrochanteric fractures (67-1B) and those subtrochanteric fractures in which the contraction of the iliopsoas has not flexed the upper fragment so much as to bring it seriously out of line with the shaft (67-1C)

(c)In the femoral shaft region: all adult femoral shaft fractures, including overlapped, double, spiral, comminuted and open fractures, and fractures with severe soft tissue injury (67-1D)

N.B. Perkins traction is particularly well suited to comminuted fractures.

(d) In the knee region: those supracondylar factures in which the lower fragment has not been too severely flexed by the contraction of gastrocnemius (67-1E) and all condylar fractures of the femur, except those in which a condyle has rotated completely (67-1F).

CONTRA-INDICATIONS TO PERKINS TRACTION

(a) In the hip region: All complete fractures of the femoral neck (67-1G), displacement of the proximal femoral epiphysis (67-1H), subtrochanteric fractures with severe flexion of the proximal fragment (67-1I)

(b) In the knee region: Supracondylar fractures with marked flexion of the distal fragment (67-1J), displacement of the distal femoral epiphysis (67-1K) and fractures of the condyles in which a fragment has rotated completely (67-1L)

(c) All children whose tibial epiphyses have not united: *the pin may damage the epiphyseal plate*.

(d) Arthritis or stiffness of the knee, which will make exercise impossible without moving the fragments excessively.

(e) Non-union treated by other methods.Perkins traction gives good results if you persist with it, and follow the details carefully. The secret of success is to start periods of 10-30mins active exercise several times a day from the 3rd day onwards. This early movement is critical. It is the callus formed during the 1st 10 days that determines the outcome. Most failures are due to not starting exercise early enough, or not doing it vigorously enough. Patients need to be coached into exercising their knees. If you have more than one such patient, let them do their exercises together, so that they can encourage one another. *Quadriceps* exercises by themselves *are not enough to achieve satisfactory union*.

Make sure all your team understand the principles of Perkins traction. Setting up and managing it are not difficult and medical assistants soon learn to manage it most competently.

EXERCISES IN THE 1st 10 DAYS ARE CRITICAL

There are several less satisfactory conservative alternatives to Perkins traction. They are:

(1) Böhler-Braun traction (70-10) takes longer to achieve union, and because it does not allow active knee exercises, the *quadriceps* atrophies, and the knee usually stiffens, unless it is carefully exercised daily. *Use Bohler-Braun traction only for extensively displaced supracondylar femur fractures*.

INDICATIONS & CONTRA-INDICATIONS TO PERKINS TRACTION

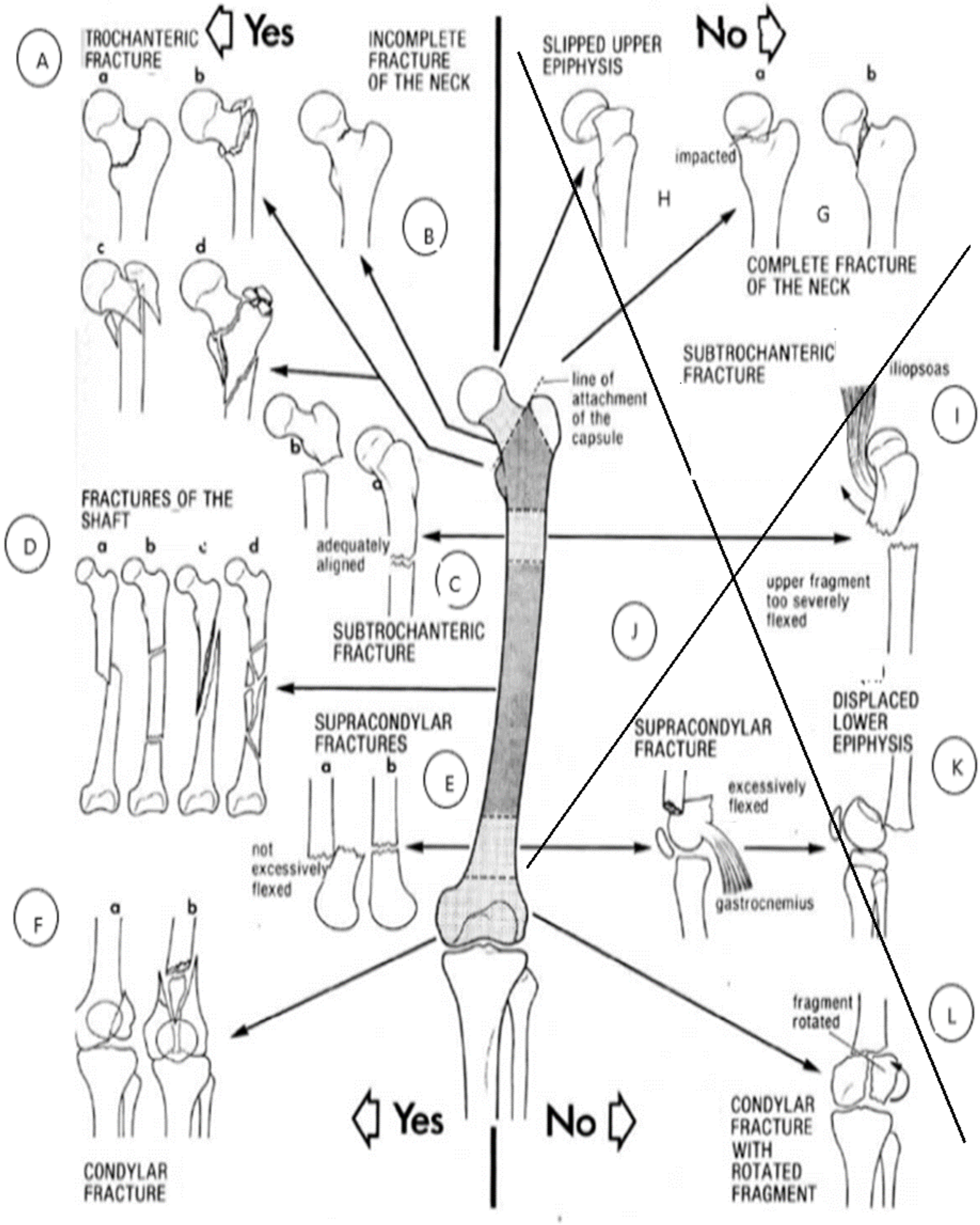


Fig. 67-1 Indications for Perkins traction: A, incomplete femoral neck fracture. B, inter-trochanteric fractures. C, subtrochanteric fractures. D, femoral shaft fractures. E, supracondylar fractures, not excessively flexed. F unrotated condylar fractures.
Contra-indications: G, complete femoral neck fractures H, slipped upper epiphysis. I, malaligned subtrochanteric fracture. J, flexed supracondylar fracture. K, displaced lower epiphysis. L, condylar fracture with a rotated fragment. *Kindly contributed by Peter Bewes & John Stewart*

(2) Thomas splints are excellent for first aid, and for treatment during the first few days, *but not for definitive treatment*. They too will stiffen the knee, and may cause pressure sores in the groin. They also make nursing more difficult.

(3) A hip spica results in prolonged disability and seriously stiffens an adult knee. It may also cause excessive shortening.
One disadvantage may be that Perkins traction lengthens a patient's stay in hospital, and increases the pressure on scarce beds.

CONVERTING A BED

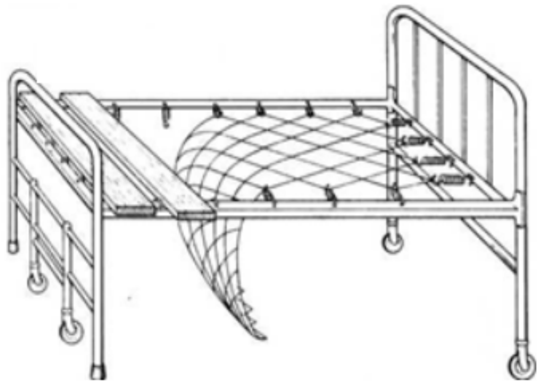


Fig. 67-2 CONVERTING AN ORDINARY BED for Perkins traction. *Kindly contributed by Peter Bewes.*

EQUIPMENT FOR PERKINS TRACTION
(1) An ordinary hospital bed from which the lower springs have been removed or tied back (67-2). You may have some broken beds you can use, and you may find it convenient to convert several beds for Perkins traction permanently. Ideally, these beds should have large castors so that you can wheel the bed to the X-ray department with traction *in situ*.
(2) Use a mattress in 2 parts, or let the lower $^1/_2$ hang down.
(3) Put fracture boards across the lower half of the bed.
(4) Blocks to raise the foot of the bed 25-50cm.
(5) A sharp, thick (4mm) Steinmann or Denham pin. Sharpen it on a grindstone regularly.
(6) Thomas pin mounts or a Bohler stirrup. *Don't use an unmodified Bohler stirrup*: it will rub on the skin, or the rope will get in the way of the skin, so convert it into 2 Thomas pin mounts by cutting and bending it (67-3C).
(7) Picture or orthopaedic traction cord.
(8) Weights of 2 & 5kg. These can be bags of sand, or bricks.
(9) A set of pulleys to fix to the foot of the bed. These are not essential, and the cords can, if necessary, pass directly over the rail at the end of the bed, preferably over a cylinder of old X-ray film rolled round the rail. If the lower rail is too low, consider reversing the bed, and using the rail at its head.

PERKINS TRACTION

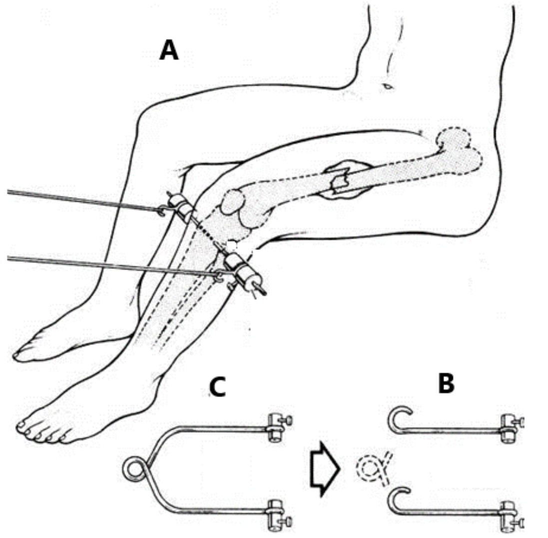


Fig. 67-3 Perkins traction. A, place a Steinmann pin perpendicular to the tibial shaft 3cm distal to the tibial tubercle. B, attach 2 Thomas pin mounts (better than C, Böhler stirrups, which you can cut in two if necessary)

INSERTING THE PIN Do this in the theatre, or in a treatment room off the ward, using LA (59-14,15).

INSERTING A TIBIAL PIN

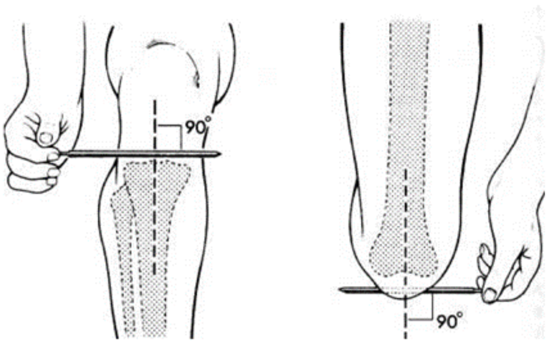


Fig. 67-4 INSERTING A TIBIAL PIN. Make sure the alignment is perpendicular (90^0) in both planes. *Kindly contributed by Peter Bewes.*

SETTING UP PERKINS TRACTION Apply weights to each end of the pin. Apply traction equal to $^1/_7$ the patient's weight. A man needs 10-14kg (5-7kg on each end of the nail) and a small woman perhaps only 7kg. Raise the foot of the bed 4cm/kg. You will find 25cm blocks useful. If possible, pass the cords over pulleys, and make sure they clear the toes.

CAUTION! The cords must pull equally on each end of the pin (59-14). Put a folded towel or small pillow under the fracture to give the femur the correct degree of anterior bow.

The movement of a pin in the bone promotes infection. So try to stop it moving, by using low friction swivels, and, if possible, a Denham pin which you can screw into the tibia, rather than a Steinmann pin. Another precaution is to *make sure that traction is applied equally and at right angles to the pin. Make sure the cords join through a pulley or a ring attached to the weight.*

Another way of preventing movement of the pin is to incorporate it in a below-knee cast. Watch carefully for pain, but only if the patient complains should you window the cast, and look at the skin round the pin. *Once a pin has become loose, a cast is useless.*

RADIOGRAPHS IN PERKINS TRACTION
The need for radiographs to adjust traction varies with the site of the fracture. *Don't remove the traction to get a picture!*

In a fracture of the proximal femoral $^1/_3$, get a lateral radiograph while in traction. Face the X-ray tube into the inner thigh, with the cassette above the crest of the ilium. If the proximal fragment is sharply flexed, '90-90 traction' (67-5) will be more appropriate than Perkins traction.

90-90 TRACTION

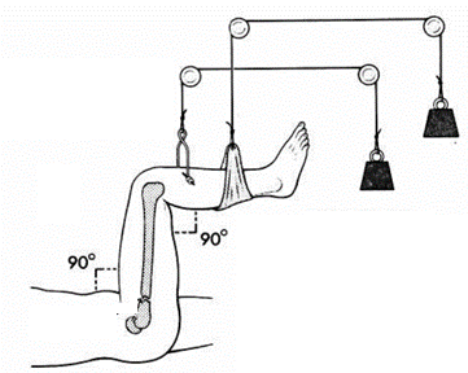


Fig. 67-5 90-90 TRACTION is ideal for subtrochanteric fractures.

In fractures of the distal $^1/_3$, including supracondylar fractures, get a radiograph to make sure the distal fragment is not excessively flexed. If it is, see 68-14.

If the fracture is elsewhere in the femur, a lateral radiograph is not essential, but an AP one is useful to see excessive overlap persists, or the fracture is too distracted (there is a gap between the bone ends).

If you cannot get any radiographs, measure both the legs from the anterior superior iliac spines to the medial malleoli, to make sure are the same length (66-3).

If necessary, adjust the traction weights and the elevation of the foot of the bed, to let the bony fragments overlap c.1cm. *A little overlap is safer than a little distraction.* Overlap ≤2cm is acceptable.
Check the leg length daily for 2wks, and adjust the traction as necessary.

N.B. After 2wks, the fragments will have started to stick together so that further adjustment will be more difficult, and need more weight. After a month it may be impossible.

If the fracture is comminuted, a little overlap is even more important.

CAUTION! (1) *Don't apply excessive traction*, because bone ends far apart cannot unite. This is particularly important if there are multiple fragments. (2) Less traction is needed after the 1st 2wks, so reduce it as necessary.

MAINTAINING PERKINS TRACTION

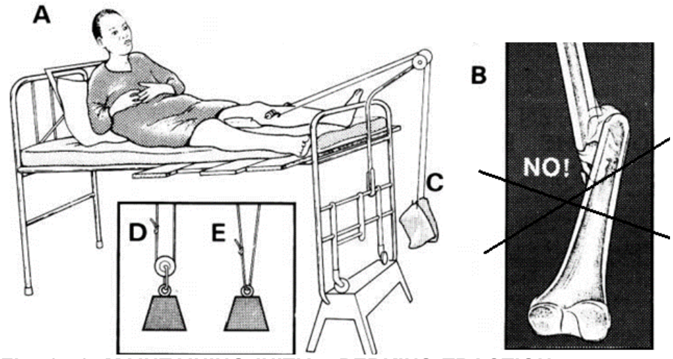


Fig. 67-6. MAINTAINING INITIAL PERKINS TRACTION. A,B,C, inadequate traction caused malunion: *entirely avoidable!* D, E types of weights & methods of hanging them. (You could also use water bottles filled to a specified volume) *Kindly contributed by Peter Bewes.*

EXERCISES
Start these as soon as possible, preferably by the 3rd day. Remove the fracture boards from the lower half of the bed, push down the mattress, and allow flexion of the knee. Replace the boards on completion of the exercises.

Encourage bending and straightening the knee. To begin with this will be painful. Minimize the pain by using a mild analgesic for the first few days, and hold the heel and allow flexion of the knee against resistance, then allow extension of the leg freely. Help is needed, but at the end of 1wk, unassisted flexion & extension should be possible. Give encouragement by explaining that the exercises will soon be painless.

To begin with allow exercises for 10-30mins at least three times a day. Encourage longer and more vigorous exercises of the leg each day, till ≥2h/day.

In fractures of the upper femoral $^{1}/_{3}$, a radiograph may be necessary to confirm adequate union. Elsewhere, they are not really necessary. Often, clinical union will seem well advanced, when there is only a mass of callus on the radiograph. Obtain images at 4, 6 & 12wks.

Follow a strict routine:
(1) Make sure your nurses understand that these regular periods of exercise are an important nursing routine.
(2) Check the leg length daily for 2weeks, and then weekly until union is complete. Reduce traction as necessary.
(3) Measure the legs soon after traction has been set up, and adjust it accordingly. Rotation will correct itself as soon as flexion of the knee reaches 90°.
(4) Check the knots daily.
(5) Each week, examine the fracture site for palpable callus, and look for the signs of union:
(a) No tenderness over the fracture.
(b) No fracture angulation possible.
(c) Full flexion possible without support.

CAUTION! (1) *Don't test for union by asking to lift the straightened leg from the hip*, because this will angulate the fracture site.
(2) Resist the temptation to apply a cast in order to secure an early discharge.

ENCOURAGING LEG EXERCISES

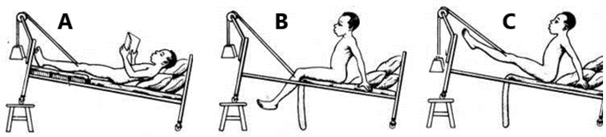


Fig. 67-7 ENCOURAGE LEG EXERCISES. This is the secret of successful Perkins traction. A, lying comfortably. B, flexing the knee when the lower part of the mattress is folded down. C, extending the leg using the weight to help. *Kindly contributed by Peter Bewes.*

Removing traction too early is worse than leaving it on too long. *Don't decide in advance, or fix a day to remove it*.
When there are definite signs of clinical union, usually at 6-10wks, remove the weights and continue exercises with the knees over the side of the bed, and the pin still in the tibia.
If you were right, and the femur has united, the range of movement will increase progressively.

If there is pain at the fracture site and the range of movement decreases, the femur is not yet adequately united. Put back the traction.

If pain or bowing of the femur occurs, keep traction longer, until the fracture is stable and the pain disappears.

If you are uncertain that union is satisfactory, continue traction, but with reduced weights.

If you are certain that union is far advanced, remove the pin, but keep the patient in bed for 2wks more and exercise the legs over the side of the bed. When flexion to 90° is possible, try to obtain further flexion in the prone position.

WEIGHT-BEARING AFTER PERKINS TRACTION
After 2wks of exercises without traction, examine the patient again. Get a radiograph without allowing weight-bearing (so use a wheelchair). If there is radiological union & the range of knee flexion is good, start protected weight-bearing with crutches (66-1).
Start by allowing the leg on the ground only to provide balance.

CAUTION! Help the patient out of bed carefully. If union is weak, the leg may re-fracture as soon as walking starts!

If there Is no radiographic callus at 4wks, suspect delayed union. Check to make sure that: (1) there is no distraction (if so, reduce the weights), (2) there are no fragments of avascular bone (if so, he will need to be in traction much longer), and (3) there is no interposed soft tissue. Fortunately, non-union is rare, provided you maintain the exercises!

When walking is safe on crutches, allow him home, but insist that exercises continue there. Most patients can be discharged with their fractures clinically united at 8wks. This period is shorter in younger and longer in older patients. Transverse and oblique fractures take longer than spiral.

When the time taken to achieve clinical union has doubled, the crutches can be discarded and full weight-bearing started. Any violent exercise (*e.g. football)* for the next 12months is not advisable. Alas, teenagers are particularly liable to re-fracture a femur.

DISTRACTION IS MORE SERIOUS THAN OVERLAP

Intramedullary nailing is the 'gold standard' for femoral shaft fractures, but 'gold standards' are for 'golden hospitals! There are strict criteria necessary to do any internal fixation, *e.g.* the possibility of using the SIGN nail system (58.6).

Your interventions should be quick, easy to perform and with as little physiological stress on your patient as possible. Traction or an external fixator should always be your preferred choice for these patients. In these settings the most important goals are: preservation of limb length and acceptable alignment of the fracture.

Rotational control, and an anatomical fracture reduction can be obtained later, after the acute presentation and should not be your main focus in the acute setting.

In case the fracture is open, your options depend on the type of fracture:
(I) Low energy injury, a wound <1cm, no contamination, a simple fracture and intact soft tissue coverage.
(II) Moderate energy injury, a wound <10cm which you can easily close, little contamination, a minimally comminuted fracture, and intact soft tissue coverage.
(III) High energy injury, a wound >10cm or deep, severe contamination and soft tissue loss.

For types I & II, *immediate* intramedullary nailing is an option, if the criteria of 58.6 pertain.

For type III, an external fixator is a better option in the acute setting, because of a high infection risk and the need of additional soft tissue intervention.

Within 2wks following the accident, you will need to decide whether you prefer to treat your patient with an external fixator to the end, or if you prefer to convert later on to a Perkins traction.
There is no simple answer to this question, and you should take multiple factors into consideration: the need for additional soft tissue intervention, how good your wound care is, the length of hospital stay, the amount of external fixator sets available in your hospital, the complexity of the fracture pattern, the presence of infection, and costs sustained.
In any case, you will need to decide which treatment type you will apply for the full treatment within the initial 2 weeks. During this period, you can still control rotation and limb length shortening by Perkins traction or by adapting your initial external fixator construction.

After 4wks, you can replace the Perkins traction by a hinged cast brace (67.4) if the fracture is adequately consolidated and if home conditions allow for adequately care.

67.4 Cast-bracing

Cast-bracing is useful after at least 4-6wks of Perkins traction. *Don't use it as an alternative to Perkins traction just to liberate a bed earlier in the ward*. You will then risk slowing down recovery, with a high risk of non-union, malunion and rotational deformities.

INDICATIONS
(1) fractures of the mid femoral shaft or distal femur,
(2) a control radiograph at 4-6wks shows a progressive bony callus,
(3) the patient understands that *weight-bearing on the affected leg is not allowed*,
(4) there is sufficient family support to take care of the patient at home
(5) the patient agrees to continue *quadriceps* and knee mobilization exercises at home, as when under Perkins traction

CAUTION! The total duration of treatment is not shortened by cast-bracing. Treatment and non-weight bearing should still be 8-12wks.
A cast-brace consists of two cast cylinders, one for the tibia and one for the femur, connected by 2 hinges. These should be solid enough to be used for this purpose, and should be easily available from any local hardware store. They are re-usable, and can be used for >1 patient.

KNEE BRACE IN EXTENSION

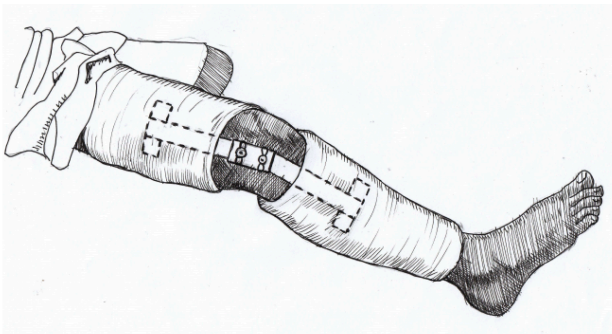


Fig. 67-8 KNEE BRACE IN EXTENSION

Before discharge, teach the patient how to walk with crutches. If he has never done this before, it can take a day or two before he feels confident enough to leave the hospital. Teach him step by step, and support him throughout the process, to avoid him bearing weight accidentally on the affected leg.

Review him weekly or 2-weekly until full consolidation of the fracture. Take radiographs at the same intervals as for the regime with Perkins traction.

KNEE BRACE IN FLEXION

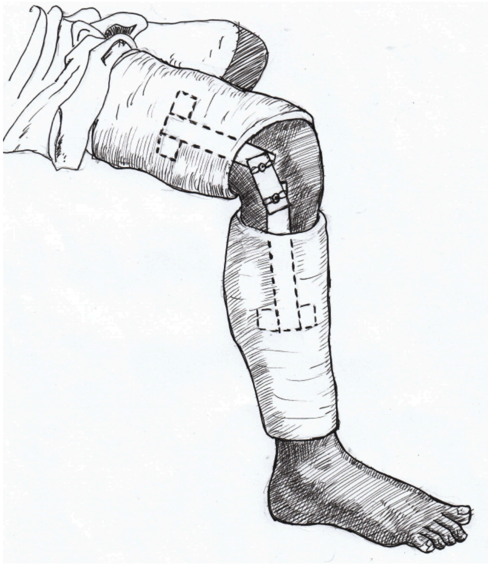


Fig. 67-9: KNEE BRACE IN FLEXION, showing hinges

ADVANTAGES
(1) earlier discharge from hospital and freeing up a bed,
(2) earlier return home
(3) psychologically beneficial

DISADVANTAGES
(1) risk of inadequate care at home,
(2) risk of too early weight-bearing
(3) follow-up consultations may be a logistical burden

67.5 Stabilization with external fixation

Read the general indications and contra-indications for external fixation (59.5). The only real indication in femoral injuries is in the open fracture. *Don't use it as a definitive treatment for closed femoral fractures*.

PLACING AN EXTERNAL FIXATOR FOR A FEMORAL FRACTURE (GRADE 3.2)

You will need all the basic external fixator equipment (59.5), a mobile Xray C-arm, and GA. You do not need a traction table or a Steinmann pin. Manual traction by an assistant should be sufficient.
Place the patient supine, disinfect the whole leg, and drape it. Mark sites for the pins, which should be as close as possible to the fracture site, without being in the fracture itself.
Decide at which angle you will place your pins, make a stab incision through the skin and dissect the muscles carefully until you reach the femur.

Put in the pins under direct vision using the C-arm. Reduce the fracture and attach bars to the pin, using a simple frame, if possible, or with 2 parallel bars
.
SAFE ZONES FOR PIN INSERTION
Always aim to insert the pins on the anterior or anterolateral side of the femur. Where exactly you place the pin, and where the safe zones are, may differ slightly.

(a) In the proximal $^{1}/_{3}$ of the femur, use an anterolateral approach and aim the pin towards the greater trochanter. This way you avoid both femoral nerve and the femoral artery anteriorly, as well as the sciatic nerve posteriorly.

SAFE ZONE FOR PROXIMAL FEMUR PINS

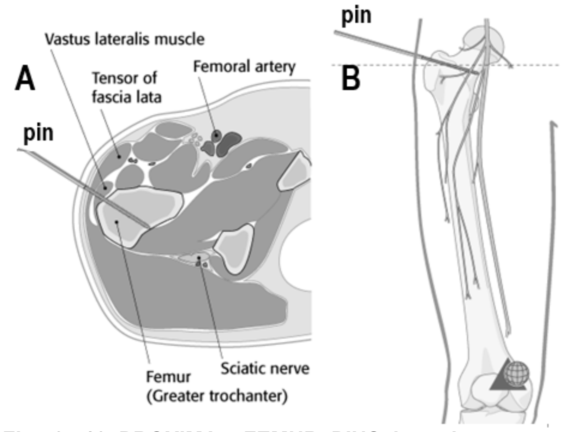


Fig. 67-10 PROXIMAL FEMUR PINS into the greater trochanter.

EXTERNAL FEMUR FIXATION

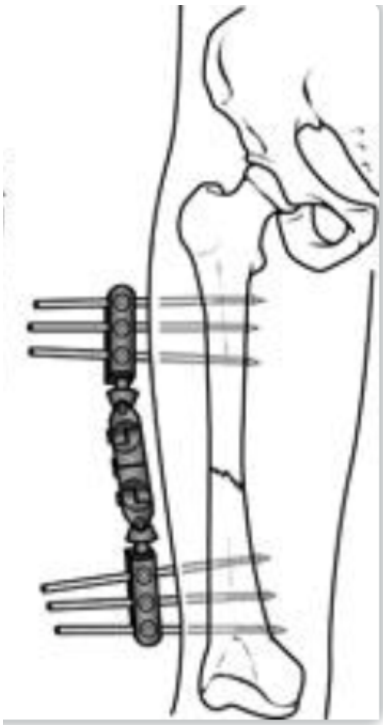


Fig. 67-11 EXTERNAL FIXATION OF THE FEMUR

(b) In the femoral mid-shaft, use an anterolateral approach at an angle of c.45°. This way the pin enters the thigh between the *vastus lateralis* and the *rectus femoris* muscles, where they will give less friction and less pain to the patient.

SAFE ZONES FOR MID-SHAFT FEMUR PINS

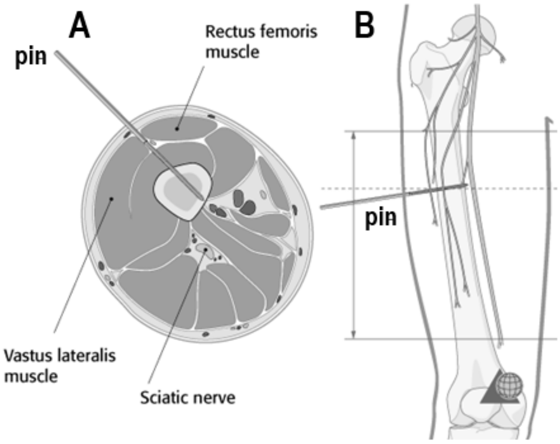


Fig. 67-12 MID-SHAFT FEMUR PINS between the *rectus femoris* & *vastus lateralis* muscles.

In the distal 1/3 of the femur, there are less soft tissue structures to worry about. Use a lateral approach at an angle of c.30°, avoiding most of the *vastus lateralis* muscle. *Here a frame is too posterior & interferes with the bed mattress.*

SAFE ZONE FOR DISTAL FEMUR PINS

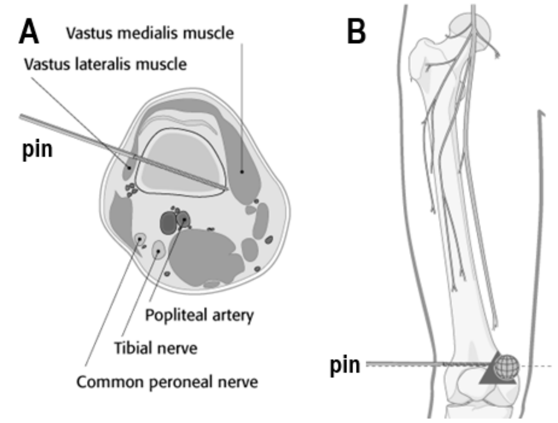


Fig. 67-13 DISTAL FEMUR PINS. Use a lateral approach.

67.6 Difficulties with femoral fractures

DIFFICULTIES WITH A FRACTURED FEMUR

If there is an open fracture, treat as for any other open fracture (58.13). Perform a rigorous wound toilet, and get the fragments into the best position you can. Unless a fragment is completely loose, leave it in place.

Provided the periosteum remains, the bone will reform. Keep the leg in traction to approximately its normal length. *Don't close the wound for 3-5days.* Either close if by delayed primary closure, or by delayed skin grafting. Then start exercises.

If the leg is pulseless and cold, the femoral fragments have probably injured the femoral artery. Apply traction which may dislodge the fragments or reduce swelling and allow the circulation to return. If after 3h, this doesn't occur, explore the artery and, if necessary, repair it (49.4f). If you don't, you may have to amputate the leg later.

If the bone ends are >1cm apart, see if this is end-to-end, or side-by-side. The former may fail to unite. If you are using traction, reduce the weights. There may be soft tissue between the bone ends preventing reduction, then try manipulation.

Fragments separated side-by-side by <1cm is still acceptable. Early active movements may promote callus formation across a gap of 2cm, but if there is >1 cm, manipulate the fragments under anaesthesia until you can feel them grating.

If the site in the tibia where the traction pin is normally inserted is injured or infected, insert the pin more distally, or through the distal femur, as in 90-90 traction' (68-14).

If a pin becomes loose and its track infected, you may have inserted it in an unsterile manner, or allowed the drill to get too hot, so that it has killed the bone around it and formed a ring sequestrum. Infection is usually not serious if you diagnose it early and don't neglect it. But it can be a catastrophe, because osteomyelitis may result and infect the knee. This is more common in older patients with soft bones, because the pin pulls through the bone.

Prevent this disaster by inspecting the pin track daily, and removing the pin if there is pain or any sign of redness or loosening. Either put the pin in again lower down, through healthy skin, or apply skin traction, or traction on a Böhler-Braun frame with the pin through the lower end of the tibia, or the calcaneus (70.11).

If the whole of the proximal end of the lower leg becomes inflamed, *don't reintroduce the pin.* Don't put it in higher up, because you will infect the knee joint.

If an infected pin track heals over but the bone remains tender, open up the track and curette it.

If a pin track is infected >1 month, get a radiogram of the tibia and look for a ring sequestrum round the track of the pin, which needs excision.

CAUTION! Remove a pin immediately it becomes loose.

If a pin track infection has already infected the knee joint, immediately incise & drain the knee through incisions on either side of the patella. Irrigate the joint, administer antibiotics and splint the knee in a windowed plaster cylinder until the infection has settled.

If you don't have a Steinmann or Denham pin, use sterilized bicycle spokes.

If there is a femoral & tibial shaft fracture in the same leg, under GA, put in the Denham pin, and then reduce the tibial fracture. Apply a below-knee cast to maintain this reduction & incorporate the nail in the cast. Leave enough space behind the knee for it to flex, then treat the fractured femur. Two fractures will divide the leg into 3 sections, so make sure they are all correctly aligned (73-24D). The femur will probably unite before the tibia, so you can then use a patellar weight-bearing short leg walking cast (69.5) on discharge.

If the fractured tibia needs calcaneal traction to reduce it, apply this for a few days first, then insert a Steinmann pin and use Perkins traction.

If, after 16wks in traction, there is malunion, this may be due to: (1) Distraction of the bone ends, caused by too much traction. (2) Interposed soft tissue. (3) Exercises that were inadequate or started too late, or quadriceps exercises that you hoped would be enough. Consider referring him.

If the femur fractures again at the same site, apply Perkins traction again; it will re-unite rapidly. *Don't try internal fixation.* Refracture is rare and usually follows a fall, particularly in a patient who is allowed up too early, or in a youth who plays football too soon.

If the knee becomes painful some years after a femoral fracture, check for angulation of the femur, which disturbs the normal knee mechanics. This requires an osteotomy.

If the knee becomes very stiff, after a supracondylar femoral fracture which is solidly united, stiffness may be due to adhesions around the knee joint. Firm, *gentle* manipulation under GA may restore movement. This may otherwise require restoration of *quadriceps* function.

If, a year after a femoral fracture, there is severe bowing of the femur, there has been premature movement at the fracture site before consolidation. This needs an osteotomy.

If, during the first 2-3days after a femoral fracture, the patient becomes disorientated, drowsy or comatose, suspect a FAT EMBOLISM (44.5), resulting from globules of fat escaping from the injured bone marrow and entering the circulation. Look for petechiae over the chest, in the mouth and in the conjunctivae. Fat in the urine confirms the diagnosis.

If, c. 7-10days after a femoral fracture, the patient complains of dyspnoea, chest pain or haemoptysis, suspect a PULMONARY EMBOLISM (44.7).

68 Knee injury

68.1 introduction

Severe knee injuries may tear the menisci, the collateral or cruciate ligaments, or break the bones that form the joint. As with the ankle, ligamentous injuries are often missed and cause prolonged disability. Occasionally, the patella or even the whole knee may dislocate.

A severe injury makes the knee swell so much that you cannot tell where the fractures are except with a radiograph.

Fortunately, there are adequate closed methods for most knee fractures, and for most soft tissue injuries. *Don't try to operate inside the knee*.

HISTORY

This is vital. If there was a direct injury to the knee, the history is straightforward. If, however, nothing touched it, but instead, the foot locked on the ground and the knee twisted inwards in flexion, and is now acutely painful, ask these questions:

How soon did the knee swell? If it swelled immediately, it is probably full of blood as the result of the rupture of a larger vessel. If it swelled more slowly over 6-8h, a smaller vessel has ruptured, or there is a sympathetic effusion.

If engaged in vigorous activity, such as playing football, is continuing playing feasible?

If the patient: (1) felt a snap or a pop, or (2) has had previous episodes, or (3) has locking and pain on weight bearing, there is probably an injured meniscus.

Where is the pain?

EXAMINATION: LOOK, FEEL & MOVE

Sit the patient on a couch with the knees over its edge, and remove trousers and shoes. Look at and feel the muscles of the thighs. Look for atrophy, and compare both sides. If necessary, compare their circumferences with a tape measure. Extend the leg, and examine the knee for fluid (68.3).

With the knee extended, hold the leg with one hand just above the injured knee, and the other just above the ankle.

With the knee just short of full extension, move the lower leg from side to side. If either collateral ligament is grossly torn, the tibia will wobble on the femur. There is very little movement in a normal knee. Repeat this test in 30° flexion, and always compare with the other knee. *Mobility with varus and valgus stress should be symmetrical if there is no lesion present.*

With the knee flexed in 90°, use both your thumbs to palpate the medial and lateral joint lines. Feel for tenderness anteriorly (anterior meniscus injury), in the mid-joint line (ligament or meniscus injury), and posteriorly (posterior meniscus injury, and for lesions of the hamstring tendons). Feel for the origins and insertions of the medial and lateral collateral ligaments above and below the joint lines.

Now lie the patient flat. Flex and extend the knee fully. The injured knee should extend and flex as much as the normal knee, with the foot touching or nearly touching the buttocks. In a normally built person, you should be able to achieve 140° flexion, and 0° extension with sometimes a physiological hyperextension up to 5° or 10°. Physiological hyperextension is more present in women and should be symmetrical.

Flex the thigh and the knee. Grasp the ankle and rotate it internally and externally, while holding the knee with your other hand (the McMurray test), to see if any meniscal tears are present. Finally, lie the patient prone, with the knee extended, and feel the back of the popliteal fossa. A large effusion of the knee,or a Baker's cyst, may be visible here, because of the capsule bulging out posteriorly.

CAUTION! In any severe knee injury, always examine the hip.

SPECIAL METHODS FOR AN INJURED KNEE

Use appropriate special tests for the following lesions: effusions (68.3), injuries of the patient's collateral ligaments (68.5), tears of the cruciate ligaments (68.6), injuries of the menisci (68.7), and injuries of the quadriceps mechanism (68.11).

RADIOGRAPHS: Take AP and lateral views.

NERVES AND PULSES
Remember to examine the common peroneal nerve (59.1), and the dorsalis pedis and posterior tibial pulses. *This is especially important with tibial condyle fractures*.

DIFFICULTIES WITH AN INJURED KNEE

If there is *varus* or *valgus* instability with the knee fully extended, there is probably a tear in the collateral ligaments, the posterior capsule of the knee, or perhaps the posterior cruciate ligament.

68.2 Plaster knee cylinder

This is the standard treatment for a soft tissue knee injury, and for some fractures. It will protect the injured knee until pain and swelling subside, and may allow walking. *If you are not careful*, it will slip down the leg and press on the Achilles tendon, or on the dorsum of the foot. You can prevent this happening by putting a 3-4cm band of soft foam plastic around the ankle which you incorporate in the lower end of the cast. This way, if the cast slips, the foam plastic will prevent the cast from hurting or creating lesions on the foot or ankle.

Apply the plaster cylinder usually with the knee in 10°, or occasionally in 30 ° or 60° of flexion. Even if you have applied it correctly, the knee is sure to be stiff and extension will be limited when you remove it, so warn about this, and show how to do extension exercises, especially cycling.

INDICATIONS
(1) Soft tissue injuries of the knee.
(2) Postoperative immobilization.
(3) Patellar fractures.

METHOD
Put a 3-4 cm band of plastic foam around the ankle, and attach both ends with a piece of tape. Make sure that it is loose & does not compress any neurovascular structures. Apply a cast from the groin to c.3cm above the malleoli with the knee in 10° of flexion. Mould the lower end of the cast on to the plastic foam band so that it becomes partially incorporated.
Start quadriceps exercises as soon as the cast is dry.

CAUTION! Never apply a plaster cylinder in full extension: the knee will be very painful and osteoarthritis may ensue.

68.3 Knee effusion

A fracture involving the knee surface rapidly fills its cavity with blood which remains liquid for a few days. Aspirating the tensely swollen knee will greatly relieve pain and make moving it much easier. Aspiration is also useful in diagnosing less obvious effusions, and especially in distinguishing between infection (7.18) and haemorrhage. *Careless aspiration can infect a sterile effusion*, so take the strictest aseptic precautions.

ASPIRATE ALL MAJOR KNEE EFFUSIONS

TESTING FOR AN EFFUSION
The first sign is the obliteration of the natural hollow on either side of the patella. Press the fluid from one of these hollows into other parts of the knee, and then, in a good light, slowly watch the empty hollow refill.

Can you 'ballot' the patella (press it down & see it bob up again)? Grasp the thigh between your fingers and thumb just above the knee. Press the effusion distally towards the patella, so as to drive fluid from the suprapatellar pouch down into the knee. Press the patella sharply. If some fluid is present, you can feel the patella tapping on the femur. This sign is absent if there is very little fluid present, or so much that the patella cannot reach the femur. Compare the injured knee with the normal side. If the knee is hugely distended and fixed in flexion, aspirate the effusion, and then re-examine it.

A KNEE EFFUSION

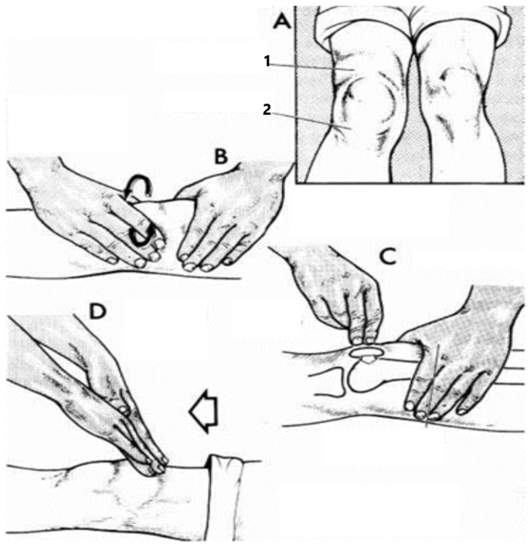


Fig. 68-1 KNEE EFFUSION. A, the 1st sign is obliteration of the peripatellar hollow with swelling in the supra- (1) and infra-patellar (2) pouches. B, shift the fluid from one side of the patella to the other. C, push the fluid in the suprapatellar pouch into the knee & then tap the patella to see if it 'floats'. D, distinguish fluid from a thickened synovium.

KNEE ASPIRATION (GRADE 2.2)

CAUTION! Never aspirate a knee in a minor theatre used for septic cases. This is a procedure for the main theatre, or a clean treatment room with full aseptic precautions. **If you do not have a sterile environment available**, limit aspiration to very acute emergencies, *i.e.* high suspicion of septic arthritis.

There are many techniques to aspirate fluid from a knee. We describe 2 techniques here, one for a knee in extension, the other in flexion. When properly performed, both techniques achieve a 95% success rate to aspirate fluid.

(a) Knee extended
Put both legs in full extension. Get as much relaxation as possible, specifically of the *quadriceps*, so that the patella becomes mobile. *Make sure that the patella is parallel to the table.* **If the leg continues to rotate externally when relaxed**, hold the leg with one hand in the correct position.

Palpate the upper border of the patella, and follow this imaginary line towards the lateral side of the knee. By doing this, you will fall automatically into a 'soft spot'. Introduce your needle in this space parallel with the patella or under a 45° angle (68-2).

KNEE ASPIRATION IN EXTENSION

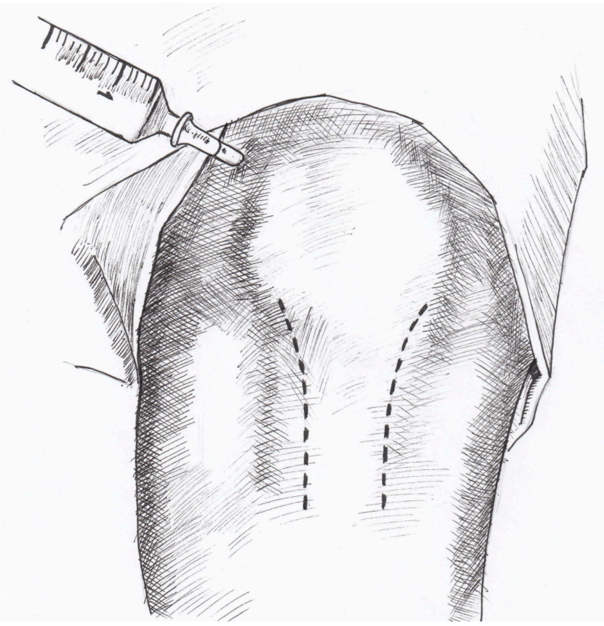


Fig. 68-2 ASPIRATION IN EXTENSION. Find the 'soft spot' at the upper patellar border moving a little laterally round it. Introduce the needle *under strict aseptic conditions* here.

(b) Knee flexed
Let the patient sit slightly above your level, *e.g.* on the side of a table with both legs in 90° flexion. Sit on a chair in front. Fix the knee you wish to aspirate to 90°. Palpate the patellar tendon and the lower border of the patella. If you move down your finger the lateral border of patellar tendon you will find a "soft spot" right between the lower border of the patella and the tibial plateau. Insert your needle here under a 45° angle (68-3).

KNEE ASPIRATION IN FLEXION

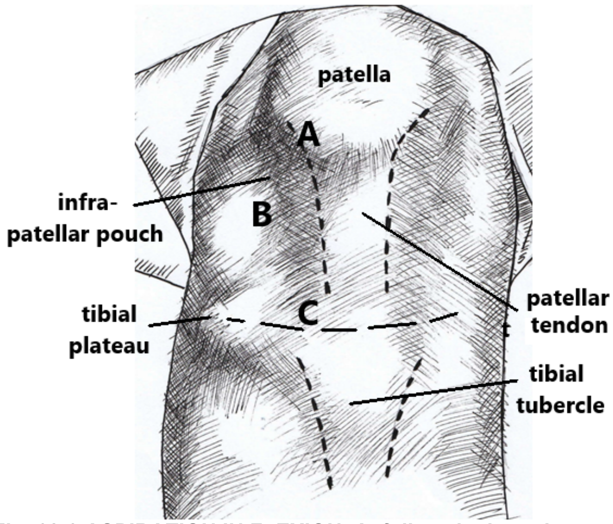


Fig. 68-3 ASPIRATION IN FLEXION. A, follow the lateral patellar border & tendon. B, find the 'soft spot' (between the lower patellar border & the tibial plateau (C). Insert the needle *under strict aseptic conditions* at B.

Examine the fluid carefully:
If it is bloody, let it settle for 5mins and then look at its surface. If fat from an injured marrow cavity is floating on the top, there is an articular fracture. Blood or blood-stained fluid is suggestive for synovial, ligamentous or capsular tears.

If it is clear, amber-coloured, this is suggestive of torn menisci, osteoarthritis, loose bodies, or synovitis.

If it is cloudy, think of septic or rheumatoid arthritis. If there are 'rice bodies' there is probably tuberculous arthritis. If it is frank pus, there is septic arthritis.
In gout, you may see crystals in yellowish fluid.

If possible, send the fluid for culture, in a blood culture bottle.

68.4 Knee swelling after minor injury

When a knee swells after a minor injury the cause can be:
(1) a minor fracture,
(2) a synovial or capsular tear,
(3) a loose body,
(4) a torn cartilage, or
(5) synovitis of obscure origin.

Take a careful history. If the patient has had previous episodes, he may have a chronic ligamentous injury, a loose body, or a torn cartilage.

A history of locking suggests a loose body, or a torn cartilage. An abduction or adduction injury suggests a torn ligament, and a rotational injury a torn cartilage. The absence of any history of force suggests a loose body or 'synovitis'. This has many causes, including rheumatoid arthritis, or infectious disease. If the swelling appeared slowly over 6-12h before producing acute pain, it is probably a haemarthrosis, perhaps from quite a minor injury. Examine the knee (68.1), aspirate it (68.3), and look at the fluid. Remember that repeated haemarthroses may be the first indication of a bleeding disorder.

TREATMENT FOR A MINOR KNEE INJURY
Minor fractures, and synovial and capsular tears Aspirate the knee as necessary. Apply a well-padded dressing, and mobilize it as pain subsides.
Loose bodies. Removing a loose body from the knee is a specialist task.
'Synovitis' Rheumatoid arthritis is responsible for 50% of cases. Treat the underlying cause and make sure you exclude TB.

68.5 Collateral ligament sprain & tear

It is possible to injure the knee while it is extended, or flexed (as when the knee hits the dashboard), and sustain a variety of complex injuries to collateral ligaments, cruciate ligaments, and menisci. Sprains (partial tears) of the collateral ligaments are usually obvious, but you can miss a complete tear because:
(1) It causes less pain than a sprain, so walking may be possible, and likewise movements of the knee.
(2) Blood can escape through the capsule in a complete tear, so that swelling is less.

COLLATERAL KNEE LIGAMENT INJURY EXAMINATION
Tenderness is a good indication as to where a ligament is injured, so feel for it carefully. The collateral ligaments may be tender over their femoral or tibial origins. Narrowly localized tenderness (usually about 2 cm above the joint line) indicates a partial tear. Severe diffuse tenderness suggests a complete rupture.

If the medial ligament is tender at the joint line, the medial meniscus may be injured also.

If you suspect that a collateral ligament may have been ruptured, test the stability of the knee like this. Hold the leg with one hand just above the injured knee, and the other just above the ankle. With the knee just short of full extension move the lower leg from side to side.

KNEE STRESS TESTS

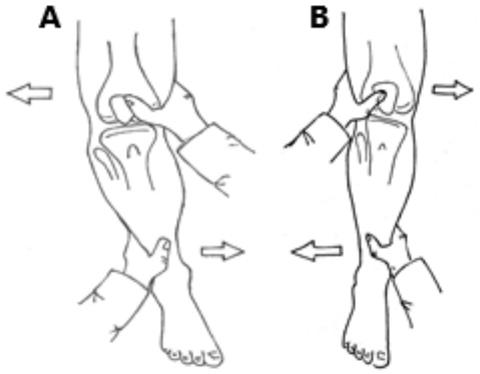


Fig. 68-4 STRESS TESTS ON THE KNEE. A, *varus*: holding the lower end of the femur medially, push the lower leg medially. B, *valgus*: holding the lower end of the femur laterally, push the lower leg laterally. *After Lubowitz JH, Bernadini BJ, Reid III JB. Current Concepts Review: Comprehensive Physical Examination for Instability of the Knee, Am J Sports Med 2008 36: 577*

This manoeuvre is called applying *valgus* or *varus* stress. The former excludes a rupture of the medial collateral ligament and the latter of the lateral collateral ligament (68-4). If either of the collateral ligaments is grossly torn, the tibia will wobble on the femur.

STRESS RADIOGRAPHS OF THE KNEE

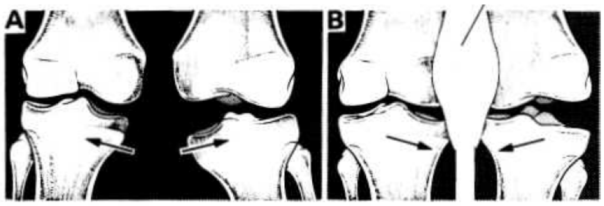


Fig. 68-5 STRESS RADIOGRAPHS OF THE KNEE. A, a medial collateral ligament tear. B, a lateral collateral ligament tear. (In both cases the cruciate ligament was also ruptured) *After Apley AG, Solomon L. Apley's System of Orthopaedics and Fractures. Butterworth, 6th ed.1982 with kind permission.*

CAUTION! (1) the knee must be just a little flexed when you do this test. If it is fully extended, the cruciate ligaments will stabilize the knee and mask tears in the collateral ligaments. (2) A fracture of the tibial plateau can also make the knee unstable and resemble a torn collateral ligament.

STRESS RADIOGRAPHS UNDER GA
Sedate the patient, put a pillow between the ankles, bind the knees together, and take an AP view to compare the joint space between the femoral and tibial condyles on either side (68-5) in 15° of flexion. In extension, the cruciate ligaments can make the leg appear to be stable, even when the collateral ligaments have been torn. With a few degrees of flexion, the cruciates are relaxed and the tears of the collateral ligaments will become more obvious. If the ligament is completely ruptured, you will be able to open the joint space on the affected side by >1cm with your hands when applying *varus* or valgus stress and the tibia will visibly wobble under the femur.

TREATMENT
For incomplete tears, fit a plaster cylinder (68.2) to relieve pain and protect the sprained ligament. After 2wks, if walking is easy without pain, remove the PoP, otherwise leave it for 2wks more, then start active knee exercises.

If *varus* or *valgus* stress causes an opening of <1cm on the side of the knee joint, use a plaster cylinder as above, but apply it in 30° of flexion (to relax the torn ligament) and continue immobilization for 6-8wks. Warn that extension will be slow to return, and encourage progressively increasing extension exercises. This gives as good results as attempts at secondary repair.

If lateral angulation causes an opening of >1cm on one side of the knee joint, the collateral ligament on that side Is torn, and perhaps the meniscus also. Refer immediately for primary repair. This, however, gives only fair results in most cases. If referral is impossible, fit a plaster cylinder as described below.

68.6 Cruciate ligament rupture

(a) The posterior cruciate ligament is attached posteriorly on the proximal surface of the tibia, and anteriorly on the inner part of the medial femur condyle. It tightens when the tibia is pushed backwards on the femur. It can rupture when the tibia hits the dashboard of a car and is driven back on the femur.

(b) The anterior cruciate ligament is attached anteriorly on the proximal surface of the tibia, and posteriorly on the inner part of the lateral femur condyle. It tightens when flexing the knee at 30° and as such, by mobilizing the tibia forward on the femur. It can rupture if the foot remains on the ground, and the femur is driven backwards by some twisting injury. This is a typical sports injury and happens frequently playing football.

Anterior are much more common than posterior cruciate ligament injuries.

HISTORY
A rotatory mechanism of injury is suggestive for an anterior cruciate ligament tear, while a direct impact on the tibia on a flexed knee (*e.g.* a car accident) is suggestive for a posterior cruciate ligament tear.
Ask additionally about complaints of instability or pain with certain movements or activities to exclude possible additional lesions.

EXAMINATION
In a very recent injury, examine under GA. Otherwise, with the patient sitting up, bend the knee to 90°, and sit on the foot. Take hold of the proximal end of the tibia with both hands, and move it forcibly backwards and forwards (the posterior & anterior drawer tests). There should be very little movement.

SIGNS OF CRUCIATE LIGAMENT RUPTURE

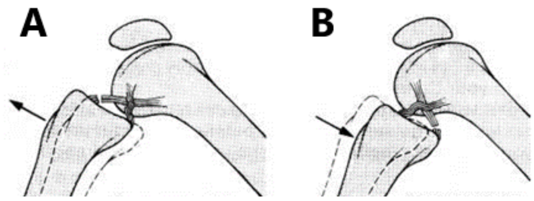


Fig. 68-6 SIGNS OF CRUCIATE LIGAMENT RUPTURE. A, forward movement of the tibia implies the anterior cruciate is torn. B, backward movement of the tibia suggests the posterior cruciate is ruptured. *Kindly contributed by John Jellis.*

Now with the normal knee in the same position, look at the outline of both the knees from the side. Observe especially the relative positions of the tibial tuberosities and the patellae. Compare the normal with the injured knee. If you see 'tibial sagging', meaning that the tibia is relatively posterior in relation to the patella (68-6B), this is suggestive of a posterior cruciate ligament tear.

Isolated posterior cruciate ligament rupture is rare, but can easily go unnoticed even when the knee is examined under GA because of swelling.

N.B. Aspirate an effusion when testing for a posterior cruciate ligament tear to have full range of movement in the knee.

If you suspect a posterior cruciate ligament tear, always examine for additional lesions. These may be:
(1) A popliteal artery injury.
- check the distant pulses.

(2) Posterolateral ligament injury
- **if there is >10mm movement in a knee**, this suggests an additional lesion of the capsule and the ligaments in the posterolateral corner of the knee. Confirm this with the patient prone; flex both knees to 90°, and take the left foot in your left hand and the right foot in the right hand. Turn both feet outwards. The range of rotation on one side will be larger than on the other side.

(3) Avulsion fractures of the tibial plateau
- always get a radiograph of the knee

O'DONOGHUE'S UNHAPPY TRIAD
This triad in football players includes a torn anterior cruciate ligament, a torn medial collateral ligament (68.5) and a meniscal tear (68.7). Refer such a patient for further treatment.

TREATMENT
Treat isolated anterior and posterior cruciate ligament tears conservatively with a plaster cast.
For the anterior cruciate ligament tear, rest in bed for 5days until most of the pain has gone. Then start active *quadriceps* exercises. Hypertrophy of the *quadriceps* can compensate with complete return of function.
For the posterior cruciate ligament tear, immobilize the knee in 60° of flexion for 6wks.

68.7 Meniscus damage

A footballer playing on hard ground can easily injure the menisci. The pressure of the femoral condyle against the tibia may split one of them, so that a piece becomes loose at one end and may lock the knee. A history of injury to a flexed loaded knee is highly suggestive, especially if it sometimes locks. The *quadriceps* will often already have started to waste, there may be an effusion, and the knee joint line will be tender. Most patients learn how to move their knees so as to unlock them.

If a patient has repeated episodes of locking with effusion, refer him for meniscectomy. This suggests the presence of a large tear which will eventually cause osteoarthritis.

EXAMINATION
Tests for injuries to the menisci are not reliable, so place great importance on the history of the injury (flexion of a loaded knee) and a history of locking.
(1) Sit the patient down and extend the knee. With the tip of your fingers press firmly over the joint line just medial to the patellar tendon. Now, still pressing hard, flex the knee and at the same time rotate the tibia to and from on the femur several times. You may feel the torn meniscus click and move under your finger, or roll against the head of the tibia, showing that it is displaced.
(2) Press with your thumb close beside the patellar tendon over the anterior horn of the medial meniscus. Flex and extend the knee passively. Do the same thing with the anterior horn of the lateral meniscus. Compare the tenderness with that of the normal leg. Significant tenderness in one place suggests that the meniscus under it is injured.
(3) Lie the patient prone. Hold the foot, and flex the knee, until the heel almost reaches the buttock. Rotate the foot externally as far as it will go and then extend it. If you feel a 'click' while you do this, the posterior horn of the medial meniscus is probably torn.

TREATMENT
Late meniscectomy results are poor.
If the knee is locked, and you cannot refer, manipulate the knee under GA. Use combinations of flexion, extension, rotation, abduction, and adduction. You may be able to unlock it, temporarily at least.

68.8 Knee dislocation

A violent injury such as a road accident can dislocate the whole knee. This is not the same as a patella dislocation (68.9); rather it is dislocation of the tibia off the femur. It can dislocate in any direction: posteriorly, anteriorly, medially or laterally. There is an extremely high risk of concomitant soft tissue lesions: torn cruciate ligaments, menisci (one or both), patellar tendon, capsule, *quadriceps* tendon or one or both collateral ligaments. The popliteal neurovascular bundle may also be damaged.

KNEE DISLOCATION REDUCTION
(GRADE 1.3)
Reduction is usually easy, but the easier it is, the more likely the knee is to be unstable afterwards. If the knee is completely dislocated, it is unlikely to function normally again. An injury severe enough to dislocate the knee may also injure the hip, so check that too.

If the patient presents with a highly unstable, but undislocated knee after a violent injury, be very suspicious. It may have dislocated knee during the trauma, but reduced spontaneously. Treat it as a dislocated knee, even though you haven't witnessed the dislocation and reduction yourself.

A DISLOCATED KNEE IS A TRUE ORTHOPAEDIC EMERGENCY!!

Check the circulation distally in the leg. Reduce the dislocation as quickly as possible, and, if necessary, aspirate the knee. If there is a skin wound, toilet it.

If you cannot refer, apply a plaster cylinder with the knee flexed to 90°, and split it to allow for swelling. Leave it on for 3-4wks. Then remove it and start gradual extension exercises. It will take several months to regain normal movements. Start *quadriceps* exercises from the beginning. Allow weight bearing in the cast as soon as lifting the leg is possible.

If reducing the dislocation does not restore the circulation to the leg, the popliteal artery is probably injured. You will not have time to refer, so get what help you can and explore the popliteal space (49.4h). If you cannot restore arterial flow, a knee level amputation will result.

68.9 Patellar dislocation

A sudden uncoordinated movement of the leg may dislocate the patella outwards, and rotate it so that its articular surface lies against the outer side of the femur. The fibres of *vastus internus* tear, and the knee fills with blood. There is great pain; the knee is flexed and immobile. It has an abnormal shape, with the patella obviously out of place.
A less serious movement may cause a subluxation, which is more common in women.

SKYLINE VIEW OF THE KNEE

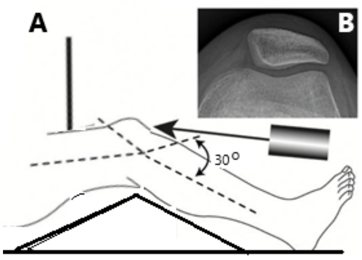


Fig. 68-7 SKYLINE VIEW A, with a support under the knee, keep it at 30° of flexion. Get the patient to hold the cassette (if you cannot keep it fixed in a holder) but *make sure it stays vertical & does not fall backwards. Also make sure the toes do not get in the way of the rays!* . B, clear space between patella and tibia.

Always get a post-reduction radiograph to exclude any avulsion fractures. If possible, take a skyline view (68-7) and look for displaced bony fragments free in the joint.

Early after injury, you may be able to reduce a dislocation spontaneously by extending the flexed knee slowly. Pressure on the lateral side of the patella may flick it back into the midline. If there is too much discomfort, use sedation.

The medial attachment of the *quadriceps* to the patella may be torn, so fit a plaster cylinder (68.2) for 2-3wks, and encourage straight leg raising and *quadriceps* exercises.

If the dislocation recurs, or if there is a history of recurrence since childhood, try to get adapted physiotherapy and *vastus medialis* exercises.
N.B. Surgical repair of the medial patella-femoral ligament has mixed results.

68.10 Extensor mechanism injury

If there is a fall on the leg whilst the powerful *quadriceps* tendon is in contraction, any of these injuries may result (68-7):
(1) Ruptured extensor expansion
(2) *Quadriceps* disruption
(3) Patellar fracture
(4) Patellar tendon disruption
(5) Patellar tendon rupture
(6) Patellar tendon avulsion

***QUADRICEPS* MECHANISM RUPTURE**

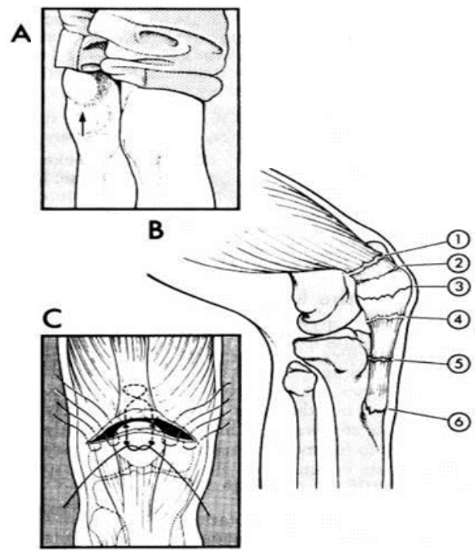


Fig. 68-8 POSITIONS OF *QUADRICEPS* MECHANISM INJURY. A, the patella is displaced upwards. B, of all these injuries, the patellar fracture (3) is by far the most common. An inferior laceration (6) needs suture repair C, exposure of the patellar tendon & its repair with at least 7-9 figure-of-8 sutures.

The results are all similar: full knee extension is impossible, with dragging of the leg on walking, difficulty climbing stairs, or going up a slope. Apart from fracture of the patella, all these other injuries are rare. Repairing them involves open joint surgery, with the risk of infection, so refer the patient if you can.

As with the olecranon (62.8), the proper management of these injuries, especially patellar fractures, depends on whether the extensor mechanism is intact or not. This is the mechanism which extends the knee.

TESTING THE EXTENSOR MECHANISM
(1) Feel the patellar tendon between the lower margin of the patella and the tibial tuberosity; ask the patient to lift the leg gently off the couch. Pain may prevent this, but if you can feel the patellar tendon tightening, you can be sure the *quadriceps* extension is sufficiently intact to justify closed treatment.
N.B. This test may be difficult.
(2) Palpate the *quadriceps* tendon, the patella, the patellar tendon, and its insertion. Feel for a transverse crack in the patella with your thumb nail.
(3) Put your hand on the patella and ask the patient to flex and extend the knee. If the surfaces of the patella and femur are rough, you may feel crepitations as they slide over one another.

(a) Undisplaced patellar fractures
Fractures of the patella resemble those of the olecranon, but are more often missed.

TYPES OF PATELLAR FRACTURES

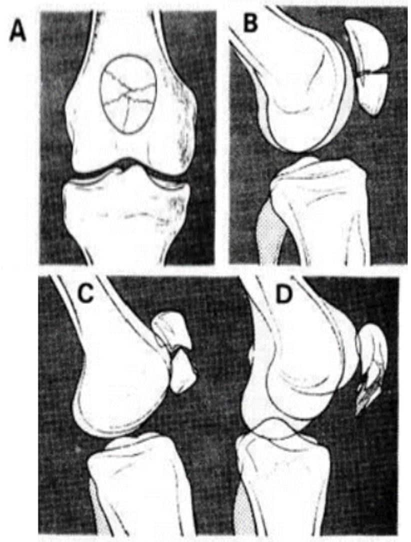


Fig. 68-9 PATELLAR FRACTURES. A, stellate fracture from a direct injury. B, undisplaced midline horizontal patellar fracture. C, displaced patellar fracture. D, comminuted patellar fracture. The important feature is whether the *quadriceps* mechanism is intact.
Kindly contributed by John Stewart.

A common mistake with disastrous results is to suture a knee laceration overlying a patellar fracture and so, an open knee injury. Such an injury needs careful wound toilet and exploration under GA.

The patella fractures in 2 ways:
(1) A direct injury causing a stellate fracture leaving the extensor mechanism intact (68-9A). The *quadriceps* remains intact.
(2) A fall whilst the *quadriceps* are contracting, typically someone >40yrs who misses a step, hears something snap in the knee, and then falls to the ground. There is subsequent difficulty walking.
The injury has split the patella horizontally into two halves, separated them, and torn the patellar *retinacula*. This is the tough fibrous capsule of the knee on either side of the quadriceps tendon, the patella, and the patellar tendon. In both kinds of fractures, the knee swells with blood making it impossible to extend.

INDICATIONS FOR CLOSED METHODS
An intact extensor mechanism as tested (68.10), with:
(1) A nondisplaced fracture of the patella,
(2) A nondisplaced fracture with a lesion of the extensor mechanism in zone 3 (68-7B),
(3) A vertical split fracture of the patella,
(4) Fragments separated ≤3mm or with an intra-articular step-off >2mm.

TREATMENT
There will be blood in a painful swollen knee, so aspirate it under strict sterile conditions.

If pain and swelling are mild, mobilize with crutches (66.1).

If pain is moderate, bandage the leg from the ankle to the groin with alternate layers of cotton wool and crepe bandage, making 4 layers in all. Maintain bedrest until control of the knee is regained. Then allow standing with active knee movements within the limits of the bandage. After 2wks, remove the bandages and add knee flexion exercises.

If the extensor mechanism is torn in zone 3 or if pain and swelling are severe, fit a plaster cylinder (68.2).

(b) where the *quadriceps* mechanism is torn, and there is a displaced patellar fracture, repair is mandatory for otherwise knee extension beyond the final 20° will not be possible, although walking may.

If the skin over the patella is normal, operate as soon as is practical.

If it is bruised, operate immediately and toilet the wound.

If it is infected, wait for 7-10days until infection subsides and treat the infection in the meanwhile.

N.B. These interventions are all truly intra-articular, with a risk for post-operative septic arthritis. Consider carefully if the patient has a better option being referred or being treated locally.

Reduce and fix the patella if it is displaced, so that you obtain a smooth posterior surface. The fracture may be in the middle of the patella, in which case it will be in two halves, or it can be at the top or bottom of the patella, in which case there may be one large fragment and one small one.

QUADRICEPS MECHANISM REPAIR (GRADE 3.1)
Use a GA or spinal anaesthetic and apply a tourniquet. Make a longitudinal skin incision, centred on the patella. Be sure that the incision goes far enough to visualize the upper and lower poles of the patella clearly. If an area of skin is bruised, avoid it, or excise it. Reflect the skin proximally and distally to expose the whole anterior surface of the patella, the patellar tendon, & the *quadriceps* tendon. Inspect this medially and laterally. Remove any small detached fragments of bone.
The knee will be full of blood; wash out all the clots 7 & débris. Use a litre bag to squirt saline under high pressure into all its recesses, until the fluid comes out clear.

SUTURING THE EXTENSOR EXPANSION

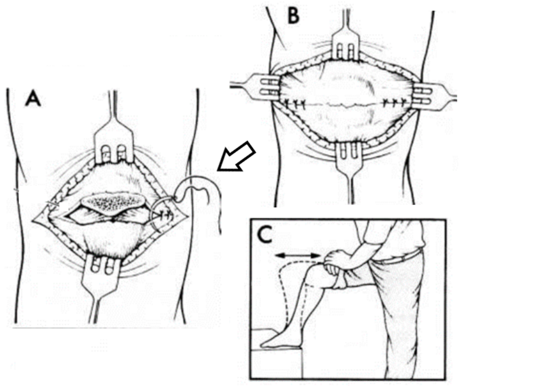


Fig. 68-10 SUTURING THE EXTENSOR EXPANSION. A, expose the whole torn extensor expansion. B, having brought the expansion together, wire the patella together. C, encourage postop knee exercises. *Kindly contributed by John Stewart.*

QUADRICEPS REPAIR (GRADE 3.1)
Repair the tendon from outside inwards using strong slowly absorbable suture.

If the *quadriceps* tendon has torn away from the patella, drill some holes for sutures through its edge (68-8C). Otherwise use strong slowly absorbable suture to bring the ends together.

If the injury is an old one, and the *quadriceps* muscle has retracted, pass a Steinmann pin through the *quadriceps* tendon, apply traction, and when, after some days, the muscle has lengthened sufficiently, suture the tendon.

HORIZONTAL PATELLAR FRACTURE FIXATION (GRADE 3.2)

If the patella is in 2 halves, and the extensor expansion is torn, sew it up from the sides towards the centre with strong monofilament sutures, (68-10A). Put 2 K-wires of 1.6-2mm diameter from proximally to distally to keep the fragments stabilized. Bend the upper ends so they do not cut through the skin when flexing the knee; put a ‘figure of 8’ tension band wire around the K-wires (68-11).

TENSION BAND WIRING

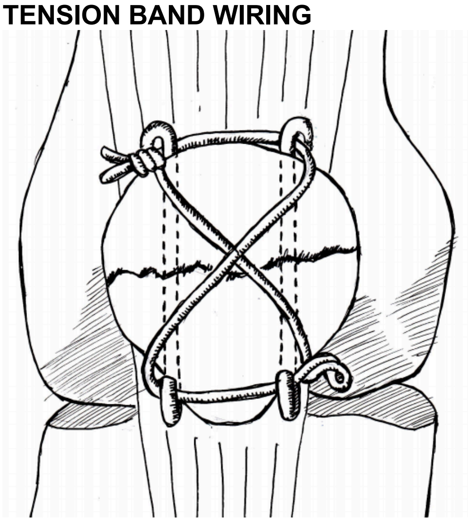


Fig. 68-11 TENSION BAND WIRING for a simple horizontal patellar fracture.

COMMINUTED PATELLAR FRACTURE FIXATION (GRADE 3.3)
Bring together the different fragments as well as you can using the tension-band wiring technique (68-11). Then encircle the patella with 1mm stainless steel wire, preferably using a large Gallie needle, or alternatively, threading it through a large intravenous needle. Pass the wire in and out of the *quadriceps* expansion, taking big bites very close to the patella. Pass all around the superior and lateral borders and straight through the patellar tendon, close to the patella itself.

Finally, bring the ends together and twist them tight. This circumferential wiring prevents the fragments separating.

Place this wire superficially in the patella, so that when the knee flexes, the posterior aspects of the fragments are brought together in compression. *The wire must lie close to the patella, particularly above and below,* or it will cut out when the knee flexes (68-12).

If there are still several widely separated fragments, remove the entirely loose fragments.

WIRE CERCLAGE

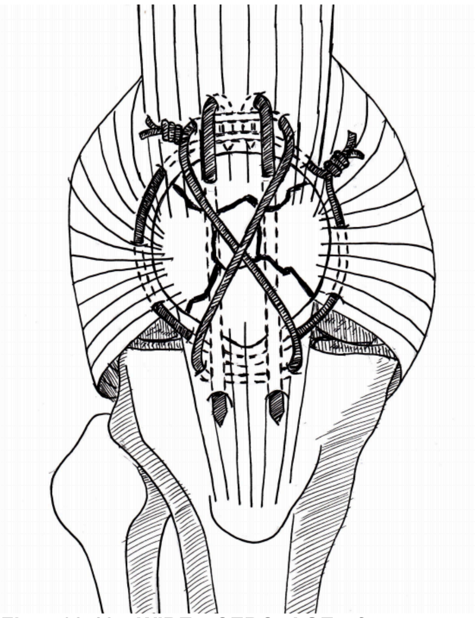


Fig. 68-12 WIRE CERCLAGE for a vertical or comminuted patellar fracture.

PATELLAR EXCISION (GRADE 3.3)
This treatment is rarely needed, and should only be considered if you do not have any other treatment option available. Get advice before you proceed!

If the patella is in several widely separated small fragments, use a very sharp scalpel to cut them out of the tendon. Keep the edge of the scalpel close to the bone all the time. Change the blade frequently as it blunts, and preserve the soft tissue coverings of the excised fragments. Excise all fragments except for a small anterior chip in both proximal & distal tendons. Preserve as much tendon as you can.

Repair the medial and lateral tears in the *quadriceps* expansion with interrupted sutures of thick slowly absorbable sutures, beginning at the sides of the knee and working towards the gap created by removing the patella.

Pass a purse string suture around the edges of this gap and pull them together. If one purse string does not seem to be enough, put in another one.
Don't worry if you have a gap in the middle where the patella was.

If the *quadriceps* expansion is torn at the sides of the knee, be sure to repair it.

PATELLAR TENDON REPAIR (GRADE 3.1)
Suture the torn ends of the patellar tendon with strong slowly absorbable sutures. If necessary, drill some holes through the lower pole of the patella to hold the sutures. If the patellar tendon has pulled away from the tibia, drill some holes in it to hold wire sutures, or hold the patellar tendon in place with a screw.

If the injury is old and the patella is much retracted, push the skin upwards and the patella downwards. Pass a K-wire through both sides of the patellar tendon and exert traction for ≥2wks. Keep the wire in place and incorporate it (without its tensioner) in a long leg plaster cylinder (68.2). Then operate and repair the tendon.

POSTOPERATIVE CARE FOR OPERATIONS ON THE EXTENSOR MECHANISM
Dress the wound with gauze, cover this with plenty of cotton wool from 10cm above the knee to 5cm below it. Hold this firmly with 2 15cm crepe bandages. Apply a cast cylinder (68.2). Allow immediate weight-bearing, with the protection of 2 crutches.

After 12days, remove the cast and dressings. If the wound is clean and dry, take out the sutures. Apply a new plaster cylinder.

At 4wks bi-valve the cast and start non-weight bearing extension exercises under supervision. Abandon the cast when flexion to 90° and extension against resistance are possible. This is usually after 6-8wks. At 6wks start gentle active flexion exercises, and at 8wks, begin the passive flexion exercises shown (68-10C).

Gradually increase the exercises, provided active full extension is present. *If this ceases, don't allow flexion of the knee any further until active extension resumes*.

Expect the recovery of flexion to be slow. Full flexion takes 4-6months.

DIFFICULTIES WITH PATELLAR FRACTURES
If the knee is stiff, continue progressive active movements. *Don't try forcible manipulation under GA*, or you may rupture the repair, tear the ligaments, or break the lower end of the femur.

68.11 Supracondylar femoral fracture

A direct impact on the knee above the femoral condyles, may cause a fracture. Usually, there is little displacement, but it may be severe (68-13A). Occasionally, the *gastrocnemius* flexes the proximal end of the distal fragment, so that the shaft of the femur displaces anteriorly. The distal fragment may then press on the popliteal vessels and occlude circulation in the leg.

DISTAL FEMORAL FRACTURES

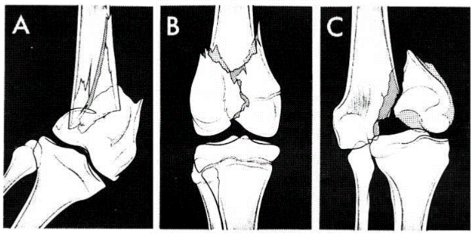


Fig. 68-13 DISTAL FEMORAL FRACTURES. A, supracondylar fracture with severe angulation. B, T-shaped fracture. C, rotated condylar fracture. *Kindly contributed by John Stewart.*

MILD DISPLACEMENT
If the distal fragment is only mildly angulated and the peripheral pulses are normal, apply Perkins traction (67.3) but with the hip and knee flexed, (68-14). Encourage movements of the knee. Ignore lateral displacement, and flexion of the distal fragment on the radiograph. Concentrate on getting good antero-posterior alignment.

PERKINS TRACTION

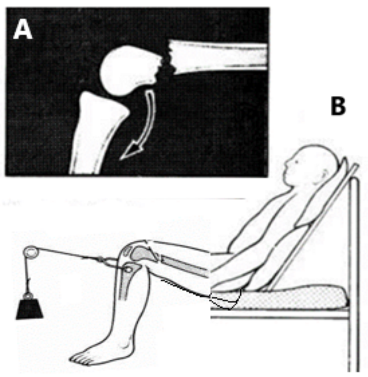


Fig. 68-14 PERKINS TRACTION FOR SUPRA-CONDYLAR FEMORAL FRACTURE. A, mildly angulated fracture. B, knee flexion helps to compensate flexor pull of *gastrocnemius*. *Kindly contributed by Peter Bewes*

SEVERE DISPLACEMENT

If the distal fragment is severely flexed, under ketamine, insert a Steinmann or Denham pin through the upper tibia (70.11, 78.4). If there is lateral displacement, try to push medially to effect reduction. Then apply traction in a Böhler-Braun frame (68-14).

BÖHLER-BRAUN FRAME

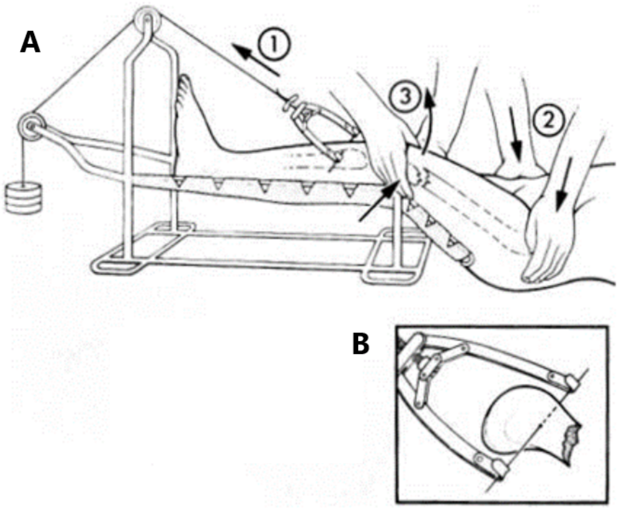


Fig. 68-15 REDUCTION OF A SEVERELY ANGULATED SUPRACONDYLAR FEMORAL FRACTURE ON A BÖHLER-BRAUN FRAME. A, under suitable anaesthesia, having inserted a proximal tibial pin and attached the weights (1), reduce the fracture (3) whilst an assistant holds the pelvis down (2). B, you may occasionally need to insert a pin through the distal femoral fragment to get adequate traction.

Exert traction in the line of the femur (68-15A). Ask another assistant to hold the iliac crests (68-15B). When the femoral length is corrected, grasp its distal end with both hands, and bring it forward (68-15C). Leave the patient on a Böhler-Braun frame for 10days, until the bone ends have become sticky, before starting Perkins traction, as for a fracture of the femoral shaft (67.3).

If reduction fails, pass a K-wire or Steinmann pin through the anterior margin of the distal fragment, and pull on it anteriorly and distally.

N.B. A disadvantage of this method is that you have to insert the pin or wire through the joint capsule with the risk of infecting the knee. So, remove it as soon as the fracture is stable, usually c. 3wks, and continue with Perkins traction, with the knee in 90° flexion.
Alternatively, you may be able to get the distal fragment into a suitable position by putting a padded block under it.

CAUTION! As always in fractures of the lower limb, correct rotation (78-3).

LATER CARE

Maintain traction until there is clinical union, usually c. 8wks. After 2wks more, allow non-weight bearing with crutches (67.1), then after 2wks more, if radiographs show solid union, start protected weight bearing. *Don't allow unprotected weight bearing until the fracture has consolidated*. The knee is likely to be stiff for a long time, and will need continued exercises to help extension.

Alternatively, at 4-6wks, apply a long leg cast while standing, keep this on until the fracture has consolidated, usually after 2-4wks more. This is a poor alternative to continued Perkins traction.

If you still cannot achieve satisfactory reduction, refer him for open reduction.

If there is a T-shaped fracture into the knee joint (68-13B), the 2 condyles are separated. Any or all fragments may be displaced, angled or rotated. Perkins traction usually reduces the displacement satisfactorily.

If one of the fragments has turned through 180° open reduction is essential, so refer him.

If there is a single lateral femoral condylar fracture (68-13C), Perkins traction is satisfactory if there is little displacement.

However, when there is failure of reduction (usually owing to severe angulation, displacement or rotation), operative intervention will be necessary. You may be able to use an X-fix across the knee (69.5) temporarily but this risks the knee becoming stiff.

69 Proximal tibial injury

69.1 Extra-articular tibial plateau fracture

An extra-articular fracture, in the area 5cm below the tibial articular surface, not entering the knee joint capsule (69-1A) is usually the result of a violent blow to the leg most commonly occurring in road traffic crashes. Although the lower leg may bend in any direction, there is usually only a slight lateral shift and no overlap nor rotation. The fracture does not enter the knee joint. You can treat this in a long leg cast or in a cast-brace (67.4), just as you would if the fracture were more distal in the tibia.

If the fragments are displaced, manipulate them into position, and apply a long leg cast (70.4) for 6wks. Then remove it and start protected weight bearing with crutches for another 6wks.

69.2 Intra-articular tibial plateau fracture

There are 3 groups of fracture patterns with an intra-articular aspect.

(a) T-shaped tibial shaft fracture extending into the knee

An adult falls from a height, drives the shaft of the tibia up between the femoral condyles, and injures the soft tissues of the knee severely.

The condyles of the tibia may split apart (69-1B), with the tibial shaft riding up between them. Distal tibial traction (69.5) will often reduce these fractures adequately, as no fracture line affects the weight-bearing surfaces of the tibial plateau.

(b) Tibial condyle ('bumper') fracture

This fracture is usually the result of a blow to the outer side of the knee from the bumper of a car, which fractures one of the tibial condyles, usually the lateral.

There are 3 varieties of this fracture:

(1) The lateral or medial condyle may split vertically and hinge outwards (69-1C), while the fibula remains intact.

(2)The articular surface of the lateral or medial condyle may be depressed or pulped without harming the fibula (69-1D).

Minor varieties of this fracture may be difficult to see on a radiograph, so look carefully.

(3) The lateral tibial condyle may be displaced downwards, while breaking the fibular neck (69-1E).

(c) Comminuted upper tibial fracture

Here, the fragments are usually held in a sleeve of intact periosteum (69-1F). If so, try to reduce them by strong traction, and then treat use distal tibial traction (69.5).

UPPER TIBIAL FRACTURES

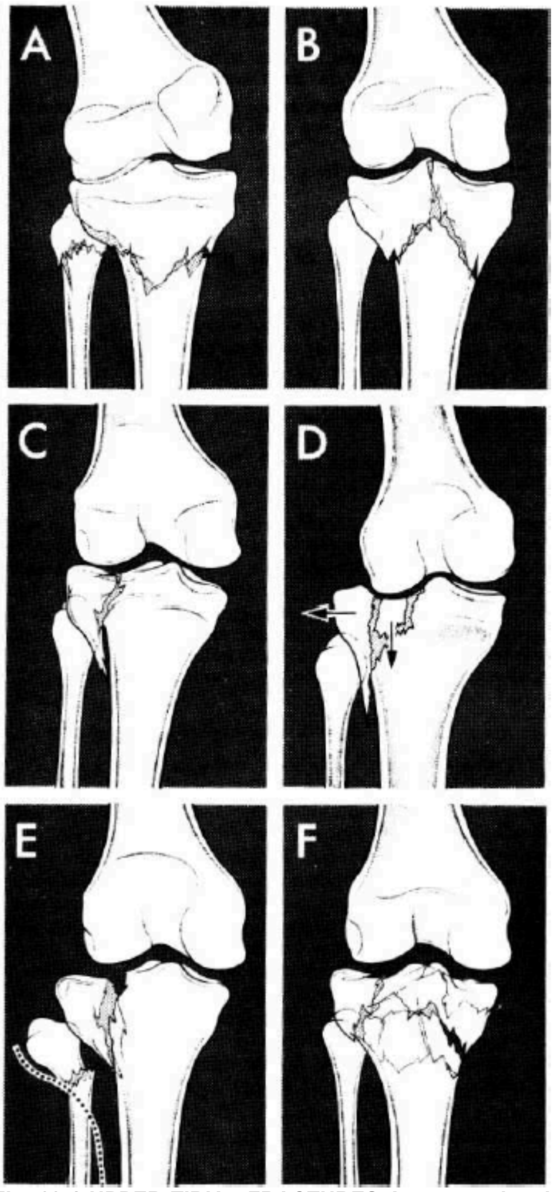


Fig. 69-1 UPPER TIBIAL FRACTURES A, an angulated infra-condylar fracture. B, a T-shaped fracture. C, a lateral tibial condylar fracture. D, a lateral tibial fracture with depression of the central part of the tibial plateau. E, downward displacement of the lateral tibial condyle with fibular neck fracture. ***Note the relation of the common peroneal nerve to this fracture.*** **F, a comminuted upper tibial fracture.** *Kindly contributed by John Stewart*

69.3 Distal tibial traction

The treatment for fractures of the proximal tibia differs considerably from the treatment of those of its shaft. If the knee joint is not involved, treat this in a long leg cast, in the same way as a distal tibial fracture, or with a cast-brace as for femoral shaft fractures (67.4). But if the fracture enters the knee joint and disturbs its articular surface, early active movements to mould the articular surfaces of the disturbed knee joint into place are necessary. *Perkins traction is not safe* because a pin through the upper tibia would pass too close to the fracture line, or through it, and might cause osteomyelitis, or infect the knee. Therefore, put a pin through the lower tibia as the middle of the tibia is much too hard. This is much better than a cast, because it reduces most of the displacement, maintains reduction, and provides early movement without weight- bearing. Early movement helps the surfaces of the knee to slide over one another and minimizes stiffness.

FRACTURES OF THE UPPER TIBIA

N.B. If you intend to refer a patient for internal fixation, *don't delay for ≥7days because the cancellous bone of the tibia soon becomes soft and difficult to fix*.

If there is a tense haemarthrosis, aspirate it.

Perform the following manoeuvres, where necessary, under ketamine, before applying distal tibial traction.

If the lateral tibial condyle is displaced, apply a strong *varus* strain on the knee, while moulding the displaced fragments proximally into place. Similarly, for a displaced medial condyle, apply a strong *valgus* strain.

If the tibial condyles are comminuted, flex and extend the knee a few times to mould the fragments into shape. If they are severely displaced, ask an assistant to pull on the leg while you squeeze them into place between both hands.

Then insert a distal tibial Steinmann pin (59.4). Use an ordinary bed with a pulley over the end. Apply 5kg or $^{1}/_{14}$ the body weight. Place a pillow lengthwise under the lower leg.

For traction if an assistant's pulling is insufficient, use 10-15kg traction for a few minutes on the Steinmann pin, and manipulate the knee.

If the knee feels unstable, test for additional soft tissue lesions while still under anaesthesia. *Look especially for meniscal* (68.7) *and collateral ligament tears* (68.5).

If there is a suspicion of a knee dislocation, or the leg is white or cold, act urgently (68.8).

CAUTION!

Never put a pad directly under the heel, or pressure sores will form. Instead, support the lower leg to keep the heel off the bed.

Don't put a pillow under the knee where it may obstruct vessels or press on the popliteal nerves.

The 2nd day, encourage hip, ankle, tarsus & toe movements. Exercise the leg gently at first, and then more vigorously.

Put a sling under the lower thigh, with a cord passing over an overhead pulley (69-2), and ending in a handle so that raising the thigh, and exercising the knee is possible, eventually up to 90°.

Don't put a sling directly under the knee, because it may injure the common peroneal nerve. However, a sling is essential because you cannot lower the fracture boards and let the leg dangle, as you can with Perkins traction.

LATER CARE

Fully controlled flexion and extension of the knee to ≥90° should be possible by 4wks. Continue to apply traction for 6wks, then walking on crutches for another 6wks (66.1), without weight bearing but following the normal movements of walking. Follow this by partial weight bearing with crutches for 6wks more.

At 12wks, walking without a stick should have commenced, except in the frail & elderly.

N.B. If traction is continued for too short a time, there is risk of lateral angulation. Most patients can move their injured knees and walk normally at 6months.

DISTAL TIBIAL TRACTION USING A SLING

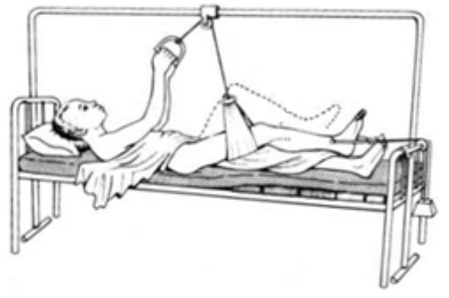


Fig. 69-2 DISTAL TIBIAL TRACTION WITH A SLING UNDER THE THIGH. *This must avoid the common peroneal nerve!* If there is an upper tibial fracture involving the knee joint, put a pin through the distal tibia and exercise the knee like this. *N.B. If the pin is placed in the distal tibia, you cannot lower the fracture boards.*

69.4 Surgical treatment for proximal tibial fracture

Surgical treatment of proximal tibia fractures is complex, so plan referral when this is necessary. Refer early enough, preferably ≤7days after trauma, to allow for correct soft tissue management and surgical planning.

Indications are, if you have performed the reduction manoeuvres under anesthesia described and correctly applied tibial traction:
(1) an articular step >3mm,
(2) distance >5mm between the condylar fragment and the rest of the tibia,
(3) fracture with *varus* or *valgus* instability because of high suspicion of associated lesions
(4) all bicondylar fractures
(5) all medial plateau fractures because of the high risk of associated vascular lesions owing to fracture-dislocation of the knee
(6) severe open fractures needing several soft-tissue interventions

69.5 External fixation for proximal tibial fracture

When placing an external fixator for a fracture around the knee, *it must span the knee*. This means that the construction is biomechanically less sound than an external fixator for a diaphyseal injury. Knee-spanning external fixators are known to have a very high rate of non-union and will lead inevitably to a stiff knee. Therefore *don't use the X-fix outside the limited indications listed:*

INDICATIONS FOR X-FIX
Tibial plateau fracture with:
(1) severe open fracture needing several soft-tissue interventions, to facilitate the wound care and the repetitive visits to the operating theatre,
(2) severely comminuted fractures that cannot be transferred and that you cannot reduce adequately using traction and reduction manoeuvres,
(3) as a temporary measure to transfer a patient to another hospital, where you want to avoid losing the (partially) obtained reduction of bone fragments.

PROCEDURE (GRADE 3.2)
You will need all the basic external fixator equipment (59.5), a C-arm X-ray machine & GA (*e.g.* ketamine). *You do not need a traction table nor a Steinmann pin to provide traction*. Manual traction by an assistant or nurse should be sufficient.

Place pins in the distal part of the femoral shaft and in the tibial diaphysis. With the patient supine, disinfect the whole leg & place the sterile drapes. The most practical is to disinfect & drape the whole leg, so you can mobilize it per-operatively. Place the pins as closely as possible to the fracture zone without being in the fracture. Check where and under which angle to place the pins. Make a stab incision through skin and dissect the muscles carefully until you reach the femur. Place the pins under direct visualization using the C-arm. Reduce the fracture and attach the pin bars using a simple frame, preferably with 2 parallel bars (59.5).

SAFE ZONES FOR PIN INSERTION

In the femur place the pins as closely as possible to the joint line, without putting them intra-articularly. A safe distance is 1.5cm away from the joint line.

SAFE ZONES FOR PIN INSERTION IN THE DISTAL FEMUR & PROXIMAL TIBIA

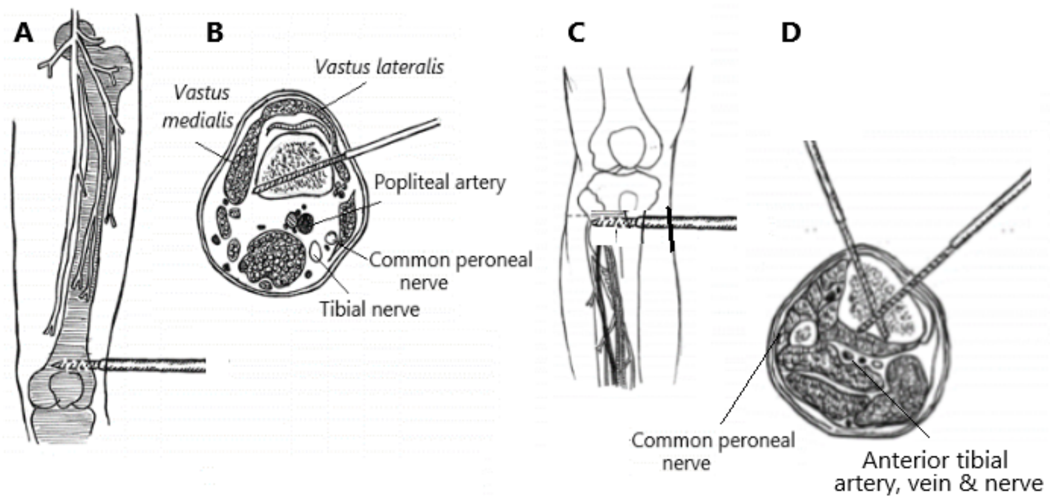


Fig 69-3 SAFE ZONES FOR PINS IN THE DISTAL FEMUR & PROXIMAL TIBIA. A,C, a-p views. B,D, cross sections.

In the distal femoral $^{1}/_{3}$, there are less soft tissue structures to worry about. Make a lateral approach under an angle of c.30°. This avoids most of the *vastus lateralis* muscle, and the frame is then not too posterior to interfere with the bed mattress.

In the proximal tibial shaft, distal to the tibial tuberosity, there is very little soft tissue covering the anterior tibial crest and the medial face of the tibia. These are both safe zones for pin insertion. The easiest zone is the medial surface of the tibia. Take this between the thumb and index finger of one hand and with the other hand, locate the midline of the medial surface. Make this your point for pin insertion & insert the pin perpendicular to the medial surface. Always try to put your pins across both cortices in the tibia for increased stability. *But make sure the pins don't extrude >2mm* in order to avoid lesions to the neurovascular bundle which lies immediately posterior to the tibial surface.

Your final construction will look like (69-4). Because the tibial pins are inserted on medially and the femoral pins laterally, you cannot connect both using a single bar. You need to attach a bridging bar connecting the tibial pins, a bridging bar connecting the femoral pins, and then a 3rd bar connecting the tibial and femoral bars. This construction is called a modular construction. Use double bars when possible.

KNEE-SPANNING EXTERNAL FIXATOR FOR TIBIAL PLATEAU FRACTURES

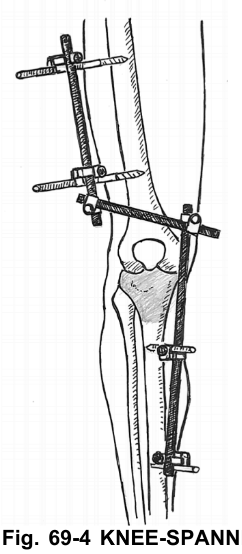


Fig. 69-4 KNEE-SPANNING EXTERNAL FIXATOR FOR TIBIAL PLATEAU FRACTURES. Femoral pins are lateral & tibial pins medial, so you need a connecting cross bar

70 Tibial shaft injury

70.1 Introduction

The tibia is the most commonly fractured long bone, because of its exposed location. The worst civilian injuries occur in motorcyclists and pedestrians struck by motor vehicles. Tibial fractures occur also in the osteoporotic elderly. Because ⅓ of the tibial surface is subcutaneous throughout most of its length, open fractures are more common in this bone than in any other major long bone. However, tibial fractures vary greatly in severity, so we provide guidance which should cover most situations. These fractures will, however, challenge your judgment and skills. If you don't treat these them carefully, they can cause severe disability (70.8).

DIAGNOSIS
You can usually identify an acute tibial shaft fracture from the localized pain after injury and the typical physical findings of deformity, tenderness, instability, swelling, and possible open wounds. The mechanism of injury, if known, and so the amount of energy transmitted in causing the injury is the major determinant of its severity. Did the patient trip on a curb, or get struck by a car, or get run over and crushed by its wheels?

As many as 30% of victims with a tibial shaft fracture will have additional injuries, especially after road traffic accidents. Rule out any other life-threatening injuries and perform immediate life sustaining interventions according the ABC algorithm (41.1). Similarly, identify and treat any limb-threatening injuries, such as major arterial injury (49.1), compartment syndrome (49.6), and open fractures (58.12), which are potentially life-threatening as well. Note the time, place, and events surrounding the injury as precisely as possible. Note the time elapsed especially for vascular injuries, compartment syndromes, and open wounds.

The soft-tissue envelope is the most important component in the evaluation and subsequent care of tibial fractures. A complete circumferential inspection of the limb is essential to prevent overlooking even the smallest wound.

As the tibia lies directly beneath the skin, tibial fractures are usually associated with an injury to this most delicate skin cover, especially in high-energy trauma.

Compartment syndrome (49.6) occurs more often with tibial fractures than with other long bone fractures, from swelling, bleeding, ischemia, or rebound oedema following restoration of blood supply (ischemia reperfusion injury).

The anterior compartment is most commonly involved. The usual signs of severe pain, pain with passive stretch, and localized loss of sensation demand a prompt operative fasciotomy, combined with appropriate fracture stabilization. A compartment syndrome generally develops some hrs after injury, although of course may be present at initial evaluation if this is late after the event. Thus you may need emergency treatment early in the care of a tibial fracture.

Occasionally, undisplaced or incomplete acute injuries or more chronic stress & pathologic fractures may be difficult to identify.

IMAGING
You need an AP and lateral radiographs with both knee and ankle joints included. Ultrasound can readily show up a fracture of the subcutaneous parts.

TREAT MOST CLOSED TIBIAL SHAFT FRACTURES CONSERVATIVELY!

PRINCIPLES OF TREATMENT
Considering the tibial shaft fracture itself, evaluate the injury, anticipate any problems that might develop, and choose from among several alternatives an appropriate plan of management that will be simultaneously safe and effective. The main goals of treatment are to obtain a healed, well-aligned fracture with pain-free weight bearing and a functional range of motion of the knee and ankle joints, without an unduly long period of disability.

Open fractures usually need surgery, by debriding the contaminated wound, by applying traction or an external fixator for stabilization of the fracture, by repairing a major arterial injury and if necessary by closing the wound with secondary skin grafts or even rotational flaps (70.7).

Don't be tempted to fix closed tibial fractures. External fixation is an option in certain situations, especially open fractures (59.4). A simple type of external fixation is the use of 2 Steinmann pins in a cast (70.2).

Closed treatment with casting or functional bracing is effective in treating many tibial shaft fractures. For such treatment to succeed, the cast or brace must maintain acceptable fracture alignment and the fracture pattern must allow early weight bearing to prevent delayed union or non-union.

Axial or rotational malalignment and shortening cause cosmetic deformities and alter the loading characteristics in adjacent joints, and so may hasten post-traumatic arthritis. *Avoid an excessive amount of malalignment and shortening*.

Acceptable amounts are not exactly known, but this gives some guidance:
(1) 4-10° *varus-valgus* malalignment,
(2) 5-20° anteroposterior malalignment,
(3) 5-20° rotatory malalignment, &
(4) 1-2cm shortening.
However, union of a comminuted tibial shaft fracture, with some shortening or malalignment is a reasonable price to pay. *Non-union is very likely to lead to persistent disability.*

Unless there is acute arterial insufficiency, compartmental ischemia, or the presence of an open wound, *there is little urgency for definitive reduction and stabilization of a closed tibial shaft fracture*.
What is important, however, is restoring the overall alignment with the application of a well-padded splint or cast and elevation and rest for the injured limb.

Repeated manipulations, cast changes or wedging and the use of prolonged anesthesia, striving for a perfect reduction must not be a part of the early care for a tibial fracture, because this:
(1) may add to the soft tissue injury,
(2) is painful,
(3) interferes with discovery of developing ischemia,
(4) is often followed by the need to loosen or remove a laboriously adjusted cast, and
(5) is often performed in a rush with insufficient assistance.
Thus, a much better policy is prompt and gentle realignment of the injured limb, followed by the application of a well-padded cast.

Elevating an injured lower leg in a distal limb injury:
(1) eases the pain,
(2) reduces the swelling,
(3) minimizes the stiffness that follows the organization of any oedema fluid,
(4) enables application of a cast to a limb from which most of the swelling has subsided.
This will make the cast less likely to become loose subsequently. *So splint and elevate all leg fractures before you manipulate them, operate on them, or put them in a cast.*
N.B. Continue to elevate an injured leg during an operation, and afterwards.

Elevate the leg from the moment you see the patient, until swelling is no longer a problem. *Resting the leg on a chair or on pillows is not enough*. The injured leg must be above the level of the heart. Raise the end of the bed on a stool or chair, or on 30cm blocks for several days if necessary. Encourage movements of the foot and ankle actively, so as to improve the circulation in the calf muscles. Explain how important this is to all your ward staff.

N.B. **If you suspect a developing compartment syndrome**, place the affected limb at the level of the heart. Elevation is contraindicated because it narrows the arterio-venous pressure gradient.

ELEVATING AN INJURED LEG

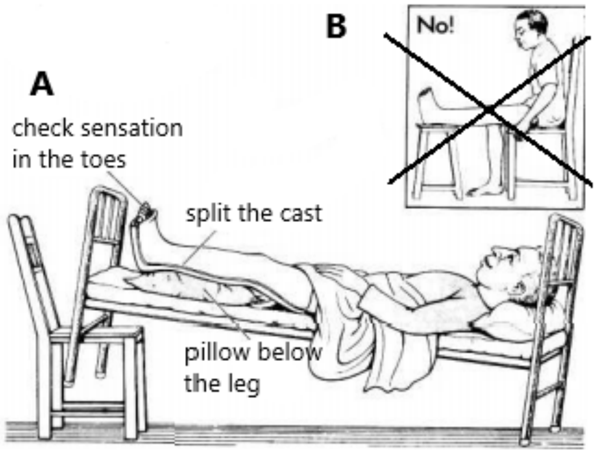


Fig. 70-1 ELEVATING AN INJURED LEG A, (1) eases the pain. (2) reduces the swelling. (3) minimizes the stiffness that follows the organization of oedema fluid. (4) enables easy application of a cast after most of the swelling has gone. B, *putting the leg on a chair does not lift it high enough!* *Kindly contributed by Peter Bewes.*

70.2 Tibial shaft immobilization

EARLY EMERGENCY IMMOBILIZATION
Reduce the fracture as soon as you can, *e.g.* under ketamine, and apply a well-padded cast or splint. Realign the leg with manual traction and support. How good the reduction after a single good attempt is a guide to subsequent therapy. Generally, use a splint for stable injuries and an emergency circumferential well-padded split cast for unstable fractures (58.2). *Never keep a cast closed*!

The cast should extend from mid-thigh to the metatarsal heads. Padding is essential to avoid skin breakdown and to accommodate some swelling, but too much padding, or a splint that is too flexible or excessively padded, will not immobilize well enough.

If the fracture is open, clean the wound by irrigation with copious amounts of water, and apply a sterile dressing before putting on the cast with a window exposing the wound (70.7). Administer prophylactic antibiotics.

The fragments of the broken tibia are much more likely to unite satisfactorily if:
(1) you get the fragments into an acceptable position to begin with, and
(2) you allow walking on the fracture inside a snug well-fitting cast early, and continuously.

Start as soon as the swelling has subsided, preferably during the first few days after injury. Early weight-bearing will *not* make infection worse, but it may shorten the leg by 1-2cm, particularly in oblique fractures, where one fragment can easily slip over another.

Although not ideal, this is not so important, because compensation of ≤4cm shortening by tilting the pelvis, or wearing a shoe-raise.

Prevent excessive shortening by a short period of traction at the start. A little shortening (66.1) is a small price to pay for the much greater certainty of union. *There is no compensation, however, for non-union which all too often complicates attempts to prevent shortening*. Although traction for >6wks is very useful for treating fractures of the femur, *never apply it for >2wks for an uninfected fracture of the tibia,* because traction for longer than this encourages non-union.

For an open or infected tibial fracture, traction for as long as 3wks may be necessary while you treat the soft tissue injury. Apply traction from a Steinmann pin through the calcaneus (70.7) *but don't distract the fragments.*

GOOD PLASTER TECHNIQUE

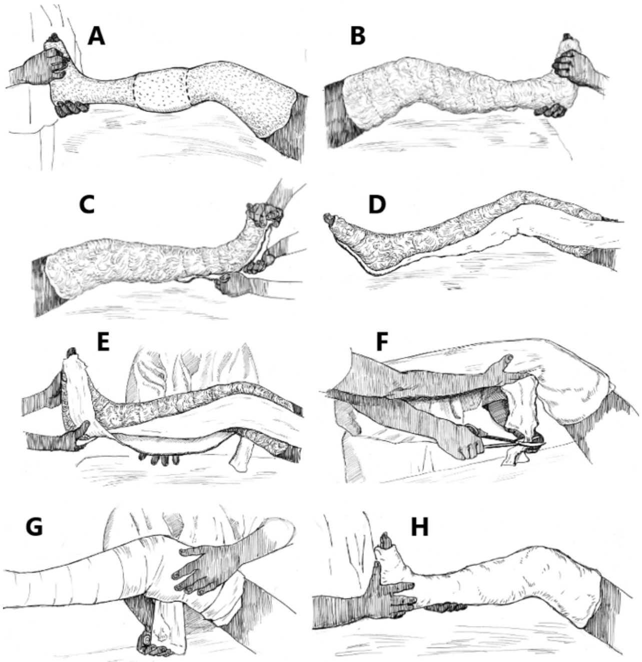


Fig. 70-2 GOOD PLASTER TECHNIQUE makes all the difference! A, apply a stockinette to the leg over any wound dressing. B, put padding over the stockinette to malleoli, the heel, the patella & fibular head (pressure points). C,D, apply the 1st wetted plaster so it encloses the 5th toe, & the lateral border of the foot, posteriorly over the heel, and moulds onto the calf, continuing behind the knee to mid-thigh. E, apply a 2nd slab starting over the hallux & medial border of the foot, crossing over the 1st slab behind the knee and finishing on the lateral thigh. *The cross-over in the popliteal fossa is critical to give the PoP its strength.* F, trim any excess plaster: *don't fold it back as it becomes lumpy & uncomfortable.* G, apply gauze or elastic bandage *firmly but not too tightly.* H, hold the backslab with the knee at 15^0 of flexion *(put a vacolitre behind the knee to make this smooth & easy),* & the ankle at 90^0 neutral position. *Check the finished edges do not dig into the skin, and rest the backslab on a pillow. Write the 'passport' details on the PoP* (59-7). *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

GET THE FRAGMENTS INTO AN ACCEPTABLE POSITION

Uncomplicated fractures of the adult tibia take 16 weeks to heal. Healing is delayed if the tibia is comminuted, if soft tissue injury is severe, or if a fracture is open or infected; union may take a year or more.

DEFINITIVE IMMOBILIZATION

There are 4 different casts in which a patient can walk and bear weight.

In order of decreasing stability, but increasing mobility and, convenience, they are:

(a) a long leg walking cast from the groin to the base of the toes,

(b) a short leg walking cast from just below the knee to the base of the toes,

(c) a plaster gaiter from just below the knee to just above the ankle,

(d) a plaster incorporating Steinmann pins.

Apply a long leg cast first, and renew it if necessary, and follow by making shorter casts as the fracture heals.

Keep in mind that if the fracture is very recent, you must apply a *split* circular cast. *You should only apply a closed cast when there is no further risk of swelling.*

If a patient walks on the sole of the cast, it soon becomes useless. Consequently, it is important how the cast is made:

(1) The ankle should be in neutral position.

(2) The heel and foot must also be in neutral and not be everted or inverted.

(3) The sole of the cast should be strong enough to bear weight.

(4) To prevent the cast spoiling in rain, cover it with oil paint, or a disposable plastic bag.

(5) Fit the cast with a stirrup or, less satisfactorily, with a walking heel (70-4), which will raise it out of mud and puddles.

N.B. A stirrup will last longer, because it is stronger and will distribute weight more evenly. You will get the stirrup back when you change the cast, so a stock of stirrups is a useful investment.

AVOIDING ROTATION OF THE LEG

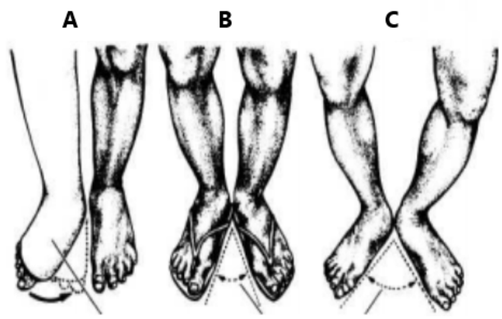


Fig. 70-3 FEET POINTING IN THE RIGHT DIRECTION. A, the cast was applied with the lower fragment in too much external rotation. This is undesirable, *but too much internal rotation would have been worse.* B, has markedly externally rotated feet, but which are equal. C, has bow legs and equally externally rotated feet since childhood. Symmetry is much more important than parallel feet. *Kindly contributed by John Stewart.*

A patient should be able to pivot on a walking heel:
(1) it must be sufficiently narrow,
(2) it must project c.2cm below the sole of the cast to allow the foot to rock, and
(3) it must be aligned with the anterior surface of the tibia.

N.B. There is no point in removing any leg cast, unless it is loose, until the patient is walking on it painlessly without a stick. If walking gives rise to pain or difficulty, replace the cast with another one in which treatment can continue.

LONG LEG WALKING CAST
(1) *Make sure that the foot points in the right direction* (70-3). So, in all tibial and malleolar casts (70.3), *make sure that the foot points in the same direction in relation to the knee on the injured side as it does on the contralateral one.*
(2) The cast must stop the distal fragment rotating on the proximal one, and so delaying union. When union is well advanced, rotation is less likely, but the fragments can easily rotate in a recent fracture. Prevent the proximal fragment from rotating by applying a long leg cast with the knee in 15° of flexion. Prevent the distal fragment from rotating by including the foot and ankle in the cast.

MAKE SURE ROTATION OF THE FEET IS SYMMETRICAL

PREVENT THE FRAGMENTS FROM ROTATING ON ONE ANOTHER

Let the leg hang over the edge of the table. The fully flexed knee relaxes the calf muscles, helps control rotation, and permits ankle dorsiflexion to neutral (90° to the leg). Pull the fracture with both hands on the heel and ankle to overcome any shortening. Cast application is far easier if you have 2 assistants. Repeatedly verify the reduction during cast application. One assistant pads the injured leg paying special attention to the malleoli, the subcutaneous surface of the tibia, and the head and neck of the fibula while you hold the reduction.
N.B.
(1) **If you neglect to pad the neck of the fibula**, the cast may compress the common peroneal nerve and cause a foot drop.
(2) ***Don't apply the cast with the leg horizontal*,** since controlling the position of the fragments will be more difficult.
(3) **If you fail to align the fragments**, union will take longer and the leg will be crooked.

You may be able to supplement an initial cast. Otherwise, make the cast in 2 parts:
(1) Use 2 15cm PoP bandages to make a thin below-knee cast which is just strong enough to control the fragments.
(2) When this cast has hardened, ask one assistant to hold the lower leg, and another to support the thigh. Cover the 1st part of the cast with a further layer of plaster from the toes to the groin, with the knee in 15° of flexion. Apply enough layers of plaster bandage for the upper part of the cast to grip the lower part. Incorporate medial and lateral slabs to strengthen the knee part of the cast. Finally, apply some more turns of bandage to make the upper part adequately strong. Always support the wet plaster with the flat hand, *don't press dimples into the plaster with the fingertips*, as this can cause pressure points inside.
N.B. **If you apply the cast in full extension**, it will be less effective in controlling rotation, and the knee will be painful.
CAUTION!
(1) While applying the cast, check the position of the ankle carefully; it should be in neutral, and neither inverted nor everted.
(2) Make sure that the foot has the same relation to the patella as on the uninjured side.
(3) A normal tibia has a slight natural inward bow, so try to restore this.
(4) Make a shelf of plaster under the toes, to protect them and prevent flexion contractures.
(5) Hold the knee position until the entire cast is firm.
(6) Take care to strengthen the knee, and the ankle parts of the cast, because here they are weakest.

LONG LEG WALKING CAST

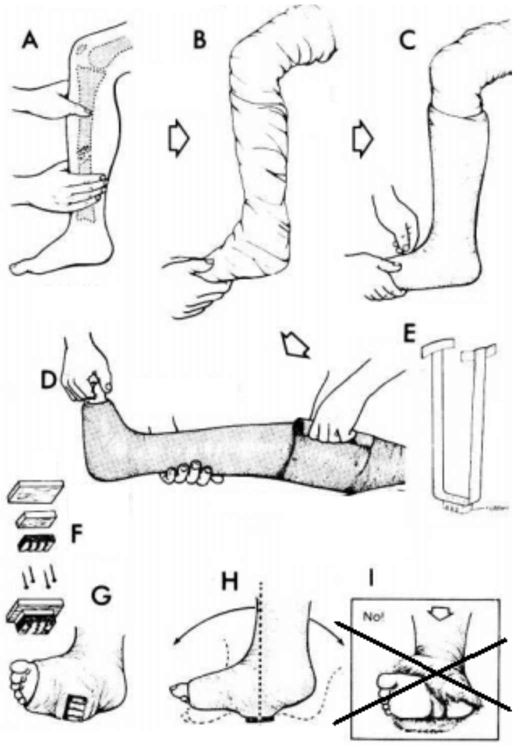


Fig. 70-4 A LONG LEG WALKING CAST. A, the leg must hang down so that you can align the fragments more easily. B, apply the padding. C, apply the distal part of the cast. D, the distal part of the cast is now firm; complete the upper part. E, a stirrup fitted to the walking heel. F, parts to make up the heel. G, a locally made walking heel. H, the walking heel correctly aligned with the tibia. I, the result of walking on a plaster without a heel. *Kindly contributed by John Stewart.*

SPLITTING A CAST

If the fracture is very recent, split the cast from top to bottom 2h after applying it (59.2). Meanwhile monitor the circulation in the feet. *Don't split it immediately*, because the junction of the top to bottom parts of the cast take 2h to become sufficiently firm to split. *Don't forget also to split the padding!*

After 2wks of calcaneal traction, any swelling will have subsided, so there is less need to split the cast. *Don't worry about a slight angulation in a recent fracture*. If necessary, correct this 2-3wks later, when the healing bone at the fracture site is still soft, but more stable. Either wedge the cast (59.2) or, preferably, replace it by another one with the leg in a better position. Replacing a cast is safer and less likely to cause pressure sores than wedging.

CAUTION!

(1) Ensure that there is no weight-bearing until the cast is dry and hard. This may take >24h in wet weather. *Walking on a soft cast will soon make it useless.*

(2) Even if you split the cast, further swelling may still produce a compartment syndrome or pressure sore. Inappropriate, increasing pain, or loss of sensation in the toes are indications to remove or change the cast. *It is best to observe a patient for 24h after applying a cast*.

(3) *Be sure to tighten or renew the cast if the leg becomes loose within it*. If you fail to do this, the fragments may displace.

CLOSING A CAST

After splitting a cast and letting the swelling disappear, close it with a few turns of plaster bandage. If it is still loose, remove a small strip of plaster from its anterior border, and close it with a few turns of plaster bandage. This is easily done with electric plaster shears.

FITTING A STIRRUP OR A WALKING HEEL

A metal stirrup or a walking heel is necessary when a patient starts to bear weight (70-4E-G)

ALTERNATIVELY:

(1) Start the cast by applying medial and lateral slabs, or a posterior slab only. This will make a smoother cast.

(2) Incorporate strips of bamboo in the cast, particularly across fracture lines and joints. This is a considerable economy in plaster.

DIFFICULTIES WITH LONG LEG CASTS

If the ankle swells when the cast is removed, treat it by elevating the leg, encouraging exercises, and compressing the swelling with a crepe bandage. Swelling is very common, but soon improves.

A stiff knee is usually the result of leaving a cast on too long.

DON'T LET A PATIENT WALK HOME IN A WET CAST

SHORT LEG WALKING CAST

For mid-shaft and more distal tibial fractures you can use a shorter cast, the patellar tendon-bearing (PTB) cast as described by Sarmiento.

Either just shorten a long leg walking cast to a short leg walking cast once the fracture is sticky (approximately after 6wks), or remove the old cast and apply a new one.

For more stable fractures, apply this cast even earlier than 6wks. For undisplaced tibial shaft fractures without significant swelling you may even use it as the initial cast. The application of such a cast requires considerable experience, especially its moulding in the infrapatellar region.

SARMIENTO TYPE SHORT LEG WALKING CAST

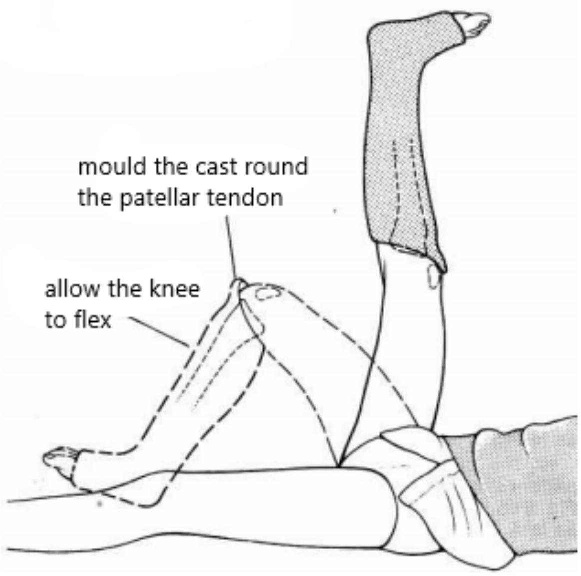


Fig. 70-5 SARMIENTO TYPE SHORT LEG WALKING CAST. Apply this with the knee flexed to 90°. It has an oblique upper edge, and is moulded by triangular compression (70-6)**.**

An advantage of a short cast is that it allows earlier movement of the knee. If you fit a gaiter this allows earlier ankle movements. Of course, a short cast uses less plaster than a long one.

As with a long leg cast, prevent the fragments from rotating. Achieve this in one of 3 ways:

(1) Mould the cast carefully to the upper leg, using Sarmiento's total contact method of triangular compression, as described below.

(2) Pass a Steinmann pin through the proximal end of the tibia and incorporate it into the cast. This is the more certain method, and is necessary if there is also a femoral fracture in the same leg (58.13).

(3) Using an X-fix.

To apply the Sarmiento cast, have the patient sitting on the edge of a table. Steady the lower leg and apply stocking and padding above the knee. Protect all bony prominences by extra padding.

Apply the cast from just proximal to the toes to as high as possible in the popliteal fossa with the knee flexed at 90°. Bring the cast to above the knee and trim it later to above the patella in front and below the popliteal fossa at the back, so that it has an oblique upper end (70-5).

As the cast hardens, apply compression between the upper calf and the anterior surface of the leg (70-6). This will give the cast a triangular cross-section, which is flat posteriorly, and moulded to match the prominent tibial tubercle (70-6A), and help prevent rotation. This moulding forces the cast away from the fibular head and peroneal nerve, helping to avoid local pressure there.

TRIANGULAR COMPRESSION OF A SARMIENTO CAST

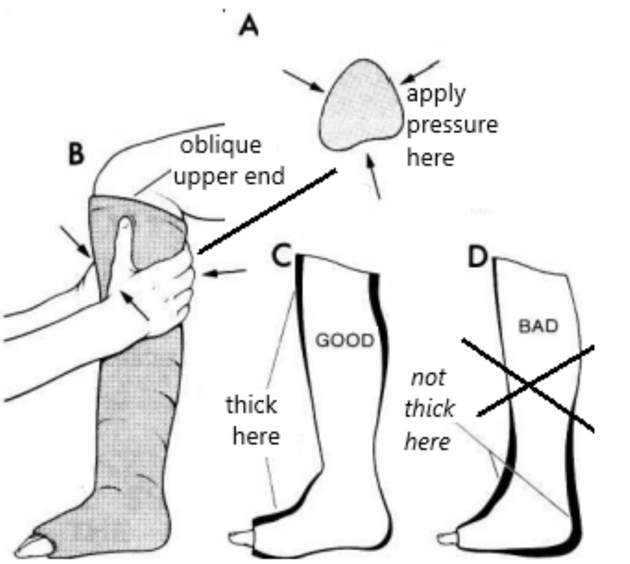


Fig. 70-6 TRIANGULAR COMPRESSION OF A SARMIENTO CAST. A, B hold the knee flexed, while the short leg cast is setting, compress its upper end to mould it to the leg. C, where the PoP should be thick. D, *where it should not!* *After Sarmiento A. Closed Functional Treatment of Fractures. Springer 1981.*

CAUTION! (1) Triangular compression is safe in a short leg cast where muscular activity can relieve excessive pressure. But, *don't apply it in a long leg cast*, as pressure necrosis may occur.
(2) *Don't try to economize by cutting off a long leg cast below the knee:* it will always be loose and render the leg unstable.

Once firm, trim the proximal margin of the cast circumferentially from the proximal pole of the patella to the proximal part of the calf. Note that the posterior trim line is thus more distal than the anterior edge of the cast, since you must position it just below the popliteal flexion crease. *Make sure that the knee is extended, and that it can flex to 90^{o}*. Pad the cast edges by turning down the padding and stocking to provide cushioning. Secure the stocking to the outside of the cast with a little additional plaster.

A PLASTER GAITER
The success of functional bracing depends on the fact that total immobilization of the joints above and below a fracture is not necessary for fracture healing and maintaining alignment. Controlled motion allowed by the brace at the fracture site is conducive to osteogenesis.

This is the simplest and lightest leg cast; it is the easiest to walk with, but also the least stable and secure. Use it for protecting fractures of the middle tibial ⅓, *after union has taken place.*

A PLASTER GAITER

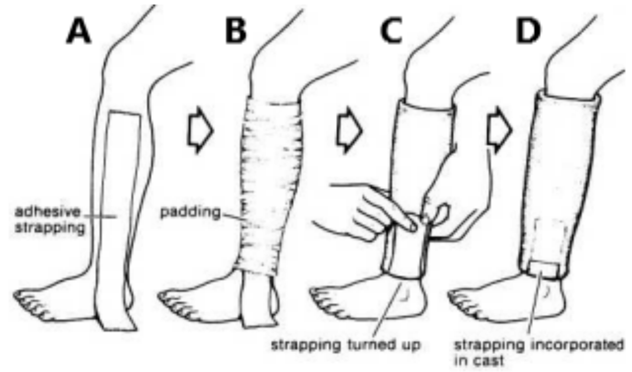


Fig. 70-7 MAKING A PLASTER GAITER. Use this for protecting fractures of the middle tibial ⅓ as it heals. *Kindly contributed by Peter Bewes.*

It does not provide enough stability for fractures of the proximal or distal ⅓. If you apply it immediately after removing a long leg cast, the foot and ankle will swell immediately. There exists a manufactured brace made of plastic and velcro fastener, which is more expensive than making one yourself from plaster.

Apply pieces of adhesive strapping to either side of the leg (70-7A), as if you were going to apply skin traction. Pad the leg and especially the Achilles tendon (70-7B). Then apply the cast. As you apply the last layer of plaster bandage, fold up the 2 pieces of strapping (70-7C) and incorporate them in the cast (70-7D). They will stop it slipping down the leg and rubbing against the top of the foot.
As the cast sets, mould it around the expanding upper and lower ends of the tibia, so that it grips them firmly. The knee, foot, and ankle should be free.

STEINMANN PINS INCORPORATED IN THE PLASTER
Fix pins passed through the proximal & distal tibia into the cast to aid reduction prevent displacement. Insert the pin from lateral to medial through the middle of the tibia anterior to the fibula in the frontal plane, so that it emerges medially through the subcutaneous surface of the tibia. Apply some antibacterial ointment, such as iodine and a sterile dressing over the pin site.

N.B. Use the transfixion pins as reduction aids. Apply traction, rotation, or angulation to the pins to correct deformities. Do this before fixing them in PoP.

Then, when you have held the fracture reduced, apply the PoP incorporating the pins.

CAUTION! This technique is hugely inferior to external fixation: pin track infection is common. *Use it only if external fixation is not available.* However, it is indicated in unstable, oblique, and comminuted fractures, where stable apposition at the fracture site is impossible, or when there is a simultaneous femoral or ankle fracture (70.7).

Apply the cast by rolling the PoP smoothly up, incorporating the pin on each side with a thick 2cm cuff of PoP around each pin. *Be careful not to pull the plaster tightly from one end of the pin to the other*, since there should be no extra pressure on the skin. Cut off excessive pin length with a pin cutter, but fix at least 2cm of pin into the plaster, both medially and laterally.
Once hardened, the cast functions as the frame of an external fixator, using the transfixion pins to maintain fracture alignment.

GET THE PATIENT WALKING EARLY WITH A CAST

DON'T REMOVE A CAST UNTIL THE PATIENT IS WALKING PAINLESSLY WITHOUT A STICK

DON'T LET A PATIENT WALK ABOUT IN A LOOSE CAST

70.3 Isolated closed tibial shaft fracture

Usually, 4 kinds of injury can break the tibia without breaking the fibula:
(1) If the leg is struck from the side, it may break transversely or obliquely, leaving the fibula intact, and thus splinting the fragments, so that they shift only very little.
(2) A combination of compression and twisting can cause a long spiral oblique fracture with almost no displacement, and very little soft tissue injury. These fractures usually heal fast.
(3) A gunshot to the tibia. The healing depends on the soft tissue and bone loss.
(4) Isolated tibial fractures in the osteoporotic elderly, usually due to simple traumatic torsion.

REDUCTION
If fragments are significantly displaced, reduce them.
If the fibula splints the tibial fragments apart, remove a segment of fibula by an osteotomy.

Apply a long leg cast or medial and lateral splints, held with a crepe bandage until the acute swelling has subsided. Close the cast, fit a walking heel, get the patient up as soon as he can bear weight with crutches, making him bear weight on the leg.

If there is a long, spiral oblique fracture, discard the long leg walking cast after c.6wks, and apply a protective gaiter for another 2wks. These fractures usually heal fast. *Make sure the fragments are not kept apart.*

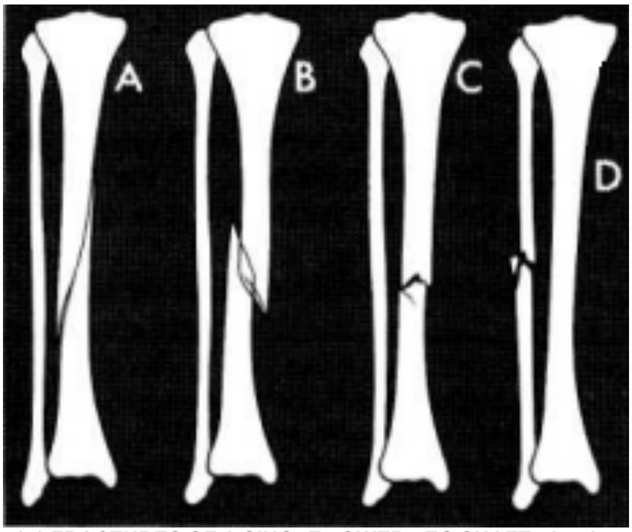
If there is a transverse fracture, it will probably take 3-4months to heal. It will heal sooner if the fragments are nicely impacted and weight bearing starts immediately. *Make sure no butterfly fragment or spike* (70-9D,E) *holds the bone fragments apart.*

If the fracture is in the middle tibial ⅓ *and union is present,* fit a Sarmiento brace.

If the fracture is elsewhere, fit a short leg walking cast. Continue protection until there is no pain on springing the tibia and fibula together. As soon as the tibia is solid and no longer springy, remove the cast or gaiter.

If the patient has a short oblique fracture, expect it to heal more slowly owing to the shearing stress. Apply a long leg cast for 2months, and test for clinical union (58.7). If then radiographic and clinical union *is not* present, apply a close fitting short leg cast (70-5) for another 6wks. But if clinical union *is* present and the fracture is in the mid-shaft, apply a Sarmiento brace.

FRACTURES OF A SINGLE LOWER LEG SHAFT



70-8 FRACTURES OF A SINGLE LOWER LEG SHAFT. A, a long spiral oblique fracture heals readily. B, a short oblique fracture takes longest to heal. C, a transverse fracture. D, a single fibular fracture.

70.4 Tibial stress fracture

If bones are repeatedly stressed without adequate training, they may break as `fatigue' or 'stress' fractures. This can happen when an athlete starts training too hard after a break, when a raw recruit starts marching extensively, or when an invalid gets out of bed.

Fatigue fractures start without any history of injury as microscopic lesions which steadily progress. The tibial diaphysis is the commonest reported location and comprises up to 75% of all stress fractures. Anterior tibial fractures are less common but more problematic than postero-medial fractures.

The first symptoms are bone pain at night after use. The callus that forms presents as a tender bony lump and the fracture may not be visible on radiographs for 5wks, or may even remain completely invisible. The only signs may be slight periosteal elevation and increased density of the cancellous bone. The danger of these fractures is that you can mistake them for tumours.
In general, management includes rest and immobilization, for example by the protection of a plaster gaiter for the tibia. If the fractures don't heal by 6-9months, compression plating or intramedullary nailing might be needed.

70.5 Closed fibular shaft fracture

A force applied to the outer side of the leg can break the fibula transversely anywhere. The tibia remains intact, so that there is either no displacement, or only a little shift sideways. The patient is usually able to stand. The muscles of the leg cover the fracture, so you need radiographs to confirm the diagnosis.

Reduction, splinting, and protection are unnecessary. Provided that the ankle joint is normal, encourage walking as soon as any soft tissue injury allows.

N.B. Rule out a Maisonneuve fracture, which can cause much disability if wrongly treated (71.6). It usually presents as a spiral fracture in the proximal fibula with a severe ankle injury.

70.6 Closed tibial & fibular fracture

These fractures are usually less stable. By twisting the leg, both bones break obliquely, commonly in the lower ⅓ of the leg. Alternatively, a high energy injury impact, *e.g.* from a motorcycle accident or a fall from a great height causes the fragments to shift laterally, overlap, or rotate.

Treatment depends on whether or not there is shortening. A week of calcaneal traction will reduce significant shortening (70.7). Admit the patient, who needs close observation, because the leg may swell severely and may develop a compartment syndrome (49.6).

WHERE THERE IS NO SIGNIFICANT SHORTENING
If there is swelling or signs of threatened ischaemia, maintain the position of the fragments by applying either medial and lateral slabs from the foot to the groin held on with crepe bandages, or a temporary long leg cast split to allow swelling.

When the swelling has subsided, apply a long leg walking cast (70.2), or close the split in the cast he already has.

If the fracture is oblique, *take care to correct rotation*.
Then continue weight bearing on crutches. Review the patient and X-ray the fracture regularly. Wedge (59.3) and replace the cast as necessary. A closed transverse fracture should unite in 3-4months. The last 2months can be in a short leg cast, especially if it is a total contact cast of the Sarmiento type (70.2).

If there is significant shortening, there is probably an oblique, spiral or comminuted fracture. Under ketamine, apply medial and lateral slabs as above. Pass a Steinmann pin through the calcaneum (59.4) and rotate the leg to correct any rotation.

Apply 5kg traction, raising the foot 25cm off the bed as counterbalance. Put a pillow longitudinally under the leg, which will hold the knee in a comfortable semi-flexed position and prevent the heel from pressing uncomfortably on the bed.

Leave the leg in traction for 1wk while treating its soft tissue. Encourage movement of the toes, the ankle, and the knee. This period of traction will allow the soft tissues to heal.

After 1wk, remove the pin, apply a long leg cast, and encourage walking. Leave the cast on for at least 8wks. Then remove it and examine the leg for signs of clinical union (58.7)

If the fracture is uniting and barely springy, apply a close fitting short leg cast for 6-8 more weeks. Encourage the patient to walk normally.

If the fracture has not united, reapply a long leg cast and continue weight bearing for another 5wks, then apply a short leg cast.

70.7 Open tibial & fibular fracture.

Familiarise yourself with the general principles of open fracture treatment & external fixation (58.12)

The tibia and fibula are the commonest sites of open fractures in men, and one of the more unfortunate results of a traffic accident, particularly a motorcycle accident. They vary from a minor cut over a broken bone to the grossest mutilation and displacement of the bony fragments. This is worst when the wheel of a car has run over the leg, squashed the muscles, and torn the skin from the underlying fascia over a wide area (46.4), or because of a gunshot injury (46.8).

The fracture may be transverse oblique, or comminuted.

Open tibial fractures are dangerous because:
(1) They are often infected and, may be fatal if necrotizing fasciitis or gas gangrene develop (58.15).
(2) They are often transverse and pieces of bone may be lost, so that great care has to be taken to make the bones unite.
(3) If treatment is prolonged, victims may become demoralized or may lose their job owing to a long absence from work.
(4) Serious complications may occur later, including a stiff ankle or foot drop.

Owing to the high risk of complications, conservative methods are most likely to get good results in most cases. Several factors are important, though:
(1) Aggressive and repeated debridement of all devitalized tissue, including fragments of bone.
(2) Stabilization with as little additional devascularization as possible. (Vascular soft tissue and bone are essential for resisting infection and providing a bed for reconstruction.)
(3) Leaving the wound open and repeated debridement as necessary until closure at 5-7days by delayed primary closure, skin grafting, or local flaps.
(4) Antibiotic & tetanus prophylaxis.

Management of the soft tissue is the most important factor in determining the outcome of open tibial fractures. An external fixator is of great help; temporary calcaneal traction or a cast with a window are alternatives. As soon as the wound is healing, apply a long leg cast and encourage walking. *The secret of success is early weight-bearing while the leg is still in a cast, even while the skin wound is still incompletely healed.*

N.B. Many severe injuries heal dramatically; even some which might at first seem to need a bone graft.

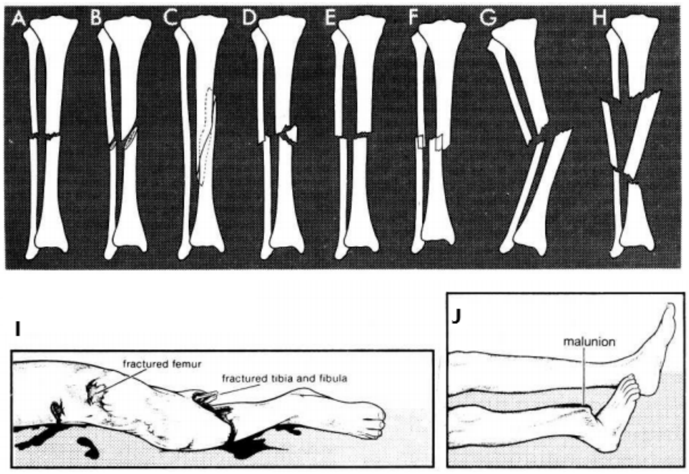
TREATMENT
Minimize the delay between injury and formal debridement under ketamine in the operation theatre, especially if you suspect a major vascular injury.

Reduce the fracture as best as you can immediately after the wound toilet is complete, and while the patient is still anaesthetized.

Bringing the fragments into contact with one another is more important than correcting angulation, because you can correct this later while the bone ends are still sticky. If the fracture is transverse, try to get as much as possible of the diameters of the fragments to touch one another. Even if they only touch over part of their circumference, this will be useful. Bringing them into contact may be difficult if there is soft tissue interposed. *Don't leave the bones overlapped* (70-9F).

A THOROUGH WOUND TOILET IS CRITICAL

TIBIAL & FIBULAR FRACTURES



70-9 TIBIA & FIBULA FRACTURES. A, transverse, B, oblique C, spiral. D, transverse fragment with a triangular butterfly fragment. E, a transverse separated & F, overlapping; *never leave fractures like this*. G, angulated fractures. H, double fractures of both bones. I, open fractures of femur, tibia & fibula in the same leg. J, malunion because a severely angulated fracture was not adequately reduced & held.

If reducing overlap is difficult, insert a periosteal elevator or some other suitable instrument between the bone ends and lever them into position.
If you cannot get enough traction on the foot to reduce the fragments, insert a Steinmann pin temporarily into the calcaneus and exert traction on this. Do this now while the patient is still in the theatre. If you cannot reduce the fracture at all, *e.g.* because the fracture is some days old, you can carefully shorten the tibia until reduction is possible.

N.B. In a transverse fracture avoid any end to end distraction, no matter how slight; it is the great enemy of union.

If the fracture is oblique or comminuted, calcaneal traction is particularly useful. You may be unable to prevent a mild overlap. Some separation of the fragments is inevitable, but they will unite slowly.

N.B. Beware of the butterfly fragment (which readily becomes ischaemic) *and will then act to keep the tibial bone fragments apart.*

If a pointed fragment of bone is protruding through the skin and you cannot readily reduce it, nibble it away.
Dress the wound, then either splint the leg with a padded backslab or medial and lateral slabs held together with crepe bandages, or apply an external fixator as temporary or definitive fracture stabilization.

LEAVE A WOUND UNSUTURED UNTIL THE DANGER OF INFECTION IS OVER, ESPECIALLY GUNSHOUT WOUNDS

CLOSURE
After 3-5days, open up the dressings and look at the wound.

If the wound looks clean and you can close it without tension, perform a delayed primary suture.

If the wound looks clean but you cannot close it without tension, apply a split skin graft if there is an adequate wound bed (50.12). You may need to repeat the dressing change on 8th and if necessary again on the 13th day. *Don't try grafting until there are good granulations*. *Don't allow weight-bearing until the graft has taken*.

If there is exposed bone in a rather small wound but you cannot close it without tension, apply a simple fascio-cutaneous flap (46.5). *Don't leave the fracture exposed too long, waiting for secondary healing*. The risk of infection is very high.

If there is exposed bone and you cannot close it with a simple fascio-cutaneous flap, use a pedicled or a muscle flap. The medial gastrocnemius flap (46.5) is very reliable, especially for wounds in the upper tibial ⅓.

N.B. Don't wait for a secondary healing as the fracture site is likely to get infected.

-

If the wound is still very dirty, toilet it again surgically in theatre.

N.B. The wound should be clean after the first debridement, and if it is not, your first debridement was probably not adequate.

DEFINITIVE TREATMENT
When the wound is for the most part closed either by skin suture or by a skin graft or flap, fit a long leg walking cast (70.2). Provided the swelling has subsided, there is no need to split the cast. Even so, monitor the circulation in the foot carefully.

Put a dressing over the wound if necessary, but preferably *don't cut a window in the cast* because it increases the risk of loosening (59.3). Inspect the wound again when the cast needs changing.

N.B. ***If the wound is still septic****, an X-Fix is best.*

Apply the cast with the ankle in 10° dorsiflexion, unless this position causes posterior angulation of the bone fragments (70-10A), as it may do in a lower third fracture when a piece of the tibia is comminuted anteriorly.

If dorsiflexion does cause posterior angulation, leave the foot in *equinus*, but fit a stirrup (70-12), or a high enough walking heel (70-4G). Make the cast strong enough to last 6-8wks. Elevate the leg for 12h after fitting the cast. Put a heel raise in the opposite shoe.

The next day allow the patient to put the cast on the floor. Provide crutches and encourage walking on the broken leg within the cast, bearing as much weight as is tolerated. Allow gradual increase in weight bearing, but *don't push this to the point of pain*. Even if there is crepitus or a sensation that the fragments are moving, encourage perseverance. Explain that such movement helps the bones to unite.

EARLY WEIGHT BEARING IS ESSENTIAL

N.B. Early walking is critical to the success of conservative treatment.

Early on, when the patient is not actually walking around, advise elevation of the leg to minimize swelling and make it more comfortable.

When full weight-bearing on the injured leg, exchange the crutches for a stick. Most patients reach full weight bearing in a few weeks, some even within a few days. When walking well, you can allow discharge, but review in 3wks. Make sure proper walking is possible and the plaster is still in good condition. Remember that a perfectly moulded cast is essential for this method. *This is your responsibility.*

ANGULATION
If the fracture is angulated >5° in any direction, correct it by renewing the plaster or, less safely, if plaster bandages are scarce, by careful wedging (59.3). *Don't do this immediately*. The best time is usually at 3-4wks, in an adult. Be sure you do it while the patient's bone ends are still sticky, before they have united.

Use an opening wedge a little above the fracture, so that pressure does not increase over it. If the leg is angulated in two planes, you may be able to control it with 1 wedge, but you may need 2. *This may make the cast look ugly*, but it will improve the final look and function of the leg!

N.B. Don't try to wedge a cast more than once; change it, as the risk of pressure sores is too high.

DRESSINGS
Change any dressings when you change the cast. This is more effective than repeatedly changing them through a window.

N.B. Infected wounds always need a thorough debridement.

If the cast is snug and comfortable, leave it for 5-8wks. Change it earlier if it becomes loose or uncomfortable, because reduction is easily lost inside a loose cast. If plaster bandages are scarce, cut a longitudinal strip out of a loose cast and close it up. Change the cast if pus or blood soaks through excessively or if it stinks unbearably.

N.B. You need to put 3-15 casts, on average 6.

CLINICAL UNION
At 5-8wks, remove the cast and examine the fracture for signs of clinical union (58.7). If you are in doubt, get a radiograph and renew the cast.
Don't discard a full length cast until:
(1) the patient can walk without crutches,
(2) there are signs of clinical union.

Don't leave a long leg cast on too long because it will prevent the patient from bending the knee and make it stiff. Fit a short leg cast as early as possible.
Spiral or transverse fractures reach clinical union more quickly, usually at c.12wks, especially if weight bearing starts early. A short oblique fracture usually takes 12-16wks to unite, but it may occasionally take a year or more, especially in the lower third of the leg where there is a high risk for delayed union, *and particularly if you unwisely treated it in prolonged traction!*
As soon as there is good clinical union, fit a shorter cast. If the middle ⅓ tibial fracture tibia is firm, use a well-padded plaster gaiter or Sarmiento total contact cast (70.2), because these fractures need less protection. If the fracture is anywhere else in the tibia, apply a Sarmiento cast which includes the foot. Keep encouraging walking and gradually increase the range of activities.
N.B. Pain and tenderness over a fracture site are signs that clinical union is not yet complete, so continue to protect the fracture in a short leg cast.

CONTROLLING ROTATION
A long leg cast is quite heavy, and because it prevents flexion of the knee, turning in bed is difficult; this makes nursing care arduous.

In elderly patients, or where there is a simultaneous femoral or malleolar fracture, apply a short leg walking cast and prevent rotation by incorporating a Steinmann pin. Insert the pin *obliquely* 1.5-2cm distal to the tibial tuberosity (59.2). Make sure the cast allows bending of the knee. *Don't allow weight-bearing on the cast while the pin is inside*, because it may break. Remove it as soon as the fracture becomes sticky, and then allow weight-bearing.

PROVISIONAL TRACTION
Where you cannot restore alignment because of gross comminution of fragments, insert a calcaneal pin under LA into the calcaneus 2cm below and 2cm behind the medial malleolus. Apply 3-7kg traction straight on the bed raising the foot of the bed 25cm, or use a Böhler-Braun frame which provides counter-traction.

Don't use this >2wks. Encourage exercising the foot while on traction; this will reduce oedema and minimize stiffness.
When the fragments have become sticky enough to stay in place on their own and the wound is healing, remove the traction, allow the leg to shorten (if it must) to a stable position, and apply a long leg cast.

N.B. (1) *Don't apply so much weight as to produce distraction at the fracture site* or endanger the blood supply of the leg.
(2) *Don't apply traction to a cast unless there is a pin in the tibia incorporated in it*, because it is almost certain to cause sloughing on the skin on the dorsum of the foot.

BRAUN-BÖHLER FRAME

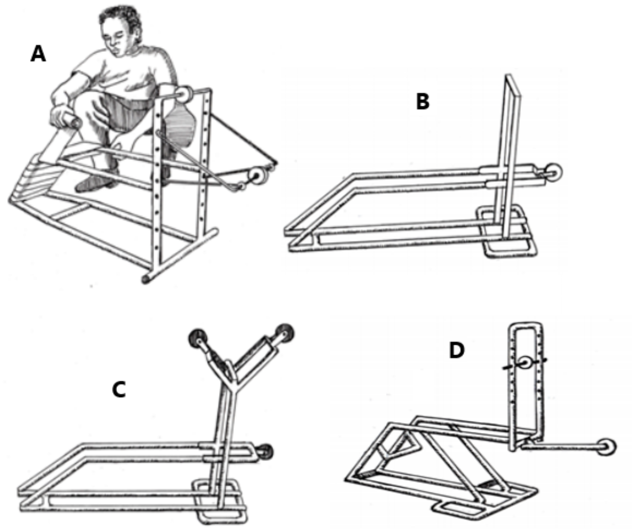


Fig. 70-10 BÖHLER-BRAUN FRAME TYPES. A, putting strapping over the bars to give limb support.

If there is a severe soft tissue injury and you don't have an X-fix system at your disposal, you can apply 2 Steinmann pins, one well above and one well below the fracture. Incorporate them in a cast, if necessary with a window. Get the patient walking soon, if the comminution is not too severe. Later, you may be able to remove the bottom pin and mould the cast around the ankle.

This will minimize shortening, but union may be slower

EXTERNAL FIXATION (GRADE 3.2)
The adaptability of external fixation makes it a veritable workhorse for the care of complex, severe tibial shaft fractures. It provides stability, easy access to the soft tissues and alignment of the fracture; it protects neurovascular structures, maintains limb length, and, in comparison to longitudinal traction, can reduce the risk of infection and non-union.

The X-fix can span the knee or the ankle for trans-articular fixation. For very distal tibial fractures, fixation should span from the proximal tibial fragment across the ankle joint to the foot. Construct a delta frame between the tibial shaft above the fracture and the foot. You need a calcaneal pin as well as one or more pins in the metatarsals to triangulate the frame and prevent the distal tibia and foot from slipping forward or backward off the plane of the proximal tibia.

Definitive treatment of the bone injury continues in a cast usually with weight bearing. If you already see some callus formation, apply a short leg walking cast. If the wound is healed but no stable callus has yet formed, it is better to apply a long leg walking cast.

MODULAR & RIGID FIXATION

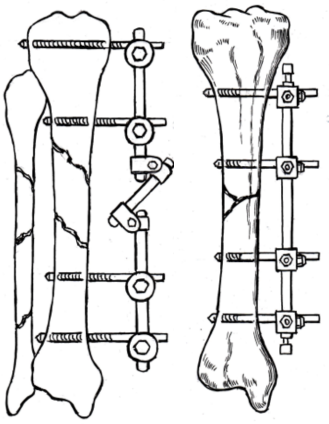


Fig. 70-11 MODULAR & RIGID FIXATION ***Remember to reduce the fracture properly before applying the fixator.*** *After Browner B, Levine A, Jupiter J, Trafton P, Krettek C. Skeletal Trauma, Elsevier 4th ed, 2019.*

In view of the importance of early motion, apply a stiffer frame to protect the fracture site during healing. Stiffer fixation, however, tends to suppress callus formation, which might prolong the need for external fixation or even lead to non-union.

When you use external fixation for definitive treatment of a fracture, it may be useful to do this with a uniplanar fixator (70-12). It requires anatomical reduction and precise application.

The advantage is that you need fewer clamps and rods than in the application of a modular external fixator and that it provides also more stability. The disadvantage, however, is that you cannot correct the reduction after two pins are placed in each fragment.
In order to adjust the position, you have to exchange the single rod for a modular X-fix with multiple rods.

DYNAMISATION OF AN EXTERNAL FIXATOR
To facilitate or accelerate callus formation during external fixation, loosen the frame construction to allow limited motion at the fracture site. You can do this easily with a single rod X-fix (70-12). Simply unlock the clamps at either site of the fracture.

Pain-adapted partial weight bearing up to full weight bearing allows axial compression across the fracture site, which improves bone healing. *But be careful in oblique or spiral fractures.* Pin loosening is a common complication.

If there is no callus formation within a few weeks or even if you have a significant initial bone loss after the wound has healed, consider bone grafting.

TIBIAL ANATOMY

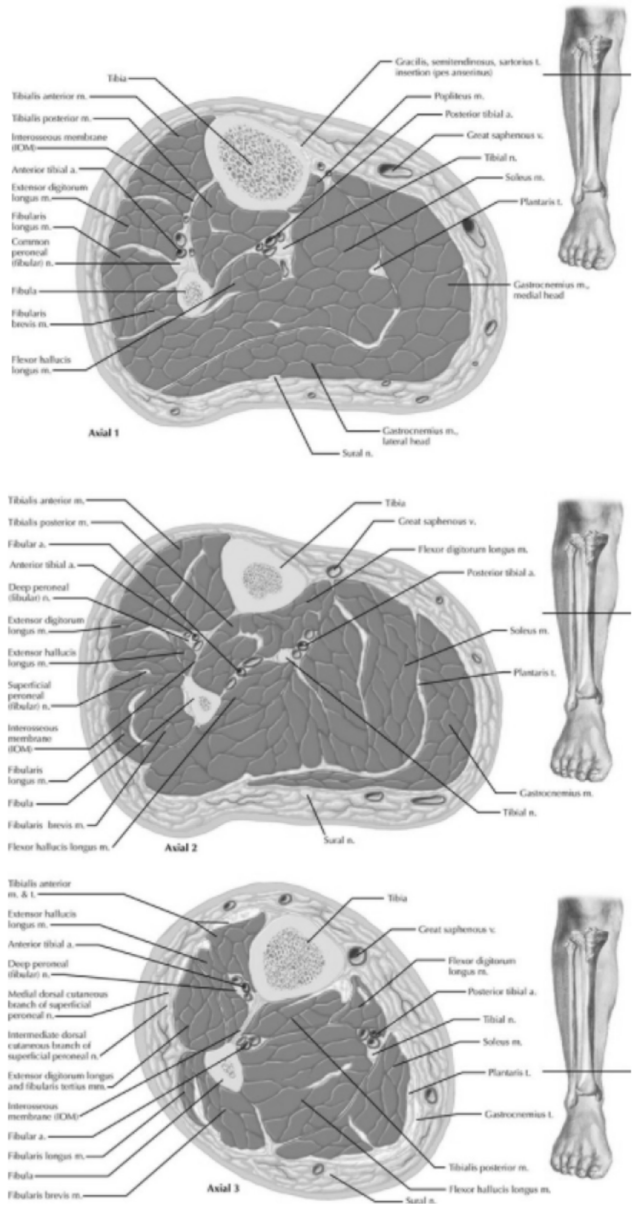


Fig. 70-12 TIBIAL ANATOMY. Cross-sections at different levels of the lower leg. The detail is to help you avoid important structures! *After Basicmedical Key ch. 42.*

If early fibular healing occurs, perform a partial fibulectomy to permit impaction of the tibial fragment. This you might achieve in a walking cast or a dynamized X-fix. Fracture healing should occur after 6-8months.

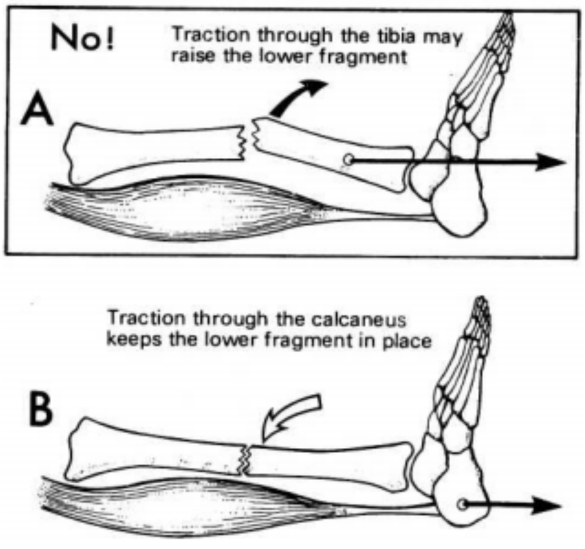
INDICATION FOR EXTERNAL FIXATION
(1) Rapid stabilization for associated vascular injury.
(2) Rapid stabilization in a multiple injured patient.
(3) Temporary support of severely injured soft tissue (*e.g.* compartment syndrome).
(4) Open fractures with the need for soft tissue reconstruction.
(5) Disaster or battlefield setting (gunshot wounds).
(6) In the management of fractures with significant bone loss by providing stabilization for autogenous bone grafting.

(7) Treatment of fracture site infection, typically after previous internal fixation or infection after an open fracture.
(8) Optionally, as definitive fracture fixation.

EXTERNAL FIXATOR REMOVAL
If you are not very experienced with X-fix and if you don't have portable X-ray machine, it's better to remove the X-fix once the soft tissue has healed, and follow on by a long or short leg walking cast. If a patient can bear significant weight across the fracture site without much local pain (though you should distinguish pin-site discomfort), this usually means the fracture is healing.

After frame removal, 30% of patients require additional casting for an average of 5months.
But if you wait with removing an X-fix until the tibial fracture is securely healed (look at the radiograph or palpate callus formation), you reduce the risk of late loss of alignment, shortening and impaired fracture healing significantly.

PROVISIONAL TRACTION FOR TIBIAL FRACTURES



70-13 TWO METHODS OF PROVISIONAL TRACTION FOR TIBIAL FRACTURES. A, traction through the lower tibia may pull the lower fragment out of the wound. B, traction through the calcaneus keeps the lower fragment in place, but if osteomyelitis occurs, it will be very troublesome. *After Charnley J, The Closed Treatment of Common Fractures. E&S Livingstone, Edinburgh 3rd ed.1961*

70.8 Difficulties with tibial fracture

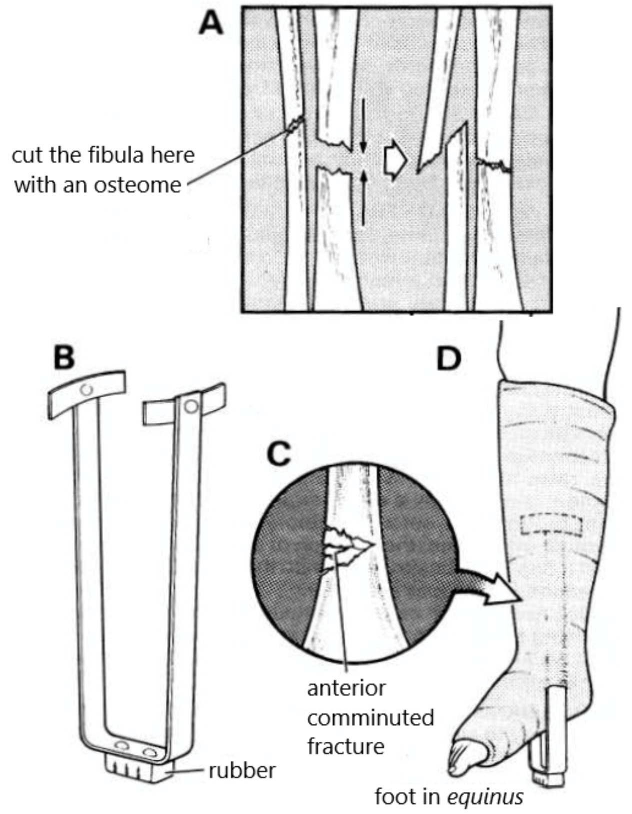
If the lower leg or foot is so severely injured that it seems completely shattered, preserve it if it still has a pulse and normal sensation. You can always amputate later, provided that you perform a thorough wound toilet and avoid the danger of gas gangrene. Stabilize and raise the leg, while resuscitating the patient. Even the severest bony injury is never by itself an indication for immediate amputation (60.2).

If a piece of the tibia is missing, treatment depends on how much is missing, and where. Try to make the broken ends of the tibia impact. *Making the bone fragments touch is more important than maintaining length.*

If a small piece of tibia is missing, it will probably heal adequately. Your goal is just to achieve a closed wound and proper stabilization.

If the tibia is intact posteriorly, but a bigger piece of tibia is missing anteriorly, the lower fragment is in danger of bending forward. Prevent forward angulation by putting the foot into plaster in *equinus*, (70-16), until the comminuted area has stabilized. Fit a metal stirrup instead of a walking heel.
This will enable walking on the injured leg, even though the ankle is in *equinus*. As soon as the fracture is stable, put the foot back in a neutral position.

A PIECE OF TIBIA MISSING



70-14 A PIECE OF TIBIA IS MISSING. A, if a piece of the tibia is missing anteriorly, the fibula will probably be broken also, so you can let the fragments of the fibula override one another and push those of the tibia together. If the fibula is intact, cut it. B, C, and D, if the tibia is comminuted anteriorly, fit him with a stirrup with the foot in the *equinus* position. If you don't have a stirrup, fit a wooden block under the heel. *Kindly contributed by John Stewart.*

BRING THE ENDS OF THE TIBIA TOGETHER

This is crucial, because with a fixed *equinus* foot, there might be even more problems with walking than with a non-union of the tibia.

If <3cm of tibia is missing, wait for the wound to heal and for the skin to become clean. If the fibula has not already been broken by the injury, make a separate lateral incision far enough above or below the tibial fracture to leave some stability at the fracture site. Cut the fibula obliquely with a sharp osteotome. Push the ends of the tibia together, so that the fragments of the fibula overlap. If absolutely necessary, you can remove a piece of fibula. Apply a long leg cast and commence walking and weight bearing as soon as possible. The tibia will unite, but it will take several months. If necessary, raise the shoe to compensate for shortening.

If >3cm of tibia is missing, apply calcaneal traction or an external fixator, but *don't try to maintain its full length*. Traction or external fixation will stabilize the leg and make wound toilet easier. If referral is impossible, you will have to treat as indicated above; here, *you cannot prevent shortening* but can handle it with raised shoes.

N.B. Remember that a shortened but stable leg is less disabling than a painful, non-united leg.

If pus gathers in the wound, it fails to heel, and the tibia fails to unite, open the wound widely so that it can drain. Remember that wounds drain by gravity or suction; if possible, open the bottom of a pus pocket. Infection may have been caused by a late presentation and treatment of an open fracture or by your initial inadequate wound toilet. Continue irrigating and toileting the infected wound as necessary.
You must stabilize the fracture temporarily by a cast, an X-fix or calcaneal traction. Stabilization is key in treating infected fractures. As soon as it is reasonably clean, apply a long leg cast and start walking.

If you suspect acute osteomyelitis, X-ray the fracture. If there are signs of periosteal elevation (7.3), under GA in theatre, remove all pieces of dead bone, irrigate the wound, and provide drainage. If the tibial fracture has already healed and is stable, you won't have to worry too much. Your main goal in such cases is to treat the wound.

If there is dead bone at the bottom of an infected wound (70-16B), take the patient to theatre, and under GA, use a bone gauge or chisel and hammer to remove any dead bone until you get to healthy, bleeding bone. *Dead bone looks white, does not become pink and is not bleeding*; make sure you remove any exposed bone. Later, when granulations have appeared, graft the wound (46.5).
However, *don't remove too much bone*, or you will weaken the tibia. Removing it to a depth of 1-2mm is usually enough.

If the wound does not heal and there is a chronic discharge from the bone, advise the patient to irrigate the wound daily with clear water followed by a thorough drying of the wound. *N.B. If there is metal inside the wound, it needs to come out!*

Patients with such a chronic osteomyelitis can live with these wounds for many decades. Sometimes they will heal spontaneously, even after some years. But advise your patient to seek immediate medical treatment if the leg becomes swollen and painful again, especially if combined with fever and general sickness. Chronic osteomyelitis can always develop into a severe acute osteomyelitis, which can threaten limb and even life (58.15).

If an acute osteomyelitis prevents the tibial fracture from uniting, it becomes more complicated. You need to remove all infected necrotic tissue, including the suspected infected bone, even if you have to shorten the tibia and fibula. If the patient is old or diabetic, consider an amputation. To achieve fracture healing, you need to remove bone until you see punctate bleeding from the bone (the 'paprika sign'). However, even if you have removed all necrotic tissue, the remaining bed of tissue may still be contaminated. Close the wound if clean, & drain it with suction drainage, stabilize it with a cast, and raise the leg on a Böhler-Braun frame. In bigger wounds, apply calcaneal traction or, better, stabilize the leg with an X-fix.

Continue regular dressing changes and irrigating the wound or surgical debridement until the wound is clean. Then close it as soon as possible without tension, if necessary with a local flap. Otherwise, get special help.

Later, if the wound is healing or already closed, reapply the cast, keep the patient walking, and change the cast only when it becomes soft or stinks excessively.

SKIN GRAFTING AN EXPOSED TIBIA

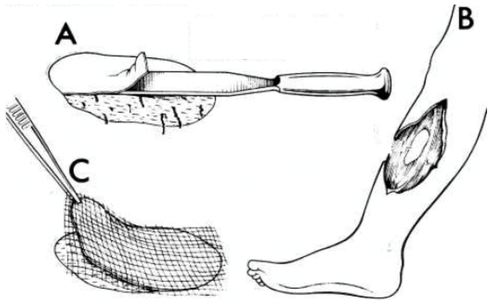


Fig. 70-15 SKIN GRAFTING AN EXPOSED TIBIA. A, chip away dead bone to get to healthy tissue. B, expose bone underlying an open fracture. C, graft healthy granulation tissue. *N.B.* If you are confident with a local fascio-cutaneous or a muscle flap, this would be the better option. *After London PS. Practical Guide to the care of the injured. E & S Livingstone 1967 with kind permission.*

If gas gangrene develops, immediate amputation may be necessary to save the patient's life (6.24). In order to prevent this disaster, make sure you: (1) explore and excise the wound properly, (2) open up all the fascial spaces where pressure could build up, & (3) lay the wound open without an encircling cast, after you have explored it, and administer the proper antibiotics.

If the tibia has not united after 4months, *don't be alarmed*. Fractures of the upper tibial ⅓ usually unite quite easily, but those of the lower ⅓, however, often don't. Some take 1 or even 2yrs. Give the fracture a further 6months to unite in a *well fitted* short leg walking cast. If there is no union in a year, bone grafting is probably necessary.

NON-UNION (58.7) may occur for different reasons. In the lower leg, specific problems are due to:
(1) Inadequate exercise of the broken leg.
(2) The fibula splinting the tibial fragments apart.
(3) Extensive injury of the tibia.
(4) Too large a gap between bony fragments.
(5) A bony spike holding fragments apart.
(6) A butterfly fragment preventing contact.
(7) Too rigid fixation, external or internal.
(8) Infection in the fracture site.
(9) Necrosis of a central segment of bone where there are 2 or more fractures.
(10) Excessive traction.
(11) Excessive wedging of the PoP.
(12) Inadequate immobilization in PoP.

If the ankle is immobilized in *equinus* without the application of a stirrup, putting the foot on the ground bends the callus around the fracture, thus causing hinging stresses which lead to healing with fibrous tissue, rather than with bone. So, either immoblize the ankle in neutral position or, if you have to immobilize it in *equinus*, fit a cast with a stirrup.

However, a non-union of the tibia does not automatically prevent walking! In case of a rigid non-union that may even be supported by a healed fibula, many patients can mobilize reasonably well. A stick to aid walking may be necessary, but as long as the non-union is rigid and mainly pain free, it is better to leave it alone. For further support to the lower leg, use an easily applicable gaiter/brace made either of leather or plastic.

If there is unbearable pain in the non-union site, it may well be infected.

MALUNION can take several forms:
(a) Shortening is usually minimal and unimportant (67.1). If the patient wears shoes, you can compensate for a loss of ≤4 cm by raising the heel of one of them while lowering the heel of the other.
(b) Angulation is serious and avoidable.

PREVENTION OF ANGULATION
(a) Align the fragments carefully to begin with.
(b) Wedge or change the cast early (70.7).
(c) Make sure that when weight bearing starts, it is in a cast which fully supports the fracture.

N.B. It is not the weight bearing that causes the malunion, it is improper casting. *Valgus* or *varus* malunion is more serious than backward or forward bowing, because there is no easy compensation.

(c) Rotation deformities in which the foot points inwards or outwards are also serious. Prevent them by making sure that the foot points in the same direction relative to the patella on the injured side as it does on the normal one (70-3). Inward rotation of the foot is more disturbing than outward rotation, because the feet can bump together when walking.

If the skin will not heal completely over the front of the tibia despite 1-2 skin grafts, leave the wound for the moment and continue walking in a cast. Remove the cast after 5-6wks and look at the wound: It will probably have healed.

If the foot swells with a cast *in situ*, admit the patient overnight. Keep the foot raised. The following day, *before you allow being out of bed,* apply a new cast which fits properly.

If the cast has been in place many weeks, the foot is sure to swell when it is removed. If necessary, compress it with an elastic bandage, elevate it at night, and advise continued exercises.

If the foot is stiff and painful after cast removal, there is unfortunately very little you can do. There is always some stiffness, especially after a fracture of the lower tibial ⅓, owing to scar tissue forming around the extensor tendons.

If there is a foot drop, the common peroneal nerve is injured, either (a) at the time of the accident, or (b) when inside a cast, especially if you did not pad it around the neck of the fibula, or (c) because of a compartment syndrome (49.6). Provide a brace to support walking and by keeping the foot in a neutral position. These are usually made out of plastic (48.1).

A MULTIFRAGMENTED INJURY HEALED

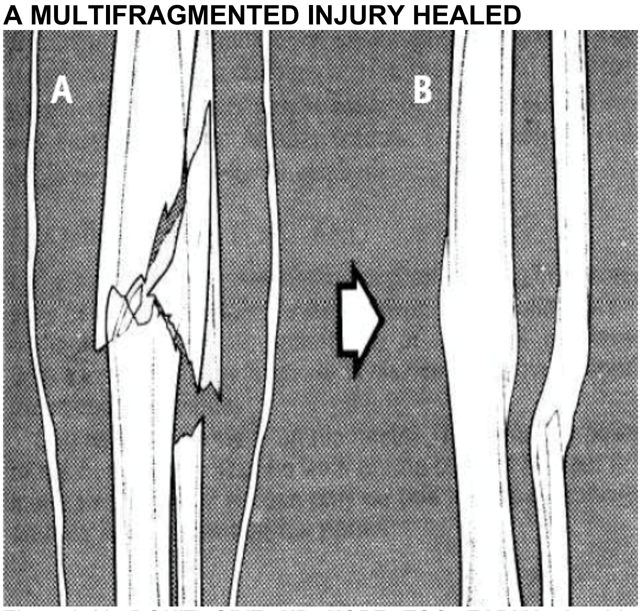


Fig. 70-16 *DON'T GIVE UP HOPE TOO EARLY*; A, this comminuted tibial fracture healed well after 28wks walking in a cast (B). *Kindly contributed by John Stewart*

71 Ankle injury

71.1 Introduction & examination

Ankle injuries are common and if mismanaged serious outcomes are frequent. (71-16) Injuries include minor sprains, disabling tears of the collateral ligaments, usually the lateral ones, serious malleolar fracture-dislocations, compression fractures of the lower tibial end or the talus and ruptures of the Achilles tendon.

EXAMINING THE FOOT AND ANKLE
Is this an acute or recent injury or a chronic condition?

LOOK for:
(1) loss of normal alignment with the leg,
(2) internal or external rotation, eversion, inversion or swelling,
(3) abnormal prominence of one malleolus,
(4) backward displaced or broad, heel,
(5) open wounds

FEEL for:
(1) unstable, painful movements,
(2) impaired sensitivity,
(3) absent pulses
(4) intact Achilles tendon
(5) site of maximal tenderness
(6) crepitus & integrity of the tarsus, metatarsals (especially the 5th), calcaneus, and tibia.

MOVE.
How far is flexion, extension, inversion & eversion possible.
Grasp the heel with one hand and the lower tibia with the other, and test side-to-side movement.

N.B. For a chronic condition**,** watch the patient walking, and note any limp, whether the heel & toes strike the ground normally. Examine the wear on the shoes and compare both sides. Is there recurrent pain and swelling after long walks? Do other joints cause similar problems?

RADIOGRAPHS
Decide if you want images of the ankle or the foot.
(a) For the ankle, obtain an AP view in 20°-25° of internal rotation to compensate for the external rotation of a normal ankle, (this gives you a clear view into the ankle mortise) and a true lateral view.

(b) If you think the collateral ligaments, especially the lateral, are damaged, obtain forced inversion views (talar tilt test) and measure the angle between the talar and tibial joint surface lines. *Don't attempt this by twisting only on the foot* but twist the heel.
(c) For the foot, obtain an AP, lateral, and oblique views.
(d) For the calcaneus, obtain a lateral and special axial view..

STANDARD & FORCED ANKLE VIEWS

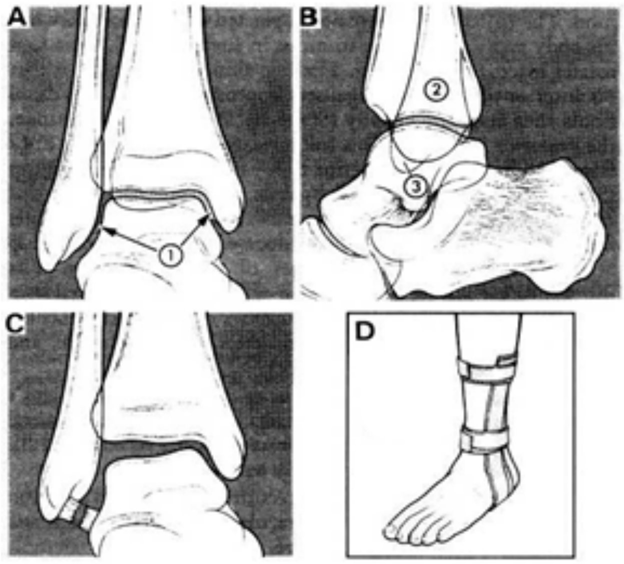


Fig. 71-1 STANDARD & FORCED INVERSION VIEWS. A, the joint space (1) between the talus and both malleoli should be simultaneously visible in the AP view, at 20° of internal rotation. B, the fibula (2) should lie just within the posterior border of the tibia (3) You should just be able to see the lower end of the fibula outlined against the talus. Note how smooth & congruous the normal joint surfaces are in a normal ankle. C a forced supination AP view with a talar tilt angle >20° indicating a total rupture of the lateral ligament complex. Get an oblique view if there is much pain & you haven't spotted a fracture. ***Note the widening of the joint space.*** **D apply strapping to support a sprain.** *Kindly contributed by John Stewart.*

71.2 Sprained & torn ankle ligaments

A sprain tears only some of the fibres of a collateral ligament, more commonly on the lateral side in an inversion injury and the medial side in an eversion injury.
A sprained ankle is swollen, and the corresponding collateral ligament is tender. Although walking is possible with difficulty, the ankle will eventually recover, even without treatment. But if the ligament complex is completely torn, the ankle will be unstable and will cause difficulties, especially when walking on rough ground.

This instability can produce a chronic chondropathy and finally an osteoarthrosis with impaired walking capacity, range of movements and chronic pain.

Ruptures of the lateral ligaments are often missed because the talus tilts over temporarily and then returns to its normal position, and ordinary AP and lateral radiographs look normal.

This is why you must test the stability of the ankle: a positive anterior drawer test (talar shift) compared with the normal side is sign of a rupture. If the diagnosis is seriously in doubt, or to determine the degree of rupture, obtain forced inversion (or eversion) views (71-1C).

N.B. Rupture of the medial (deltoid) ligament is usually combined with a fracture of the lateral malleolus.

TREATMENT
If there is only minor swelling & no instability (1°) apply adhesive strapping and encourage walking normally. This should heal in <1wk.

If the ligament is partially ruptured (2°) with <20° talar tilt) apply a below-knee walking cast with the ankle in neutral, provided there is little swelling. Encourage walking in the cast. Remove it after 3-4wks and apply adhesive strapping (or an ankle boot) for 3wks more.

If there is serious swelling apply a below knee plaster back slab elevate the leg and wait a few days until you can change the slab in a walking cast.

If the ligament is totally ruptured (3°) or **there is a luxation** (talar tilt >30° & talar shift >15mm), only contemplate repair in an active young person. Apply a below-knee walking cast as above, but leave it on for 6wks, and then strapping (or a boot). Encourage walking without a limp, which uses some muscles excessively and others not at all. The latter waste, and contribute to permanent instability, which then requires an Evans/Watson-Jones ligamentoplasty.

As a rule of thumb, **if a patient cannot weight-bear on the ankle**, a cast is needed.

A NEGLECTED TORN LIGAMENT MAY BE AS SERIOUS AS A FRACTURE

71.3 Malleolar fracture

Malleolar fractures are particularly common in young active and elderly people.
Displaced malleolar fractures are major injuries and emergency conditions. They are often not taken seriously enough. Incorrect treatment will result in a stiff, painful *equinus* ankle (71-11), and lifelong disability unless a difficult arthrodesis can provide a useful foot.

There are 3 types of malleolar fractures: unimalleolar (68%), bimalleolar (Pott's) (25%), & trimalleolar (7%).

These injuries arise when the foot remains fixed on the ground in an abnormal position, while the body continues moving forwards. The position of the foot and the movement of the body relative to it, determine how the ankle bones & ligaments will break. The movements of the foot are complex, and similar to those of the hand. Supination combines inward rotation of the forefoot with inversion of the hindfoot. Pronation combines outward rotation of the forefoot and eversion of the hindfoot.
There are four groups of fractures of various stages of severity within each group:

SUPINATION ANKLE FRACTURES

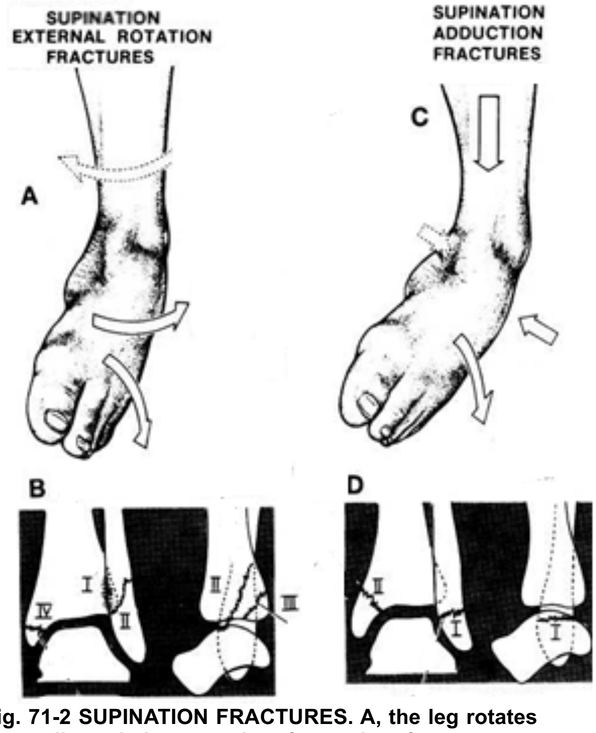


Fig. 71-2 SUPINATION FRACTURES. A, the leg rotates internally relative to the foot, the foot rotates externally to the leg, and supinates. B, stages I-IV of severity of fractures. C, the foot is forced medially into adduction by a downward force, and supinates. D, stages I-II of severity. *Adapted from Lauge-Hansen N. Fractures of the Ankle. Acta Orthopaedica Scandinavica. 1978: 51;181-192*

(a) Supination-external rotation fractures are the most common: the foot remains supinated on the ground, while the foot rotates externally on the leg.

Stage I: the anterior tibio-fibular syndesmosis ruptures,
Stage II: there is a spiral distal fibular (Weber B) fracture & talar displacement.
Stage III: the posterior tibia fractures, creating a posterior tibial fragment (Volkmann's triangle), with or without rupture of the posterior tibio-fibular ligament.
Stage IV: the deltoid ligament ruptures or there is a medial malleolus (Pott's) fracture (71-2B).
Stage V: the ankle dislocates.

The distinguishing feature of this group of fractures is the spiral fracture of the distal fibula.
Other varieties of this injury are a fibular fracture several cm above the ankle joint line, sometimes even as high as its neck.

(b) Supination-adduction fractures: the body moves laterally on the supinated foot.
Stage I: The lateral collateral ligaments rupture, or the fibula fractures transversely (Weber A).
Stage II: there is an additional medial malleolus fracture, usually vertical (71-2D).

(c) Pronation-abduction fractures &
(d) Pronation-external rotation: are less common.

One of the advantages of describing these fractures by the force that caused them is that you can use the opposite force to reduce them. In practice, recognition of the exact type of fracture is not important. The main principle is to recognize the incongruity between the talus and the tibia, to replace them exactly in contact with one another.
Then to immobilize the foot without weight bearing (except for undisplaced Weber A fractures) until the broken bones and torn ligaments have healed.

The mortise between the talus and the tibia is small, and transmits all the body weight, so *you must replace its joint surfaces exactly,* to enable normal weight bearing. Unfortunately, the ankle is not a joint which you can allow to mould itself by early active movements (70.4).

(e) 'Trimalleolar fractures'. Ignore minor extra-articular fragments of the posterior edge of the distal tibia. But intra-articular pieces >25-30% of the total tibial joint surface may dislocate proximally producing a step and a tendency to dislocate the talus posteriorly. These injuries are usually combined with lesions of the cartilage and damage to the joint surface, and so are serious.

SERIOUS MALLEOLAR FRACTURES

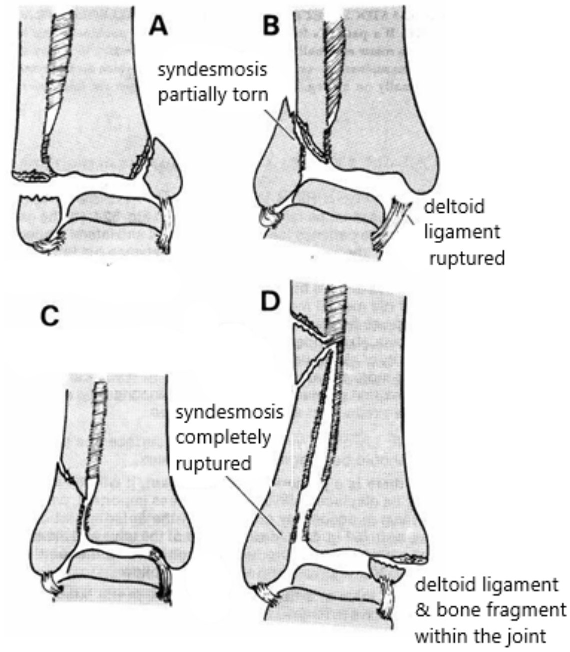


Fig. 71-3 SERIOUS MALLEOLAR FRACTURES. A, a supination-adduction Weber B fracture at the level of the joint. B, supination-external rotation fracture at the level of the syndesmosis, pulling the medial collateral (deltoid) ligament off the medial malleolus. C, a Weber C fracture above the syndesmosis, with a fragment of the deltoid ligament inside the joint prevents reduction. D, comminuted high Weber C fracture with a ruptured syndesmosis and interosseus membrane, with widened mortise (71.4)**.** *Adapted from Weber BG. Die Verletzungen des oberen Sprunggelenkes. Hans Huber,Bern 2nd ed. 1972.*

Danis-Weber Classification (Types A B C)
A: Fracture of the distal fibula below and up to the level of the syndesmosis (anterior and posterior tibio-fibular ligaments) but below the joint space. If there is only a minimal fragment of the tip of the fibula, this corresponds to a tear of the lateral ligaments. This fracture can be combined with a tear or rupture of the medial (deltoid ligament or a fracture of the medial malleolus. The syndesmosis always remains intact.
B: Fibula fractured at the level of the syndesmosis and slightly above the ankle joint space. The syndesmosis is usually partly or sub-totally ruptured. Medial side as in A.
C: Fibula fractured above the level of the syndesmosis. The syndesmosis is ruptured and tibio-fibular joint space is widened. This widening increases as the fibular fracture is more proximal, and means the interosseus membrane is also ruptured, usually to the level of the fibular fracture. So the attachment of the fibula to the tibia is lost all along the lower fibular fragment. You can diagnose this loosening by holding the foot tilted in pronation with your left hand and pressing the distal fibula against the tibia from behind at the joint level with your right hand. If a Weber C fibular fracture is high in the subcapital region, it is called Maisonneuve fracture (71.4)

ANKLE DISLOCATION REDUCTION (GRADE 1.3)
Reduction is often difficult if the patient arrives long after the injury.
If the talus is dislocated (grossly out of place),
If the foot is in *equinus*, or
If there is no swelling yet but significant dislocation, *reduce the dislocation urgently*

CAUTION! Blood vessels, nerves, ligaments & tendons will be compressed or stretched. Later, the joint capsule and ligaments will tighten, and *reduction will be difficult or impossible*.
N.B. Wait for 2-7days if there is marked swelling.

Lift the leg by the heel. Frequently reduction occurs spontaneously with a snap. If it does not, ask an assistant to stabilize the leg with the knee slightly flexed, while you pull on the heel and foot in the axis of the leg, thus bringing the foot upwards.
You often don't need anaesthesia for this, but administer analgesia. Put a pillow or sandbag under the knee and heel and *accompany the patient* to the X-ray department, taking care that you maintain the reduction.

Compare the radiographs with your clinical findings and make a therapeutic plan. The majority of malleolar fractures can be treated by closed methods with good results.

If you fail to hold the reduction, use calcaneal traction 3-5kg for 1wk and try exact reduction once more leaving the Steinmann pin in place, fixing it in the below knee PoP.

STOCKINETTE (QUIGLEY) TRACTION
If you need to wait for swelling to reduce, or between trials of reduction, keep the ankle meanwhile in stockinette (Quigley) traction. Thread the leg through a tube of stockinette, and fix this to the thigh with several short pieces of zinc oxide strapping (71-4). *Don't put strapping around the thigh* because it may obstruct the circulation. Suspend the loose end of the stockinette from a drip stand, so that the foot rests c.20cm above the bed. Most fractures will reduce themselves automatically in 2 or 3 days, while the swelling subsides.
If you don't have stockinette, and the swelling is severe, reduce the fracture and temporarily hold the best position with a long horseshoe plaster splint which extends down one side of the leg, around the foot, and up the other side. Hold it with a crepe bandage.

STOCKINETTE (QUIGLEY) TRACTION

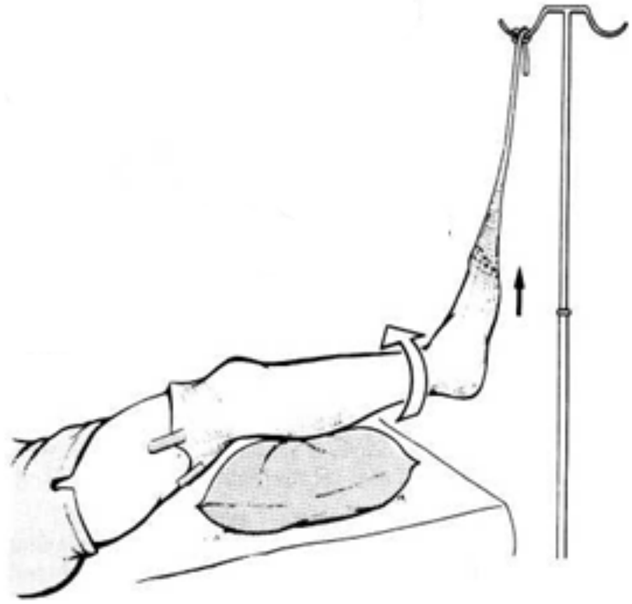


Fig. 71-4 STOCKINETTE TRACTION FOR A MALLEOLAR FRACTURE. Hold the leg like this with stockinette and it will tend to rotate externally relative to the foot, reducing the common supination-external rotation fracture in which the foot rotates externally on the leg. *Kindly contributed by Peter Bewes & John Stewart.*

Keep the patient in bed with the foot of the bed raised until the swelling has subsided. Tighten the crepe bandages as swelling subsides, and then apply a cast (71-9). If there are skin lesions (contusion marks or blistering, usually over the medial malleolus) make a window over the medial malleolus but keep the foot fixed. In this way, you can assess the swelling and treat the wound.
The purpose of reduction is to align the talus with the anterior part of the joint surface of the tibia. So look for congruity there.

Gross displacement or widening of the ankle mortise is easy to recognize, but minor degrees of non-congruity may be difficult to distinguish from a normal joint. When you reduce the fracture, take great care to obtain the highest possible degree of congruity. *A common error is to accept an unnecessary degree of non-congruity.*

A certain amount of deviation from normal anatomy is acceptable especially in unimalleolar and stage 1 & 2 fractures. *In general, however, the end results are commensurate with the accuracy of the reduction.*

POST-REDUCTION RADIOGRAPHS
Obtain AP views and in 20° of internal rotation (71-1)
(1) The gap between the talus and the medial and lateral malleoli should be about the same as the gap between the talus and the lower surface of the tibia.
(2) The saddle-shaped surfaces of the talus and the tibia should be congruous.
(3) Close reduction of the medial malleolus should show that there are no soft tissues between the fragments.
(4) The lateral malleolus should project more distally than the medial malleolus.

N.B. Inadequate correction of proximal displacement (shortening of fibula with luxation or subluxation in the tibio-fibular joint owing to a ruptured syndesmosis (Weber C fractures) or obvious incongruity, requires fixation, if possible.

If there is a posterior tibial fragment, it will almost certainly be displaced upwards. This is less important, provided the talus is accurately aligned with the anterior part of the tibia (71-5B). Misalignment of the talus and the shaft of the tibia (71-5C) produces a high point on the joint surface ensuring osteoarthritis will follow.

If the talus and tibia are misaligned, in the lateral view, remove the cast and try to improve reduction.

If a gap remains in the AP view between the medial malleolus and the talus, there is soft tissue in the joint.
This is especially likely to happen if the medial malleolus is intact, trapping the torn deltoid ligament in the ankle joint between the talus and the medial malleolus (71-3D).

Simple conservative methods are satisfactory in most stable Stage I & II or Weber A & B type fractures (without dislocation or widening of the ankle mortise). Other Weber C and a good number of displaced fractures are not easy to treat.

They need particular attention:
(1) 10-14days of in-patient care,
(2) Manipulation using 3-point fixation,
(3) Radiographic checks,
(4) Several well-applied casts,
(5) Proper follow up & re-manipulation if necessary.

CONGRUITY IN THE LATERAL ANKLE RADIOGRAPH

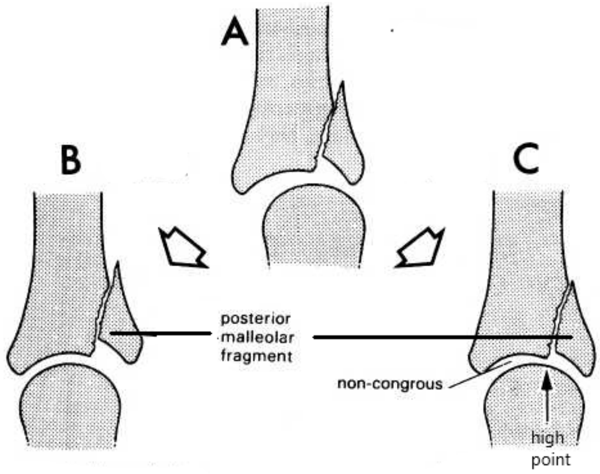


Fig. 71-5 CONGRUITY IN A LATERAL ANKLE RADIOGRAPH. A, if there is a large posterior tibial fragment, try to make the anterior part of the ankle joint congruous. B, it is congruous. C, there is a high point, which will lead to osteoarthritis later. *After Charnley J, The Closed Treatment of Common Fractures E&S Livingstone, Edinburgh 3rd ed. 1961*

If in a lateral view, >25-30% of the posterior lip of the tibia is fractured, the ankle will be unstable. The irreducible posterior fragment needs fixation.

Application of the casts is critical: this is your responsibility. Your main difficulty will be less in reducing the fracture, than in making sure it stays reduced.
In spite of the complexity of these fractures, in most of them there are really only 2 main fragments. The shafts of the tibia & fibula form one, while the foot and the malleoli form the other. The fragments attached to the foot move as 1 piece because they are all firmly joined by ligaments.
If you succeed in replacing the talus accurately under the tibia, the other fragments will usually follow suit. Align the foot on the leg by eye and by feel, and you will find you have reduced the fracture. You will be able to feel that the talus is back under the tibia more easily when there is no plaster on the foot. So explore the mobility of the foot before you apply it. Start by getting the feel of where the talus should be. Then apply plaster, fit the talus back in position, and hold it there until the plaster has set (71-9B).

The common supination-external rotation fracture (71-2A) needs moderate internal rotation of the foot to correct its position. Use one of your hands to support the heel and nudge the lateral malleolus medially, while your other hand presses the tibia laterally.

Meanwhile, ask your assistant to steady the knee, and so get help to apply 3-point fixation. *After reduction, the foot must not rotate on the leg*; if it does, reduction will certainly be lost. So, the cast must extend above the knee, and the knee must be gently flexed. There are no short cuts. Be sure to:

(1) apply the cast as described.

(2) X-ray the ankle again <2wks, so that another attempt at reduction is possible before it is too late.

N.B. Most reductions are lost during this period.

(3) Prevent walking on the cast too early.

N.B. This is a common error in unstable fractures.

TWO MAJOR FRAGMENTS IN ANKLE FRACTURES

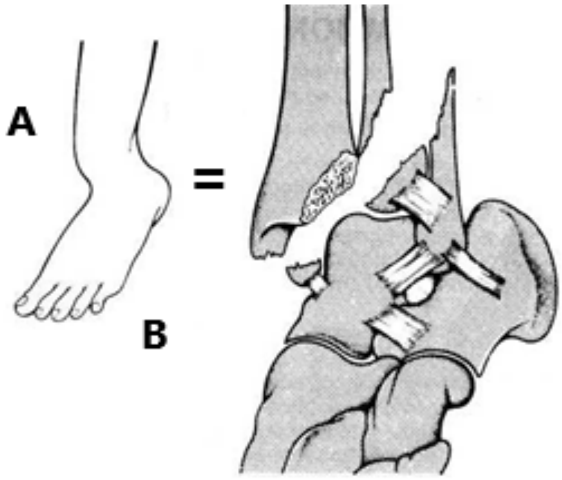


Fig. 71-6 MOST MALLEOLAR FRACTURES HAVE ONLY 2 PARTS. A, the leg. B, the foot. If you can put these together, you will have reduced the fracture. *After Charnley J, The Closed Treatment of Common Fractures. E&S Livingstone, Edinburgh 3rd ed. 1961*

If there Is more than a hairline crack, but no incongruity in the joint surfaces, apply a short leg walking cast (*not a malleolar cast*) for 2wks.

If there is any incongruity of the joint space, admit & treat by closed reduction.

If there is a large upwardly displaced posterior tibial fragment, expect difficulty, and try to reduce it by the special method described later.

SUCCESS DEPENDS ON GETTING THE DETAILS RIGHT

EXPLORING MOBILITY OF A MALLEOLAR FRACTURE

For Stage III or IV supination-external rotation trimalleolar fractures, in which the talus and the foot together are displaced posteriorly. In other fractures, and particularly for those in which the talus is displaced anteriorly, adjust your manipulation appropriately.

TESTING ANKLE MOBILITY

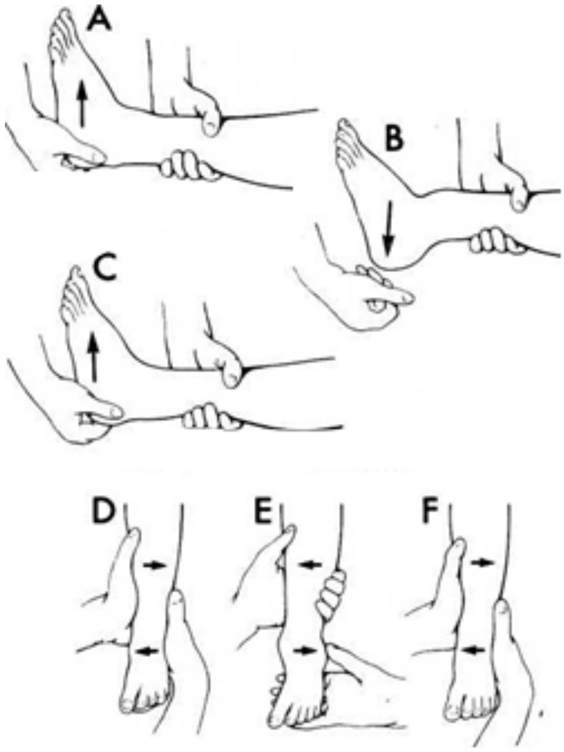


Fig. 71-7 EXPLORING THE MOBILITY OF A MALLEOLAR FRACTURE. A, hold the leg by the calf and the heel. B, the heel will fall when you remove your hand. Remember how far you have to lift the foot in order to replace it. D,E,F Similarly, remember how far you have to move it sideways. to reduce it. *After Charnley J, The Closed Treatment of Common Fractures. E&S Livingstone, Edinburgh 3rd ed. 1961*

Lie the patient with the legs over the end of the table. Find an assistant. Under ketamine, find the position of reduction. Explore the up & down and side-to-side mobility of the ankle joint (71-7A,B,D-F), while you try to find the best position of reduction.

If you hold the heel in the palm of your hand, with the leg horizontal and in slight external rotation (71-7C), the fracture will probably reduce itself.

If it is not reduced, rotate the foot internally a little, and fit the talus back into the lower end of the tibia. Align the patella carefully with the toes, so that it is the same on the fractured side as on the normal one. In this position the fracture should stay reduced.

Ask an assistant to hold the leg, and see if you can improve the position by applying 3-point fixation (71-8B).

Memorize the most stable position where you can most easily apply pressure to reduce the fracture. Remember carefully just how far forwards and how far medially you have to move the foot. You will need to return it to this same position while the plaster sets.

APPLYING THE FIRST MALLEOLAR CAST
Ask your assistant to hold the toes. Apply 1cm of cotton wool padding to the foot, ankle, and calf. Bind the wool on tightly and smooth it carefully. Use *cold* water to make the cast set slowly. Quickly wet and apply 3x 20cm plaster bandages lightly from the mp joints to just below the knee. A total of 3 bandages will make the cast thick enough to hold the foot reduced, without obscuring the feel of reduction. At this stage disregard the reduction of the fracture, and the position of the foot. As soon as the plaster is on, and *while it is still soft,* take the leg from your assistant. Massage the plaster thoroughly to remove air bubbles from between the layers of the bandage.

If the posterior tibial fragment is small (extraarticular or only minimally involving the joint surface), ignore it. Feel the fracture by moving the foot about inside the soft cast. Use the experience you have already gained to reduce it.

Apply 3-point fixation (71-8B). Ask your assistant to steady the knee.
(1) With one of your hands press the lower end of the tibia laterally
(2) With your other hand press the heel upwards and press the lateral malleolus medially
(3) While you rotate the foot internally a little (4). The lateral malleolus is attached to the foot. So, the pressure of the palm of your hand medially on the ankle will restore it to its correct position. Very little force is necessary, and if you have placed the foot correctly, gravity alone should be almost enough.

CAUTION!
(1) Keep the foot absolutely still until the cast has set. *Don't apply any finishing touches until it is hard.*
(2) *Don't apply the cast with the ankle inverted.*
(3) *As an additional check, make sure both the feet are similarly aligned in relation to the patellae.*
(4) *Avoid common errors* (71-9).

3-POINT PLASTER CAST FOR AN ANKLE FRACTURE-DISLOCATION

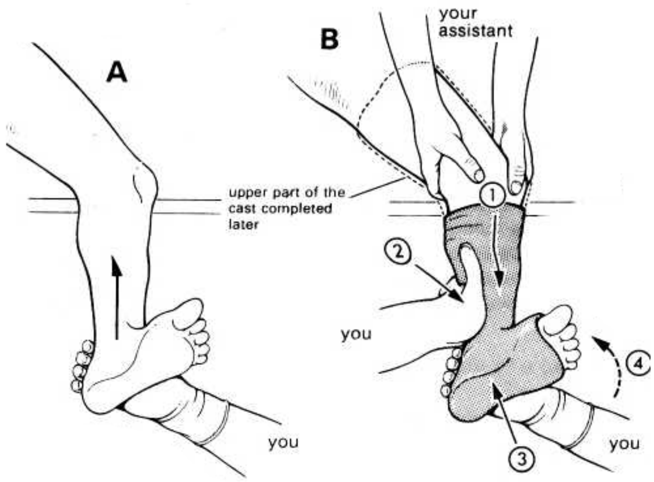


FIG. 71-8 3-POINT FIXATION FOR AN ANKLE FRACTURE DISLOCATION. A, hold the foot like this, and the fracture will probably reduce itself. B, if it is not reduced, rotate the foot internally a little, and fit the talus back into the lower end of the tibia. Align the patella carefully with the toes, so that it is the same on the fractured side as on the normal one. In this position the fracture should stay reduced. Ask an assistant to hold the leg, and (1) press the lower end of the tibia laterally, (2) with your other hand press the heel upwards and press the lateral malleolus medially. (3) While you rotate the foot internally a little (4), the pressure of the palm of your hand medially on the ankle will restore it to its correct position. When you have reduced the fracture, apply the cast below the knee. When this has set, extend it above the knee with the knee slightly flexed. *After Charnley J, The Closed Treatment of Common Fractures. E&S Livingstone, Edinburgh 3rd ed. 1961*

If the posterior fragment is large, is displaced upwards, & does not come down on the 1st manipulation, make use of the distal tibial origin of the *flexor hallucis longus* muscle. Strongly plantarflex the ankle into *equinus*. Dorsiflex the hallux sharply. Then, holding the toe dorsiflexed, bring the foot into the neutral position. Hold the foot in this position and apply a cast as described above.

If the posterior fragment is too large & does not reduce by this method as it is >⅓ the width of the tibia, proceed to fixation.

After the first coating of plaster has set, and there is no danger of the fracture slipping, complete the cast up to mid-thigh, with the knee flexed to 20°. Finish its top and bottom edges, and apply extra plaster bandages to strengthen it if necessary. *While it is still soft,* split the lower leg portion anteriorly down to the skin, *but don't spread it.*

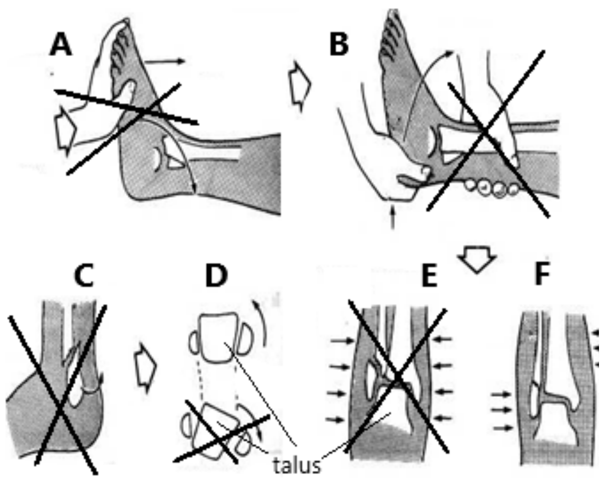
CHECK RADIOGRAPHS
Take an AP view in 20° of internal rotation and a lateral view immediately after reduction. If the talus is not in exactly its right place (71-5), remove the foot and ankle part of the cast, have another try, and complete the cast once more, making sure that the junction of the new & old parts don't press on the skin.

POST-REDUCTION CARE FOR AN ANKLE FRACTURE
Put the patient to bed, raise the leg to reduce swelling and observe the circulation of the toes carefully for 24h. If it is impaired, or if there is pain, spread or remove the cast and reduce the fracture again later. Ask the patient to move the leg and toes inside the cast as much as he can. Keep him in bed for 2 wks.

If the swelling has subsided, keep the patient in bed for a few days, and then get him up on crutches.
Check with a radiograph that the position has not been lost. If reduction is satisfactory, discharge him not weight bearing on crutches.

If reduction is not satisfactory, have another attempt at closed reduction. If this fails, proceed to fixation.

COMMON ERRORS IN ANKLE REDUCTION



71-9 COMMON ERRORS IN ANKLE REDUCTION. A, *don't flex the ankle to 90° by pressing on the toes* B, instead raise the heel, but *don't reduce the fibular displacement by squeezing the ankle from the lateral & medial sides.* C, *don't externally rotate the foot.* D, the lateral malleolus is already displaced posteriorly so further external rotation will separate the malleoli from their normal positions. E, *don't squeeze the ankle by pressing over both malleoli;* F, instead, exert pressure at different levels. *After Charnley J, The Closed Treatment of Common Fractures. E&S Livingstone, Edinburgh 3rd ed. 1961*

Check the position again after 2wks. **If reduction is not satisfactory,** have a final attempt at reduction. If this fails, proceed to fixation.

If reduction is impossible by 3-point fixation, & there are probably soft tissues between the fragments, or in the joint cavity (71-3C), proceed to fixation.

CAUTION!
If the fracture is unstable, make sure the patient understands that he must not bear weight on the ankle until 6wks after the injury.
Keep on with crutches. If the fracture is less severe, weight-bearing may start at 2-4wks if the injury does not involve the joint surface.

Remove the long leg cast and test for stability at 6wks, & obtain a check radiograph. If fracture healing seems to be progressing satisfactorily and the patient is cooperative, start mobilization with a protecting ankle shoe gradually increasing weight bearing. Encourage physiotherapy to build up muscle strength.

If you are not sure about the stability, change the malleolar cast for a short leg walking cast (70-4). Carefully mould its upper end by triangular compression (70-5) and fit it with a walking heel.
Allow continued walking on crutches with increasing weight bearing to tolerance for 3-4wks more.

REDUCE THE FRACTURE CAREFULLY
APPLY THE CAST PROPERLY
GET RADIOGRAPHS AT THE END
OF THE 1ST, 2ND, & 6TH WKS
DON'T ALLOW WEIGHT BEARING
BEFORE 6WKS !

OPERATIVE FIXATION (GRADE 3.2)
Indications:
(1) irreducible shortening of the fibula: Weber B,C and Maisonneuve fracture (71.4),
(2) syndesmotic disruption (tibio-fibular gap >6mm),
(3) impacted tibial roof comminuted tibial pilon fracture (71.5),
(4) irreducible posterior fragment >⅓ the width of the tibial roof,
(5) irreducible large fragment of the medial malleolus
(6) open fracture
(7) repeated failure in maintaining reduction,

N.B. Use closed, manipulative and minimally invasive methods for lower leg, ankle & foot injuries: they give acceptable functional results with far less risk in the majority of cases, and avoid disastrous complications of infection, and wound healing, even death!

Where you cannot satisfactorily reduce & hold a displaced fracture with the foot plantigrade, use fixation with Steinmann pins through the 1^{st} & 5^{th} metatarsals (71-10)

You can also use a Steinmann pin where there is serious posterior malleolar instability, by fixing the calcaneum, talus and tibial shaft (after you have relocated the talus under the tibia) and incorporate this in a below-knee cast.

PLANTIGRADE FIXATION BY PINS

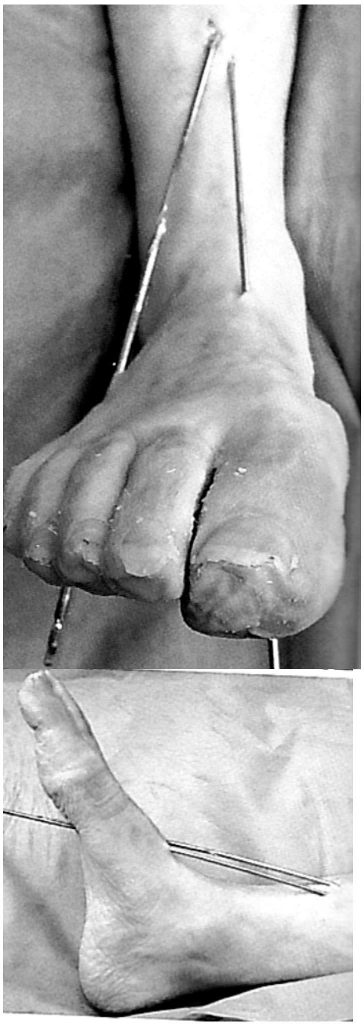


Fig. 71-10. PLANTIGRADE ANKLE FLEXION. This is useful to hold an unstable fracture or in burns to the dorsum of the ankle. Drill Steinmann pins through the 1^{st} & 5th metatarsals at 45^0 to engage the tibia through small stab wounds. *After Gosselin RA, Spiegel DA, Foltz M. Global Orthopaedics. Springer 2^{nd} ed 2019*

71.4 High spiral (Maisonneuve) fibular fracture

This rare injury is really a variety of a malleolar fracture in which the fibula, instead of breaking at the ankle, separates from the tibia at the ankle, twists, and breaks just below the knee.
The lower tibio-fibular ligamentous structure (syndesmosis) ruptures, as does the whole of the interosseous membrane from bottom to top. *You can easily miss this fracture unless you look for signs near the knee.*

The radiograph of the ankle may not reveal any bony injury in spite of the severe pain and swelling there. Even if you evoke only minimal pain laterally below the knee joint, suspect the Maisonneuve fracture.
The displacement can be minimal. Usually the fracture line is spiral or oblique. *Don't confuse it with the more common fracture of the shaft of the fibula* caused by direct trauma (not necessitating any treatment). Reduce the fracture as above, but apply a long leg cast.

If reconstruction of the ankle mortise is unsatisfactory owing to shortening and lateral displacement of the distal fibula fragment, this is a real indication for external fixation (71.6).

71.5 Explosion comminuted 'pilon' tibial fracture

Comminuted malleolar fractures don't fit in the Lauge-Hansen nor in the Weber system. Their injury mechanism is by severe axial compression: the talus is driven up into the tibia, which is often comminuted (71-4). In addition, one or both malleoli may fracture or one or both collateral ligaments of the ankle may be stretched or ruptured. Usually the foot is dislocated; frequently sharp fragments of the lower end of the tibia perforate the skin on its antero-medial aspect.

Apply calcaneal traction (initially 5-7kg to be reduced after 1wk to 4-5kg) elevate the lower bed end and obtain a check radiograph after 2-3 days. Combine traction with early active movements. After 4wks, if the alignment of the fragments and range of movements are acceptable, proceed with a long leg non-weight bearing cast keeping the Steinmann pin as a transfixation device in place. Remove it after 2-3 wks, leaving the cast for 4wks.

EXPLOSION ANKLE FRACTURE

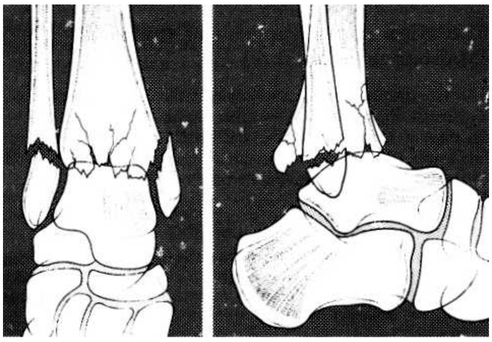


Fig. 71-11 AN EXPLOSION (Comminuted Pilon) ANKLE FRACTURE. This patient has little hope of a pain-free, moveable ankle. Make sure that what little movement he will have will be about the neutral position (the position of function). ***A fixed equinus foot is a real disaster.***

Check stability & union clinically and decide whether a below knee cast would be sufficient, combined with starting weight bearing (10kg) to be increased by 10kg/wk. At 14-16wks, you should achieve full weight-bearing. An arthrodesis of the ankle joint will be necessary if severe osteoarthrosis supervenes.

71.6 Open ankle fracture

Any malleolar fracture-dislocations may have minor or major skin and soft tissue damage, even with a protruding bony fragment. Even if the exposed fractured bone has slipped back after emergency reduction, *the risk of bone and joint infection is high and you must treat the fracture as an open one*.

TREATMENT
Under ketamine in theatre, perform a *thorough* wound toilet (54.1), under strict antiseptic measures & with prophylactic antibiotic cover. Restore the position of the bones as best you can. *Make a special point of trying to align the talus with the malleoli and the tibial plateau.*

CAUTION! Don't close the wound!

After dressing the wound, immobilize the limb on a below knee PoP back slab in the neutral or best possible position and elevate the leg. Continue IV antibiotics for a minimum of 3 more days and change the antiseptic dressing (starting after the 2^{nd} day without taking the leg out of PoP).

If no infection develops and the wound is healing, proceed as for a closed malleolar fracture depending on the fracture type. Check the radiograph and apply calcaneal traction with 3-5 kg.

N.B. Whenever you apply calcaneal traction for an unstable bi- or tri-malleolar fracture, reduction may initially be perfect, but there is a high risk of re-dislocation if the leg is mobile.

So apply a stable Braun's splint or similar device on which you can fix the injured leg using 2-3 stabilizing sandbags on both sides of the lower leg and strong large crepe bandages. Check the position regularly visually, by palpation and radiographically. You may need to re-position the sandbags. *Don't delegate this to auxiliary staff*.

EXTERNAL FIXATION (GRADE 3.2)
For unstable Weber B,C, pilon, open fractures, crush injuries, or badly infected wounds, and damage control, external fixation is indicated. The simplest type has ankle spanning fixed by an anterior tibial pin to a calcaneal pin.

Mark out the surface anatomy: the tibial tubercle and crest, the lateral & medial malleoli, and the line of the tibio-talar joint.

Place a pillow under the ipsilateral hip, and supports under the foot, so that the knee is slightly flexed, and the patella facing vertically.

Under LA or ketamine, it is best to insert 2 Schanz pins just lateral to the tibial crest c. 6-8cm superior to the fracture and wound site.

Start drilling at 30^0 to the tibia, so the drill bit does not slide off the bone surface, and when it has purchased, re-align the drill perpendicular to the leg (71-12). When you insert the pins, start them in the first direction, perpendicular to the bone, and then re-align them vertically, so the thread catches in the correct direction.

N.B. If the direction is wrong and you start screwing the pin in, you will not be able to get it right later.

DRILLING INTO THE ANTERIOR TIBIA

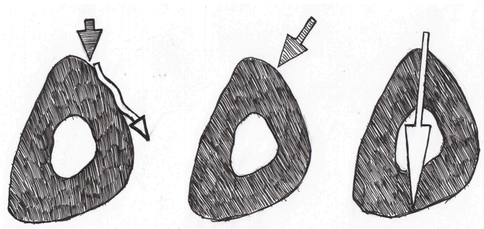


Fig. 71-12 DRILLING INTO THE ANTERIOR TIBIA. A, if you drill perpendicular to the leg, the drill will veer off the bone surface. B, so angle the drill ***perpendicular to the bone.*** **C. the correct direction of the drill.**

Check with a radiograph, if possible, that the pins have just crossed the opposite cortex.

ANATOMY OF THE HEEL

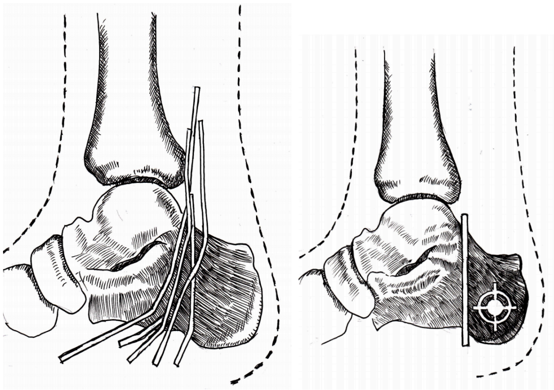


Fig. 71-13 AVOIDING THE NEUROVASCULAR BUNDLE. A, the variable position of arteries & nerves. B, place your pin well behind a line posterior to the tibio-talar joint.

Now place another pin across the calcaneum. *Make sure you place this posterior to a vertical line posterior to the subtalar joint*, in order to avoid the neurovascular bundle (71-13).

Link these pins preferably with a double X-fix bar (71-14). Depending on the instability of the fracture, you will be to hold a reduced position at least for the initial phase until the wounds have healed. *Make sure the rods are far enough from the skin surface to allow the leg to swell.*

SIMPLE ANKLE SPANNING FIXATION

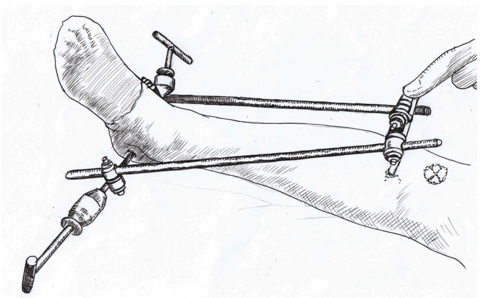


Fig. 71-14 SIMPLE ANKLE SPANNING FIXATION. You can achieve this with just 2 pins and two connecting bars

You can build a more stable bilateral triangle-shaped construction (71-15) if you add 4mm pins into the base of the 1st mt (palpate the anterior & posterior borders of the bone with the drill and then drill into the middle of the bone), and the base of the 5th mt (or cuboid).

N.B. Don't drill into the tip of the 5th mt!
The tibial pins should be parallel to each other, and the foot pins likewise.

MORE STABLE ANKLE SPANNING X-FIX

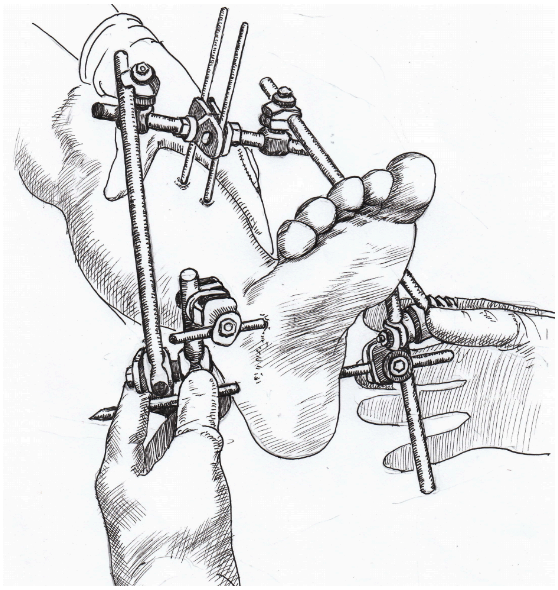


Fig. 71-15 MORE STABLE ANKLE SPANNING X-FIX. You can achieve a very versatile system by this frame. Turn the foot part of the fixator like a steering wheel.

Once you have reduced the fracture, tighten the links first by hand, and when you are satisfied by the position, with the wrenches. If possible, make a check radiograph, and if necessary re-position the fragments.
After 4-6wks, when the wounds have healed and the fractures have stabilized, remove the pins and apply a PoP, in order to reduce the risk of pin track infection and consequences of long immobilization.

If you have no X-fix or if you are not familiar with it, you can achieve useful temporary stabilization by inserting a long Steinmann-pin or strong K-wire through the middle part of the calcaneus and talus from inferiorly up into the tibial shaft.
Alternatively, introduce 4-pilon, 6 medium strong K-wires near the tips of the malleoli from both sides in oblique directions to fix the major fragments to the distal tibia through its metaphysis. Then fix the tips of the K-wires together in the cortex on the opposite sides of the tibia.

N.B. Make sure your pins are far from the wounds! You really need intra-operative radiology (or ultrasound) to do this properly.

71.7 Neglected ankle fracture

Not all untreated or badly managed ankle fractures turn out as bad as in 71-16. In remote rural areas native healers (bone setters) may achieve initial reduction and fixation with traditional techniques which might be helpful.
It is difficult to achieve a sufficient congruency of the ankle joint and re-dislocation after some days or wks is often inevitable.

Take an exact history and make a meticulous clinical examination including radiographs. You might find already united fractures in malunion or nonunion, or subluxed positions of the talus etc.
Some reconstruction or arthrodesis may be possible at a specialist centre. Both interventions are very tasking and have uncertain outcome. Otherwise an orthopedic shoe, intensive physiotherapy and analgesics are worth pursuing. All this should remind you of *the importance of taking malleolar fractures very seriously!*

A BADLY TREATED ANKLE INJURY

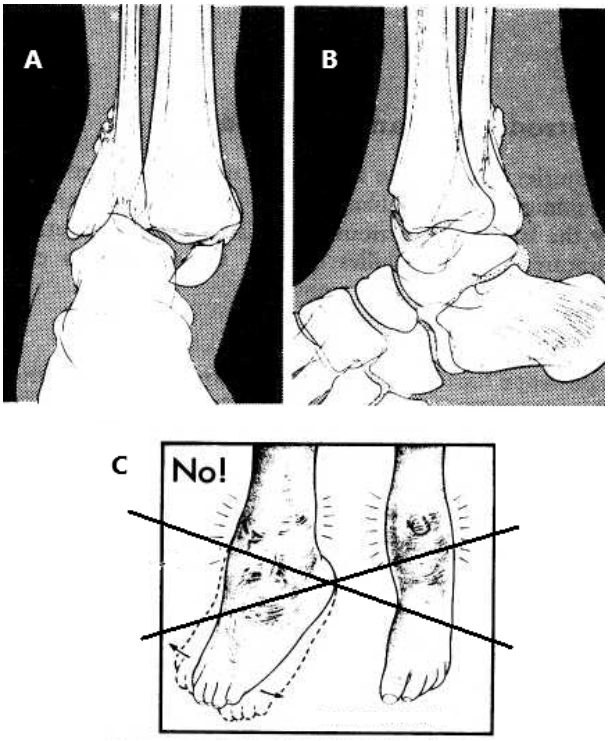


Fig. 71-16 A BADLY TREATED ANKLE INJURY. A, the foot is in *equinus*, and the little movement there is, is about this position. This makes walking impossible, except with a crutch, and is a very great disability. B, there is non-union & stiffness. *The fracture should have been reduced and put in a malleolar cast*; instead, she was given a backslab and not prevented from walking on it. C, there is permanent pain & disability.

71.8 Flexion ankle injury

Injuries of the flexor mechanism of the ankle are more common in males and arise typically between the ages of 20-50yrs.
They can be open, as when cut by a knife, or closed. Closed injuries are the result of spontaneous rupture of the flexor mechanism during violent or even moderate activity. They take 3 forms:

(a) Rupture of the *plantaris* tendon,
(b) Minor tear of the *gastrocnemius* muscle. These present with sudden pain in the calf muscle, often during only minor exertion, accompanied by exquisite tenderness in the middle of the calf. A raised shoe will ease symptoms. It resolves in 1wk.
(c) Achilles tendon rupture.
The Achilles tendon is the biggest tendon in the human body and, if it is not damaged by previous trauma or degenerative disease, is capable of withstanding the tension of 10x the body weight.

Risk factors for rupture are strenuous sports such as football, sprints, badminton, baseball as well as the use of quinolones, anabolic or cortisone steroids. Any movement producing a sudden maximum tension on the tendon can lead to a partial or total rupture. Usually there is a loud snap and immediate inability to rise on the ball of the foot or stand on the toes.

Grasping the calf (*gastrocnemius*) muscle fails to make the ankle plantarflex (71-13A). By palpating all along the Achilles tendon you may feel a gap which widens on dorsiflexion of the foot.
Usually you can clearly see the defect and measure its length by ultrasound scan.

If you can bring the ends of the ruptured tendon together by plantarflexion, apply a gravity *equinus* cast (this is the mount of *equinus* which gravity alone produces but no more, usually 30° of plantarflexion) for 2wks without weight bearing. Then build up the base and attach a walking heel (71-17B) and encourage weight bearing for 4wks more. Get a cobbler to prepare a heel raise of 2-3cm. Remove the cast at 6wks and protect the tendon for a further 4wks with the heel raised shoe.
Advise against running, or any violent exercise for 3 more months. Then arrange muscle strengthening exercises with physiotherapy.

ACHILLES TENDON INJURY

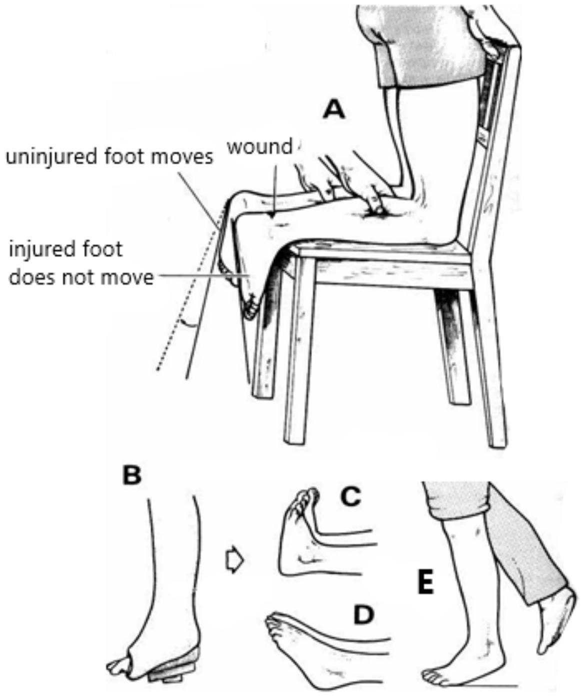


Fig. 71-17 ACHILLES TENDON INJURIES. A, squeeze the calf: if the foot does not plantarflex, the Achilles tendon mechanism is damaged. B, the walking *equinus* cast. C, D, E, after 6wks of active walking in the cast, there should be normal range of dorsiflexion & normal lift off.

ACHILLES TENDON REPAIR (GRADE 1.4)
Repair a rupture with a persistent gap of >2cm. In such cases a simple adapting tendon suture should be augmented by a ligament repair: pull a distally pedicled *soleus* flap (46.5) down, overlap the tendon suture and fix it laterally and distally to intact tendon with some single Z-sutures.

Repair an open injury, after a thorough toilet by standard figure-of-8 suture (47.1) keeping the foot in 30° of plantarflexion, and immobilize the ankle in an *equinus* cast.

If the wound is ragged or dirty, treat it in an *equinus* cast with a window, till you can perform a delayed primary suture.

ANKLE BRACE & BOOT

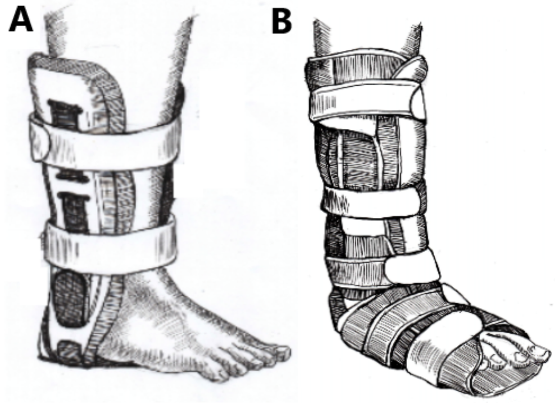


Fig. 71-18 ANKLE BRACE (A) & BOOT (B)

72 Foot injury

72.1 Conservative treatment

Because feet are usually hidden inside shoes, injuries to them tend to be neglected, especially in diabetics or where there is a peripheral neuropathy. You can treat most foot injuries conservatively, and only a few need manipulation. A calcaneal body fracture is the most important. If you have no X-ray facility, or diagnosis is difficult, proceed as follows:

If there is any obvious displacement of the foot bones, correct it as best you can and then apply a short leg walking cast (72-1), taking care to mould its sole to both the longitudinal and transverse arches of the foot. Keep the patient in bed until the pain subsides and then start walking with crutches. If you cannot hold any reduction in PoP, fix it with K-wires (58.6)

If there is no obvious displacement, fit a short leg walking cast as above.

If the pain is severe and there is only a minor injury, or the radiograph shows no pathology, a short leg walking cast will usually also help.

DON'T FORGET TO REDUCE SEVERE DISPLACEMENT

ADAPTED SHORT LEG WALKING CAST

Fig 72-1 A SHORT LEG WALKING CAST. Make sure you mould it to the patient's foot arches. *Kindly contributed by Benjamin Mbindyo.*

72.2 Talo-navicular dislocation

The joint between the talus and the navicular is often strained, and occasionally dislocates, sometimes in association with a dislocation of the forefoot. After some violent injury, the foot is turned inwards and displaced under the talus, which remains in its normal place in the ankle joint. The displacement of the front of the foot from around the talus forms a swelling on the dorsum of the ankle, which quickly presses on the skin causing it to slough (72-2A).

There is great pain, and the extreme inversion of the foot makes the diagnosis obvious. Occasionally, the foot is displaced laterally instead of medially. Sometimes the cuboid and the calcaneal head are fractured also. You will see these best after you have reduced the talo-navicular dislocation, but even if present, they do not alter the treatment.

TALO-NAVICULAR DISLOCATION (GRADE 1.4)
Reduce the dislocation quickly before the skin over the talar head becomes necrotic. Use ketamine & move the foot back into position, If the foot remains unstable, fix it with a K-wire (58.6). Splint the ankle, raise it apply a crepe bandage, and keep the patient in bed until the swilling subsides. Then apply a cast with a walking heel, and start walking using crutches. Teach walking without a limp. Remove the cast at 3-8wks.

72.3 Talar dome fracture

In this injury, the patient twists the foot inwards, and shears a small fragment off the upper surface of the talus. An AP radiograph shows a small triangular fragment, like a loose body, at the upper lateral talar angle. As the foot returns to its normal position, this fragment may turn upside down, and then needs removal.

N.B. **If the fragment is the right way up,** no intervention is needed.

EXCISION OF A TALAR LOOSE BODY (GRADE 2.5)
Make an antero-lateral incision just lateral to the long foot extensors to avoid the superficial peroneal nerve, and extract the loose bone.
Fit a short leg walking cast for 10-14days, after which you should encourage walking without a limp, as soon as possible.

72.4 Talar body fracture

This rare injury results from a fall from a height onto the heels which crushes the talar articular surface. The ankle becomes swollen & painful.

If the talar fracture is comminuted, try to mould the fragments by active movement. As soon as moving the ankle without too much pain is possible, allow walking with crutches, without weight-bearing for 3months. If it becomes too painful, an arthrodesis is needed.

TALAR INJURIES

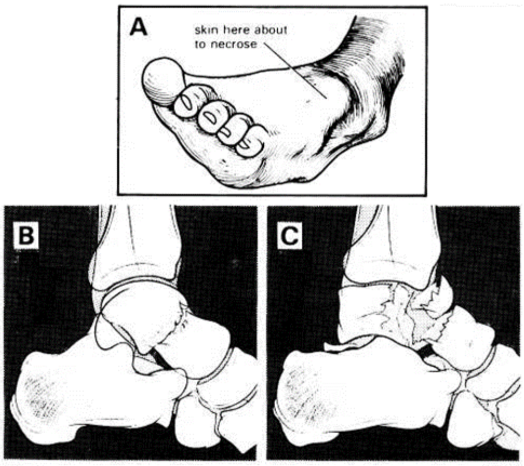


Fig. 72-2 SOME TALAR FRACTURES A, the dislocated talo-navicular joint forms a swelling on the dorsum of the ankle, risking skin damage. B, an undisplaced talar neck fracture (no angulation). C, a comminuted talar body fracture.

72.5 Talar neck fracture

This rare fracture is the result of forced dorsiflexion of the foot, and may injure the soft tissues severely. The fracture line runs through the talar neck in a coronal plane just in front of the anterior tibial margin.

There are several varieties:

(1) no displacement,

(2) angulation of the fragments so that the posterior half of the talus is plantarflexed, whilst its anterior half is dorsiflexed.

(3) displacement of the posterior half of the talus out of its mortice, with the anterior half still in place.

DIAGNOSIS

You can easily spot lateral displacement, but miss an angulation deformity on a lateral radiograph; so examine the posterior half of the subtaloid joint carefully: if its 2 articular surfaces are not parallel, the fragments have angulated at the fracture line.

If there is no angulation, apply a short leg walking cast from below-knee to toes, with the foot in neutral position. Get the patient up and teach walking with weight-bearing; at 3months, you can remove the cast.

ANGULATED TALAR NECK FRACTURE REDUCTION (GRADE 1.5)

If there is angulation, try to reduce the fracture by forcibly plantarflexing the foot (72-3) under ketamine. Place a canvas sling round the distal thigh (72-3C1) and flex the knee to 90^0. Grasp the heel with one hand and the forefoot with the other (72-3C3). external fixation may be possible. Pull the foot forward into full dorsiflexion (72-3C4), and at the same time strongly evert the foot (72-3D5): this will unlock the *sustentaculum tali.* Then, while your assistant, using the thumbs, presses on either side of the Achilles tendon (72-3E6), plantarflex the foot (72-3E7); a crunching noise indicates your reduction is successful.

Confirm reduction by a check radiograph. If it is successful, apply a cast from below-knee to toes, holding the foot in *equinus.* Keep the patient in bed, and encourage daily muscle exercises within the cast. Leave it for 5-6wks, and then replace it by another cast with the foot in neutral position for a further 5-6wks.

REDUCTION OF AN ANGULATED TALAR NECK FRACTURE

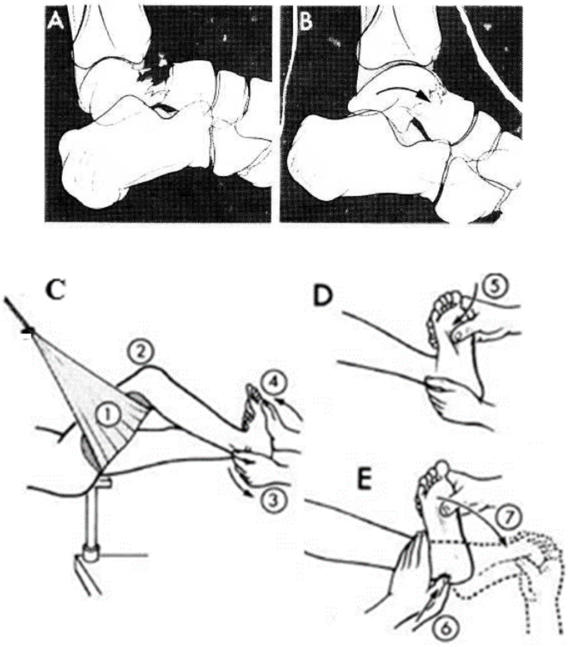


Fig. 72-3 REDUCING AN ANGULAR TALAR NECK FRACTURE. A, fracture before reduction. B, the way in which reduction occurs. C,D,E the method of reduction. *After de Palma AF, Management of Fractures and Dislocations, An Atlas, WB Saunders, 2nd ed 1970 with kind permission.*

If you have not been able to reduce the fracture, external fixation may be possible.

If there is forward displacement, forcibly plantarflex the foot & push it backwards. Apply a cast in *equinus,* as above.

If there is backward displacement, insert a Steinmann pin through the calcaneus (70.7), & exert traction to create space between it and the tibia, so that you can push the posterior talar fragment into the ankle mortice. Then apply a cast in *equinus* as above.

If reduction fails, an open reduction is necessary.

If, some months later, the foot is still painful & part of the talus looks dense on a radiograph, this is a sign of aseptic necrosis. This is common, and may eventually require an arthrodesis

SIGN OF A FRACTURED CALCANEUM

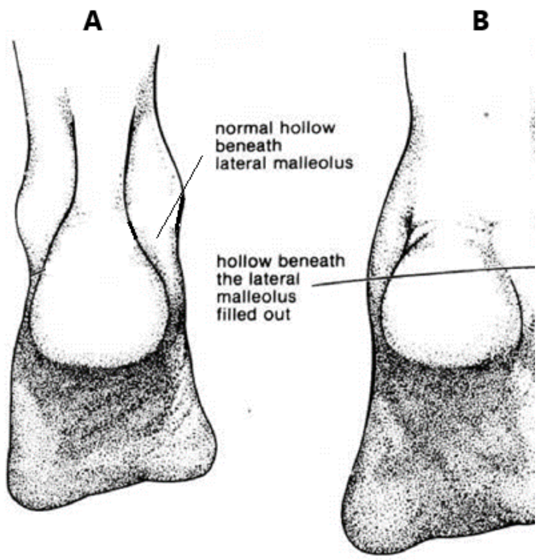


Fig. 72-4 SIGN OF A FRACTURED CALCANEUM. A, normal. B, filling out of the normal hollow below the lateral malleolus. *Kindly contributed by Peter Bewes.*

72.6 Calcaneal body fracture

This common fracture results from a fall onto the foot, usually from only quite a small height. Sometimes, both left & right fracture, and *also the spine*. So, *always Xray the vertebral spine also!* (54.10).

CALCANEAL FRACTURES

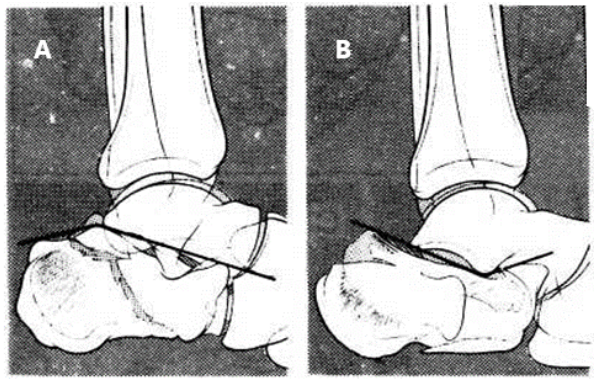


Fig. 72-5 CALCANEAL BODY FRACTURES. A, with mild displacement. B, with angulation & severe displacement. *After Perkins G. Orthopaedics. Athlone, London 1967 with kind permission.*

Although the foot may look normal, there are always 2 signs:
(1) The injured calcaneum looks wider, and the hollow beneath the lateral malleolus disappears (72-4B).
(2) There is no movement in the subtalar joint; although the ankle can move through about half its normal range of plantar- & dorsiflexion, everting the heel on the ankle is painful.
The fracture lines may not be easy to see on a radiograph, so take a lateral & special axial view, and look for widening of the calcaneum. Fractures take many forms & vary from small cracks to extensive fragments; however you treat them all the same way.

TREATMENT
Don't try to reduce this fracture! Instead, compress the swollen ankle with a tight crepe bandage. Advise 3days of bedrest, until the pain is bearable and putting the foot onto the ground is not too painful. Then, without full weight-bearing, with much encouragement & careful supervision, encourage active movements of the hip, knee, ankle & toes for 3wks. Follow this by active exercises with partial weight-bearing using crutches. Cycling is very useful. Early on, all such activity will be painful, so administer enough analgesia. Total recovery may take 2yrs.

If the fracture is bilateral, early mobilization will obviously be more difficult and take longer.

CAUTION!
If you have to apply a cast to ease the pain, or to allow out-patient treatment, leave it on only for a few days.
N.B. some patients will have disability which warrants a subtalar arthrodesis later, but *don't recommend this before 12 months!*

72.7 Other calcaneal fractures

These are all quite minor injuries. They are not Easy to diagnose, but since you can treat them all by active movements, this is unimportant.
(a) Calcaneal tuberosity fracture features either a fragment prised from the posterior calcaneal angle (visible on a lateral view), or a vertical fracture (seen on an axial view).
(b) *Sustentaculum tali* fracture is difficult to see on a radiograph. Displacement is slight, and no reduction is necessary.
(c) Anterior calcaneal fracture occurs when the foot inverts severely, or in a subtaloid dislocation. A small fragment comes off the upper surface of the bone.

72.8 Navicular & cuboid fracture

When the foot is crushed, the navicular or cuboid, or the metatarsals may fracture, or the midtarsal joint dislocate. These may all occur singly or together, and are serious injuries.

REDUCTION MIDTARSAL DISLOCATION (GRADE 1.4)
Under ketamine, try to manipulate the bones into a good position, especially those of the subtalar joint.
If you succeed, apply a short leg walking cast (70.2) with the foot in neutral position. Keep it raised until the swelling subsides. Then encourage walking with crutches, starting with partial weight-bearing. After 3wks, remove the cast. Check to see if pain & swelling have diminished enough to start walking full weight-bearing with crutches.

72.9 Tarso-metatarsal fracture-dislocation

This is difficult to see on a radiograph, but at the bases of the metatarsals, multiple fractures with little displacement is the norm. This is a severe injury and osteoarthritis often follows, sometimes needing an arthrodesis.

If there is severe displacement of the tarso-metatarsal joint, try to hold the broken bones in place with a well-moulded cast, holding the forefoot in plantarflexion. After 1wk, change this to a short leg walking cast & encourage walking.
External or internal fixation may be necessary (GRADE 3.1); make dorsal incisions between the 1st & 2nd & between the 3rd & 4th toes.

Pass a K-wire through the distal ends of the metatarsals, hold it in a tensioner, and use it to help manipulate the distal part of the foot to hold it in good position with crossed K-wires.

72.10 Crush metatarsal fracture

Any crush injury to the forefoot is serious, and can be disabling. The metatarsals usually fracture at the neck; there may be an open wound. Diagnosis is hard without a radiograph. These fractures are difficult to reduce; remember that the 1st mt is a weight-bearing bone!

If there is little or no displacement, the bones heal without reduction. When walking is possible, apply a tight crepe bandage & encourage walking. You may need a below-knee walking cast for 3wks otherwise.

N.B. if the bones heal in a grossly displaced position, the foot may be painful permanently.

If there is obvious gross displacement, reduce the fracture as best you can, apply a below-knee walking cast (70-2) & elevate the foot (70-1). Take care to mould the sole to both longitudinal & transverse arches of the foot (72-1). If you fail to correct the displacement, external or internal fixation is needed.

METATARSAL FRACTURES

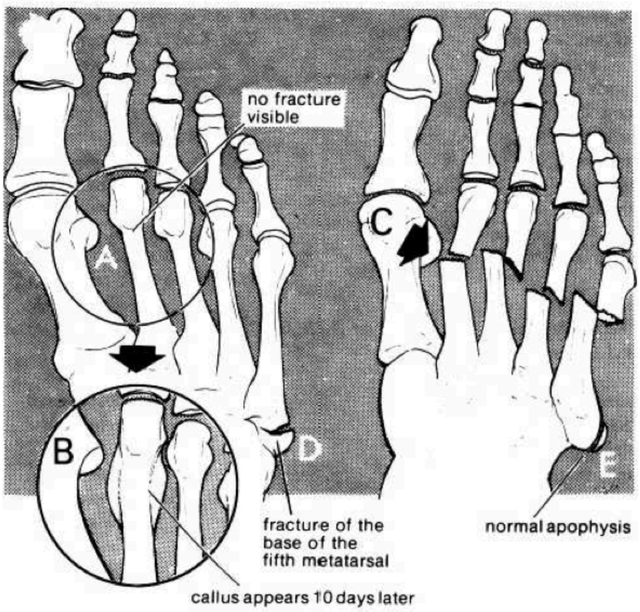


Fig. 72-6 METATARSAL FRACTURES. A, a March fracture with no immediately visible sign. B, the callus appearing 10days later. C, severely fractured metatarsals. D, fracture of the 5th mt base. E, comparing it with the normal apophysis.

If intense pain & swelling, marked stiffness, & warm smooth glossy skin, with bone rarefaction on radiographs, this is Sudek's atrophy (whose cause is unknown), but may persist for several years. Try to keep encouraging walking as bone rarefaction will deteriorate otherwise!

72.11 Fatigue (march) fracture

Without any history of injury, a metatarsal, usually the 2nd, fractures spontaneously. There is localized pain, particularly at night, and tenderness over the fracture site. At first, the radiograph shows only a fine transverse crack, or nothing at all. But after 10days, a mass of callus appears, which you might confuse with a sarcoma, as in the tibia (70.8). So, strap the front part of the foot, and avoid stress on the fracture site!

72.12 5th mt base fracture

Severe twisting of the front half of the foot tears a fragment bone from the base of the 5th metatarsal. Don't confuse this fracture with an ununited apophysis, which has a characteristic smooth comma shape, and is usually bilateral.
If you are in doubt, X-ray the other foot.
A history of spraining the foot or ankle is typical, but the lateral malleolus is not tender, and there is no tenderness over the front of the calcaneus. Instead, there is marked tenderness over and underneath the prominence formed by the base of the 5th metatarsal.
This is a painful injury, so fit a below-knee walking cast for 2wks, or longer if necessary.

72.13 Fracture of the toe phalanges

A weight falling onto the toes sometimes breaks them. Reduction is unnecessary, but it may be advisable to evacuate a painful subungual haematoma (65.4). These fractures are not serious and always unite. Splint the injured toe with zinc oxide strapping to the adjacent normal toe. Pad it with a little cotton wool to absorb moisture. As soon as the shoe can be worn, discharge the patient. A metal stiffener driven down between the layers of the sole of the shoe will help return to work sooner.

73 Child orthopaedic injury

73.1 Fractures in children

Play is the occupation of children and sometimes, they do not play safely. They are not exempt from road traffic injuries, assault, and abuse. Children living with disabilities that impair movement or who are malnourished may have osteoporotic bones that render them soft and more prone to breaking.

A child's bones differ from those of an adult. Instead of fracturing completely, they often bend like a stick (incomplete or greenstick fractures), or there may only be a small swelling of the cortex (buckle fractures).

This chapter deals with issues specific to children, and where treatment differs from that for adults.

The child's long bone has two ends, proximal and distal, linked by an intervening shaft, the diaphysis. Between the ends and the shaft, there is a growth plate, the physis, where which the bone increases in length. The physis is a layer of radiolucent cartilage and is weaker than the bone. The epiphysis is the bony region beyond the physis and adjacent to the joint surface, while the metaphysis is the flared part of the bone that blends with the diaphysis.

There are 2 types of epiphyses: (1) pressure (compression) epiphyses at the ends of long bones near joints, and (2) traction (tensile) epiphyses where muscles are inserted. These are called apophyses and are often prone to displacement. Apophyseal injuries are usually only a minor nuisance, with the exception of the important medial epicondyle injuries of the humerus (73-13).

Injuries to long bones often affect the growth plate more than the adjacent bone. The epiphyses are sites where cartilage is converted into bone and growth in length occurs. When poorly managed, epiphyseal injuries lead to deformities (asymmetric growth, growth arrest or length discrepancies).

Fractures in children unite quickly and rarely need surgery; they need immobilization for a shorter time, and you can almost always manage them by closed methods.

BONY INJURIES IN CHILDREN

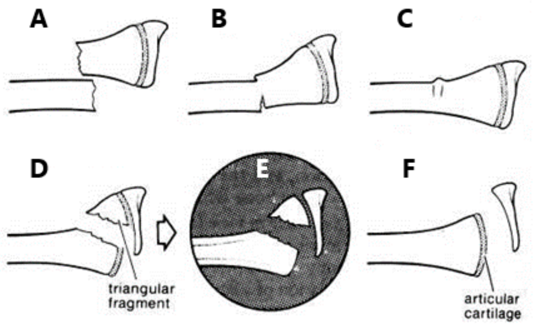


Fig.73-1 BONY INJURIES IN CHILDREN. A child's bones are different from those of an adult; instead of breaking, they often bend like a stick. A, complete fracture. B, greenstick fracture. C, buckle fracture. D, epiphyseal fracture Type II. E, Xray view of D. F, epiphyseal fracture Type I. *Kindly contributed by Peter Bewes*

The periosteum is a membranous tissue covering the bone surfaces where there is no cartilage nor attachment of tendons & ligaments. It has an outer fibrous layer that lends structural integrity and an inner *cambium* that has significant osteoblastic potential. This contains blood vessels and nerves and is important in bone repair and appositional growth. The periosteum is generally thicker in children than adults, and limits displacement of bone fragments after fracture and provides a hinge which might either help or hinder reduction..

SIGNS

Examination normally reveals the site of injury, with swelling, tenderness, deformity or abnormal movement. Angular deformity and length discrepancy may be a feature of late presentation.

Although some severe malunion slowly disappears as a child grows, other apparently mild malunion becomes steadily worse. *So, you must know which positions you can accept, and which you cannot.* Here are some general principles. *Note a child's fracture becomes 'sticky' within 1wk.*

(1) Try to get the fragments into line. They don't necessarily have to be end to end. In younger children, especially, side to side alignment may also be acceptable.

(2) Try to stop them from rotating, because growth will not correct a rotation deformity.

(3) Be cautious about how much angulation you accept. This depends on:
(a) The age & gender of the child, and particularly on whether the epiphyses have united or not. The younger the child the higher the remodelling potential. The epiphyses remain open longer in boys than in girls.
(b) The distance in a long bone fracture from the knee or elbow. Remodelling potential increases the further away from the elbow and the closer to the knee. The younger the child, the greater the angulation you can accept. Uncorrected angulation, shortening or rotation in the middle of a long bone causes severe deformity, especially in the forearm, but also in the femur and tibia. Angulation is likely to be permanent.

(4) Overlap and moderate shortening are unimportant. In fractures of the femur and humerus in younger children, *overlap is even desirable*, because these bones show overgrowth after a fracture. So you can leave a fractured long bone to unite with its fragments side to side up to the age of 10 in girls, and 12 in boys. The fragments unite rapidly, and the bone soon remodels.

(5) Beware displaced intra-articular fracture displacement with the axis at right angles to the plane of movement, and displaced fractures crossing the growth plate at right angles: these need reduction.

Children may be difficult to manage in an emergency and whenever possible and safe, they should have their fracture reduction and immobilization done under GA in the OT, especially if fluoroscopy is available. You may decide to admit or discharge a child once awake according to the type of fracture and procedure, and the risk of neurovascular complications. We mention here special instances where childhood injuries require a different approach than adult injuries.

73.2 Epiphyseal injury in children

At the end of this book you will see charts showing the epiphyses, and stating both the time they appear and when they unite.

N.B. A rural African child's epiphyses may remain open almost to the age of 20yrs, rather than 14 in a girl and 16 in a boy as in Western countries. This is probably a genetic difference. Some epiphyses are much more often injured than others.

The cartilage joining epiphyses and apophyses to the shaft of a bone is weak, and is often the site of displacement.
Suspect an epiphyseal injury whenever a child has an injury near the end of a long bone, even if it seems only to be a sprain.

On rare occasions, an epiphyseal injury may reduce spontaneously. This kind of epiphyseal injury cannot be diagnosed on a radiograph, since the bone will appear normal, but you can visualize the epiphysis with ultrasound, and the child will be in pain.

Fortunately, most epiphyseal injures cause no harm to bone-producing cells. However, if these they are injured, partial or complete growth arrest can occur. If injury is unilateral, or if injury is greater in one bone in a parallel pair, such as the radius and ulna, progressive angular deformity may occur slowly over several years, and then needs an osteotomy for correction.

There are 5 types of epiphyseal injury, each requiring different management, with a different prognosis.

EPIPHYSEAL INJURIES

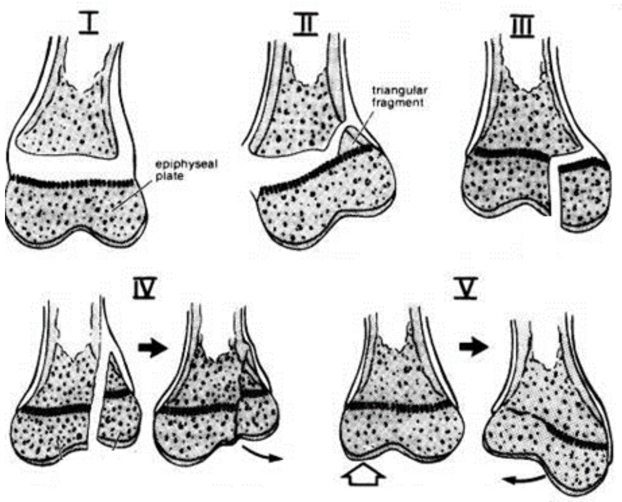


Fig. 73-2 EPIPHYSEAL INJURIES. Type I, a slipped epiphysis. Type II, epiphyseal separation which takes a triangular piece off the shaft. Type III, partial epiphyseal separation with fracture of a distal fragment, involving the joint. Type IV, a lateral condylar fracture through the epiphyseal plate into the joint. Type V, a crushed epiphyseal plate, leading to deformity later. *After Salter RB, Harris RW, Injuries involving the epiphyseal plate. J Bone Joint Surg Am 1963; 45(3): 587-622 with kind permission.*

Type I: The epiphysis slips completely off the end of the shaft, without a fracture. These injuries are common at birth and in early childhood. Reduction is usually not difficult, and the prognosis is good, *except at the upper end of the femur* (73.12).

Type II: The line of separation runs through **a** part of the epiphyseal plate and then out through the shaft, where it produces a characteristic triangular fragment (73-1D). This is a common epiphyseal injury, particularly at the distal end of the radius.

Type III: The fracture extends from the joint surface into the epiphyseal line and then along into the periphery. These are rare injuries, usually at the ends of the tibia. Accurate reduction is essential to restore a smooth joint surface and align the epiphyseal plates. An open operation may be necessary.

Type IV: The epiphysis and part of the shaft split, particularly at the lateral condyle of the humerus (72.13). Perfect reduction is essential, and open reduction is often necessary.

Type V: This is another rare injury, usually of the ankle or knee, with a poor prognosis. The epiphyseal plate is crushed and at least part of it subsequently closes early, resulting in severe shortening & deformity. The 1st radiograph may look almost normal, and you may think the child has a sprain. Suspect an injury of this kind if there is a history of a crush injury, and don`t allow weight bearing for at least 3wks. Inform the parents about this potential devastating result right at the beginning.

Treat epiphyseal injuries with splinting to minimize swelling and discomfort. Gentle, timely and appropriate reduction may be necessary as well as further immobilization. Close, repeated follow-up is important during the growth of the child.

RADIOGRAPHS
Take 2 views of the child`s injured limb at 90° to each other; always include proximal & distal joints not to miss Monteggia (63.3) or Galeazzi (63.4) fractures, for example. Take care to position the limb correctly.

If you find the radiographs difficult to interpret, you may have to compare them with exactly the same views of the opposite limb, *although this exposes a child to extra radiation! Failure to do this is, however, responsible for most of the errors in treating children's fractures.*
Diagnosing an epiphyseal separation is difficult before the centres of ossification have appeared. Suspect epiphyseal separation if there is displacement of the shaft and soft tissue swelling.

REDUCTION
An epiphyseal plate is easily damaged, so reduce the displacement gently. If a Type I or II injury is >10 days old, leave it. The epiphysis will probably have started healing in this position already. *An attempt to reduce the epiphysis at this time may actually damage it permanently*.

If the displacement is too big to ignore, an osteotomy will be necessary at a later point in time.
CAUTION! Reduce these injuries immediately, especially in the lower limbs. Any delay will make reduction more difficult.

IMMOBILIZATION
Immobilize epiphyseal injuries for the same time as for a shaft fracture for a child of the same age.

FOLLOW UP
See the child regularly. You may have to compare radiographs of the injured side with the opposite side. If there has been little growth, review every 3-6 months.

PROGNOSIS
This is good for injuries of Types I & II and poor for Types III-V, particularly Type IV if there is gross displacement needing internal fixation. The younger the child, the more growth ahead, and the worse the deformity that may follow a given injury involving bone-producing cells. An injury in the last year of growth is likely to cause little disability.

REDUCE EPIPHYSEAL INJURIES IMMEDIATELY

73.3 History in child trauma

OF UTMOST IMPORTANCE IN PAEDIATRIC TRAUMA: ASKING HOW DID IT HAPPEN?

The history of trauma/accident must reveal an adequate explanation for the injury. This is of utmost importance, especially in younger children, to distinguish accidents from non-accidental injuries (47.1), particularly pathological fractures or child abuse.
If trivial trauma results in broken bones, a pathological fracture in the presence of a juvenile bone cyst could still be the cause.

Delayed presentation, unmentioned secrets, inconsistent or contradictory history in front of an 'extraordinary looking' fracture *will point to child abuse*.

Typical patterns are metaphyseal fractures or bony fragments, subperiostal haematomas, and fractures of different ages. Last but not least, *beware spiral shaft fractures in infants who are yet not walking themselves!*

N.B. If a child has pain in a bone or joint, especially at night, think of infection or tumour!

A CHILD COMPLAINING ABOUT A CAST ALWAYS HAS A GOOD REASON!

Tell the guardians the same!

Take the opportunity to teach the family after any accident regarding child safety protection means (*i.e.* wearing helmets on motorcycles, or safety belts in cars).

For children, the guardians are of utmost importance in encouraging exercises, getting acute pain relief and providing encouragement!

SHANTI (8yrs) had an undisplaced fracture of the distal end of her radius. There was almost no swelling. A circular cast was applied. She returned the next day crying in pain. She was given aspirin and sent home. Three days later she returned with a gangrenous hand and sloughing forearm muscles. Her forearm was amputated. LESSONS (1) *Never treat a painful cast with analgesics only!* (2) Pain, numbness, and paralysis are signs of impending compartment syndrome.

ABDULLAH (8yrs) had a supracondylar fracture. It was successfully reduced within 1h and a skin tight cast was applied. He returned the following day saying that the fingers hurt, but was sent home without removal of the cast. A mere 5 days later he returned. This time all the fingers and thumb were black and gangrenous, and had to be amputated. LESSONS (1) A closed cast is *not* the treatment for this fracture; a posterior plaster slab is preferred. (2) *Take any complaint of pain seriously and split or remove a cast immediately*.

N.B. Always demonstrate the equipment for removing a cast to a child beforehand, & apply ear plugs (if possible) when using an electric saw.

N.B. Treat girls after their first menses and boys after their growth spurt as adults.

73.4 Fracture immobilization

PLASTER OF PARIS PoP CASTS
Casts are frequently used in children, and unsplit circular casts pose little risk in children compared to adults when used correctly.

Use PoP, since it is cheap, easy to apply, very malleable and can be taken off by parents themselves by submerging the plaster in water in case of emergency.

Explain to parents what the alarm symptoms for a compartment syndrome are: increased pain, change of colour of fingers or toes, complaints of tingling, numbness or paralysis and explain how to take of the cast at home for every cast you apply.

N.B. In small children a compartment syndrome may present with agitation and anxiety instead of the classic 6 P's (49.2).

N.B. Never use an unsplit cast:
(1) for an elbow fracture
(2) for a swollen joint
(3) where there is a distal neurological deficit.

Keep in mind that the patient in the cast still needs to go to toilet and attend to personal hygiene. So tape exchangeable plastic onto the edges of the cast near to the body orifices

SKIN TRACTION

Skin traction is much more satisfactory in children than it is in adults, and, because a child`s joint does not become stiff permanently, it seldom needs physiotherapy.

This is particularly useful for treating elbow and femoral fractures in children.

(a) Gallows traction
Suspend the legs of a small child with a fractured femur from a bar with adhesive strapping.

(b) Extension traction
Use adhesive strapping to treat femoral fractures in an older child or teenager with the knee extended. This is also useful for some femoral neck fractures (67.3, 73-10A).

(c) Forearm (Dunlop) **traction**
Apply adhesive strapping to a child's forearm when the elbow is so swollen from a supracondylar fracture that it cannot be reduced immediately. (73-10B)
CAUTION! *Don't let the strapping interfere with the circulation of the hand.*

N.B. Don't use skeletal traction across joints in children. It may damage the growth plate and/or ligaments.

For TRACTION WEIGHTS, use bottles filled with water. *Don't exceed 10% of the child's body weight!*

FIXATION
It is essential in children to cover *ALL* external wiring safely, because at a certain age, children put everything in their mouth and therefore might ingest your K-wire etc.

EXERCISES
When the time is right, encourage exercises; active physiotherapy is rarely needed, but parental encouragement is ideal. Mostly, all a child needs is to play outside! *Active movements are safer than forced passive manipulation!*

73.5 Shoulder injury in children

(a) Clavicular fracture
Fracture of the clavicle is common in a child, who cries on moving the arm, but there may be little to suggest that the clavicle is broken. Feel carefully, and you will find an area of tenderness but no swelling.
The fracture may be a greenstick and difficult to see on a radiograph (easier on ultrasound), but is not really necessary unless there are unusual symptoms. Rarely there is an acromio-clavicular dislocation or brachial plexus injury. A young child may resolutely refuse to use the arm.
A figure-of-8 shoulder strapping eases the pain. The fracture heals easily, but if there is gross displacement or serious tenting of the skin, reduction & internal fixation is necessary.

N.B. Sometimes there is a swelling without any history of injury, so always consider child abuse (47.3)!

N.B. A congenital pseudo-arthrosis may occur in the absence of trauma, especially associated with dextrocardia, if on the right.

(b) Humeral neck fracture

Fractures of the surgical neck are relatively common in children; more commonly metaphyseal <11yrs and epiphyseal >11yrs. Some children are in great pain and are quite unable to move the arm; others have little pain and a surprising range of shoulder movement.

If a child is in pain, don't try to examine the shoulder; get a radiograph. Take 2 views to determine the position of the fragments.

In young children, the fracture is transverse and is 2cm below the epiphyseal line. When the fracture is complete, the shaft rides up in front of the upper fragment, and overlaps it.

Epiphyseal fractures are sometimes associated with a slowly evolving brachial plexus palsy, especially if axial reduction is delayed. Try to get as correct reduction as possible. In severe cases external fixation is advisable.

Fractures of the proximal metaphysis are more common between 5-11yrs. Greenstick fractures are common in the youngest, but seldom occur with significant angular deformity. Pathological fractures, *e.g.* from a juvenile bone cyst, are quite frequently found in this area.

The neck of the humerus breaks, either at the time of the accident, or while a simple dislocation is being reduced with excessive force. The head of the humerus lies in front of the glenoid, or it may be displaced into the axilla. The axillary vessels and the brachial plexus are sometimes injured at the same time.

In children 5-15yrs, the head of the humerus sometimes becomes detached from the shaft, and may take a piece of the shaft with it. The head of the humerus is very mobile, so reduction can be difficult. Perfect reduction is not necessary because the head readily remodels. Check for any involvement of the brachial plexus: check the radial pulse and the axillary nerve (48.1).

TREATMENT
If the fragments are not widely separated, put the arm in a sling and encourage the child to move it.

If the fragments are widely separated, try to get them to hitch (61.12). Use GA with full relaxation.

Ask an assistant to pull the arm into abduction, (61-14). As he does so, use both your thumbs to press the humeral head towards its socket.
If possible, get radiographs to check reduction whilst the child is still anaesthetized. Maintain traction in bed for 2wks. Then protect it in a sling for another week.

If you succeed in reducing the humeral head, treat this as an uncomplicated fracture of the humeral neck (61.12).

If you cannot reduce the head the first time, try only once more. If you fail again, it will need open reduction.

If you fail to get the humeral fragments to hitch, use traction for 2wks, using overhead suspension (73-10), a pulley, and enough weight to keep the arm raised: 2kg will probably suffice. *Don't tie the arm to a pole*, because on sitting up, reduction is lost. Continue until the fragments are 'sticky'. Then start pendulum exercises.

Acceptable alignment and angulation per age group are:

Age	Varus/Valgus Angulation	Displacement	Shortening
<5yrs	60°/10°	100%	2cm
5-12yrs	30-60°/10°	50-100%	2cm
>12yrs	<30°/10°	<50%	2cm

DIFFICULTIES WITH HUMERAL NECK FRACTURES IN CHILDREN

If the sharp end of the distal fragment has perforated the shoulder muscles, and you can feel it under the skin, use GA and manipulate the broken end of the humerus back through the muscles.

Use a combination of pulling and twisting movements, and get it to hitch with the proximal fragment. Sometimes the distal fragment goes right through the skin.

N.B. Treat this as a compound fracture!

73.6 Upper arm injury in babies

A baby's humerus is often fractured during a difficult delivery, or in a non-accidental injury. It heals rapidly with massive callus formation and needs no treatment, unless there is >30° angulation or >2cm shortening. Bind the arm loosely to the chest wall with a crepe bandage for 1wk to prevent further injury.
At the end of 1yr there will be no trace of the fracture.

N.B. **A brachial plexus injury** may also occur from vigorous pulling of the arm, or from an obstetric injury to a neonate.

73.7 Elbow injury in children

AGE INCIDENCE OF CHILD ELBOW INJURIES

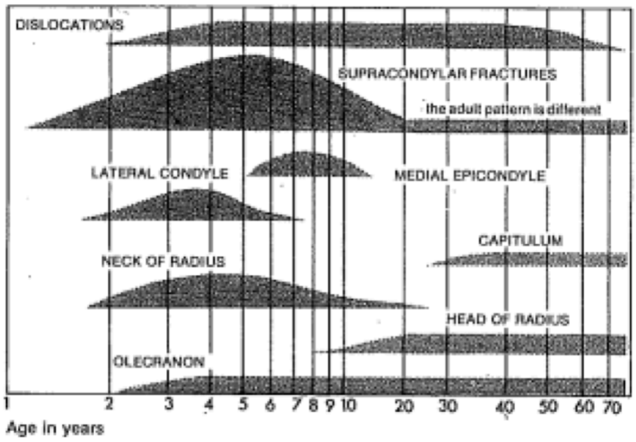


Fig. 73-3 INJURIES AROUND THE ELBOW have a characteristic age incidence. Dislocations occur at all ages. Supracondylar fractures are the most common elbow injuries with a modal age c. 7yrs. The medial epicondyle is injured in teenagers, and the lateral condyle in young children. The neck of the radius fractures in children, and its head in adults.

Feel the bony anatomy of the child's elbow carefully; this may be difficult if it is very swollen. Note especially the position of the olecranon in relation to the humeral axis. This is a useful guide to satisfactory reduction. Feel how much external rotation of the flexed elbow is possible on the normal side.

FEATURES OF ELBOW INJURIES:
Dislocation
(1) Any age.
(2) Contour normal.
(3) Severe swelling.
(4) Elbow fixed at 45°.
(5) 3 Bony points misaligned.

Supracondylar fracture
(1) Common in children.
(2) Contour abnormal.
(3) Severe swelling.
(4) Some movement possible.
(5) 3 Bony points aligned but displaced posteriorly relative to the humeral shaft.
(6) Lower humeral fragment mobile + crepitus

Fractured medial epicondyle
(1) Older children & adolescents.
(2) Contour normal.
(3) Medial epicondyle tender and swollen.
(4) Some flexion and extension possible.
(5) Rotation painful but possible.

Fractured lateral condyle
(1) Children.
(2) Contour normal.
(3) Lateral condyle tender and swollen.

Fractured radial neck
(1) Children <4yrs.
(2) Contour normal.
(3) Flexion and extension possible.
(4) No rotation.
(5) Radial head tender.

Pulled elbow
(1) Young child.
(2) Contour normal.
(3) Child refuses to use the arm.
(4) No rotation.
(5) *The arm hangs straight down with the forearm in pronation*

Fractured olecranon
(1) All ages.
(2) Contour normal.
(3) Moderate swelling.
(4) Olecranon tender, with palpable gap.
(5) 2 varieties: active extension or not.

ELBOW RADIOGRAPH: 10-YR OLD CHIILD

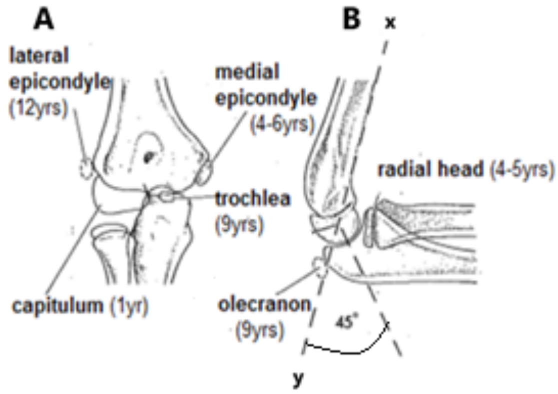


Fig. 73-4 10YR OLD CHILD'S ELBOW RADIOGRAPH. A, find 6 centres of ossification in the AP view, but they are not always present at the same time. A large centre for the capitulum appears in the 1st yr. A smaller one for the medial part of the trochlea appears at c.9yrs. A centre for the medial epicondyle appears about the 5th yr. It is entirely outside the capsule and unites with the shaft at 20yrs. The lateral epicondyle starts to ossify at about 12yrs. The centres for the capitulum, trochlea and lateral condyle join one another and the shaft at puberty. A centre for the head of the radius appears in the 4th or 5th yr, and unites with the shaft at puberty. There is also a centre of ossification for the olecranon, and another centre for the trochlea (not shown). These appear at c.9yrs and unite at puberty. B, in a lateral view, the shaft of the humerus and its lower epiphysis overlap one another and obscure most of the epiphyseal space, which is wider behind than in front. A normal epiphysis lies in front of the lower end of the shaft, so a line xy drawn down the anterior border of the shaft meets the epiphysis at its middle. A supracondylar fracture disturbs these relationships. *After Perkins G. Fractures and Disclocations,. Athlone, London, 1958, with kind permission.*

ELBOW DISLOCATION
A child may fracture the medial epicondyle which may become trapped inside the dislocated elbow.
Reduce an elbow dislocation in the same way as in adults. Always get a radiograph after reduction to check for additional fractures. Put on a posterior plaster slab for 2wks for protection.

If you cannot reduce an elbow dislocation, the medial epicondyle may have broken off and be inside the joint. If in doubt, compare with the other elbow, and look for a small centre of ossification in an abnormal position.

ELBOW FRACTURES
A child falls on the outstretched arm, and breaks the lower end of the shaft of the humerus just above the epiphyseal line in one of four ways:
(1) In $^1/_3$ of cases, there is no displacement, or the fracture is incomplete, so that the child needs no treatment except for a collar-and-cuff.
(2) In the remaining $^2/_3$, the distal fragment is diplaced posteriorly (62-10A). There is tenderness just above the elbow, which swells rapidly and obscures the bones around the fracture
(3) Occasionally, the lower fragment is displaced anteriorly (73-6C).
(4) Occasionally, separation takes place at the epiphyseal line and displaces the epiphysis. Treat these epiphyseal displacements exactly as if they were supracondylar fractures, and reduce them immediately. Like all epiphyseal injuries, they unite rapidly.

Supracondylar humeral fractures are very common in children. They may be complicated by radial or median nerve as well as vascular injuries. Malunion, with a consequent restriction of function, follows if the fracture is not well reduced.

The history is usually of a fall during play followed by a painful, swollen elbow with marked limitation of movement. Antecubital ecchymosis is a sign of subcutaneous bone fragments with soft tissue interposition. It often results in severe swelling and reduction will be difficult.

Check the colour of the skin of the hand on that side, for warmth and capillary refill.

N.B. The radial pulse may still be palpable with a severe vascular injury!

Rule out nerve injuries by asking the child to cross the index and middle fingers of the affected limb (73-5A), make an 'O' sign (73-5B) and give a 'thumb's up' (73-5C) sign.

HAND SIGNS FOR ELBOW INJURY

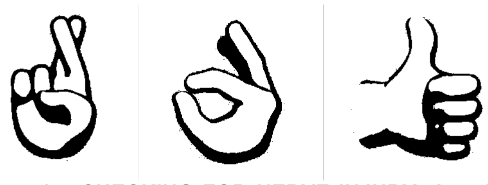


Fig. 73-5 CHECKING FOR NERVE INJURY. A, ask the child to cross the index & middle fingers. B, make an 'O'. C, give a 'thumbs up'

The lower end of the humeral shaft break may be undisplaced or incomplete. Commonly there is a posterior (73-6A) or more rarely, an anterior (73-6C) displacement of the distal fragment.
Bony landmarks are the radial & ulnar epicondyles and the olecranon. *If these are tender or can be moved*, a fracture may be present.

Check the ulnar and radial collateral ligament stability in extended elbow position; pronate and supinate the forearm in 90° of flexion: you will be able to feel the radial head moving.

If the 3 bony points are in their correct relation to one another but are displaced in relation to the lower end of the humerus (62-1), there may be a supracondylar fracture. *This is a critically important sign in very young children before much ossification has taken place in the lower end* of *the humerus.*

You can only make a safe and correct diagnosis of any elbow fracture or dislocation by x-ray of the elbow in AP & lateral planes. The films of a child's elbow are difficult to interpret; sometimes it is helpful to x-ray the other elbow and compare both films. If you are in doubt, apply a posterior plaster slab and re-evaluate after 1wk.

N.B. (1) in children a mildly oblique radiograph can both resemble and disguise a dislocation, and (2) the radial read and medial & lateral epicondyles can be displaced before their centres of ossification appear. This makes diagnosis difficult.

If the radiograph of a child's injured elbow looks normal, & the 3 bony points are in their normal places, consider a 'pulled elbow' (actually a subluxation of the radial head).

(a) Posteriorly displaced supracondylar humeral fracture
This is a particularly important fracture as the wrong treatment can easily result in a useless elbow. They are common, arising from a fall on the outstretched arm, between the ages of 3-11yrs, and are rare >18yrs,
The radial nerve and brachial artery are in danger.
A child falls on the outstretched arm, and breaks the lower end of the shaft of the humerus just above the epiphyseal line in one of 4 ways:
(1) In $^{1}/_{3}$ of cases, there is no displacement, or the fracture is incomplete, so that the child needs no treatment except for a collar-and-cuff.
(2) In the remaining $^{2}/_{3}$, the distal fragment is diplaced posteriorly. There is tenderness just above the elbow, which swells rapidly and obscures the bones around the fracture
(3) Occasionally, the lower fragment displaces anteriorly (73-6C).
(4) Occasionally, separation takes place at the epiphyseal line and displaces the epiphysis.

DISPLACED SUPRACONDYLAR FRACTURES

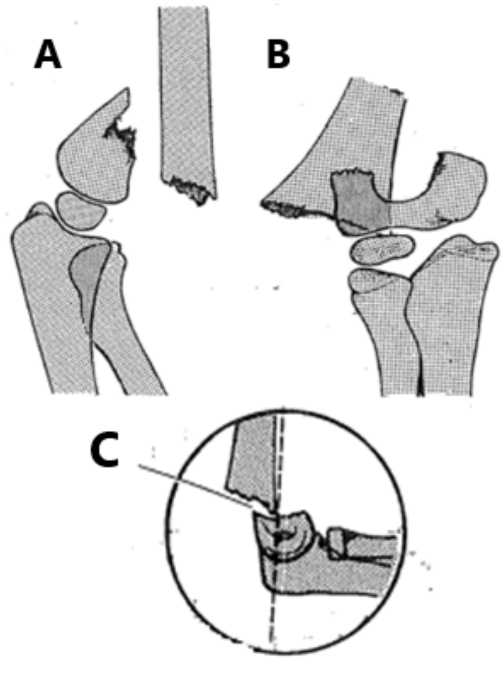


Fig. 73-6 SUPRACONDYLAR FRACTURES. A, lateral view of posterior displacement. B, anterior view. C, lateral view of an anterior displacement: the anterior humeral line should pass through the middle $^{1}/_{3}$ of the ossification centre of the capitulum

Treat these epiphyseal displacements exactly as if they were supracondylar fractures, and reduce them immediately. Like all epiphyseal injuries, they unite rapidly.

The force causing the injury pushes the distal fragment posteriorly and proximally, and the proximal fragment anteriorly and distally. The sharp proximal fragment pierces the periosteum, and comes to lie under *brachialis*. If the force continues the proximal fragment goes straight through *brachialis* into the antecubital fossa, and may even penetrate the skin.

As it moves forwards it may tear the brachial artery, or make cause spasm of the artery, or injure the median, or occasionally, the radial nerve. The artery and the nerve may also come to lie between the proximal and distal fragments, and so prevent reduction. Worse, the antecubital fossa fills with blood. This obstructs the collateral vessels which impairs the venous return from the forearm. The ischaemic forearm muscles swell and the compartment syndrome develops (49-6). *Bending such an acutely swollen elbow is like trying to bend a balloon.*

COMPLICATIONS

(1) **A rare immediate danger**, both with this fracture and with posterior dislocations of the elbow, is that the fracture can impair the blood supply to the lower arm, and cause a compartment syndrome. If the forearm remains warm, splint & watch. *If it is cool & pale, explore!*

N.B. Contracture from a supracondylar fracture is much rarer than from *failing to split a circular cast* on a fracture of the forearm.

(2) **The most common later danger** is a very stiff, or fixed elbow. This is caused by the post-traumatic ossification that may follow repeated manipulation or early aggressive physiotherapy. *So reduce the fracture with a maximum of 2 attempts.* Your 1st attempt is the most likely to succeed, and later tries will be more and more difficult.

(3) **The other common late disability** is a deformed elbow.
The displacements which remodel are:
(a) Minimal angulation of the lower fragment in the axial plane of the elbow
(b) Minimal displacement of the lower fragment; growth of the epiphysis corrects this.

(4) **If there is a neurological deficit distally,** consider exploration if there is poor reduction or after 6months.

UNCORRECTED ANGULATION IN A SUPRACONDYLAR FRACTURE

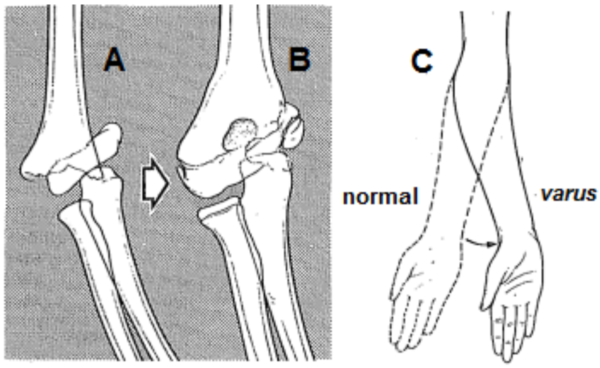


Fig 73-7 UNCORRECTED ANGULATION IN A SUPRACONDYLAR FRACTURE. C, *varus* angulation is common and results in a loss of carrying angle in mild cases, or in an ugly deformity in more severe cases, as in this child. It does not affect flexion and extension, so that disability is mild, but it does not look good. *After Perkins G. Fractures and Disclocations. Athlone, London, 1958, with kind permission.*

The displacements which don't remodel are:
(a) Severe angulation of the lower fragment in the plane of the elbow. If you leave this unreduced, or reduce it badly, the child will be left with permanent hyperextension and severe loss of flexion
(b) *Valgus* & *varus* angulation, however mild it is or young the child. *Varus* angulation is common and is usually accompanied by internal rotation and medial displacement. The result is a loss of the normal carrying angle in mild cases, or an ugly *varus* deformity in more severe ones, (73-7). This is common, and although it does not affect flexion or extension, so that disability is mild, it does not look good, and makes it difficult for the patient to carry a basket.

The fragment may also injure the median or occasionally the radial nerve. Soft tissue may also come to lie between proximal and distal fragments, and so prevent proper reduction.
A later complication is post-traumatic ossification following repeated manipulation, as with elbow dislocation (62.3).

N.B. Never treat these fractures with a circular cast. The risk of Volkmann`s ischaemic contracture is great. If you do apply plaster, it *must* be a backslab.

NEVER PUT A CIRCULAR CAST ON A SUPRACONDYLAR FRACTURE

This description is of reduction of a fracture on the *right side*, (73-8).

Flex the child`s normal elbow, feel its bony anatomy carefully, and compare it with the injured elbow. Feeling the bony parts of the injured elbow may be impossible if it is very swollen. Note especially the position of the olecranon in relation to the axis of the humerus. This is a useful guide to satisfactory reduction.

Feel how much external rotation of the flexed elbow is possible on the normal side. Later, when you come to reduce a medially displaced fragment, you will need to rotate the injured forearm externally to the limit of what is possible on the normal side, and a bit more. This external rotation may be critical. Sideways displacements either corrects itself, or is easily corrected.

Note what happens to the pulse if you flex and exert gentle traction on the arm. If the pulse disappears and only reappears when the arm is nearly straight, it may merely be due to the swelling round the elbow, or there may be a brachial artery lesion.
Try to check with an ultrasound Doppler.

If possible, reduce the fracture immediately. If there are signs of ischaemia this is urgent.

If immediate reduction is impossible because the arm is swollen like a balloon, apply forearm traction (73-9), and reduce the fracture as soon as the swelling has subsided sufficiently for you to feel the fragments.

Reduction is possible up to 7days after the injury, but not more.

If the fracture is >7days old, manipulation is very difficult, so leave it. Six months later, if there is a severe deformity, refer for a corrective osteotomy. Check the median, ulna, and radial nerves (65-3).

REDUCTION OF A POSTERIORLY DISPLACED SUPRACONDYLAR FRACTURE (GRADE 1.3)

The principles of reduction are:
(1) To exert traction on the elbow, and while doing this to correct the sideways displacement of the distal fragment.
(2) Then to flex the arm while still exerting traction, so as to use *triceps* tendon action to hold the lower fragment in place.
A common error is to try to correct sideways displacement *after you have flexed the arm*.
(3) Finally to flex the wrist maximally and keep everything fixed by taping the lower and upper arm in this position with a figure-of-8 adhesive.

N.B. If you have fluoroscopy, supinate or pronate gently, until you see exact anatomic reduction.

SUPRACONDYLAR FRACTURE REDUCTION

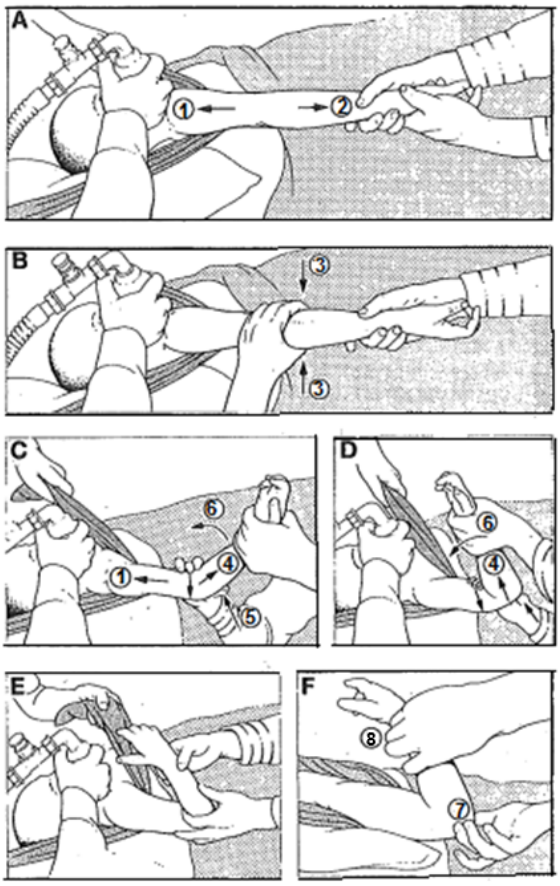


Fig. 73-8 RIGHT SUPRACONDYLAR FRACTURE REDUCTION. A, an assistant steadies the shoulder (1), and keeps the elbow slightly flexed; you disimpact the fracture by pulling on the forearm (2) for ≥1min. B, feel for the distal fragment and push it to the middle if displaced medially or laterally (3). C, keep pulling on the forearm with your left hand (4), and press the olecranon fragment with your right thumb (5), and start flexing the elbow to 90^0 (6). D, keep pressing on the olecranon & externally rotate the forearm a little more than the left side can. E, continue flexing past 90^0 pushing posteriorly on the humerus & pulling on the forearm. F, check the position of the olecranon (7) & feel the radial pulse (8). *Kindly contributed by Peter Bewes.*

Get an assistant to exert traction with a towel in the axilla. Pull to disimpact the fracture and correct the angulation. Extend the elbow gently, gripping the wrist and distal forearm. Pull hard in a longitudinal direction *for a full minute* (73-9A).

As you feel the fragments disimpacting, check that the lower humeral fragment is free. Correct medial and lateral displacement of the distal fragment now (73-9B).

Whilst exerting longitudinal traction with your left hand, press on the olecranon with your right thumb, starting to flex the elbow to 90º (73-9C). Keep pressing the olecranon & externally rotate the forearm a little more than was possible on the normal side (73-9D). (This helps to restore the normal carrying angle).

Continue flexing the elbow past 90°, push posteriorly on the humerus, and pulling on the forearm (73-9E).

CAUTION! Use only moderate tension as the arm reaches 90°. If you pull too hard at this stage, you can pull the distal fragment in front of the end of the humerus. (Fortunately, this is rare!) Now complete the flexing.

N.B. Beyond 90°, further flexion does not improve reduction, but does stabilize reduction by wrapping the *triceps* tendon round the distal fragment and fixing it. This also impacts the fragments. *You cannot now correct lateral displacement of the distal fragment.*

Check the position of the point of the olecranon (73-8F). It should be in line with the axis of the humerus or perhaps little anterior to it.
You should also be able to feel both epicondyles forming, with the tip of the olecranon, the 3 bony points of the elbow (73-4)

Check the child`s pulse. This may be difficult because of oedema. If the pulse disappears when you flex the arm, extend the elbow until it reappears.

Check the function of the median and ulnar nerves (65-3). They may be injured, but function usually recovers eventually**.**

ELEVATION WITH A STOCKINETTE

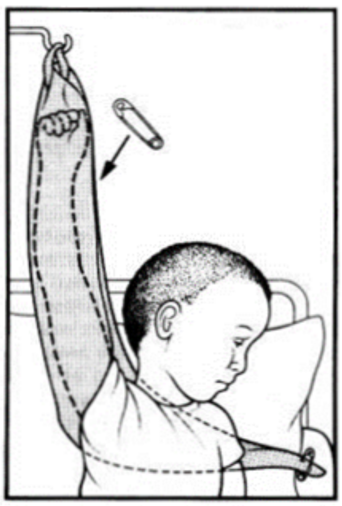


Fig. 73-9 SIMPLE EFFECTIVE ELEVATION

If there is a good radial pulse, put the elbow in a posterior plaster slab with sufficient padding to allow for swelling. Check the neurovascular status frequently during the 1st 24h. Remove the posterior plaster slab after 3wks and let the child move the elbow freely.

If you cannot get the arm beyond 70° without the pulse disappearing, use forearm traction (73-10).

If you are not sure if you can feel the pulse or not, put a warm towel for some time around the elbow to increase the perfusion.

Once the anaesthetic has worn off, ask him to flex the fingers. If this is not possible, follow instructions (73.10).

FOREARM TRACTION

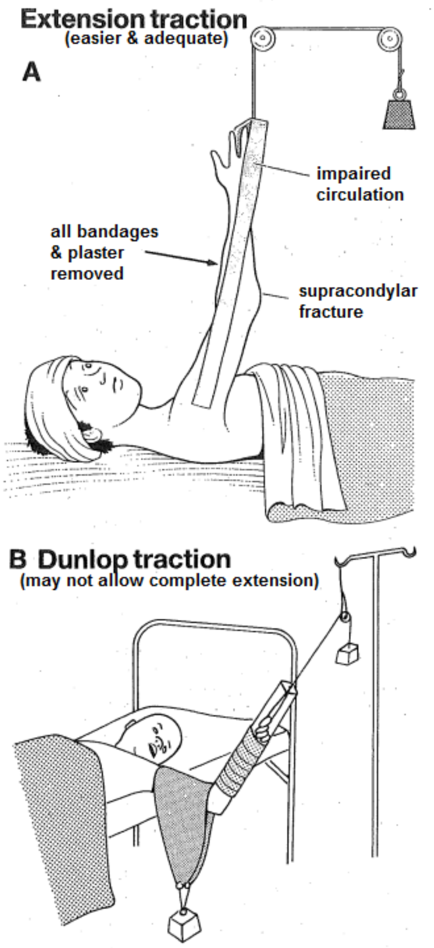


Fig. 73-10 FOREARM TRACTION is useful first treatment for ischaemia following a supracondylar fracture. If this fails to restore the circulation you need to explore the arm. A, traction in extension *(not a method of reduction)*: use a pulley, so the traction is maintained even if the child moves about in bed. B, Dunlop traction (more widely used). *After Rang M, Children's Fractures, Lippincott Williams & Wilkins, Philadelphia 1973, with kind permission.*

CHECK REDUCTION
The post reduction radiographs are of not much help in seeing if you have successfully corrected any angulation because: (1) you must keep the child`s arm flexed after reduction, and (2) the centres of ossification in the lower fragment may still be small.

There should be no angulation of the lower fragment in the AP view, no significant forward bowing in the lateral view, and the fragments must be in contact. Pay also attention to the lateral view: *there must be no step in the anterior cortex*, as this would be a typical sign of malrotation instability.

GETTING A GOOD RADIOGRAPH TO CHECK REDUCTION

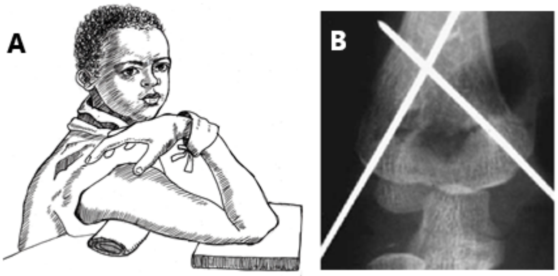


Fig. 73-11 CHECKING SUPRACONDYLAR FRACTURE REDUCTION. A, positioning the arm and the film to take the radiograph. *Don't let an assistant remove the collar & cuff to X-ray the arm. Make sure it is held in place without safety pins!* B, the post reduction radiograph. B, take a lateral and an AP view through the point of the elbow as shown. *Note the K-wires in place.*

If the reduction is unsatisfactory, have *only one further attempt at reduction*, not more, *or you will damage the elbow,* and increase the chances of post-traumatic ossification. Refer for internal fixation with K-wires in case reduction remains unsatisfactory after 2 attempts.

POSTOPERATIVE CARE AFTER REDUCTION
Make sure the child can flex and extend the fingers. Check the function of the median and ulnar nerves.

Monitor the circulation in the hand carefully for 36h. Watch for early signs of ischaemia. Check the pulse, and then assess capillary refill (which should be <2sec).

The first signs of ischaemic paralysis are: (1) pain on passive extension of the fingers, (2) paraesthesia, (3) pallor, and (4) finally the inability to use the fingers. In smaller children, anxiety & agitation may be the only signs.

N.B. Make sure all ward staff know why they are monitoring the pulse and what signs they should watch for. Otherwise, they may be quite content to feel the pulse in the normal arm!

If you have to reduce the flexion of the elbow because of impaired circulation, flex it again as the swelling decreases. Then, put a new posterior plaster slab & a repeat radiograph.

CAUTION! (1) *Forceful passive movements after removal of the cast will make the stiffness worse.* (2) *Don`t try to straighten the elbow by suggesting carrying weights.*

(b) Anteriorly displaced supra-condylar fracture of the humerus

Anterior displacement of the distal fragment of a supracondylar fracture is rare, and the signs are milder than a posterior displacement. *The ulnar nerve is in danger*.

A lateral radiograph (73-6C) may be difficult to interpret because the lower end of the diaphysis overlaps the epiphysis, especially in a young child, so that the epiphysis may appear to be displaced when it is not. Check the anterior humeral line's relationship to the epiphysis (73-4)

ANTERIORLY DISPLACED SUPRA-CONDYLAR FRACTURE REDUCTION (GRADE 1.3)

Under GA, extend the forearm. Ask an assistant to exert steady traction in the line of the arm with the forearm supinated. Steady the lower end of the humerus with one hand, and correct the sideways displacement of the lower fragment with your other hand.
Either, use traction (73-9), or apply a 10cm plaster slab along the back of the arm and forearm with the elbow extended. Keep this in place with a posterior plaster slab.

Confirm reduction with a radiograph. Remove the posterior plaster slab in 3wks and then put the arm in a sling.

Follow postoperative care as above (73.8)

DIFFICULTIES WITH SUPRACONDYLAR FRACTURES

(1) ISCHAEMIA
Early warning symptoms are pain or paraesthesiae and an early sign is difficulty to move the fingers after the reduction of a supracondylar fracture (49.2).
Be vigilant for ischaemia, quick and decisive.
If symptoms or signs are getting worse, decompression is urgent.
You have no time to refer the child. You must act immediately:

(1) Remove all bandages & any plaster cast.
(2) Apply longitudinal traction to the forearm (73-10).

If the pain disappears, the circulation improves, and the fingers start to move, maintain the traction till most of the swelling has gone, usually in c.7days.
Then reduce the fracture as well as you can, accepting a malposition, and put the arm in a posterior plaster slab.

If pain, paraesthesia, pallor, or paralysis persist for >1h, explore the antecubital fossa and, if necessary, decompress the volar aspect of the forearm if there is a compartment syndrome (49.6). *You need to do this within 3h!* Wrap the elbow in a warm towel to reduce vascular spasm whilst you prepare theatre.
N.B. Don`t explore the antecubital fossa until you have tried to reduce the fracture, because this may itself be enough to improve the circulation in the forearm.

EXPLORING THE ANTECUBITAL FOSSA

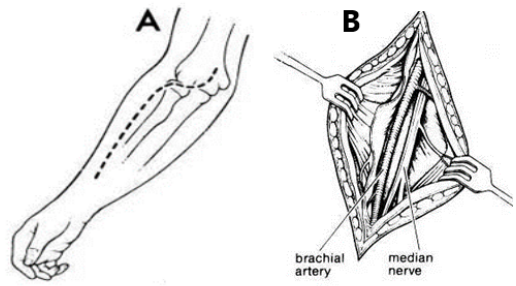


Fig. 73-12 EXPLORING THE ANTECUBITAL FOSSA. *Don't explore the antecubital fossa until you have tried to reduce the fracture*, because this may itself be enough to improve the circulation in the arm. A, incision (extended in the forearm if needed for decompressing a compartment syndrome) B, the median nerve lies medial to the brachial artery. *After Grenshaw AH, Campbell's Operative Orthopaedics Mosby 8th ed. 1961, permission requested.*

OPENING THE ANTECUBITAL FOSSA (GRADE 2.4)

Make a lazy 'S' incision (73-12A), beginning above the flexor crease & the inner border of the *biceps* tendon. Pull back the flaps, incise the tight deep fascia and the bicipital aponeurosis. Pale or blue-black muscle will bulge from the wound.

There may be a tight hematoma. Remove it. This may be enough to relieve the obstruction and restore the circulation. Carefully expose the brachial artery and the median nerve medially.
CAUTION! Don`t meddle with the artery or try to resect the spastic section.

Soak the wound with warm swabs, and dilute lidocaine or glycerine trinitrate spray.

If this fails, and the forearm is swollen, extend the incision down the forearm (73-12A). Slit the deep fascia the length of the incision. Decompress the superficial and deep volar compartments.

Leave the flaps open, and dress the wound.
If the fracture is not reasonably reduced, apply forearm traction. If it is reduced, apply a collar- and-cuff.

Close tissue over the artery & nerve; skin graft the defect after 4 days.
You may need to deal with a contracture later (34.2).

TREAT THE EARLIEST SIGNS OF ISCHAEMIC PARALYSIS IMMEDIATELY

(2) NERVE INJURIES
These are more common than vascular injuries but are less serious. Alone, *they are not an indication for an immediate operation*. Refer for exploration if there is no recovery after a month.

(3) POST-TRAUMATIC OSSIFICATION.
This occurs after 3wks, when the collar-and-cuff are removed; the elbow doesn't move, or if there is some little movement, this gradually decreases.
The anterior elbow is tender; there is muscle spasm and the *biceps* tendon stands out as a taut band. Radiographs may show a vague shadow like callus, or it may be so dense that it looks like bone. Sometimes a stiff painful elbow with new bone around it is the presenting symptom.
Put the injured elbow through several 15min periods of gentle active movements each day, both flexion and rotation. You must be patient, persistent and gentle. *Forced movements and even too vigorous passive movements will make the elbow worse.* Explain this to the child.

If the movements of the arm are diminishing, put the arm in a collar-and-cuff until muscle spasm has disappeared, which may take a month.

If the child cannot flex the elbow enough to get the hand to the mouth, put it in a loose collar-and-cuff and gradually tighten it until he can. After prolonged rest the spasm disappears and movement returns, but there is usually some permanent loss of movement.

Unfortunately, post-traumatic ossification is common, and is a major disability, especially when pronation is lost. Osteotomy followed by an arthrodesis in the position of function (c. 90°) may be necessary.

(4) SEVERE PERSISTENT *VARUS* DEFORMITY
Refer the child for corrective osteotomy, after the growth spurt. Explain to parents that remodelling is possible.

(5) MALUNION
If the fracture was never properly reduced, with only ≤30° flexion, an osteotomy may improve the range if it is around full extension,

NEVER MOVE AN ELBOW CONTRACTURE FORCEFULLY

(c) Medial humeral condylar fracture

A medial condylar fracture is a rare type of intra-articular fracture involving the trochlea and the medial part of the distal humerus.
A high level of clinical suspicion is necessary not to miss this type of injury, especially in the really young. An elbow dislocation in combination with a medial condylar fracture is rare. However, the elbow may subluxate posteriorly because of loss of stability due to the fracture.

After a fall, an older child or youth may complain of a painful elbow. The contour of the arm is normal, but the medial epicondyle is tender and swollen. Rotation is possible but painful and some flexion and extension is usually possible. Compare the radiographs of both elbows.

From 5-20yrs, the centre of ossification of the medial epicondyle is a separate piece of bone. The flexor muscles of the forearm are attached to it, and if pulled hard enough by a fall on an outstretched hand, they can pull it away from the humerus. The detached medial epicondyle may remain outside the elbow joint or enter it and lock it. Closed methods may succeed in removing it, but if they fail, an open operation is necessary. Often the elbow is dislocated also.

Test for *varus* and *valgus* instability in the elbow. A medial epicondylar fracture will only have valgus instability, while a medial condylar fracture will show both *valgus* & *varus* instability. Any suspicion of identifying ossified metaphyseal bone attached to the epicondylar fragment on a radiograph is a reason for further examination.

You can easily misclassify a medial condylar fracture as a medial epicondylar fracture. Careful clinical examination and history of the fall will help to differentiate between them.

If the medial condylar fragment displaces <4mm, treat the fracture with a posterior plaster slab for 4-6wks. Regular follow-up radiographs are necessary to monitor for secondary displacement.

If the medial condylar fragment displaces >4mm, refer for an open reduction and internal fixation to preserve elbow function. Put the elbow in a posterior plaster slab for comfort during transport.

MEDIAL CONDYLAR FRACTURE

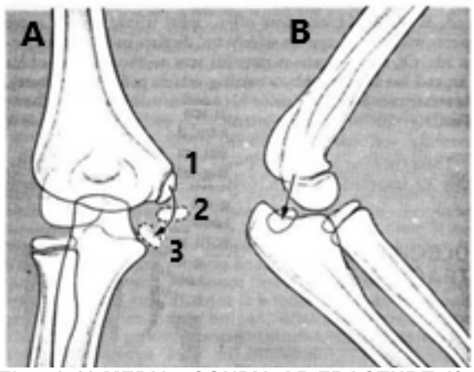


Fig. 73-13 MEDIAL CONDYLAR FRACTURE. If the child is >5yrs, the age at which the centre of ossification appears, you will be able to see if it is in its normal position A or not. If it is displaced, it may not prevent the elbow moving (B), or it may be inside the elbow and locking it (C). *After Perkins G. Fractures and Dislocations. Athlone, London, 1958, with kind permission.*

If the elbow moves adequately & the fragment displaces <2mm, put the arm in a posterior plaster slab for 2-3wks. Encourage active movements after removing the cast. Full movements may not return for 1yr.

If the elbow does not move adequately, or the fragment displaces >2mm, extend the wrist under GA to tense the flexor muscles. Flex, abduct, and supinate the elbow, then suddenly extend it. The fragment may reduce with a sudden clunk. Xray the elbow, and repeat the manoeuvre twice if necessary.

If then you can move the elbow through its full range of movement and it is stable, check that a radiograph shows good reduction and apply a posterior plaster slab as above.

If you cannot move the elbow through most of its full range, and you cannot reduce the medial epicondyle, an open reduction is necessary.

This is not an operation for the beginner, because the ulnar nerve will not be in its normal position and may be kinked into the joint with the medial epicondyle.

Make all incisions in the line of the nerve, *not across it.* Make a 5 cm longitudinal incision 1cm anterior to the medial epicondyle. Find the ulnar nerve and take care not to injure it. You will see the fibres of the common flexor origin emerging from the joint cavity. Pull on these fibres with a hook or forceps, and pull the epicondyle out of the joint. Find the rough place on the medial side of the elbow from which the epicondyle broke off. Fix it with two short K-wires or, if possible, with sutures. Apply a posterior plaster slab for 3wks. Remove the wires 4-6wks later.

DIFFICULTIES WITH MEDIAL CONDYLAR FRACTURES

If the ulnar nerve is injured, paralysis may be due to stretching and only be temporary. If recovery is delayed >6wks, a nerve transposition is needed.

If the fragment has been left inside the joint, and you discover it some time later, arrange for its removal. Warn that full movement may not return.

(d) Lateral condylar fracture of the humerus

The elbow is swollen and will not move. The posteromedial side of the arm is not tender, showing that there is probably no supracondylar fracture.
Sometimes the elbow is dislocated also.

This is a serious, but rare, Type IV epiphyseal injury (73-2). It occurs at a younger age than an injury to the medial epicondyle, and the displaced fragment is larger. The fracture line runs from the middle of the articular surface of the elbow upwards and laterally, isolating part of the trochlea, the whole of the capitulum, and often a small part of the shaft of the humerus (62-15).

Sometimes, there is only a little lateral shift which need not be reduced. More often, the lower fragment turns over completely inside the joint.

If this type of fracture is not reduced, it unites to the shaft with fibrous tissue, and growth in the lateral half of the epiphysis stops. The result is a severe valgus deformity of the elbow which increases until growth ceases.

Distortion of the path of the ulnar nerve round the severely deformed elbow causes a late ulnar paralysis with wasting of the small muscles of the hand.

The radiographs of the elbow are difficult to interpret, because a large part of the fragment is cartilage and casts no shadow.
Ultrasound may be more helpful. An AP view shows that the epiphysis of the capitulum is missing; instead, there is an abnormal mass of bone on the outer side of the elbow. In a lateral view this may hide behind the humerus, but usually displaces anteriorly.

In young children the flake of metaphyseal bone attached to the lateral condylar fragment can be very small and difficult to identify on a radiograph. If in doubt, compare the image of the injured side with that of the normal one. Look at the relationship between the olecranon and the distal humerus (ask yourself if there a lateral shift of the ulna) and the relationship between the radial head and the capitulum (does the articulation look congruent or not?) *Don't mistake this injury for a supracondylar fracture!*

LATERAL CONDYLE FRACTURE

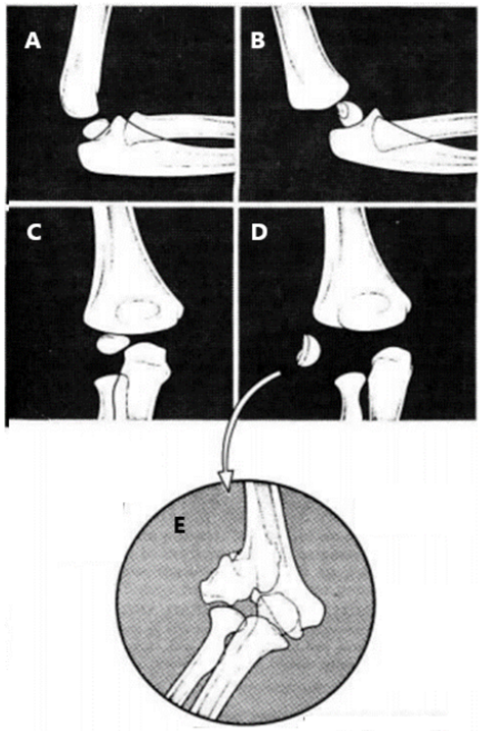


Fig. 73-14 LATERAL CONDYLAR FRACTURE is a serious Salter Harris Type IV epiphyseal injury; it occurs at a younger age than injuries of the medial condyle, and the fragment is larger. A, normal. B, displaced epiphysis. C, the lateral condyle did not take a piece of the shaft with it. D, late result of displacement, resulting in E, severe valgus deformity & probably an ulnar nerve palsy. *Kindly contributed by John Stewart.*

If there is <2mm displacement, apply a posterior plaster slab; after 5days get a control radiograph. If there is no secondary displacement, treat with the backslab for 4-6wks.

If there is 2-4mm displacement, try reducing and fixating it percutaneously. Introduce a 1st K-wire into the lateral condyle and use that to reduce the fracture. Add a 2nd and maybe a 3rd for additional rotational stability.

If the fracture is clearly unstable or cannot be reduced, an internal fixation is necessary: perform a 5cm longitudinal incision over the epicondyles, dissect bluntly to the bone, reduce the fragment and fix it with 2 K-wires putting pressure on the fracture line. If available, take a small screw to fix it. Apply a posterior plaster slab also for 4-6wks.

CONSEQUENCES OF LATERAL CONDYLAR FRACTURE

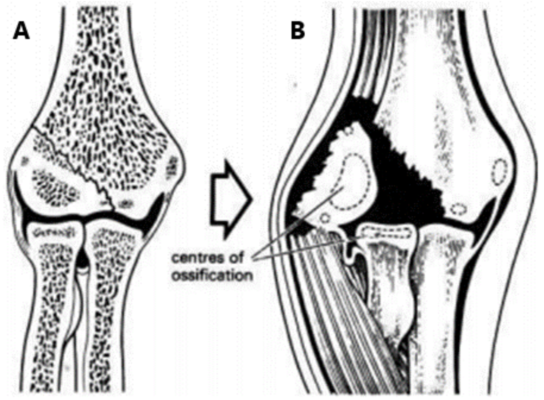


Fig. 73-15 LATERAL CONDYLAR FRACTURE CONSEQUENCES. If this injury is not treated correctly, it will be followed by a severe valgus deformity which increases until growth ceases. *After Watson Jones R, Fracture & Joint injuries, 4th ed. Churchill Livingstone 1976 with kind permission.*

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DIFFICULTIES WITH FRACTURES OF THE LATERAL CONDYLE

If 10-30yrs later, there is numbness and tingling in the ulnar side of the hand, followed by wasting of the small muscles of the hand, there is an ulnar nerve paralysis. Warn that this may follow the progressive valgus deformity of the elbow many years later, because the patient may not connect it with the injury. The ulnar nerve should be moved anteriorly in the elbow *before* the small muscles of the hand start to waste.

N.B. Fracture-separation at the epiphysis, especially if the child is <18months, suggests child abuse (47.1).

This needs reduction, holding at 90º, with the forearm pronated, in a posterior plaster backslab for 3wks.

DISTAL HUMERAL EPIPHYSEAL INJURIES

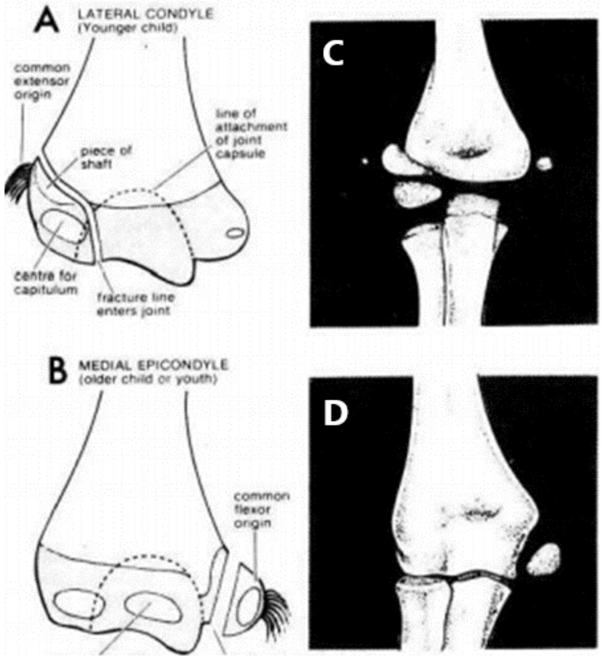

Fig. 73-16 DISTAL HUMERAL EPIPHYSEAL INJURIES. The medial & lateral condyle differ considerably. A, the lateral condyle is a pressure epiphysis to which the common extensor origin is attached. It is fractured in young children. The fracture line enters the joint displacing the centre for the capitulum and sometimes part of the shaft. You must accurately replace the displaced fragment (B). C, the medial epicondyle is a traction epiphysis outside the elbow joint to which the common flexor origin is attached. It is displaced in teenagers, and D, unless it happens to enter the elbow joint, it need not be removed or reattached.

(e) Pulled elbow

This common injury is the result of lifting up a child by one arm, or swinging him around on it. Many minor and otherwise undiagnosed injuries are probably pulled elbows. The head of the radius slips out partially from the annular ligament and subluxes. The injury is very rare after 5yrs, because of changing physiology in the child's elbow.

A child with a pulled elbow holds the hand in pronation, refuses to use the arm, and cannot rotate the wrist, but generally will not complain of pain. Sometimes, the head of the radius is tender. Radiographs are normal. The differential diagnosis is a fracture of the radial neck.

If the clinical presentation and history match with the diagnosis of a pulled elbow, there is no need for a radiograph. Continue immediately with the reduction manoeuvre.

PULLED ELBOW

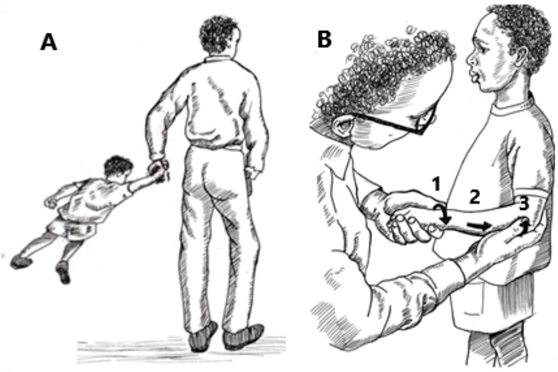

Fig. 73-17 PULLED ELBOW. A, the mechanism of the pulled elbow: all the child's weight is transmitted to the elbow! B, Reduce it this way: cup the elbow, apply slight traction on the forearm, and then suddenly supinate (1) and drive it elbow-wards (2), whilst pushing the head of the radius with your thumb (3).

Treatment is usually easy (73-17). Rotate the forearm in extreme pronation while holding the elbow joint. If this does not work, follow the manoeuvre using supination (73-17). Keep the child for evaluation for 30mins after reduction. If the arm moves normally at that point, the problem is solved.

If the arm still doesn't move correctly obtain radiographs of the elbow to exclude a fracture or dislocation. Otherwise, apply a sling and reassess in 5-10 days. This will usually free the head of the radius from the annular ligament. Sometimes, just extending the elbow will do the same.
The child may cry loudly, but then will usually be able to move the arm. In this case, apply a backslab in full supination for 3days.

(f) Radial neck fracture

In this common injury, a force travelling up the arm drives the head of the radius against the capitulum. In a child, the neck of the radius bends displacing its head anteriorly and laterally, but the head itself almost never fractures.

A child falls on the outstretched hand and breaks the neck of the radius just distal to the epiphyseal plate, proximal to the attachment of the biceps. The head of the radius angulates anteriorly and laterally on its broken neck, and usually remains attached to the shaft.

The same injury may fracture the medial epicondyle, strain or rupture the medial ligament of the elbow, or fracture the upper third of the ulna.

RADIAL NECK FRACTURE

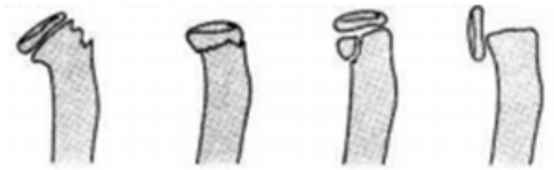

Fig.73-18 RADIAL NECK FRACTURE Treat this conservatively. *Never excise the head!* *Kindly contributed by Peter Bewes*

The contour of the elbow is normal, and flexion and extension are less painful than rotation. The posterior interosseous nerve (PIN) may be injured; check extension of the wrist, fingers and thumb.
As a child may complain only of wrist pain because of referred nerve pain, *always get a radiograph of both elbow & wrist.*

If this injury occurs before the centre of ossification appears in the head of the radius at 10yrs, the only radiological sign is an irregularity in the metaphyseal margin.

Treatment depends on the degree of angulation and on the child's age. Mild angulation needs no treatment. You must correct moderate and severe angulation, because the head may grow abnormally and ultimately dislocate, particularly after severe displacement in an older child. In very young children, the head may grow almost normally, even after severe displacement. *Never excise the head*, because this is sure to cause a severe growth deformity.

TREATMENT
For a child >10yrs, with the head angulated <30°, a posterior plaster slab for 10days.
With the head angulated >30°, try a closed reduction, even if the head is severely displaced

For a child <10yrs, with the head angulated <45°, a posterior plaster slab for 10days.
With the head angulated >45°, try a closed reduction.

If the child's elbow Is also dislocated, reduce it and then treat the radial head.

If the radial head is completely separated, an open reduction is needed.

CLOSED REDUCTION (GRADE 1.3)
If the child's elbow is very swollen, suspend the arm in extension traction (73-10), until the swelling has reduced. Then try reduction under GA (73-19)

If this fails to reduce the angulation to 30° (child>10yrs) or 45°(child< 10yrs) or less, an open reduction is necessary.

POST REDUCTION RADIOGRAPHS
In both AP & lateral views, the surface of the radial head should be parallel to the capitulum.

POSTOPERATIVE CARE
Apply a posterior plaster slab for 2wks.

REDUCTION OF DISPLACED RADIAL NECK

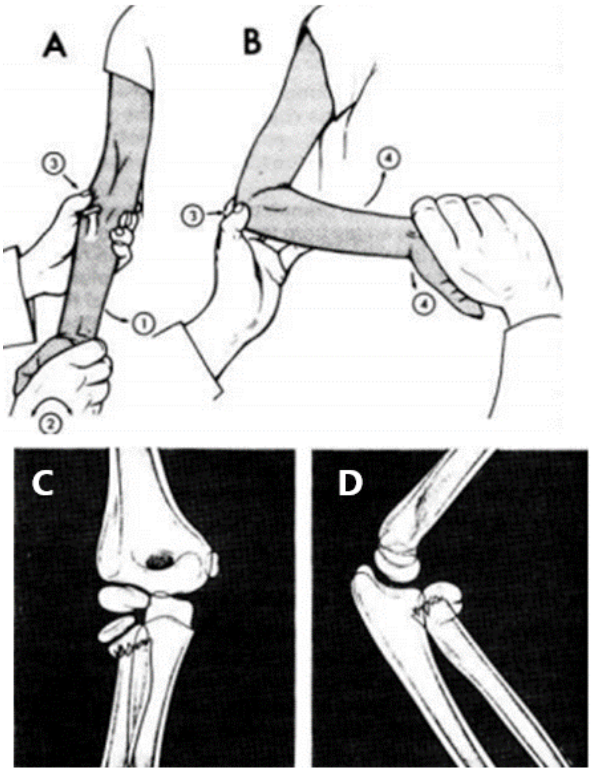

Fig. 73-19 REDUCTION OF DISPLACED RADIAL NECK. A, AP view before reduction. B, lateral view before reduction. C, with an assistant to steady the upper arm, extend the elbow, grasping the wrist with one hand and the elbow with the other, adduct the forearm at the elbow (3), so as to open the joint between the capitulum and the head of the radius a little. Rotate the forearm (2) into the position in which the most prominent part of the displaced head lies laterally and superficially. D, put your thumb over the displaced head of the radius. While you adduct the forearm, press the head of the radius proximally and medially (3). Now flex the forearm and supinate it sharply (4).

(g) Olecranon injuries

The child of 10-16yrs will present with the elbow flexed and with a swelling over the olecranon. Extension of the elbow will be difficult and painful.

A child may have several centres of ossification in the olecranon, so you may have difficulty deciding if there is a fracture or not. If in doubt, x-ray the other elbow.

The apophysis of the olecranon occasionally separates from the shaft of the ulna because the *triceps* tendon pulls it off during a fall. This fracture can occur before the centre of ossification of the olecranon appears. Treat with a posterior plaster slab for 3-4wks.

If the olecranon fracture displaces <4mm and shows adequate joint congruence, treat with a posterior plaster slab for 3-4wks.

If the olecranon fracture displaces >4mm or if there is clear joint discongruity, treat it as an adult olecranon fracture.

73.8 Forearm injury in children

The child will present with a very painful arm, usually supporting it with the other arm. He will refuse almost any clinical examination out of fear and pain and will refuse active mobilization of any part of the affected arm. Usually, the diagnosis is apparent immediately because of a gross forearm deformity.

Although adult forearm fractures are difficult, you can, however, treat most forearm fractures of children (<10yrs) conservatively, because the bones remodel.

It is important to take strict AP & lateral views, because otherwise you cannot assess the true angulation of the fracture.

Keep in mind that the wrist and elbow, also need radiographs, to exclude associated injuries. Assess the extent of deformation in terms of lateral displacement, angulation, and shortening or distraction.

The key goals of treatment are: (1) maintaining correct length of radius and ulna, (2) maintaining correct radial angulation for proper pronation & supination, & (3) maintaining the function of the proximal and distal radio-ulnar joints.

You can assess acceptable degrees of angulation and displacement by age as below:

	Location	Angulation	Displacement
<9yrs	Distal $^1/_3$	20°	50-100% without overlap
	Mid $^1/_3$	15°	50-100% without overlap
	Proximal $^1/_3$	10°	50-100% without overlap
>9yrs	All parts of the forearm	10°	0-50°

Forearm fractures in children present in 4 different patterns: bowing, greenstick, complete and comminuted fractures. All 4 patterns have their own specifics that require attention.

Bowing fractures have no one clear radiological fracture line, but are actually a combination of multiple micro-fractures across the shaft of the ulna or radius. Reduction of radial or ulnar bowing may be necessary in children >9yrs, where limited potential for remodelling remains. Cut-offs in the table above apply here as well.

Greenstick fractures pose specific challenges for treatment. If the fracture of the ulna and the radius are not at the same level, this indicates that there is a rotational component in the deformity that you need to take into consideration when reducing the fracture.

Complete and comminuted fractures are inherently unstable and will need at least a closed reduction. If this is insufficient, an internal fixation will be necessary.

If the fracture is only minimally displaced (see table above for age and location specific cut-offs), put on a well-moulded circular cast from the knuckles to the middle of the upper arm with the forearm in mid-pronation. While the cast is still soft, straighten the forearm.
Get a check radiograph at 2wks to make sure no secondary displacement has occurred. If it has, reduce the fracture under GA and re-apply the well-moulded above elbow circular cast.

ALWAYS MONITOR A CHILD FOR POTENTIAL COMPARTMENT SYNDROME FOR 24h AFTER REDUCTION AND APPLICATION OF A CIRCULAR CAST

We recommend the following positions for a child's forearm in a cast, if the child permits:
(1) distal $^1/_3$ radial fracture: pronation
(2) middle $^1/_3$ radial fracture: neutral
(3) proximal $^1/_3$ radial fracture: supination.
In this way the pull of *pronator quadratus, teres & biceps* will be neutralized; there will be less risk of permanent rotational deformity.
Otherwise place the cast in a position acceptable to the child.

If the fracture is displaced beyond the cut-offs described in the table above, reduce the fracture, and treat as above.

Correct angulation carefully, especially in the lateral (coronal) plane, which remodels even less readily than angulation in the antero-posterior (sagittal) plane.

If the fracture is higher up in the middle or proximal $^1/_3$ of the child's radius, remodelling is less rapid and less complete, especially if the child is older. So under GA, bend the radius back.

Greenstick midshaft fractures of the middle $^1/_3$ of both forearm bones cause an obvious bowing of the child's forearm. Correct angulation carefully, because the fracture has only limited potential for remodelling later in life. You will have to decide whether you will completely break the greenstick fracture to facilitate reduction or not. The remaining periosteal connection however gives stability to the fracture which is useful during the healing process. However, its pull also makes it more difficult to maintain a full reduction of the fracture. Breaking this periosteal bridge will facilitate reduction but will make the fracture more unstable, potentially risking secondary displacement. Therefore try to maintain the periosteal bridge if possible for the sake of stability, but don't be afraid to break it to obtain an adequate reduction.

CAUTION! If you fail to correct the angular or rotational deformity, loss of pronation and supination may follow.

Put on a well-moulded above elbow circular cast for 6wks. Start active movements of the shoulder and fingers as soon as possible. Repeat radiographs during the 1st 3wks, looking for angulation, and if necessary, correct it under GA.

Explain to parents that there is an increased risk of refracturing in the first 4months after the accident. The child should refrain from sports and any activity with risk of falling on the arm again.
N.B. There is no need for additional protective measures such as a sling or keeping the child longer in a cast.

If angulation in one plane persists or more compression on the site of the greenstick fracture is needed, wedge the cast after 7days. A secondary dislocation of the fragments, resulting in an angulation >10° in the check radiograph 7days later, should make you re-assessment your treatment.

Break the bones with a sharp bending force, and slightly overcorrect the deformity if reduction is not possible. Then suspend the forearm as for a complete fracture, apply a long arm cast.

If you cannot reduce the fracture adequately after 2 attempts or there is persistent secondary displacement after reduction, an internal fixation with K-wires will be necessary. Refer the child for internal fixation if you do not have the adequate equipment or skills at hand.

SPECIFIC FRACTURE PATTERNS THAT REQUIRE SPECIFIC ATTENTION

(a) The Monteggia fracture (63.3), a displaced proximal ⅓ ulnar fracture with a radial head dislocation, is commoner in children than in adults. In younger children it can also present with bowing of the ulna instead of a fracture. Unless you reduce the dislocation of the radial head (63-5), the elbow will never be able to flex again. The longer the delay, the more difficult is the reduction.

Although adult forearm fractures are difficult, you can, however, treat most forearm fractures of children <10yrs conservatively, because the bones remould.

When both forearm bones fracture in a child, the fracture is likely to be a greenstick type.

(b) Incomplete Galeazzi fractures (63.4) cause a child's lower forearm to bow forwards. There is tenderness over a greenstick fracture of the radius, usually in its distal ⅓. The distal end of the ulna is also tender. Closed reduction is usually straightforward.

(c) Fractures of the lower $^1/_4$ of the radius and ulna in young children.
In this common injury, a young child breaks both the bones transversely c.4cm above the wrist.
The fracture is usually greenstick, and the lower fragments angulate radially and anteriorly. Sometimes the ulna remains intact, and the only radiological sign is buckling of the radial cortex on one side (the buckle fracture).

If the fracture is complete, both lower fragments displace behind the shafts and produce a dinner fork deformity. The lower $^1/_4$ of the forearm bones readily remodel, particularly in very young children, so that unless there is a significant degree of angulation, no reduction is necessary. If necessary you can leave it.

The younger the child, the more the displacement you can accept.

CLOSED REDUCTION OF FRACTURES OF THE LOWER $^1/_4$ OF THE RADIUS AND ULNA

If the lower fragment of the radius is angulated, straighten it. Disregard the ulna.

REDUCING OVERLAP

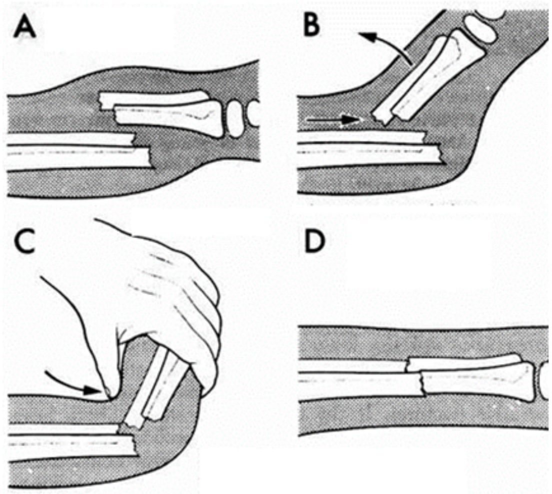

Fig. 73-20 REDUCING OVERLAP. A, before reduction. B, start by increasing the angulation. C, then get the ends of the bones to hitch by pushing as shown. D, finally, straighten them. *Kindly contributed by Peter Bewes.*

If you decide to reduce the overlap, increase the angulation as far as possible, press on the base of the distal fragments when they are fully angulated, get the ends to hitch, and then straighten and distract them (73-19). Apply a long arm cast in full pronation.
Consolidation takes 6wks. Keep the cast on for the full period.
The child may fall again and refracture the arm, so in this case, re-apply a forearm cast for another 6wks. Split the cast in children after their growth spurt, and in obese children; *not otherwise!*

IF CLOSED REDUCTION FAILS, this may be because the *pronator quadratus* comes between the bone ends. Management now depends on whether the child's epiphyseal growth lines have closed or not.

If the epiphyseal growth line at the lower end of the radius is open, it is not important if the fragments are end on or not, provided the radius is reasonably straight. They will remodel themselves completely in 2yrs, so some overlap is permissible.
If you fail after 2 attempts, stop. Apply a long arm cast, and start exercises immediately.

If the epiphyseal growth line is closed, make a 2nd attempt at closed reduction. If this fails, you can attempt open reduction if you are experienced. Do this as early as you can, but before 10 days.

OPEN FOREARM FRACTURE REDUCTION (GRADE 2.4)
Incise the back of the forearm longitudinally over the fracture, separate the muscles, open the periosteum longitudinally, and lever the displaced fragments into place with any convenient instrument, such as a MacDonald's dissector. Close the wound in layers, and apply a backslab held in place with a crepe bandage. Take out the sutures 1wk later, and apply a long arm cast as for an extension fracture of the wrist (74.2), but extending above the elbow with the wrist in a neutral position. Leave the long arm cast on for 6wks, and then apply a forearm cast for 4wks more.

73.9 Wrist injury in children

AGE DIFFERENCES
0-5yrs.
A young child usually has a greenstick fracture of the lower third of the radius, and sometimes of the ulna also. If the injury is severe, both the forearm bones may break transversely just proximal to the wrist (73.8).

5-10yrs
In an older child fractures of the lower quarter of the radius and ulna are more often complete (73.8), and the fragments may overlap.

10-15yrs
A young teen typically has a fracture separation of the distal radial epiphysis.

The bony remodelling capacities after distal radial fractures in childhood depend on:
(1) the remaining growth potential, which is a function of age,
(2) the position of the fracture along the metaphysis,
(3) the extent of angulation.

You can assess acceptable degrees of angulation and displacement by age as below:
(1) Differences in boys & girls reflect different ages of puberty.
(2) Simple distal radius fractures without significant displacement or angulation simply require a below elbow cast for 4wks.

Age	Palmar/ dorsal flexion	Displacement
Girl <8yrs Boy <10yrs	20°	50-100%
Girl 9-11yrs Boy 11-13yrs	10°	0-50%
Girl >11yrs Boy >13yrs	0°	0%

A greater deformity results in unfavourable mechanical performance & poor cosmesis.

The power of growth-associated spontaneous correction is enormous and even continues beyond the age of 10yrs. Your options are: (1) conservative treatment, (2) plaster wedging, (3) reduction and percutaneous K-wire stabilization.
N.B. An open reduction of metaphyseal fractures is almost never necessary.

If displacement is not acceptable either for cosmetic reasons or growth potential, a reduction manoeuvre is mandatory. Wedging the cast without GA is, rarely, satisfactory. In the majority of cases reduction GA is necessary.

1-2 crossing K-wires are usually sufficient to avoid secondary displacement within a plaster cast.

Distinguish between the completely slipped epiphysis and fractures with shortening and the minimally angulated fractures with maintained bony contact. The 1st need a complete reduction and, most likely, fixation under anaesthesia, while you can treat the 2nd conservatively or with wedging.

(a) Fracture separation of the distal radial epiphysis (10-15yrs)

This is the most common epiphyseal injury. The fracture passes partly through the radial metaphysis, and partly through the epiphyseal line (Type II, 73-2) or only through the epiphyseal line (Type I). Its lower end usually displaces and tilts radially and posteriorly. There may also be a fracture of the styloid process of the ulna, or a separation of its epiphysis. Fortunately, if you reduce the epiphysis, subsequent disability is rare.

If the radial epiphysis is displaced dorsally, under GA, press it firmly forwards into place. There is no need to exert traction, because the epiphysis is not impacted. It will hinge forwards on its intact dorsal periosteum, which will prevent over correction.

You should feel a distinct 'clunk' when the epiphysis falls back into its correct position. Otherwise consider fixing the epiphysis with a K-wire to avoid secondary displacement.

Apply a well moulded cast with 3-point moulding extending above the elbow with the forearm in neutral position and the wrist ulnar deviated and slightly flexed. (This looks as if the arm is ready to shake someone's hand.) Leave it in place for 6wks.

The epiphysis may displace secondarily, so x-ray the wrist at 1 & 2wks after reduction. If it displaces, it needs internal fixation.

The prognosis is good, even if there is slight residual angulation after reduction.

DISPLACEMENT OF THE DISTAL RADIAL EPIPHYSIS

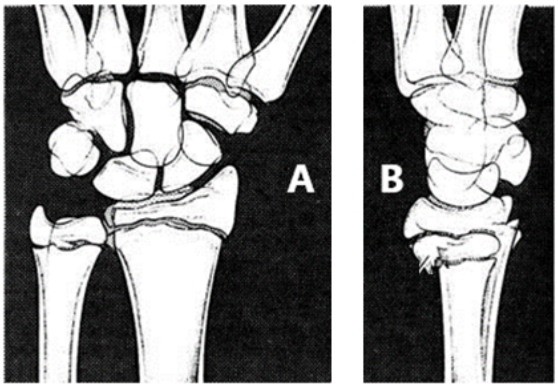

Fig. 73-21 FRACTURE SEPARATION OF THE DISTAL RADIAL EPIPHYSIS is the most common epiphyseal injury. A AP view, and B, lateral view more typical appearance is that in 73-1D,E, which show the fracture line passing partly through the radial metaphysis, and partly through the epiphyseal line (Type II), tearing the triangular ligament.

73.10 Hand injury in children

A child's epiphyses are easily displaced, especially those of a proximal phalanx close to its MP joint, sometimes with considerable rotation at the line of separation. Try to reduce these displacements as best you can.

Where you have no grip on the proximal part of the fracture or the epiphysis, put a pencil in between the fracture finger and the finger away from which the fracture finger is now pointing because of the displacement. The pencil should be perpendicular to the palm of the hand and resting in the interphalangeal web space. Now push the dislocated fracture in the direction of the pencil while stabilizing itl and the hand with your other hand.

The pencil will stabilize the proximal fragment; you can easily reduce fractures and displaced epiphysis this way.

REDUCTION OF A PROXIMAL PHALANX FRACTURE

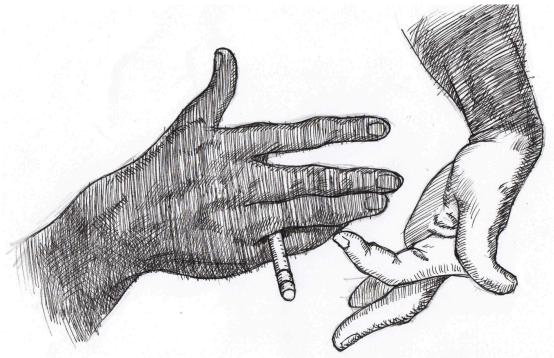

Fig. 73-22 PENCIL METHOD FOR REDUCING A DISPLACED PROXIMAL PHALANX FRACTURE.

In a child's finger, the tendon of *flexor digitorum profundus* is inserted into the phalangeal metaphysis, and the long extensor tendon into the epiphysis. A combined angulating and crushing injury (65-17C) can cause a mallet finger. Take a lateral radiograph to distinguish this from rupture of the extensor tendon, which is rare. Treat as you would treat a mallet finger in adults.

If the distal fragment of the distal phalanx is forced out through the nail bed (10 in 65-15, & 75-13)**,** re-position the distal phalanx by open reduction, and insert the proximal end of the nail into the nail fold where it will act as a splint. Splint the distal ip joint in extension (like a mallet finger) for 2wks. These are serious, difficult injuries, and a mallet deformity often follows.

If the neck or diaphysis of a phalanx is fractured, and the distal fragment is rotated (16 in 65-15)**,** you need to reduce the fracture as well as correcting the rotational deformity. Open reduction and internal fixation with a K-wire are needed when the fracture is unstable or you cannot reduce it or there is a major displacement >15° or a rotational deformity persists,.

N.B. If you fail to achieve reduction, permanent loss of flexion may result.

EPIPHYSEAL INJURIES OF A FINGER

If an epiphysis is minimally displaced (33, in 65-11), no reduction is necessary. Treat the child with a buddy tape of the afflicted finger and the adjacent larger finger for 1-2wks for comfort.

If an epiphysis is more than minimally displaced, and especially if there is any rotation deformity (34 in 65-11), be sure to correct it, so that the injured finger is in proper relation to its neighbours in both flexion and extension, and is not rotated. Then splint it, preferably with an aluminium splint. Most displaced epiphyses are in the proximal phalanx close to the mp joint. These types of injuries will remodel in the plane of flexion and extension, but lateral and rotational deformities will not correct, so accurate reduction is essential.

Metacarpal fractures are typical injuries of adolescents after hitting something with a full fist (the boxing fracture). Most are only minimally displaced and you can treat these with a boxing glove cast. This is a lower-arm cast that includes the fingers so as to stabilize both joints of the metacarpal bones. In case of gross displacements, or clear shortening of the metacarpal, reduce the fracture and keep the hand for 6wks in a boxing glove cast. In case of persistent instability refer for internal fixation.

73.11 Pelvic injury in children

Acetabular fractures in children are rare. The mechanism of accident is usually a crushing force. The child pelvis is more plastic than the adult's and can sustain more forces before breaking. Most pelvic fractures in children stem from motor vehicle accidents.

Most of the general adult pelvic trauma principles apply to children as well. Treat undisplaced and stable pelvic fractures conservatively. *Remember displaced pelvic fractures can lead to life-threatening bleeding.*

If a child presents with a pelvic fracture, examine the child fully and exclude any other potentially life-threatening injury.

As in adults, fixation is only necessary in severe dislocation. Fractures of the entire pelvic ring, such as open book fractures, cause massive haemorrhage, and therefore need emergency treatment by a pelvic binder. Always check for an associated lesion of the urethra, and other abdominal injuries.

Treat almost all undisplaced fractures of the pelvis and sacrum conservatively by bed rest and non-weight bearing until the pain subsides (c. 3wks).

Put young children in a spica cast (73-22) Isolated fractures of the iliac bone or crest, of the anterior pelvic ring are the most common.

Sometimes a child will present with an avulsion fracture of the iliac spine, most commonly after an athletic activity. Treat this conservatively with crutches and non-weight-bearing for 2wks and gradual return to weight-bearing afterwards.

73.12 Hip injury in children

Hip fractures in children are rare but can happen as part of a polytrauma or because of a fragility in the bones, *e.g.* a bone cyst or osteoporosis secondary to malnutrition. Always take a good history to understand why such a child has sustained such an injury. Treat the underlying causes if possible.

A child's femoral head receives its blood supply from the *ligamentum teres.* So, any injury to a child's hip should be treated as fast as possible to protect the blood supply to the femoral head and avoid avascular necrosis at a later stage.

Children around the age of 2yrs sometimes suddenly start to limp, complaining of pain, and have restricted movements in their hip. In most cases the pain is focused on the knee joint, but the movements there are unrestricted.

Include radiographs of the lower leg, as young children sometimes continue walking on a hairline fracture in their tibia. Otherwise consider transient synovitis, which is a painful joint effusion (visible by ultrasound) which occurs after a viral infection

Treatment is bedrest, analgesia & NSAIDs for 3days. Recovery is usually uneventful; fluid aspiration is only necessary in prolonged cases.

CAUTION! The differential diagnosis is a septic hip. If you have any clinical sign of severe infection, *e.g.* high fever, high ESR or CRP or leucocytosis, particularly with excessive pain and warmth around the joint), immediately aspirate the joint, drain the pus & flush with copious saline into the joint. Administer broad spectrum antibiotics, and later those antibiotics suggested by culture & sensitivity.

If you overlook a septic hip, necrosis will result, or even life-threatening sepsis.

HIP SPICA
You will sometimes find a plaster spica useful to immobilize the hip, or more often, the femur in young children. Unfortunately, hip spicas are expensive because they need a lot of plaster. Also, they are inconvenient, because a patient has to be lifted on to a bedpan. But, provided a family can cope, a spica can treat children with femoral fractures at home or in a near-by health centre for at least part of their illness, whereas they would otherwise need a hospital bed.

INDICATIONS
(1) Fractured femur in children, preferably after union has occurred in gallows or extension traction (73.13).
(2) Undisplaced pelvic fracture
(3) Postoperatively, following release of a flexion contracture of the hip.
(4) Septic arthritis of the hip.

EQUIPMENT
A low stool, or better, a special support;
Stockinette; Cotton wool
PoP rolls in 10,15 & 20cm breadths;
Padding material;
Crepe paper to prevent liquid PoP seeping into the wool.
[You can, alternatively use 10-20 layers of toilet paper, covered with 15cm strips of plastic from bags].

APPLYING THE SPICA
Anaesthetize the child with ketamine. Use a suitable support and pad the leg and trunk. Put extra padding over the bony points, particularly the sacrum (73-22)

If there is a femoral or pelvic fracture, continue the spica to the ankle. Otherwise, keep the knee free; you can insert a pin through the lower end of the femur and incorporate this in the cast to will allow movement of the knee but stop the femur rotating at the hip.

Remember to turn the child over, and inspect the back of the cast carefully to make sure it is comfortable and not pressing into the skin.

CAUTION!
(1) A hip spica must engage the lower ribs on each side.
(2) There must be space for the abdomen to move, otherwise respiratory difficulty or ileus may follow.
(3) Enough of the buttocks must be free to allow sitting on a bedpan.

Nursing care is not easy, and the spica soon becomes soiled; pressure sores, skin irritation, especially in the perianal area may ensue. Protect the spica with plastic in this region.

N.B. You may be able to apply gallows traction or a long leg cast first and then convert to a spica.

MAKING A HIP SPICA

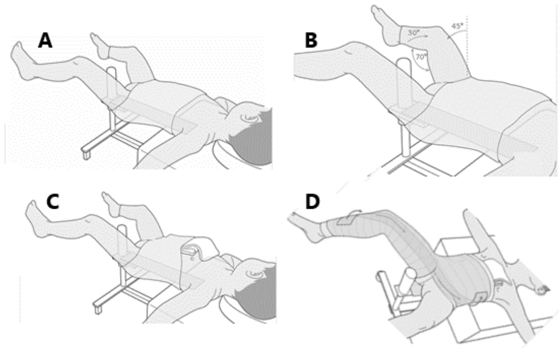

Fig. 73-22 APPLICATION OF A HIP SPICA. A, place the anaesthetized child on a suitable support which has the spine supported but the legs free. Put stockinette around the leg, hip, pelvis and chest to nipple level: it helps to sew the leg part to the trunk part so they don't separate. B, make sure there is 30^0 hip abduction, 45^0 hip flexion & 75^0 knee flexion. C, put a folded towel over the abdomen under the bandage to allow for breathing. *Keep a tail of the towel free to pull it out later.* D, apply the cast with reinforcing straps. *N.B.* Cut a hole over the central abdomen to make it more comfortable.

(a) Femoral neck fractures

Fractures of the neck of a child's femur are rare but serious. Subsequent remodelling will not correct the femur's deformities. Changes in its angle persist, so if the fracture produces *coxa vara* (lessening of the angle between the neck of the femur and its shaft), this deformity will become worse over time and be permanent.

A preferred treatment for femoral neck fractures is internal screw fixation, irrespective of stability and level of displacement. If you can, try to refer for this.

Apply extension traction and try to correct the angle of the neck of the femur correct.
Overlapping and anteroposterior angulation are less important. Correct the deformity and once callus starts to form (c. 2wks, in children <10yrs old), apply a plaster spica.
In older children continue extension traction until the hip fracture is sufficiently stable on radiographs. Continue non-weight bearing for a total of 10-12wks.
N.B. There is a high risk of aseptic bone necrosis or pseudarthrosis.

INTERTROCHANTERIC FRACTURES
Reduce the fracture using traction for c.2wks until callus appears on radiographs. Gallows traction (73-24) is suitable for children up to c.3yrs, or at the most 5yrs if the child is small.

For older children <10yrs, use extension traction. Then apply a plaster hip spica with the hip in wide abduction for 8-10wks.

Consider internal fixation for children >10yrs. If internal fixation is not possible, treat with extension traction and non-weight bearing for a total duration of 10-12wks.

Treat SUBTROCHANTERIC FRACTURES in children in the same way.

(b) Traumatic hip dislocation

Traumatic hip dislocations are rare in children and tend to reduce easily if seen early. A child's femoral head receives its blood supply from the *ligamentum teres* and therefore, there is direct correlation between the delay till reduction and the risk of avascular necrosis of the femoral head. Reduce the dislocation as you would treat an adult hip dislocation. Outcomes are generally good.

POST-REDUCTION CARE
Put the child in a hip spica (if <10yrs) or on strict bed rest if >10yrs for 4-6wks. Get a radiograph to check for an adequate position of the hip. Make sure to exclude a traumatic separation of the epiphysis of the femoral head and any fractures to the acetabulum. Just because there was no fracture to the acetabulum visible on the initial radiograph, doesn't mean that there isn't one! Check the post-op radiograph carefully as well. In case of an acetabulum fracture, treat appropriately with bedrest.

If there is a hip dislocation in combination with a femoral head, neck or pertrochanteric fracture an open reduction will almost always be necessary. Do not stall this intervention as the survival of the femoral head depends on it.

(c) Slipped upper femoral epiphysis

This is quite a common disease of obese middle to late teenagers. It is an epiphyseal injury (Type I, 73-2) in which the child's upper femoral epiphysis slips spontaneously backwards and downwards through the epiphyseal line, either gradually or suddenly, often after only a minor injury.

In 20% of cases, the other epiphysis slips too, even while the patient is in bed being treated for the first one. Try to diagnose and refer these patients for internal fixation early, because the results will be good.

If you leave an epiphysis which has started to slip, it may slip completely, so that extensive and often unsuccessful major surgery is needed.

Gradual slipping may occur; a teenager complains of pain in the hip or knee, and starts to limp. Examine especially to check if the hip externally rotates if you flex the knee (66.2), and compare the abnormal leg with the normal one, because the signs are not obvious.

Look for:
(1) limitation of abduction,
(2) loss of internal rotation, and
(3) external rotation of the hip during flexion (7-17).

Rapid slipping; the child may not have had symptoms of gradual slipping before. He falls to the ground with a severe pain in the leg, which is externally rotated and short. He cannot move the leg off the couch, cannot weight bear and finds passive movements acutely painful if it is unstable.

Although the physical signs may be minimal, a suitable 'frog leg' view radiograph (73-23) may be diagnostic, if you examine it carefully. The epiphyseal line is widened and fluffy, and the epiphysis is displaced downwards. *Include both the hips on the same film. Don't try to manipulate this under GA!*

If you cannot refer the patient, try to rest the hip in internal rotation and abduction, either in a hip spica or in extension skin traction (67-3). A hip spica needs less supervision and is more convenient, especially in younger children.

HIP SPICA
Flex the child's knee about 15°. This will enable you to rotate the leg internally and abduct it. Then apply a spica to just above the ankle. Keep it on for ≤6wks. Then keep on crutches until there are radiological signs that the epiphyses have fused, or there is no further slipping. The epiphyses may unite earlier, but crutches are still needed further.
If there are any signs of further slipping, do your best to refer him for internal fixation.

N.B. The contralateral side will probably also need treatment.

TRACTION
Apply extension traction for 8-12wks, as in (67-3), but with the leg in abduction. If neither form of treatment is practical, at least avoid further slipping by preventing him from bearing weight on the leg. Use crutches.

SLIPPED UPPER FEMORAL EPIPHYSIS

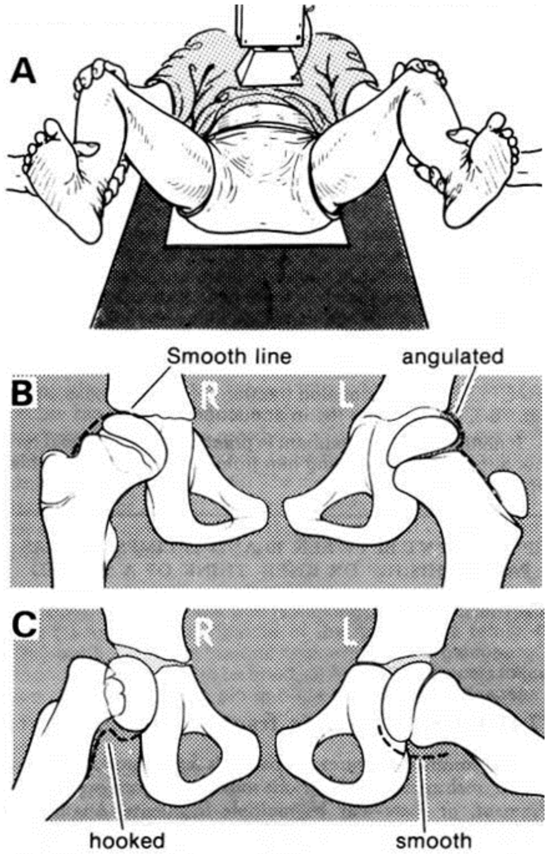

Fig. 73-23 SLIPPED UPPER FEMORAL EPIPHYSIS. A, showing a 'frog leg' view. This is essential for diagnosing a minimally slipped upper femoral epiphysis. The child's lower legs are horizontal and parallel with the edge of the table. B,C, the upper femoral epiphysis has slipped on the right. In the AP view the upper border of the neck continues on smoothly into the head whereas it normally angulates sharply. In the 'frog leg' view, the lower border of the neck is sharply hooked, instead of being smooth. *Kindly contributed by John Stewart.*

DIAGNOSE SLIPPED FEMORAL EPIPHYSES EARLY

IF A CHILD 10-15yrs OLD LIMPS, OR HAS PAIN IN THE HIP OR KNEE, THINK OF A SLIPPED EPIPHYSIS

73.13 Femoral shaft injury in children

Fractures of the central part of the shaft of the femur are common. Treatment varies with the patient's age:

(1) At birth no treatment is strictly necessary, though you may bandage the baby's thigh to the abdomen, as in the foetal position, for 10days. *Don't apply traction*.

(2) From birth to 3yrs use gallows traction or a plaster spica.

(3) Between 3-18yrs use extension traction.

In children between the ages of 0-10yrs, a shortening of up to 2cm is favourable. Because a fracture is often followed by this degree of bony overgrowth at the epiphyseal lines. This is useful in clinical practice, because it will allow you to treat a child's fractured femur in a hip spica without causing permanent shortening. From the age of 10yrs, children will not show the same degree of overgrowth: the maximum acceptable shortening then is 2cm. Minimize shortening as much as possible.

GALLOWS TRACTION

This does not need plaster and makes nursing easier. There is a risk of ischaemia in larger children. You can't send a child home with it.

LAXMAN (3yrs) fractured the shaft of his femur. He was put in gallows traction and the longitudinal strips of strapping were held in place with several circular turns. In the interests of tidiness, a sheet was put over his legs. He cried loudly during the night. Next morning both feet were cold and had later to be amputated. LESSONS. (1) *Never put circular strapping around any leg in traction*. If you want to hold longitudinal strips in place, apply figure of 8 strapping (73-24). (2) Make sure you can always see the toes.

INDICATIONS

(1) Femoral shaft fractures from 0-3yrs, provided the child weighs <15 kg. *Don`t use gallows traction in larger children:* max 3wks.

(2) Rectal prolapse (26.8): max 2wks

(3) Inguinal hernia (18.5); max 24h.

Make sure the base and the gallows are the same length. Apply skin traction to both legs. Pad the malleoli and the head of the fibulae. Apply adhesive strapping directly to his skin, *but never encircling around the legs*. Keep any knots away from the malleoli. Suspend the legs so that the pelvis is just clear of the bed, and you can slip a hand under the buttocks. The weight of the child's pelvis will reduce the fracture, and hold the fragments into position. Make sure the legs are aligned straight.

If the fracture is subtrochanteric, avoid an adduction deformity by keeping the legs well apart.

CAUTION!

(1) *Never apply circular strapping round the leg,*

(2) Make sure the strapping does not slip.

(3) Check the capillary return in both toes.

(4) *Don`t apply traction to one leg only*

(5) *Don't use in children >15kg.*

After 3wks of traction, apply a long leg cast or hip spica.

GALLOWS TRACTION

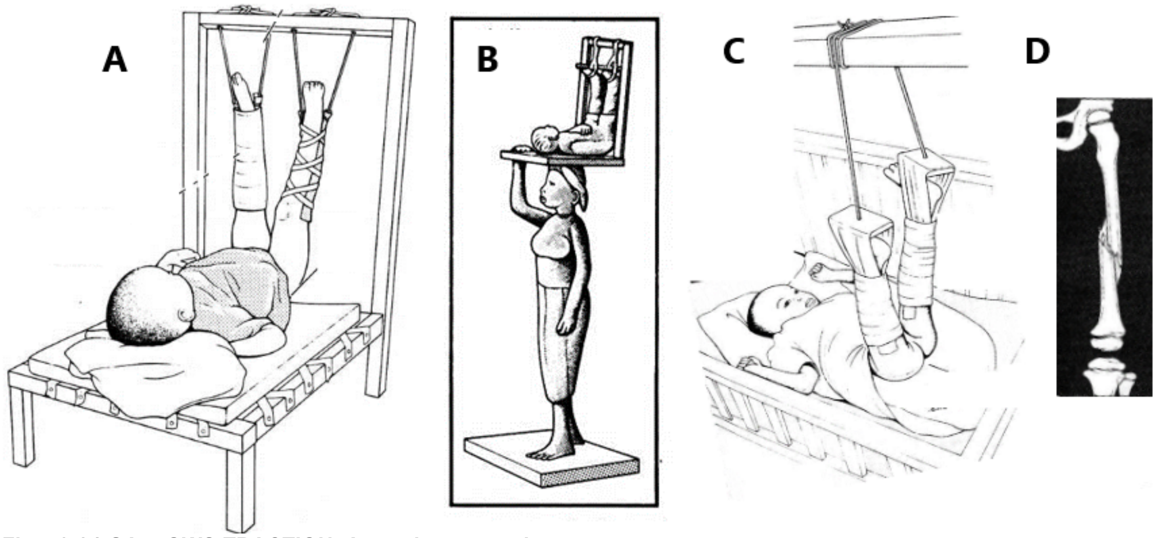

Fig. 73-24 GALLOWS TRACTION. A, cords arranged to keep knots away from the malleoli with a figure of 8 bandage on the right. B, *N.B. The statuette giving an idea of home care with a child on the head is not really recommended!* C, interrupted non-elastic bandage to hold the strapping, with a, gap under the buttocks. D, radiograph with healing callus.

MONITOR THE CIRCULATION IN HIS TOES CONSTANTLY

EXTENSION TRACTION
A child >3yrs is too heavy for gallows traction so apply traction to the extended lower leg over a pulley at the foot of the bed which is raised to apply counter-traction.

You can use this from the age of 3-18yrs, when the proximal tibial epiphysis fuses with the shaft.

N.B. If you use a pin in a child <18yrs, you may damage the epiphysis.

Extension traction keeps the leg extended so it cannot be exercised. This is less important in children and teenagers because their immobilized joints are much less apt to stiffen. Perkins traction preventing knee stiffness in older patients is thus unnecessary in children.

A femoral fracture in an older child is usually spiral. Extension traction corrects angulation, rotation, and lateral shift. It also corrects overlap, too. Actually in a child <10yrs, a certain overlap is preferable to compensate for the overgrowth that will follow.

So, subsequent growth soon corrects shortening. But avoid overlap as much as possible in children >10yrs. The shortening will not be compensated anymore.

Ischaemia is always a danger! The alternative is a hip spica. *Don`t use a Thomas splint or a Böhler-Braun frame.*

INDICATIONS
(1) Femoral shaft fractures at ages 3-18yrs
(2) Separation of the upper femoral epiphysis
(3) An unstable hip after dislocation reduction.

METHOD
Apply a long length of broad adhesive strapping from just distal to the fracture down to the lower leg. Pass it around a block of wood to act as a spreader, and then up to the outer side of the leg as far as the fracture but not beyond it.

Prevent the longer length of strapping sticking to the ankle by sticking a shorter piece to it. Pass this around the other surface of the spreader.
If necessary, make small cuts in the strapping to make it fit more closely to his leg. Pass a cord through the hole in the spreader and fix it to the foot of the bed. Raise the foot of the bed 40- 50cm, or use a weight (73-25).
Start with traction at 10% the body weight, *but not >5kg*, and compare the lengths of the legs with a tape measure to make sure you have not distracted the fragments.

Encourage the child to move about in bed.
Wait 6wks for clinical union (58.7) and then take a check radiograph or ultrasound scan. If union is satisfactory, use crutches.

CAUTION! (1) Watch carefully for signs of ischaemia, especially calf pain and pain on dorsiflexing the foot. (2) Make sure the strapping does not press on the common peroneal nerve as it winds around the head of the fibula.

EXTENSION TRACTION

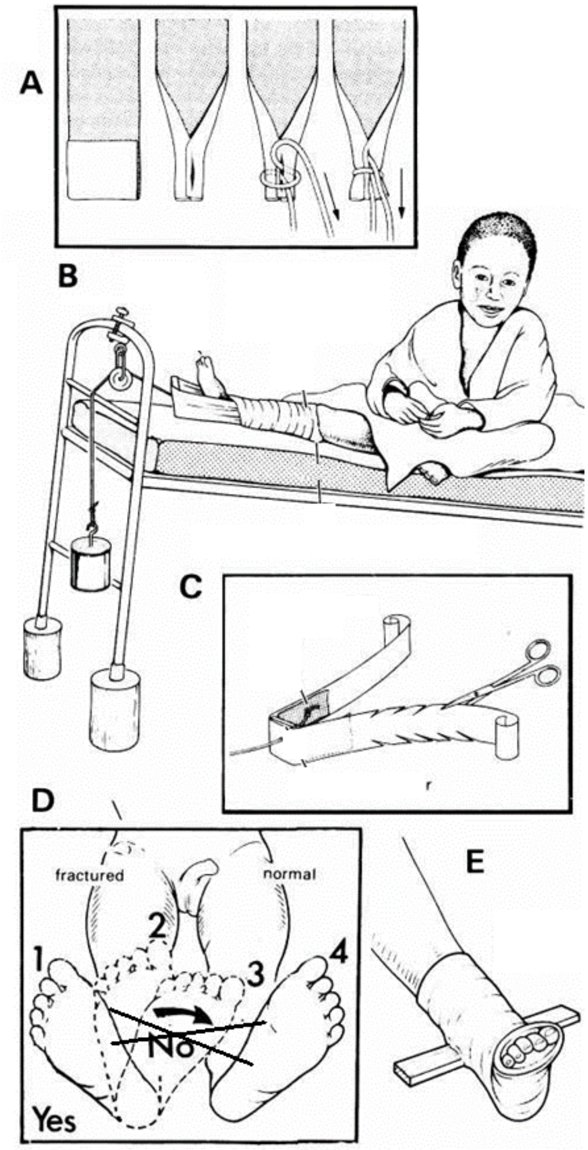

Fig. 73-25 EXTENSION TRACTION. A, one method of fixing the cord to the strapping. B, skin extension traction in action. C, fixing a spreader to the strapping. D, try to make sure the child's injured leg (1) matches his normal one (4). If you put it in position 2 it will rotate internally into position 3 when he walks (as shown by the arrow) and will cause severe disability. The anterior superior iliac spine, the patella, and the space between the 1st & 2nd toes normally lie in a straight line. E, a derotation bar in use. Note that it lies under the ankle, *not the heel. Don't fit a derotation bar to a damp cast,* or it may cause a pressure sore.
Kindly contributed by Richard Batten, Andrew Pearson & John Stewart.

N.B. Teenagers are particularly likely to refracture their femurs. Warn teenagers and parents for this. Tell them to avoid sports and intensive activities for another 4 months after treatment.

A PLASTER SPICA FOR A FRACTURED FEMUR

After 2wks' treatment with gallows or extension traction you can change to a spica cast (73-22) in children <10yrs. The child will be able to go home with it and is no longer confined to a hospital bed.
Get a radiograph to ensure that there is sufficient callus formation and that the fracture is stable. Apply the cast for 6wks. Take care to make this strong enough. Apply extra plaster at the hip.

In children >10yrs, a spica cast becomes very unpractical and is no longer an option. If the fracture is distal enough in the femur, convert treatment to a long leg cast for another 6wks.

Check for adequate callus before stopping the traction treatment and make sure the fracture is stable. The upper border of the cast should reach at least 10cm higher than the fracture in order to ensure adequate support and stability in the cast. If this is not possible to achieve, use extension traction for full treatment.

73.14 Knee injury in children

Anterior tear on the knee in a child can displace the epiphyses and also displace the tibial spine, or the tibial tuberosity. If a child has spontaneous knee pain, examine the whole lower limb from hip to ankle. The upper femoral epiphysis may have slipped.

(a) Tibial eminence (spine) **rupture**

In this uncommon injury, a child falls on the bent knee, drives the femur posteriorly on the tibia, and pulls the anterior cruciate ligament away from its insertion into the tibia. It is the paediatric equivalent of an anterior cruciate ligament rupture (68.5) seen in adults. It is mostly seen in a knee in hyperextension during sports with a rotated knee or after a fall from a motorcycle. As it tears, a wedge-shaped piece of the tibial plateau, which is usually called the 'tibial eminence' or 'tibial spine' pulls off. The knee fills with blood, either immediately, or not until the following day; it is tender all over, and the child cannot move it.

A lateral radiograph shows a thin flake of bone anteriorly between the tibia and the femur. The AP view may look almost normal.
This injury is worse than it looks, because the small bony fragment can pull much translucent cartilage with it.

TIBIAL EMINENCE FRACTURE

Fig. 73-26 TIBIAL EMINENCE FRACTURE. The AP knee radiograph may not show a fracture; *beware,* it usually hides a significant injury!

You can easily miss the diagnosis. If the loose fragment remains caught in the knee, the last 10° of full extension is lost.

If you can extend the knee, hold it in full extension (not overextended) and apply a plaster cylinder cast (68.2) from the upper part of the thigh to just above the heads of the metatarsals. Take a new radiograph in the cast cylinder to check the position of the fragment.

If the fragment is still displaced (>2mm from its anatomical position), or if the fracture is comminuted, fixation is needed.

Allow standing immediately, and advise walking as naturally as possible. Leave the cylinder cast on for 6wks. Knee movements will then return gradually as the leg is used.

If presentation is late, and you cannot extend the knee, even under GA, refer for open reduction.

(b) Femoral supracondylar fracture
Anaesthetize the child, manipulate the fragments into position, and apply a long leg cast from the ischial tuberosity to the toes. Apply it with the knee in the position that best reduces the fracture. If necessary, flex it to 90°.

(c) Slipped lower femoral epiphysis
Displacement of the distal femoral epiphysis typically follows a violent injury or blow to the knee in a teenager, or may occur in osteomyelitis (7.10).

A severe injury which would cause a supracondylar fracture in an adult, produces a Type I, II or IV epiphyseal injury (73-2), the commonest being Type II, in a child or teenager.

The child presents with an obvious deformity of the knee and severe pain. This may also be described as the knee "giving way" Undisplaced fractures tend to present with milder symptoms, and the child can sometimes even walk and bear weight on the affected knee. *Don't be fooled though by this presentation* and examine radiographs carefully.

The distal epiphysis usually moves anteriorly, displacing the distal end of the shaft of the femur posteriorly where it may obstruct the popliteal vessels. Make a proper distal neurovascular examination to make sure that there is no injury to the popliteal artery or the sciatic, tibial or peroneal nerves.

Replace the epiphysis under GA, and hold the knee in flexion in a cast. You can use Perkins traction if displacement is mild.

REDUCING A SLIPPED DISTAL FEMORAL EPIPHYSIS

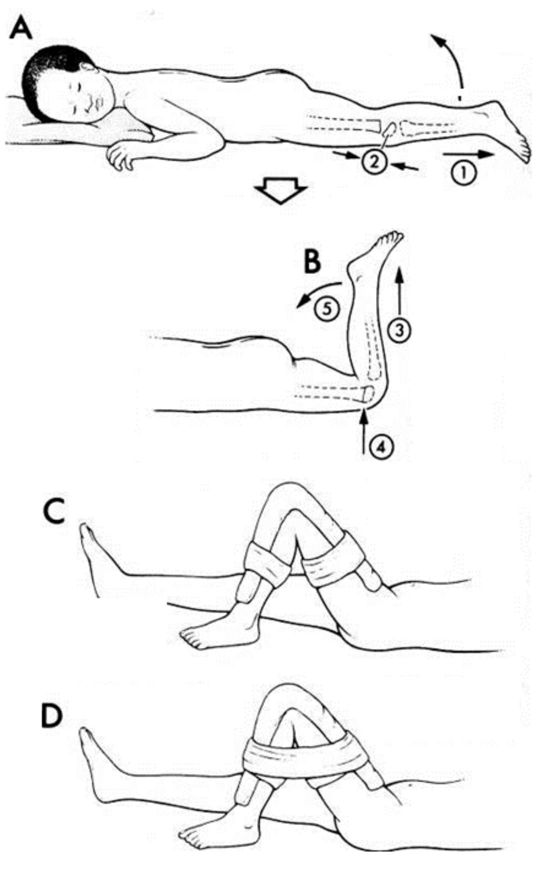

Fig. 73-27 REDUCING A SEPARATION OF THE DISTAL FEMORAL EPIPHYSIS (TYPE I). A, applying traction with the knee extended (1), try to correct lateral displacement (2). B, now bend the knee & distract the lower leg (3), and try to correct anterior displacement (4), pushing posteriorly. Finally flex the knee to 110° (5). C, monitor circulation in the toes. D, *don't continue immobilisation >3wks.* *After Rang M, Children's Fractures, JB Lippincott, 2nd ed 1983 with kind permission.*

DIAGNOSIS
If you are not sure whether a child has ruptured the medial ligament, or displaced the epiphysis, take another film with the extended knee in a *valgus* position. This will help you differentiate between them.
If the medial ligament is ruptured, the knee joint will open with *valgus* stress, but the distal femur has a normal shape and contour. If the child has a displaced distal femoral epiphysis, you will see the epiphyseal line opening up on a radiograph screening instead of the knee joint.

MILD OR NO DISPLACEMENT
Apply Perkins traction (67.3).

MODERATE DISPLACEMENT
In the more common Type I variety, with the distal fragment displaced anteriorly, the circulation in the leg may be impaired; reduction is then urgent. Under GA in a prone or lateral position (73-27A,B), manipulate the fragment and reduce the fracture.

If reduction is stable, apply an anterior plaster slab to the flexed leg (73-27C), and secure the slab to the thigh with circular plaster bandages. Then put another plaster bandage around the thigh and the lower leg (73-27D). *Don't flex the knee more than the degree of swelling will permit*.

Then, 10days later, reduce flexion to 60°. Remove the cast after a further 3wks. Movement will return slowly.

CAUTION!
(1) Monitor the circulation in the toes carefully during the early stages.
(2) *Don't prolong immobilization beyond 3wks*, because the flexion contracture that results may be very difficult to treat.
(3) Watch for loss of reduction, which may occur as late as the 3rd wk.
If reduction is unstable, refer the child.

SEVERE DISPLACEMENT
Refer the child, especially if the injury is of the rarer Type IV variety (73-2) in which the fracture line opens into the knee joint.
Long term prognosis is fair to poor. Type I fractures have the best outcomes. Types II, III and IV have a high risk of physeal growth arrest.

TOPO (14yrs) was injured in a football match, and severely displaced his lower femoral epiphysis. No attempt at reduction was made, and a cast was applied. He was referred 6wks later by which time it was too late to try to attempt reduction. The severe angulation will have to be corrected later by osteotomy. LESSONS (1) Reduce epiphyseal injuries within 3days. (2) *Casts are not universal treatment for all bony injuries.*

(d) Patellar sleeve fracture
Patella fractures typically occur in the young male adolescent following a direct blow to the knee. This type of fracture requires the same assessment and treatment as in adults.
A rarer type of patellar fracture is the sleeve fracture that only occurs in children. It typically follows after a forceful contraction of the quadriceps during a jump or a direct blow to the knee.

The *quadriceps* tendon pulls off a large osseo-cartilaginous fragment off the patella, and only cartilage and a very small bony fragment remains attached to the patellar tendon.

Patellar sleeve fractures are difficult to diagnose on radiography. Pay extra attention to the lateral view where you will find the typical findings of a high-riding patella and some small bony fragments where you would normally expect to see the patella. If the clinical presentation is very suspicious, treat the patient as if there is a sleeve fracture.

PATELLAR SLEEVE FRACTURE

Fig. 73-28 PATELLAR SLEEVE FRACTURE. Left knee radiographs. A, a small segment has detached. B, the segment is pull off completely

Treat minimally (<4mm) displaced fractures (73-28A) with a long leg cast in extension for 6-8wks.

Displacement >4mm requires an open reduction and internal fixation. In children <10yrs, you can achieve good fixation with a non-absorbent suture through the cartilaginous sleeve and the patellar tendon. In children >10yrs, a traditional tension-band wiring with K-wires (68-10) is better. Treat with a long leg cast in extension for 6-8 wks after fixation.

(e) Tibial tuberosity avulsion
During childhood, a projection of the proximal tibial epiphysis forms the tibial tuberosity & the attachment of the patellar tendon. At any age until early adult life when the epiphysis unites, sudden contraction of the quadriceps may tear the tibial tuberosity away from the tibia.

This happens most in basketball games.
Children suffering from Osgood-Schlatter disease are at higher risk of sustaining this tibial tuberosity avulsion.

TIBIAL TUBEROSITY AVULSION

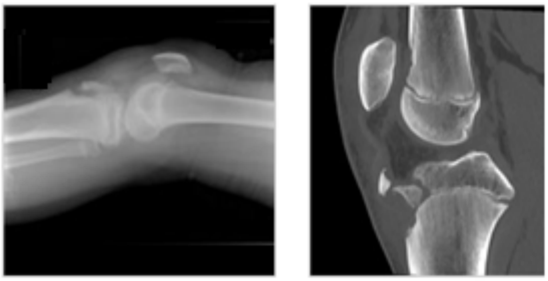

Fig. 73-29 TIBIAL TUBEROSITY AVULSION. Left knee radiographs. A, mild separation. B, severe separation affecting the joint.

Treatment depends on the degree of separation. If this is mild (73-29A), immobilize the child's knee in extension in a plaster cylinder cast for 4wks. If separation is severe (73-29B), under GA, try to push the tuberosity back into place, then apply a plaster cylinder in extension.

If closed reduction fails, open reduction & screw fixation are necessary.

(f) Slipped proximal tibial epiphysis
A Type I or II fracture of the proximal tibial epiphysis is a rare injury predominantly affecting adolescent boys. The proximal tibial epiphysis tends to displace anteriorly, in a similar way as the distal femoral epiphysis.

Study the radiograph carefully, and try to push the displaced epiphysis back into place.

Sometimes the fracture follows a Type III pattern where the fracture looks much like a tibial tuberosity avulsion. Make this distinction carefully.

N.B. Don`t miss a lesion of the peroneal nerve or a vascular lesion because of compression of the popliteal artery.

Treat minimally (<2-3 mm) displaced fractures conservatively in an extension cast for 6wks. If >2-3 mm displacement remains after 2 attempts of closed reduction, open reduction and internal fixation are needed.

If the epiphyseal line is crushed (Type V, 73-2), you should follow-up this injury by repeat radiographs until full growth is reached. Since a severe *valgus* deformity often ensues, treat this with an osteotomy when the epiphyses are closed.

73.15 Lower leg injury in children

(a) Tibia shaft fracture
A child falls, and afterwards refuses to walk. There are few signs. Radiographs usually show a long spiral or oblique fracture with little displacement, commonly in the lower $^1/_2$ of the tibia. If the fracture is transverse there is a higher risk of displacement and reduction may be necessary.

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INCOMPLETE FRACTURES
This type of fracture, also called the ‘toddler’s fracture’, is typical of the infant or young child. The fracture is sub-periosteal and is stable. On a radiograph you will see a very fine line the thickness of a hair in a spiral pattern. Apply a long leg walking cast for 2-3wks to relieve pain and prevent the fracture from becoming complete.

COMPLETE FRACTURES
If there is no significant displacement, apply a long leg cast (70-4) for 2wks until pain subsides. Then convert to a short leg walking cast for another 4wks.

If there is significant displacement, reduce the fracture under GA. Elevate the fracture above the level of his heart (70-1), by raising the foot off the bed on pillows.
Apply a well-padded circular long leg cast to maintain reduction. Keep the long leg cast until the fracture is adequately stable. Then convert it to a short leg walking cast.
Treat with a total of 6wks of casting. If you cannot maintain the reduction using a cast, refer for internal fixation.

CAUTION! Always split the cast in adolescents and, as soon as the swelling has gone down, renew or complete the cast by pulling its split edges together, and binding it round with a plaster bandage. Apply a walking heel, and allow crutches with full weight bearing as soon as pain allows. Leave the cast on for 6wks. When you remove it, full movements will return quickly.

(b) Fracture of both tibia & fibula
Regardless of the type of fracture of each lower leg bone, it is of utmost importance if the fibula is fractured or not. Always include the knee and ankle in your radiographs to assess the integrity of both the fibula and the tibia over their entire length.

If both the fibula & tibia are fractured in their middle segment, there is a risk for *valgus* angulation in tibia because of the muscle pull in the lower leg. You therefore should slightly overcorrect them to *varus*. Conversely, isolated fractures of the middle segment of the tibia have a tendency to slip into *varus* deformity.

These fractures tend to be unstable by definition. Put on a well-moulded long leg cast with the knee in 45° flexion to inhibit rotation at the knee level. Put the ankle in about 10-20° plantarflexion to avoid recurvatum (posterior bending) at the fracture site.

If you cannot achieve anatomical reduction because of swelling of the leg, cast it in the most acceptable position possible. Admit the patient for neurovascular monitoring and redress the cast after 1-2wks using the wedging technique.

COZEN PHENOMENON
Children between the ages of 3-6yrs who have sustained a proximal metaphyseal tibial fracture are at risk of developing the 'Cozen phenomenon'. A certain number of these children will develop a progressive *valgus* deformity in their proximal tibia after fracture consolidation. The aetiology of this phenomenon remains a mystery and in most cases it is self-limiting. The *valgus* will stabilize after about 2yrs and then remodel to a normal tibia again after about 4yrs post-fracture.

Some children however will not remodel and will need an osteotomy to correct valgus deformity. *Don't perform this too early*, as recurrence of *valgus* deformity after osteotomy may still occur.

Explain to parents that there is a risk for this deformity after a metaphyseal tibia fracture. Plan a long term follow-up of all children with these fractures with serial radiographs.

Children generally do not need any physical rehabilitation after a tibia fracture. Many children will walk with the leg in external rotation, with the toes pointing outwards for a few wks to a month after removal of the cast. This is normal, and will disappear by itself. Reassure parents about this.

73.16 Ankle & foot injury in children

(a) Slipped distal tibial epiphysis
This is a child`s equivalent of a malleolar fracture. You can usually treat a Type II epiphyseal injury (73-2) by closed reduction & cast immobilization. Type III & IV injuries, in which the fracture line opens into the joint, often need open reduction to restore a smooth joint surface, unless the articular step-off and displacement is <2mm.

The ankle is also the most common site for the Type V injuries which crush the epiphyseal plate. Because there is no displacement, you may think that a child has only sprained his ankle, until growth deformities occur years later. Under GA, exert strong traction on the foot and manipulate the ankle into position. Take great care to correct rotation. Apply a long leg walking cast for 6wks.

(b) Transitional fractures of adolescence
A triplane fracture is a fracture that only happens during a very specific time window during closure of the distal tibial epiphysis. As such, it only happens in adolescents between 12-16yrs. The fracture typically consists of an antero-lateral tibial fragment and a larger medial fragment with a posterior metaphyseal spike. The exact pattern is determined by which parts of the epiphysis is already closed and which part is still open.

TRIPLANE FRACTURE

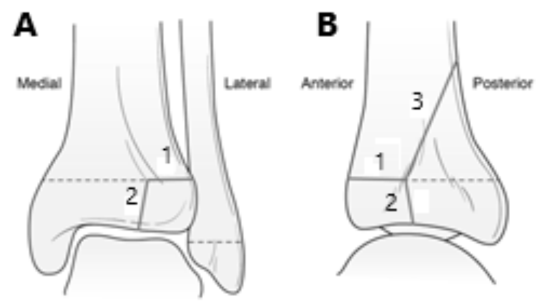

Fig. 73-30 TRIPLANE FRACTURE occurs in juveniles. Left ankle: A, A-P view, B, sagittal view. 1,2,3 typical lines of the fracture.

Because of the complex 3D nature of this type of fracture, a CT-scan is necessary to evaluate the level of displacement and need for surgical fixation. Refer this for further assessment and treatment when possible.

N.B. WALKING AIDS IN CHILDREN

Flat pieces of wood on the bottom of 2 sticks ('plonkers', 66-1F) will make them easier to use.

Serious foot fractures are rare, but *beware a missed talar fracture,* because the risk of avascular necrosis & non-union is high.

APPENDIX: GRADES OF OPERATION

You can use this chart to monitor your progress, and to give you an idea of the relative difficulty of operations. This list refers to volume 2 only.

1.2 Delayed primary or Secondary suture (46.3)
Jaw dislocation reduction (53.5)
Elbow aspiration (62.2)

1.3. Escharotomy (50.4)
Anterior shoulder dislocation reduction (61.8)
Elbow dislocation reduction (62.3, 73.7)
Wrist fracture reduction (64.2)
Posterior hip dislocation reduction (66.3)
Knee dislocation reduction (68.8)
Ankle dislocation reduction (71.3)
Supracondylar humeral fracture reduction (73.7)

1.4 Chest drain (thoracostomy) (43.2)
Anterior forearm or Leg fasciotomy (49.8)
Conjunctival repair (52.4)
Interdental wiring (53.6)
Posterior shoulder dislocation reduction (61.8)
Greater humeral tuberosity fracture reduction (61.9)
Humeral shaft fracture, angulated, reduction (61.13)
Achilles tendon repair (71.8)
Talonavicular dislocation reduction (72.1)
Midtarsal dislocation reduction (72.8)

1.5 Humeral neck fracture reduction (61.11)
Capitulum fracture reduction (62.6)
Anterior hip reduction (66.4)

2.1 Skin grafting (50.13)
Steinmann/Denham pin insertion (59.4)
Intertrochanteric femoral neck reduction (66.7)
Pinna repair (53.7)

2.2 Cricoidotomy (42.3)
Tracheostomy (50.5)
Lateral canthotomy (52.3)
Eyelid repair, simple (52.3)
Knee aspiration (68.3)
Guillotine amputation (60.3)

2.3 Wound debridement (46.2)
Tendon repair (48.2)
Eyelid repair with tissue loss (52.3)
Nasal dislocation reduction (53.4)
Skull tongs application (54.6)
Finger K-wiring (65.20)

2.4 De-infibulation (47.5)
Nerve repair, primary (48.1)
Anal repair (57.3)
Open fracture debridement (58.13)
Hand high pressure wound debridement (65.22)
Open child forearm racture reduction (73.8)

2.5 Hand-groin or Finger-abdominal flap (46.4)
Nerve repair, secondary (48.1)
Craniotomy burr hole (51.7)
Corneal & scleral repair (52.5)
Mandibular external fixation (53.6)
Rectus abdominis myoplasty (54.11)
Cervix repair (56.3)
Talar loose body excision (72.3)

3.1 Intercostal artery ligation (43.5)
Cross-leg, *Gastrocnemius*, or Rotational flap (46.4)
Craniotomy (51.8)
Zygoma fracture reduction & arch wiring (53.2)
Olecranon internal fixation (62.8)
Patellar tendon or *Quadriceps* repair (68.9)
Metatarsal fixation (72.9)

3.2 *Gracilis,* Sural, *Latissimus Dorsi*
or *Pectoralis Major* flap (46.4)
Artery suture, primary (47.5)
Femoral artery exposure (49.4)
Arterial thrombectomy (49.5)
Patch angioplasty (49.5)
Pulsating haematoma exploration (49.6)
Nose-glabellar & V-switch lip flap (53.7)
Laparotomy for trauma (55.2)
Gastric repair (55.9)
Small bowel repair (55.11)
Greater humeral tuberosity fixation (61.11)
Humeral shaft external fixation (61.15)
Elbow dislocation open fixation (62.3)
Elbow external fixation (62.4)
Forearm external fixation (63.7)
Wrist external fixation (64.2)
Carpal reduction, open (64.5)
Femoral external fixation (67.5)
Patellar fracture horizontal repair (68.9)
Tibial external fixation (69.5, 70.7)
Ankle external fixation (71.6)

3.3 Brachial, external carotid,
or external iliac artery exposure (49.4)
Arterial anastomosis (49.5)
Duodenal repair (55.10)
Ureteric re-implantation (55.15)
Sternoclavicular dislocation fixation (61.5)
Olecranon, distal excision (62.8)
Patellar fracture fixation (68.9)

3.4. Anterior neck exploration (42.5)
Lateral neck exploration (42.5)
Diaphragm rupture repair (43.4)
Thoracotomy, emergency (44.6)
Axillary, popliteal
or subclavian artery exposure (49.4)
Saphenous vein, reverse graft (49.5)
Aortic clamping (55.4)
Splenectomy, emergency (55.6)
Neo-uretero-cystostomy Boari flap (55.16)
Radial head excision (62.7)
Central acetabular fracture reduction (66.5)

3.5. Pulmonectomy, peripheral (43.7)
Right visceral medial rotation (55.8)
Pancreatectomy, distal (55.10)
Renal repair (55.14)
Hip arthroplasty, trauma, Girdlestone (66.8)

APPENDIX B: NUMBERING & NAMES

40.1 Refers to a written section in the text, with its own subject heading.
40-1 Refers to a figure in the text.

Chapters are numbered with dots (*e.g.* 40.3) and illustrations with dashes (*e.g.* 40-2). An A at the end of a number, as for example (40-2A) refers to the first illustration in a particular figure.

DIFFICULTIES WITH THE INDEX

If you have trouble looking things up, this section will probably help you.

Spelling follows the UK English tradition and usage rather than the American, so you will find 'aluminium' 'colour', 'emergency' 'haemoglobin', 'leucocyte', 'manoeuvre', 'oesophagus', 'operating theatre', 'titre' rather than 'aluminum', 'color', 'emergent', 'hemoglobin', 'leukocyte', 'maneuver', 'esophagus', 'operating room' & 'titer'.

APPENDIX C: ABBREVIATIONS

Å	Ångström (=0·1nm)	(38.1)
AAFB	acid-alcohol fast bacilli (TB)	(5.6)
Abb.	abbreviation	(5.8)
ABC	abacavir	(5.8)
ABCDE	(mnemonic for resuscitation: *Airway, Breathing, Circulation, Disability, Exposure).*	(42.1)
ABO	(system of blood groups)	(3.6)
AC	abdominal circumference	(38.3)
ACG	angle closure glaucoma	(28.6)
ACS	abdominal compartment syndrome	(11.10)
ADH	anti-diuretic hormone	(44.8)
A&E.	Accident & Emergency	(40.6)
AGS	adrenogenital syndrome	(27.27)
AIDS	acquired immune deficiency syndrome	(5.1)
AIN	anal intra-epithelial neoplasia	(5.8)
am	morning (Latin: *ante meridiem)*	(21.3)
AMBU	artificial mechanical breathing unit	(2.1)
AMO	assistant medical officer	(1.3)
ANC	ante-natal clinic	(19.1)
AO	Association (for) Osteosynthesis	(7.5)
AP	antero-posterior	(7.6)
APH	ante-partum haemorrhage	(20.2)
APM	anti-personnel mine	(60.6)
APV	aprenavir	(5.8)
ARDS	acute respiratory distress syndrome	(3.6)
ARM	artificial rupture (of) membranes	(22.2)
ART	anti-retroviral therapy	(5.1)
AVPU	alert-verbal-pain-unresponsive	(41.2)
AZT	zidovudine	(5.8)
AZV	atanazavir	(5.8)
BB	borderline (leprosy)	(32.2)
BC	(year) before Christ	(26.3)
BCG	bacilli Camille Guerin (TB vaccine)	(5.5)
bd	twice daily (Latin: *bis die)*	(2.9)
BFAT	Bilharzia fixation antibody test	(27.36)
ß-HCG	human chorionic gonadotropin	(20.12)
BIO	binocular indirect ophthalmoscopy	(28.1)
BIPP	bismuth iodoform paraffin paste	(4.11)
BL	borderline lepromatous (leprosy)	(32.2)
BMI	body mass index	(41.1)
BMVSS	Hindi: (*Bhagwan mahaveer viklang sahavata samiti*): charitable organization providing services free of charge	(35.6)
BP	blood pressure	(3.4)
BPD	biparietal diameter	(38.3)
BRS	basic radiological system	(1.12)
BSO	bilateral salpingo-oophorectomy	(23.8)
BT	borderline tuberculoid (leprosy)	(32.2)
BXO	balanitis xerotica obliterans	(27.31)
c.	about (Latin: *circa*)	(3.4)
°C	degree centigrade	(10.1)
C-ABCDE	(circulation first!)	(40.5)
CAH	congenital adrenal hyperplasia	(33.14)
CAT	combat application tourniquet	(44.2)
cc	cubic centimetre (=ml)	(22.2)
CCF	congestive cardiac failure	(44.7)
CCU	critical care unit	(41.5)
CD4	cluster differentiation (glycoprotein)	(5.3)
CDH	congenital dislocation (of the) hip	(32.14)
CF	count fingers	(28.1)
Ch	Charrière (gauge) = Fr	(4.9)
CHOP	cyclophosphamide, hydroxydaunorubicin (doxorubicin), oncovin (vincristine), prednisolone.	(17.6)
cm	centimetre	(2.4)
CMV	cytomegalovirus	(5.6)
CNS	central nervous system	(5.7)
COPD	chronic obstructive airways disease	(44.7)
CPD	cephalopelvic disproportion	(21.4)
CPR	cardio-pulmonary resuscitation	(44.9)
CRL	crown-rump length	(20.1)
CSF	cerebrospinal fluid	(17.6)
CT	computerized tomography (scan)	(43.1)
CVP	central venous pressure	(10.1)
DALY	day adjusted life-years	(40.1)
D&C	dilation and curettage	(10.2)
dB	decibel	(29.2)
DC	damage control	(41.5)
DCIS	ductal carcinoma *in situ*	(24.2)
ddC	zalcitabine	(5.8)
ddI	didanosine	(5.8)
DIC	disseminated intravascular coagulation	(2.5)
dip	distal interphalangeal	(7.18)
dL	decilitre	(1.5)
DLV	delavirine	(5.8)
DNA	deoxyribonucleic acid	(5.2)
DOTS	directly observed treatment scheme	(5.7)
DPC	delayed primary closure	(60.6)
DPL	diagnostic peritoneal lavage	(55.1)
DRV	darunavir	(5.8)
d4T	stavudine	(5.8)
DUB	dysfunctional uterine bleeding	(20.6)
DVT	deep vein thrombosis	(6.22)
EBV	Epstein Barr virus	(17.6)
ECG	electrocardiogram	(2.1)
ECV	external cephalic version	(22.7)
ed	editor, edition	(6.6)
EEG	electro-encephalogram	(45.2)
EFV	efavirenz	(5.8)
e.g.	for example (Latin: *exempli gratia*)	(1.11)
ELISA	enzyme-linked immunosorbent assay	(5.1)
EMF	endomyocardial fibrosis	(9.2)
ENL	erythema nodosum leprosum	(32.2)

ENT	ear nose throat	(2.12)
EPI	extended programme (of) immunization (WHO)	(32.7)
ESR	erythrocyte sedimentation rate	(5.6)
ET	endotracheal	(2.1)
et al	and others (Latin: *et alia*)	(5.3)
ETR	etravirine	(5.8)
ETT	endotracheal tube	(42.2)
EVM	eye opening, verbal & motor response	(51.1)
FAST	focused abdominal sonography trauma	(43.2)
FDI	World Dental Federation (French: *Fédération dentaire internationale*)	(31.1)
Fig.	figure	(1.1)
FL	femur length	(38.3)
FFP	fresh frozen plasma	(3.1)
FGM	female genital mutilation	(6.21)
FO	fibreoptic	(29.13)
Fr	French (gauge) = Ch	(9.1)
FSH	follicle stimulating hormone	(19.1)
FTC	emtricitabine	(5.8)
5FU	5-flurouracil	(34.5)
g	gram,	(2.9)
G	gauge	(4.6)
	pregnant (Latin: *gravida*)	(20.2)
G6PD	glucose 6-phosphatase dehydrogenase deficiency	(33.10)
GA	general anaesthetic	(1.4)
GCS	Glasgow coma scale	(40.6)
GI	gastro-intestinal	(13.4)
GIST	gastrointestinal stromal tumour	(13.5)
GnRH	gonadotropin releasing hormone	(24.3)
GTD	gestational trophoblastic disease	(23.10)
GUL	gestation of unknown location	(20.1)
h	hour	(3.4)
Hb	haemoglobin	(10.1)
HBV	hepatitis B virus	(2.6)
HCV	hepatitis C virus	(2.6)
HDU	high dependency unit	(41.5)
HELLP	haemolysis, elevated liver (enzymes), low platelet (syndrome)	(22.2)
HIV	human immunodeficiency virus	(1.2)
HM	hand movements	(28.1)
H_2O_2	hydrogen peroxide	(51.6)
HPV	human papilloma virus	(23.8)
HR	heart rate	(44.1)
HRE	isoniazid, rifampicin, ethambutol	(5.7)
HRZE	isoniazid, rifampicin, pyrazinamide, ethambutol	(5.7)
HSG	hysterosalpingogram	(19.3)
HTIG	human tetanus immune-globuin	(46.7)
I	(Latin: 1)	(1.4)
ICD-10	international classification (of) diseases, (10^{th} version)	(19.1)
ICU	intensive care unit	(1.8)
I&D	incision and drainage	(2.12)
IDV	indinavir	(5.8)
i.e.	such as (Latin: *id est*)	(5.6)
Ig	immunoglobulin	(5.2)
II	(Latin: 2)	(1.4)
III	(Latin: 3)	(1.4)
IM	intramuscular	(2.11)
INR	international normalized ratio	(44.7)
IOP	intra-ocular pressure	(28.1)
ip	inter-phalangeal	(8.15)
IPD	inter-pupillary distance	(28.1)
IPPV	intermittent positive pressure ventilation	(43.1)
IR	infrared radiation	(28.1)
IU	international unit	(22.2)
IUD	intra-uterine device	(5.3)
IUGR	intra-uterine growth retardation	(19.3)
IV	intravenous	(1.8)
	(Latin: 4)	(1.4)
IVC	inferior vena cava	(38.2)
IVU	intravenous urogram	(27.5)
IX	(Latin: 9)	(1.4)
JHPIEGO	Johns Hopkins Programme of International Education in Gynaecology & Obstetrics	(19.5)
JVP	jugular venous pressure	(44.1)
K	potassium (German: *kalium*)	(3.6)
	Kirschner (fixation)	(32.14)
Kcal	kilocalories	(12.4)
KCl	potassium (German: *kalium*) chloride	(1.8)
Ket	ketamine	(2.12)
kg	kilogram	(2.5)
kHz	kilohertz	(29.2)
KP	keratitic precipitates	(28.3)
KS	Kaposi sarcoma	(34.10)
kV	kilovolt	(38.1)
kW	kilowatt	(2.5)
L	litre	(1.8)
LA	local anaesthetic	(1.8)
lb	pound (Greek: *libra*)	(2.5)
LED	light-emitting diode	(1.1)
LGV	lymphogranulopma venereum	(23.17)
LH	luteinizing hormone	(19.1)
LL	lepromatous (multibacillary) leprosy	(32.2)
LMA	laryngeal mask airway	(42.1)
LMIC	low (&) middle income country	(19.1)
LPV	lopinavir	(5.8)
m	metre	(38.1)
mA	milliampere	(38.1)
mcp	metacarpo-phalangeal	(7.18)
mg	milligram	(1.8)
µg	microgram	(13.1)
MHz	megahertz	(3.3)
MI	myocardial infarction	(44.7)
min	minute	(1.8)
mIU	$^{1}/_{1000}$ of an IU	(22.2)
MJ	megajoule	(12.4)
ml	millilitre	(1.5)
µl	microlitre	(5.7)
M&M	morbidity & mortality	(1.3)
mm	millimetre	(2.5)
mM	millimolar (millimoles per litre)	(1.8)
µm	micrometre	(34.7)
µM	micromolar (micromoles per litre)	(33.8)
mmol	millimole	(10.1)
MMR	maternal mortality ratio	(1.1)
MOH	Ministry of Health	(19.1)
MOPP	mustine, oncovin (vincristine), procarbazine, prednisolone	(17.6)
MRI	magnetic resonance imaging	(7.3)
MSICS	manual small incision cataract surgery	(28.4)
mtp	metatarso-phalangeal	(32.12)
MTX	methotrexate	(23.10)
MU	mega-unit	(2.9)
MUA	manipulation under anaesthetic	(2.12)
MVA	manual vacuum aspiration	(19.1)
NaCl	sodium (German : *natrium*) chloride.	(1.8)
N.B.	note well (Latin: *nota bene*)	(2.4)
NFV	nelfinavir	(5.8)
NG	nasogastric	(4.9)
nm	nanometre	(38.1)

nil	nothing (Latin: *nihil*)	(13.3)
NNRTI	non-nuclease reverse transcriptase inhibitor	(5.8)
NPL	no perception (of) light	(28.1)
NRTI	nuclease reverse transcriptase inhibitor	(5.8)
NSAID	non-steroidal anti-inflammatory drug	(13.1)
nocte	at night (Latin)	(37.2)
NVP	nevirapine	(5.8)
O_2	oxygen	(40.1)
od	once daily (Latin: *omni die*)	(2.9)
OA	occipito-anterior	(22.2)
OGD	oesophago-gastro-duodenoscopy	(13.2)
OND	optic nerve diameter	(45.1)
ONSD	optic nerve sheath diameter	(45.1)
OP	occipito-posterior	(22.2)
OT	operating theatre	(51.5)
p.	page	(6.12)
P	born (Latin: *para*)	(20.2)
PA	postero-anterior	(9.1)
PAIR	puncture, aspiration, injection, re-aspiration	(15.12)
p_aO_2	arterial pressure of Oxygen	(32.2)
Pap	Papanicolau	(23.3)
PCR	polymerase chain reaction	(5.7)
PDS	polydioxanone sulphate (suture)	(4.6)
PE	pulmonary embolism	(44.1)
PEEP	positive end-expiratory pressure	(42.7)
PEP	post-exposure prophylaxis	(5.8)
pH	logarithmic value of acidity	(5.4)
PI	protease inhibitor	(5.8)
PID	pelvic inflammatory disease	(5.6)
pip	proximal interphalangeal	(7.18)
P-L	Proctor-Livingstone	(30.2)
PL	perception (of) light	(28.1)
pm	afternoon (Latin: *post meridiem)*	(21.3)
PMB	postmenstrual bleeding	(19.1)
PMMA	polymethylmethacrylate	(28.4)
PNM	perinatal mortality	(20.1)
PNR	perinatal mortality rate	(20.1)
PO	by mouth (Latin: *per os*)	(1.8)
POAG	primary open-angle glaucoma	(28.6)
PoP	plaster of Paris	(7.11)
POR	postoperative radiotherapy	(23.8)
PPH	post-partum haemorrhage	(22.11)
PPI	proton pump inhibitor	(13.1)
ppm	parts per million	(5.4)
PR	*per rectum*	(1.11)
PRN	as required (Latin: *pro re nata*)	(2.12)
PROM	premature rupture of membranes	(22.4)
PSA	prostate specific antigen	(5.6)
psi	pounds (per) square inch	(2.4)
PV	*per vaginam*	(19.5)
PVC	polyvinyl chloride	(60.5)
qds	4 times daily (Latin: *quater die sumendus*)	(2.9)
Rh	Rhesus (blood type: D)	(3.6)
RPR	rapid plasma reagin (syphilis test)	(24.3)
RNA	ribonucleic acid	(5.2)
RTV	ritonavir	(5.8)
RVF	rectovaginal fistula	(21.10)
SALT	(mnemonic for 'sort, assess, lift, transport/treat)	(40.6)
SC	subcutaneous	(2.11)
sec	second	(21.3)
SIV	simian immunodeficiency virus	(5.2)
SQV	saquinavir	(5.8)
stat	immediately (Latin)	(10.4)
STI	sexually transmitted infection	(23.1)
TAH	total abdominal hysterectomy	(23.8)
TB	tuberculosis	(5.7)
TBA	traditional birth attendant	(19.1)
TBSA	total body surface area	(50.1)
3TC	lamivudine	(5.8)
TDF	tenofavir	(5.8)
tds	3 times daily (Latin: *ter die sumendum*)	(2.9)
TFR	total fertility rate	(19.3)
Thio	thiopentone	(2.12)
TL	tubal ligation	(19.4)
TNM	tumour node metastasis (staging)	(24.4)
TOS	trial of scar	(21.13)
TSH	thyroid stimulating hormone	(25.6)
TT	tuberculoid (paucibacillary) leprosy	(32.2)
	Tetanus toxoid	(46.7)
TTCV	tetanus toxoid containing vaccine	(46.7)
U	unit	(20.4)
UPS	uninterrupted power supply	(41.5)
USA	United States (of) America	(5.1)
UV	ultraviolet	(28.1)
V	(Latin: 5)	(1.4)
	volt	(28.1)
	living (Latin: *vivo*)	(20.2)
VBAC	vaginal birth after Caesarean	(21.13)
VDRL	venereal disease research laboratory (syphilis test)	(24.3)
-ve	negative	(3.6)
+ve	positive	(3.6)
VF	ventricular fibrillation	(9.2)
VHF	very high frequency	(40.6)
VI	(Latin: 6)	(1.4)
VII	(Latin: 7)	(1.4)
VIII	(Latin: 8)	(1.4)
viz	namely (Latin: *videlicet*)	(1.8)
vol	volume	(3.1)
VP	ventriculo-peritoneal	(33.3)
VT	ventricular tachycardia	(9.2)
VVF	vesicovaginal fistula	(1.1)
WHO	World Health Organization	(1.1)
wk	week	(1.6)
X	(Latin: 10)	(1.4)
X-fix	external fixation	(59.2)
XI	(Latin: 11)	(1.4)
XII	(Latin: 12)	(1.4)
XIII	(Latin: 13)	(1.4)
XIV	(Latin: 14)	(1.4)
XIX	(Latin: 19)	(1.4)
X-ray	radiograph *(loosely used)*	(1.7)
XV	(Latin: 15)	(1.4)
XVI	(Latin: 16)	(1.4)
XVII	(Latin: 17)	(1.4)
XVIII	(Latin: 18)	(1.4)
XX	(Latin: 20)	(1.4)
yr	year	(1.3)
Y-V	plasty (changing shape of Y to V)	(13.5)
ZN	Ziehl Neelsen (stain)	(5.7)

PRIMARY SURGERY VOLUME 2 INDEX