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

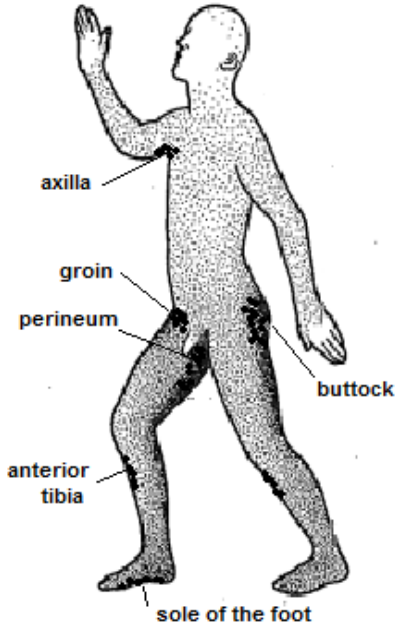


Fig. 46-1 SITES WHERE TO AVOID PRIMARY SUTURE. The darker the area, the more risky it is to close a wound by primary suture.

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

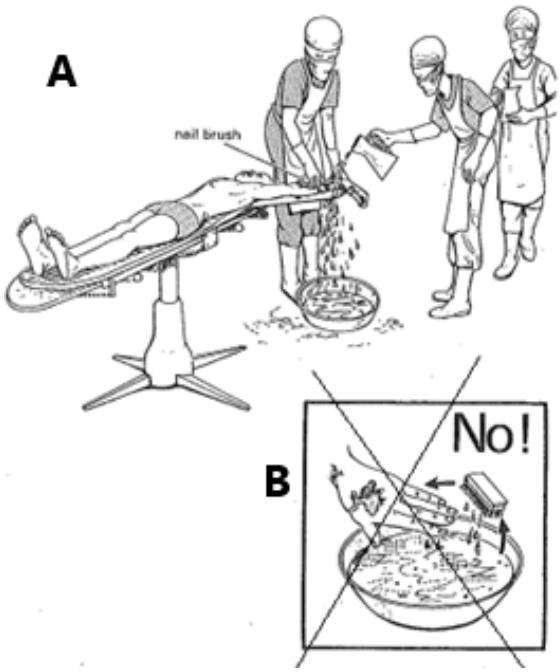


Fig. 46-2 SOCIAL WOUND TOILET. Pour on plenty of clean water over a dirty wound; *don't soak the wound in a basin. If necessary, get a 2nd or 3rd brush!*

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

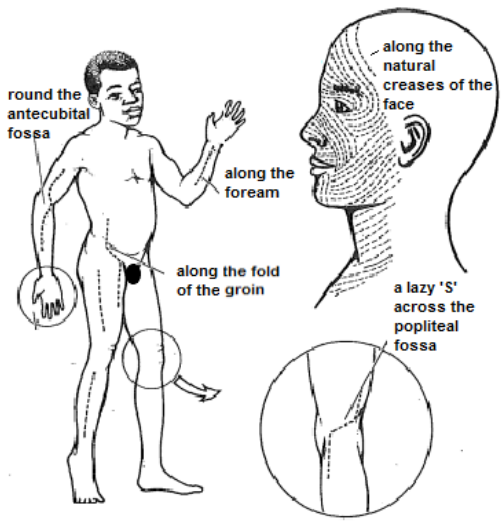


Fig. 46-3 INCISIONS FOR EXTENDING WOUNDS. A, follow the crease lines on the face. B,C, note S-shaped incisions at the elbow and popliteal fossa.

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

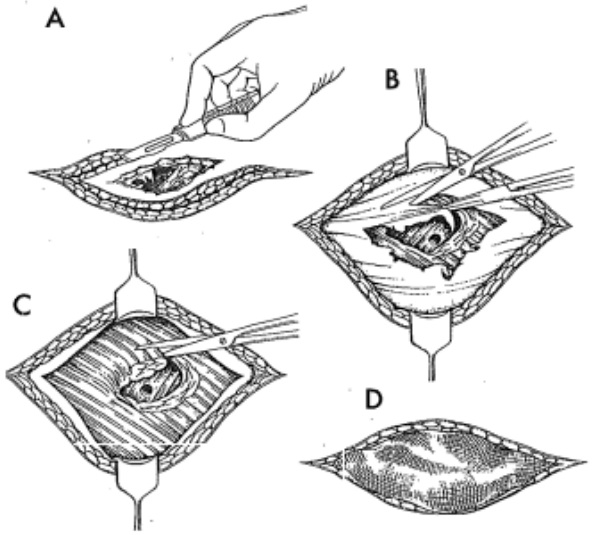


Fig. 46-4 SURGICAL DEBRIDEMENT. A, excise 2mm of skin edges. B, excise torn fascia. C, remove dead muscle. D, pack the wound and leave it open. *After Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone,7th ed. 1976 with kind permission.*

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

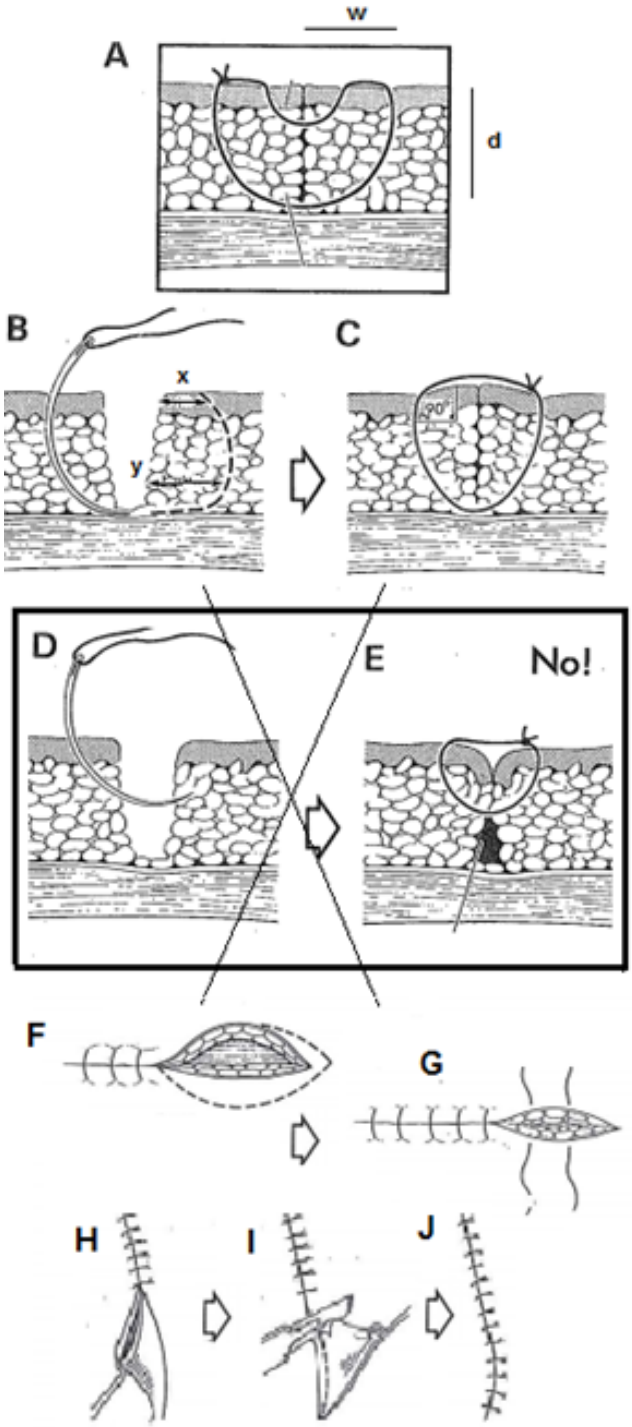


Fig. 46-5 WOUND SUTURE. A, vertical mattress everting suture; the depth (d) should equal the greater bite distance (w) from the wound edge. B,C, correct depth and apposition of a suture; if x<y, the edges will evert, if x>y, they will invert. D,E, suture too superficial and fluid trapped deep in the 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

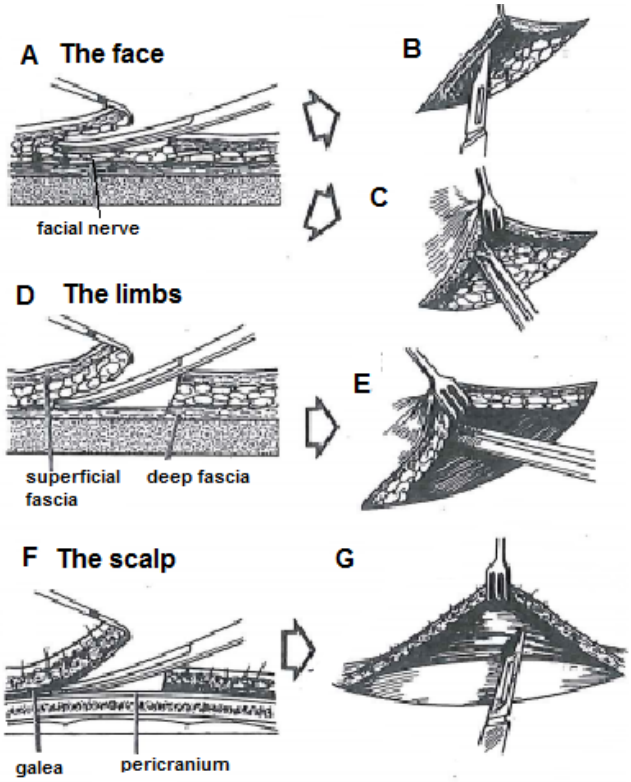


Fig. 46-6 UNDERMINING WOUND EDGES. A, in the face, just deep to the dermis, superficial to the facial nerve. B,G, using a scalpel. C,E, using scissors. D, in the limbs, between superficial & deep fascia. F, in the scalp, between galea & pericranium. *After MacGregor IA. Fundamental Techniques of Plastic 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 1º 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 2º 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.

2º 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

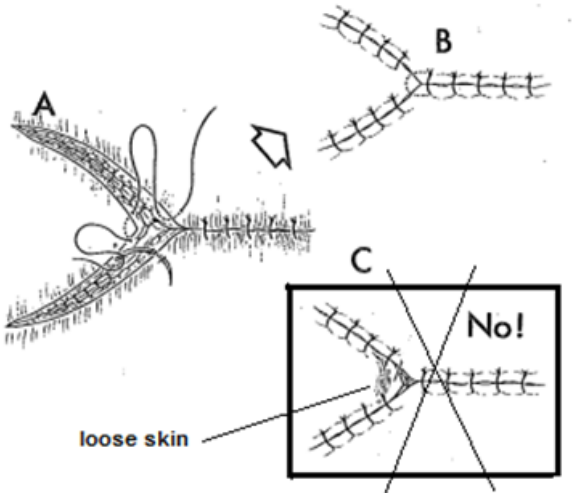


Fig. 46-7. THE APICAL SUTURE FOR Y-SHAPED WOUNDS. A, B make a 3-way suture at the apex.

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

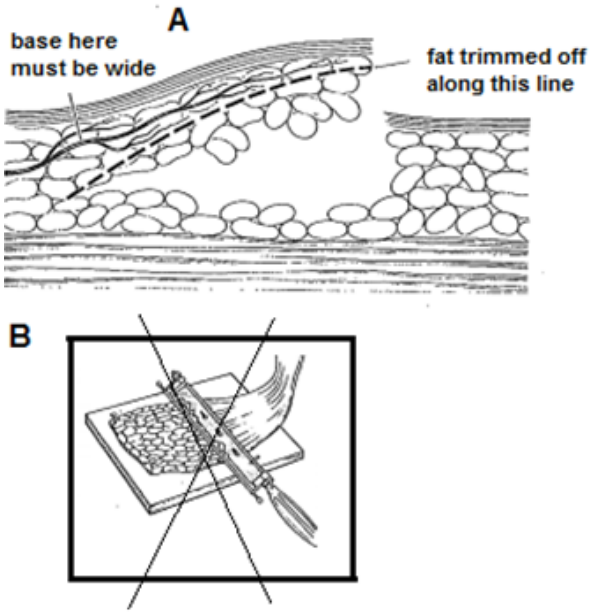


Fig. 46-8 TRIMMING EXCESS FAT OFF A FLAP.
A, preserve the blood supply at the base of the dermis.
B, *don't use a Humby knife for this,* as it will remove the vessels.

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

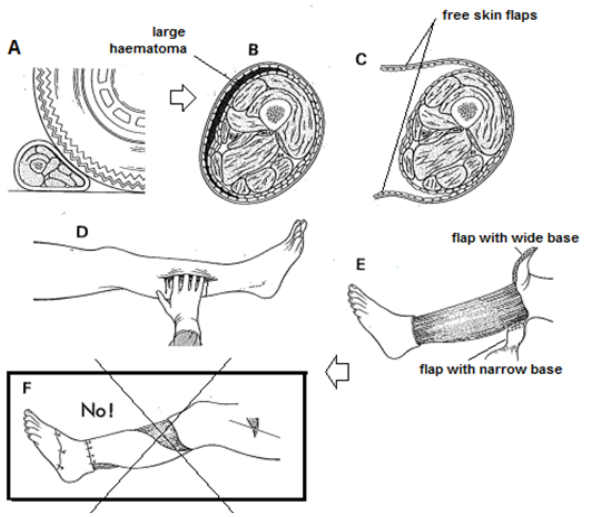


Fig. 46-9 DEGLOVING (AVULSION) INJURIES. A, vehicle tyre crushing a limb. B, undetached degloving injury with a large underlying haematoma. C, free skin flaps. D, exploring a haematoma and evacuating it. E, flaps with wide and narrow bases. F. *the narrow based flap will necrose!* *After London PS, A 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

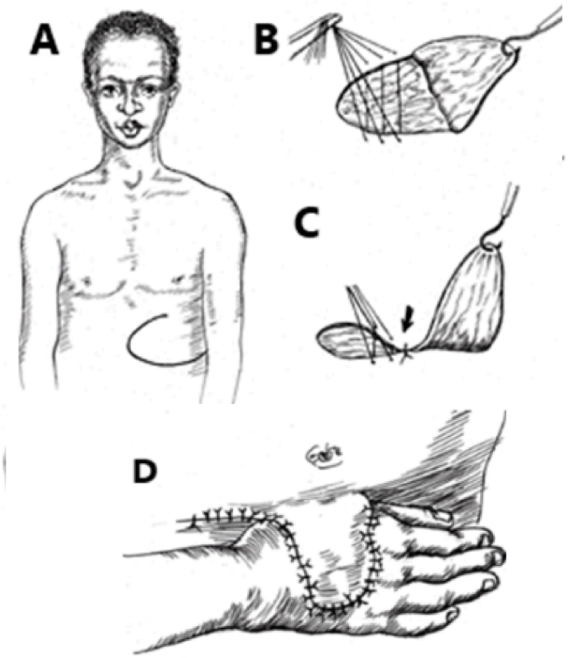
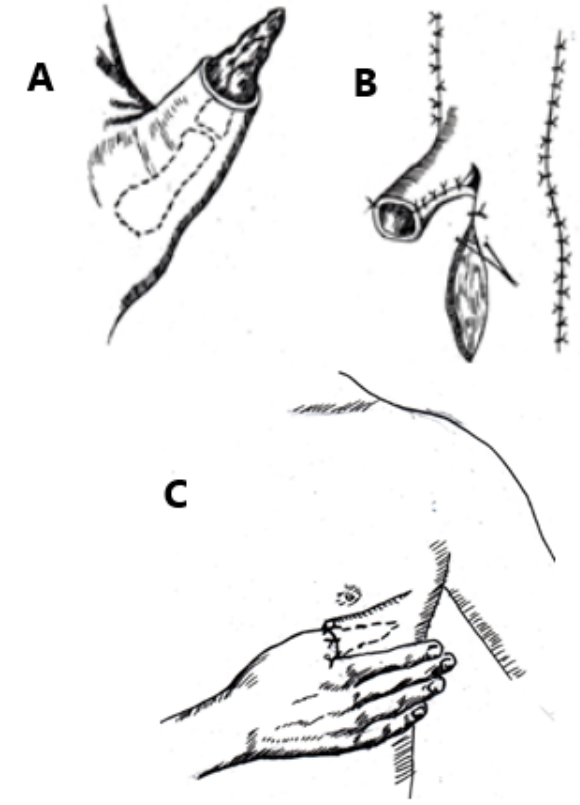


Fig. 46-10 Trunk transfer flap. A, donor site. B, mobilizing the flap. C, closing the donor site primarily. D, suturing the flap onto the hand. *After Grabb WC, Smith JW, Plastic Surgery, Little Brown, Boston 1979*

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

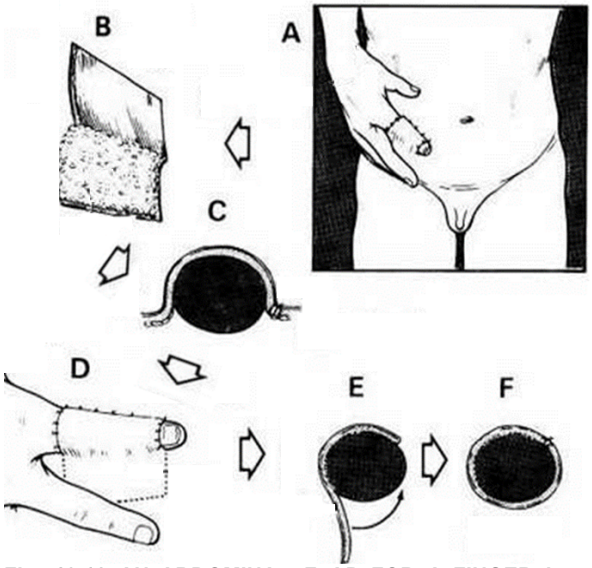


Fig. 46-12 AN ABDOMINAL FLAP FOR A FINGER is an alternative to amputation in degloving injuries. It needs care! A, strap the hand to the abdomen. B, cut the flap leaving only a little fat. C, suture the flap round the finger. D, divide the flap after 3wks, leaving enough (E) to cover the volar surface of the finger. F, suture the flap. *Kindly contributed by Mamdur Tahir*

GROIN FLAP FOR THE HAND

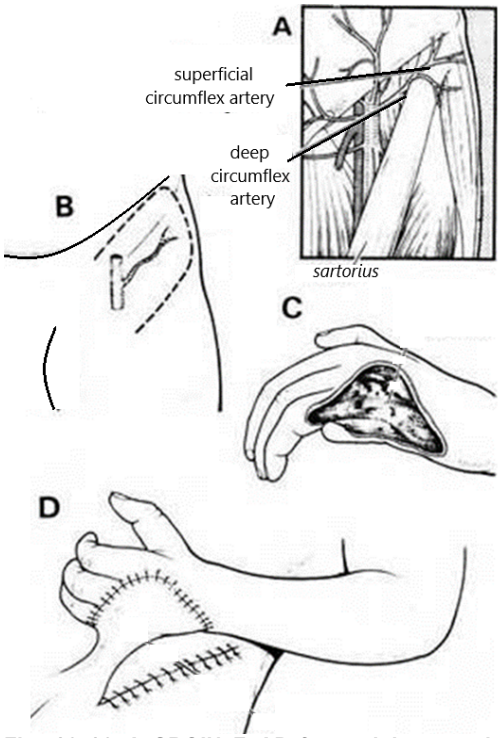


Fig. 46-13 A GROIN FLAP for an injury on the back of the hand. A, the anatomy of the superficial circumflex iliac artery. B, the anatomy of the flap. C, the defect in the hand. D, the graft sewn in place, the pedicle tubed, and the defect closed by suture with the patient's hip flexed. *Kindly contributed 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**

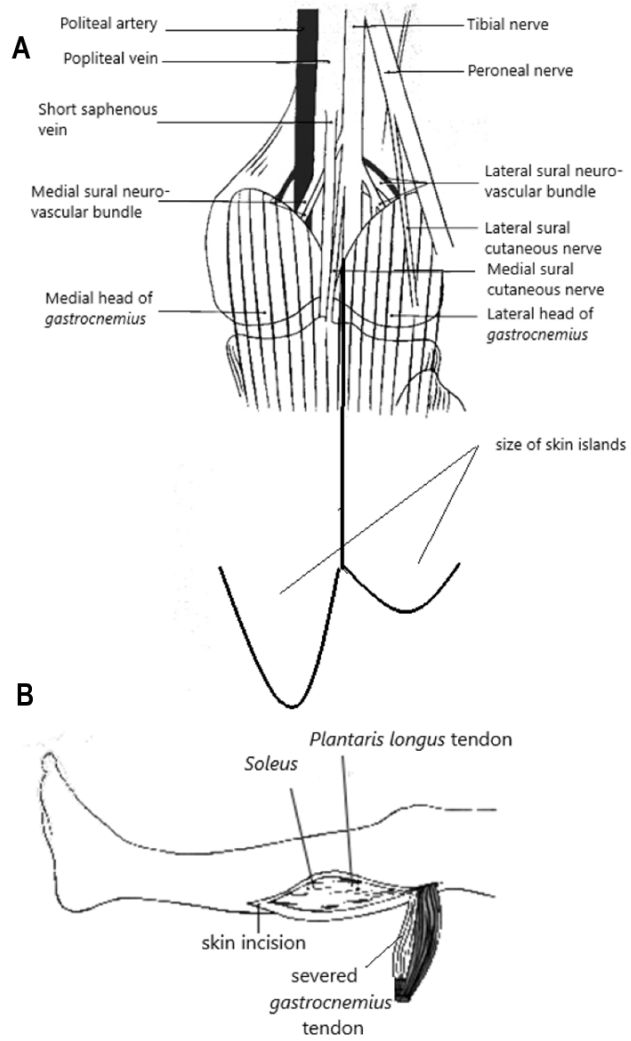


Fig. 46-14 ANATOMY OF *GASTROCNEMIUS* FLAP. A, take care at the knee where the flap arteries (popliteal & sural) originate. B, Medial view. Use a skin graft to close the defect. *After Geishausen, Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

(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

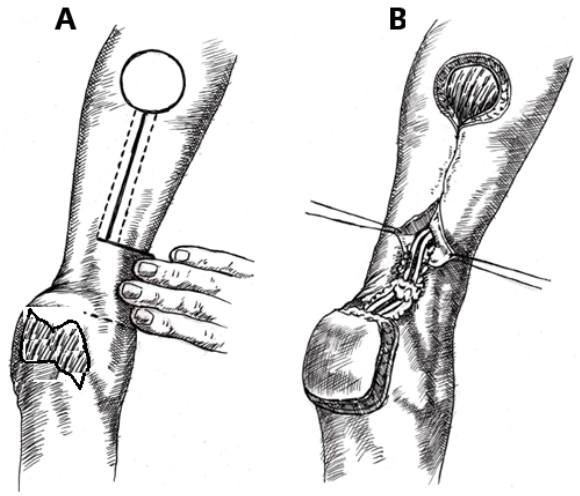


Fig. 46-15 SURAL HEEL FLAP. A, Incision. B, rotation on long pedicle and insertion into defect enlarged from debrided wound.

(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 >180^0* (46-16).

PERFORATOR-BASED PROPELLER FLAP

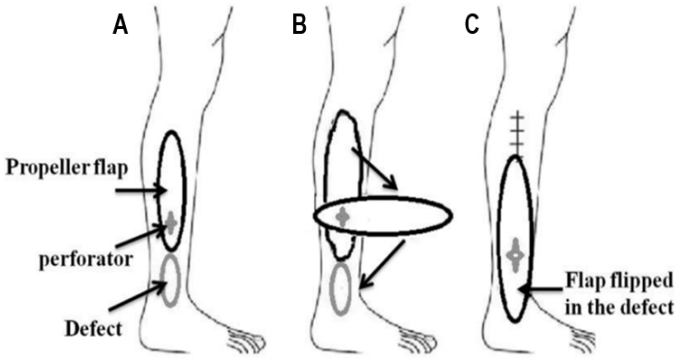


Fig. 46-16 PERFORATOR ROTATIONAL FLAP. A, position of the flap. B, flap rotated. C, flap covering the defect. *After Yadav P, Thakur S, Agarwal P, Sharma D, Kukrele R. Perforator-based prpeller flap. Trop Doc 2021.*

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 lllimited.

SUPERFICIAL CROSS LEG FLAP

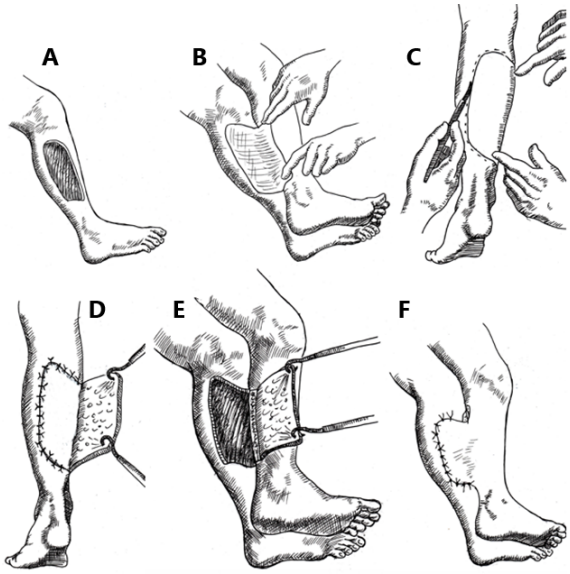


Fig. 46-17 CROSS LEG FLAP. A, defect on the lateral right lower leg. B, making a template with paraffin gauze. C, measuring the size of flap needed. D, detaching the flap on 3 sides. E, fixing the flap to the other leg. F, final result before flap division. *After Converse et al, Reconstructive Plastic Surgery Philadelphia1977*

DEEPER CROSS LEG FLAP

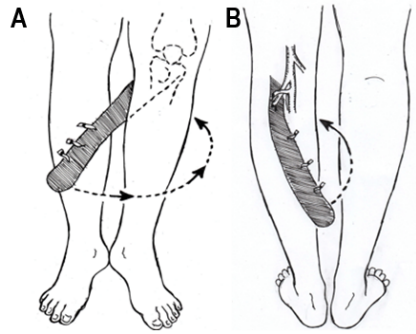


Fig. 46-18 CROSS LEG FLAP. *After Mathes-Nahai 1: Clinical Atlas of muscle and musculocutaneous flap, St. Louis 1979*

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

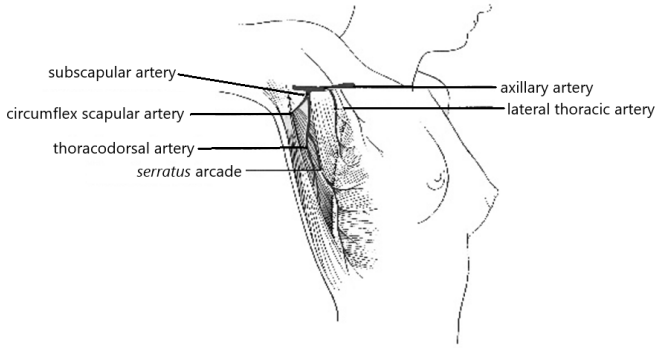


Fig. 46-19 *LATISSIMUS DORSI* FLAP. *After Geishauser/ Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

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

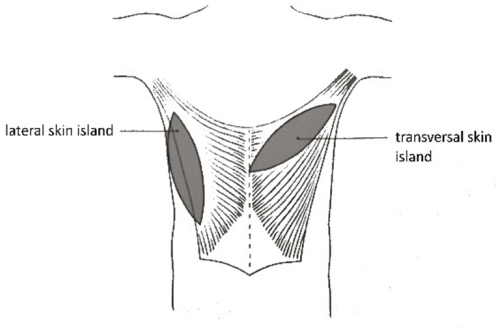


Fig. 46-20 *LATISSIMUS DORSI* FLAP. Possible skin islands. *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

Take the flap to cover the defect, and suture the muscle and subcutaneous tissue in place.

CONSTRUCTION OF *LATISSIMUS DORSI* FLAP

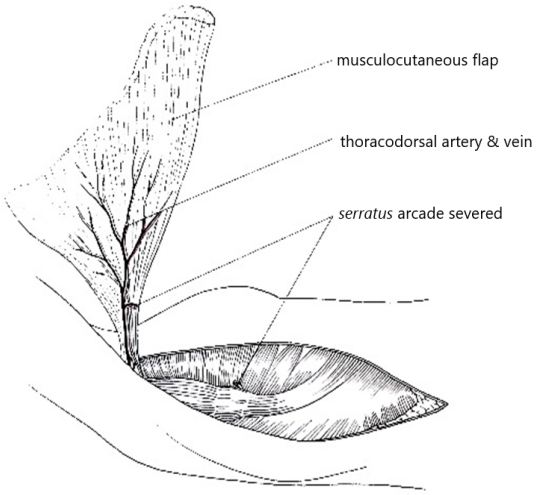


Fig. 46-21 *Latissimus dorsi* flap. *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

(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**

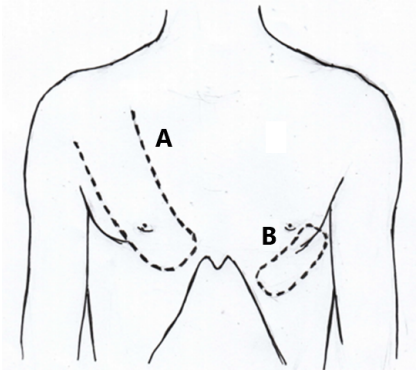


Fig. 46-22 *PECTORALIS MAJOR* FLAP. DESIGNS A, vascular pedicle flap. B, an island flap. *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

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**

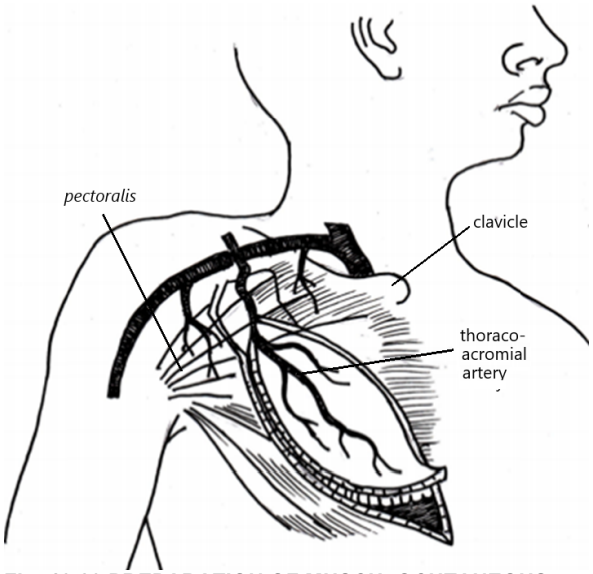


Fig. 46-23 PREPARATION OF MUSCULOCUTANEOUS *PECTORALIS ALIS MAJOR* FLAP *After Geishauser/Schwarz, Freie mikrovaskuläre und axial gestielte Lappen, Bern 1995*

(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**

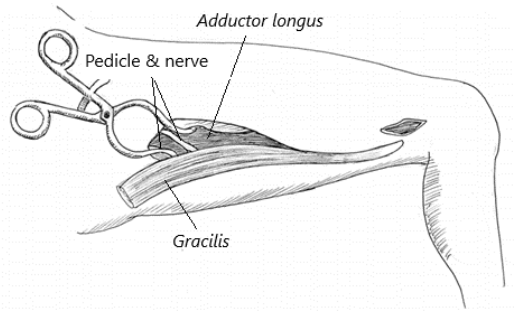


Fig. 46-24 *GRACILIS* PEDICLE separated from *Adductor Longus.* You can make a separate incision near the knee to divide the tendon if you need full length.

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

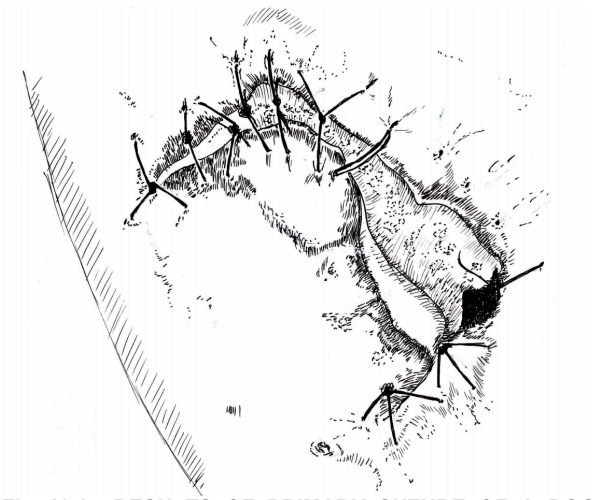


Fig 46-25 RESULTS OF PRIMARY SUTURE OF A DOG BITE. There is septic dehiscence of the wound, further tissue damage, and risk of life-threatening sepsis.

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

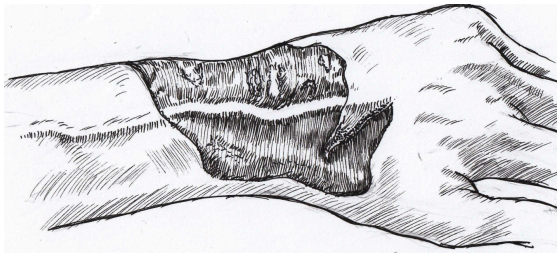


FIG 46-26 SEPTIC HAND AFTER A DOG BITE. The hand is often swollen; extension of the fingers will be painful or impossible. This needs exploration & lavage. *N.B.* There is also an extensor tendon injury of the little finger *(but don't try to repair this when the hand is septic:* just reduce the dislocation and splint the finger!)

BITES TO THE FACE

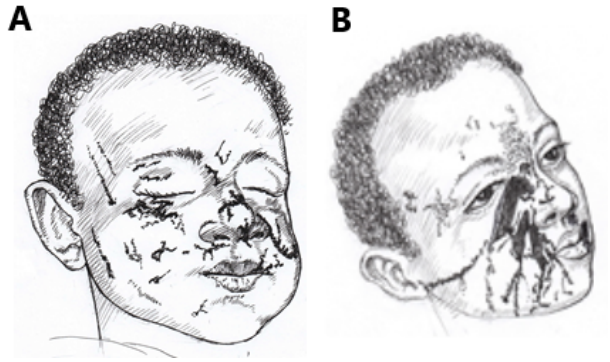


Fig. 46-27 BITES TO THE FACE. Distinguish between A, superficial injuries & B, tissue loss.

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

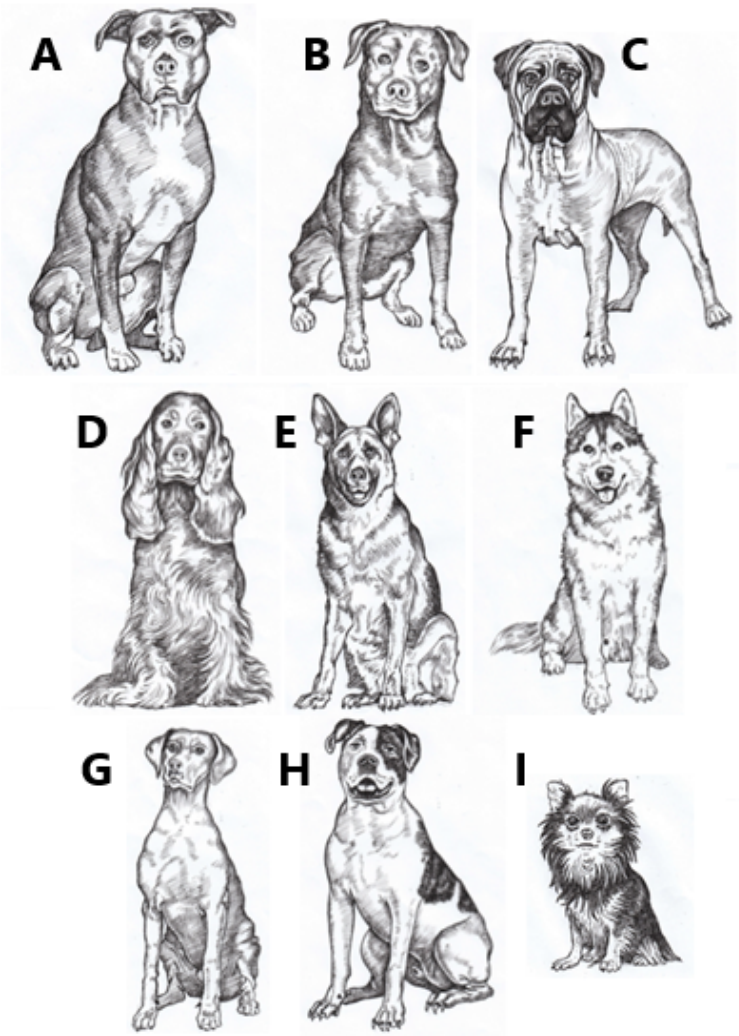


Fig. 46-28 DANGEROUS DOG TYPES OFTEN KEPT AS PETS: A, pitbull. B, rottweiler. C, mastiff. D, cocker spaniel. E, German shepherd. F, husky. G, dobermann. H, American bulldog. I, chihuahua. *(Not to scale)*

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

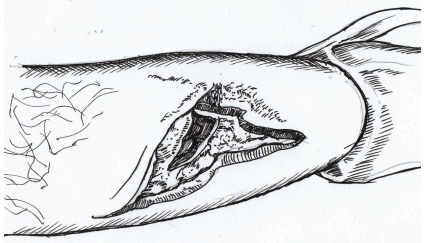


Fig. 46-29 MONKEY BITE ELBOW INJURY

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

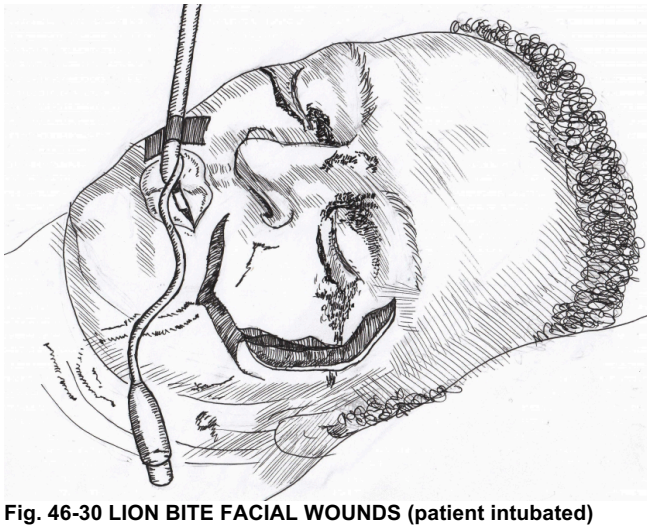


Fig. 46-30 LION BITE FACIAL WOUNDS (patient intubated)

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

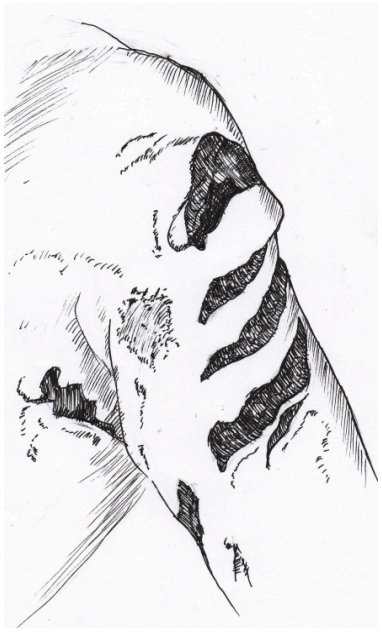


Fig. 46-31 SHARK BITE UPPER ARM WOUNDS

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

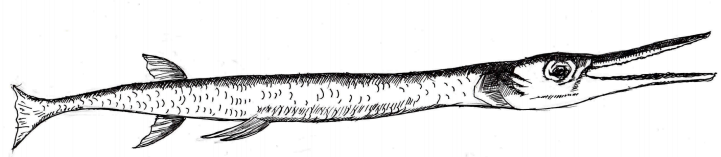


Fig. 46-32 The garfish has a very pointed beak which can cause long «stab» wounds.

(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

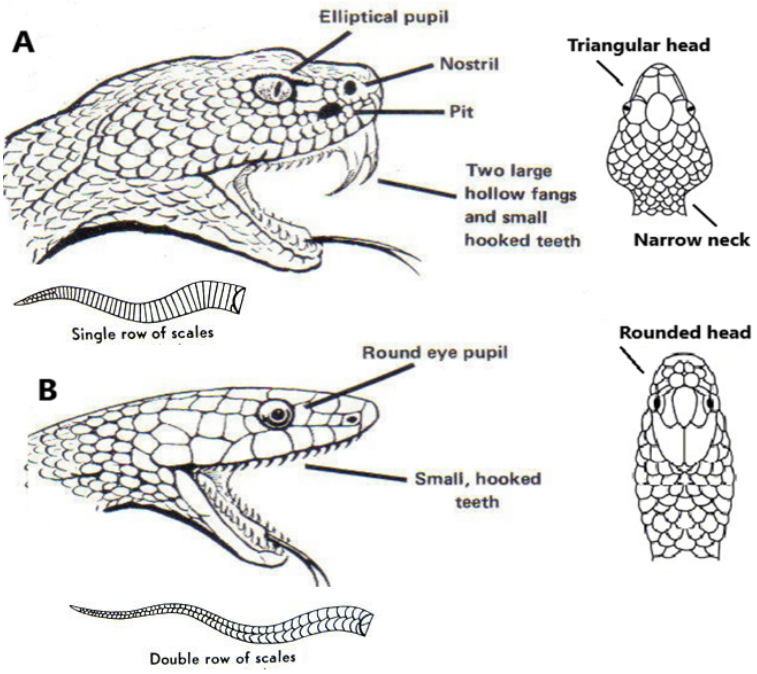


Fig. 46-33 DISTINGUISHING BETWEEN SNAKES : A, venomous snakes have an elliptical pupil, a pointed snout, a heat-sensing pit, a broad rounded head & skinny neck, 2large fangs, and single scales. B, non-venomous snakes generally have around pupil, no pit, a rounded snout, a triangular head and double tail-end 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

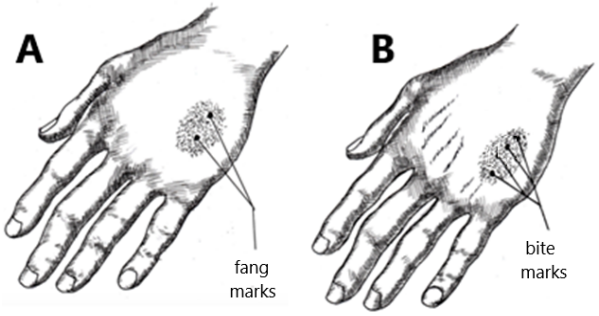


Fig. 46-34 SNAKE BITE WOUNDS. Careful examination may enable you to distinguish between A, fang marks of a venomous, and B, bite marks of a non-venomous snake.

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

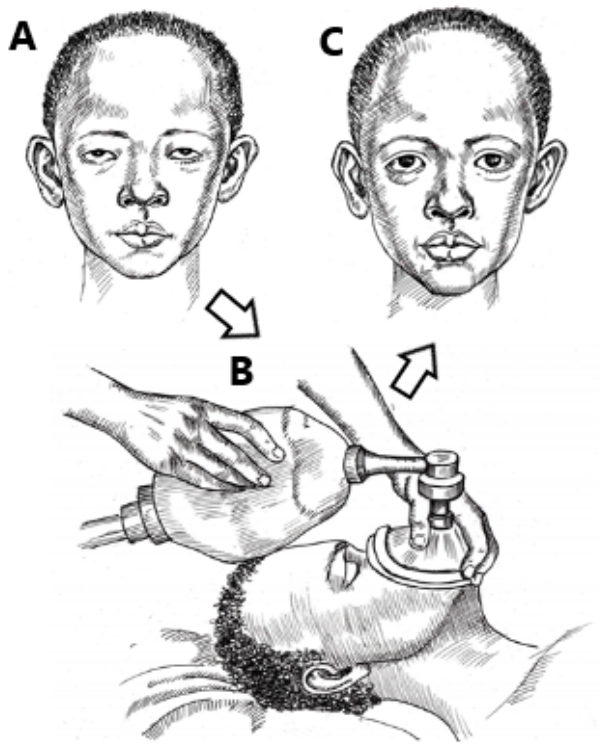


Fig. 46-35 NEUROTOXIC EFFECTS OF SNAKE BITE. A, ptosis, inability to lift the upper eyelids. B, manual ventilation. C, full recovery.

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

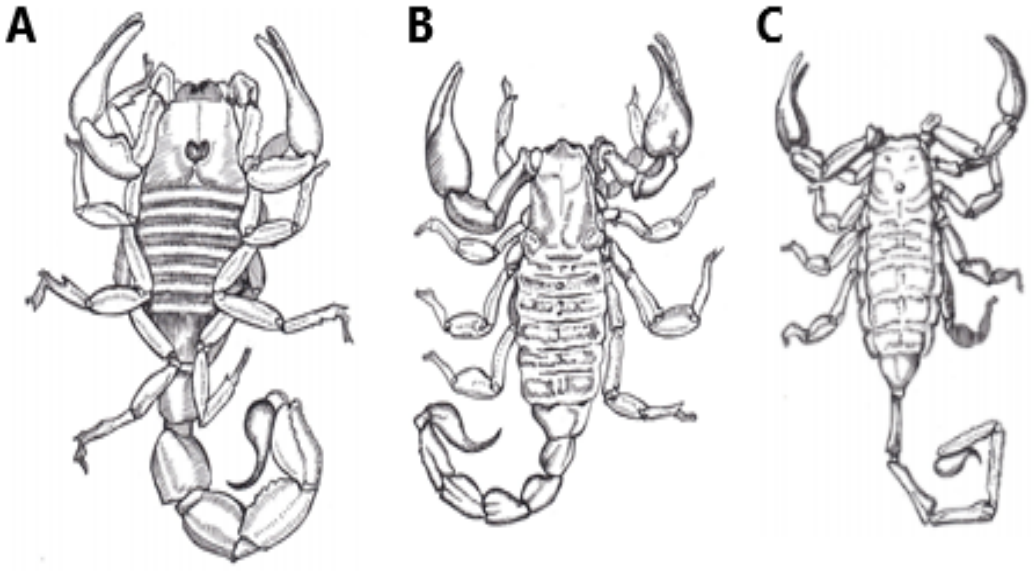


Fig. 46-36 HOW TO CHECK ON SCORPIONS. A, Thick tail & thin pincers: likely to be highly venomous. B, Medium tail & thick pincers: less so. C, Thin tail & thick pincers: not at all

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 neuro-logical 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

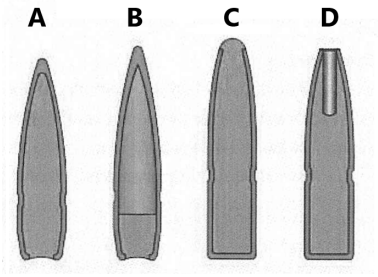


Fig. 46-37 BULLETS ACCORDING TO CONSTRUCTION. A, military bullet with a soft lead core and a full metal jacket of copper. B, hard core bullet with greater penetration : the lead is replaced by steel or tungsten. C, semi-jacketed bullet, (the point is not jacketed), should only be used in hunting animals. D, a hollow nose tip hunting bullet. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

HUNTING AMMUNITION

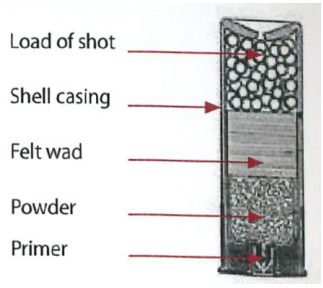


Fig. 46-38 SHOTGUN SHELL WITH BUCKSHOT. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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

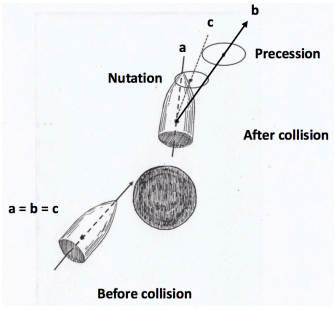


Fig. 46-39 RICOCHET: effect on a bullet after collision with an obstacle. The trajectory is changed (from b along a), but the energy impact is transferred in the arc acb. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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: $E = ½mv^2$

If a bullet passes through tissue, the energy transferred is $E = ½m (v_1^2 – v_2^2)$ 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

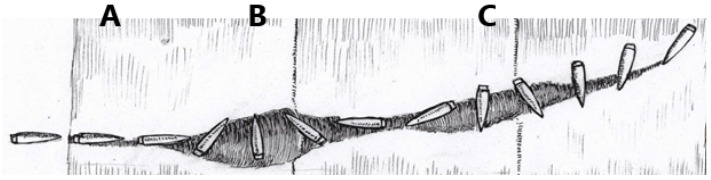


Fig. 46-40 BALLISTIC EFFECT OF A TUMBLING BULLET, *e.g.* from an AK-47 rifle travelling at >600m/sec causing A, a narrow channel. B, a short cavity. & C, an enlarged cavity of destruction in its path *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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

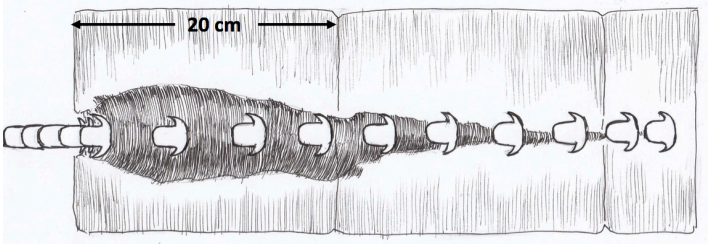


Fig. 46-41_DEFORMING SEMI-JACKETED RIFLE BULLET (SJ) mushrooms just after impact. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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

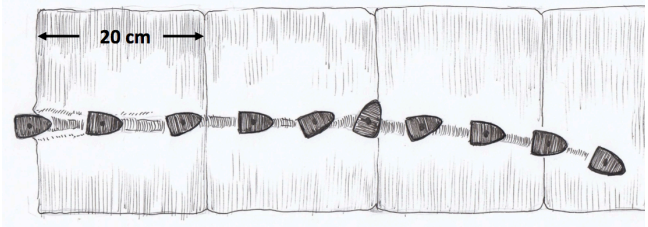


Fig. 46-42 A NON-DEFORMING BULLET at lower velocity penetrates deeply along a narrow channel. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

(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

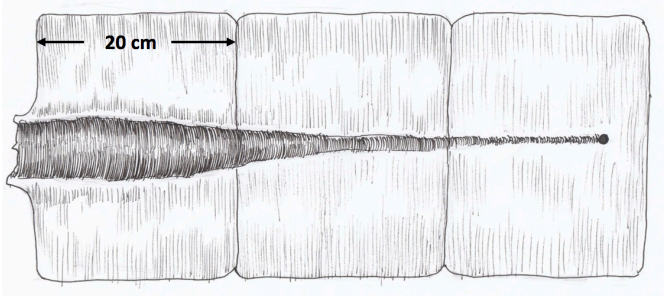


Fig. 46-43 CONING EFFECT. Profile of a metallic fragment: the widest point is at its entry. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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

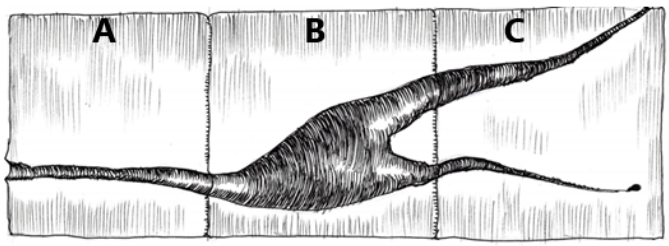


Fig. 46-44 FRAGMENTATION OF A BULLET. Typically, this deviates downwards and increases the size of the cavity, making it have two 'arms' The main part of the bullet ends up superiorly in C, but a flake of ejected lead remains in B and the rear part of the bullet inferiorly in C. Each segment is c.20cm long. *After Giannou C, Baldan M, Molde, Á. 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

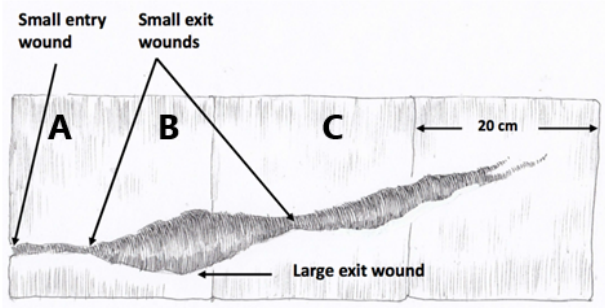


Fig. 46-45 INADVERTENT EXIT may occur before or after the cavity, depending on the length of the wound track in the body. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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

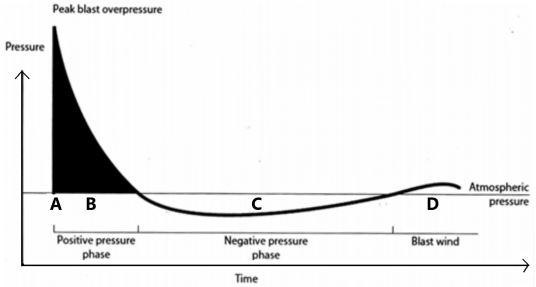


Fig. 46-47 Friedlander curve: the relationship of pressure to time of a blast wave in open air without obstacles. A, instantaneous peak pressure. B, positive pressure shock wave: pulse of overpressure (the area under the curve is the total impulse/unit area). C, negative pressure trough: a suction wave. 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) 1º 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

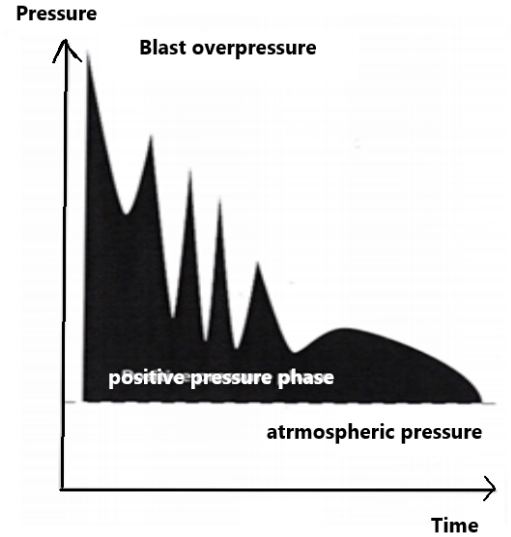


Fig. 46-48. PRESSURE-TIME RELATIONSHIP OF A BLAST in an enclosed space. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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) 2º 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, pneumo-mediastinum 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, Á. War Surgery, ICRC Geneva 2013*

ALGORITHM FOR ASSESSING VICTIMS WITH TYMPANIC RUPTURE.

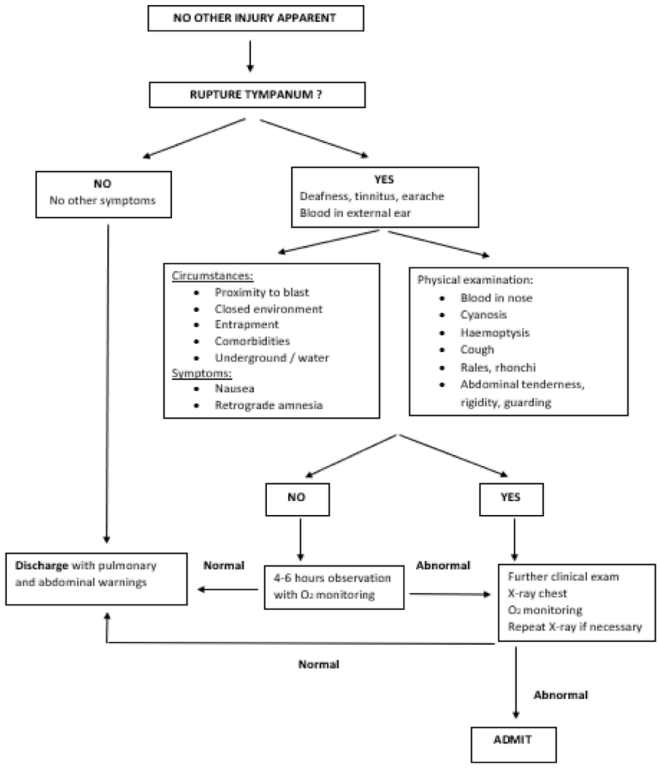


Fig. 46-50 ALGORITH FOR ASSESSING VICTIMS WITH TYMPANIC RUPTURE *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

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.