51 Head injury

51.1 Introduction

"No head injury is so severe as to be despaired of, nor so trivial as to be lightly ignored", wrote Hippocrates (460-370 BC).
This is by and large still true.

Unfortunately, seemingly trivial injuries are often ignored, and every such patient who dies is an indictment of the hospital which failed to treat him properly.

Although an injured scalp can bleed severely, and the skull bones break, it is brain concussion, contusion, or compression that usually affects consciousness.

Think always of non-accidental injury, especially in children.

(a) Concussion prevents reacting to stimuli for a few minutes after a head injury, but has no after effects.

(b) Cerebral contusion is a bruise of brain tissue, with laceration of small blood vessels and resulting bleeding into the brain tissue. The symptoms depend on the severity of the injury and the site of the contusion, and may produce coma or spastic hemiparesis, or just minor symptoms.

(c) Cerebral compression is due to raised intracranial pressure caused by increasing cerebral oedema or an expanding haematoma.

In practice, coma due to brain compression brain is rarely treatable surgically outside specialized centres.

So, try to keep a patient with brain contusion alive until natural healing processes allow recovery. You will be surprised how much a person, especially a young person, can recover from deep unconsciousness.

This means *excellent* nursing care and especially care of the airway to prevent inhalation of blood, vomit, or secretions.

A patient is more likely to die from these complications, than from any other cause, except irreversible brain injury.

N.B. Vomiting is particularly a sign of cerebral irritation in children.

Pay attention to vulnerable pressure points, urine output, and the need for a high protein/calorie diet and physical & mental stimulation.

Death is either due to the initial severe brain injury, or because you operated too late, or because you allowed complications (especially those producing hypoxia) to cause further cerebral oedema. As cerebral deterioration is so dependent on the airway, *you must always apply the ABC rules of resuscitation!* (41.2)

N.B. A head injury patient very often has other injuries also, so make sure you always examine him systematically.

Head injuries from a fall from >1m or a high speed impact are always suspicious.

Consequences of a minor head injury are greater in those with cranial malformation, bleeding disorder, previous skull injury (including surgery), osteogenesis imperfecta, or acromegaly.

CLASSICAL PATTERNS OF HEAD INJURY
Although cerebral compression from an expanding haematoma is much less common, timely intervention to evacuate such a haematoma, or just allow it to expand without pressing on the brain, may dramatically save a patient's life.

Making a burr hole in the skull is so comparatively simple that any doctor should be able to do it. Even If you fail to find a haematoma, you will have done no harm. The very fact of relieving some of the pressure may enable the brain to recover! *You will certainly not have time to refer such a patient:* the commonest mistake is to do nothing!
Cerebral compression can be the result of bleeding in 3 places within the skull.

(a) Extradural haemorrhage
Bleeding outside the dura only occurs in c.2% of all head injuries. Some of these patients have a lucid interval (51-2D) which usually lasts only 2-4h, but may be longer. Others have steadily deepening coma from time of injury (51-2F). Their important 1st symptom is increasing headache, *so take such a complaint very seriously in any patient with a recent head injury*. There may also be giddiness, mental confusion, or drowsiness; as this gets worse, unconsciousness deepens, and pyramidal signs (spasticity, weakness, slowing of rapid alternating movements, hyperreflexia, and a +ve Babinski sign) develop on the contra-lateral side.

INTRACRANIAL HAEMORRHAGE

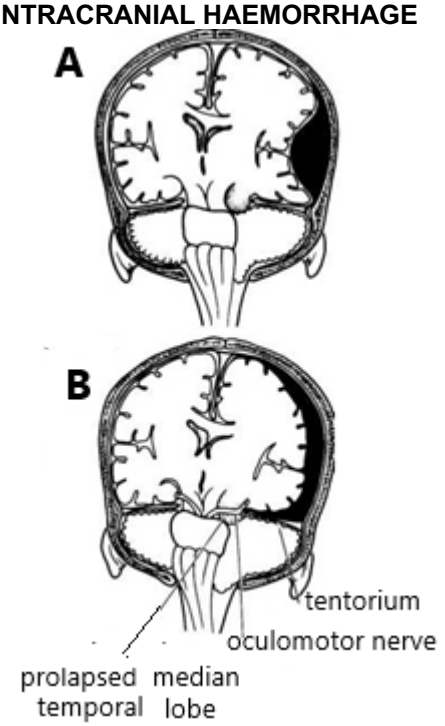

Fig. 51-1 INTRACRANIAL HAEMORRHAGE. A, extradural, usually rapid, making a concave indentation on the brain. B, subdural, usually slower, making a crescent-shaped filling defect. *After Martin G, A Manual of Head Injuries in General Surgery. Heinemann, London 1974..*

(b) Subdural haemorrhage

Bleeding under the dura occurs in c.8% of head injuries, and can follow any of the patterns (51-2D,E,F).

Unconsciousness may develop very quickly (at the scene of the injury), after some hours, or even days or months if there is a very slow bleed. Such a patient, who is usually elderly, suffers from repeated or increasingly severe headaches, drowsiness, apathy, or mental changes. The typical picture is that of a slowly developing cerebral crisis some time after a complete or partial recovery from a head injury, perhaps even a very minor one, which the patient may not even remember.

(c) Intracerebral haemorrhage

Diffuse oedema follows severe injury, where there is usually bleeding in many separate places of the brain.

(d) Cerebral oedema

Occasionally, oedema may develop after a seemingly minor injury, especially a 2nd head injury after the 1st only a short while before.

(e) Mixed picture

Sometimes, a patient may become unconscious (from a stroke, alcohol, or other cause) and then fall and hit the head. The 2nd injury may be superimposed on the 1st!

As cerebral compression increases, the blood pressure rises in line with increasing intracranial pressure, and the pulse becomes slow, full, and bounding. *These are late signs; death is imminent!* Now only strenuous efforts to reduce the brain compression will save the patient's life.

51.2 Management of head injury

MANAGEMENT OF AN UNCONSCIOUS HEAD INJURY PATIENT

N.B. This applies to all patients who have lost consciousness after an injury, even if their most obvious injury is a fractured femur.

FOLLOW ABC PRINCIPLES

TRENDS IN CONSCIOUSNESS AFTER HEAD INJURY

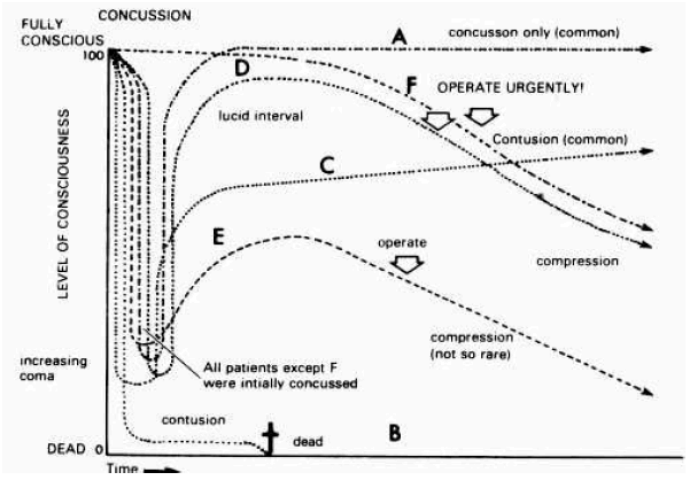

Fig. 51-2. LOSS OF CONSCIOUSNESS AFTER A HEAD INJURY. All patients, except F, were concussed to begin with. A was concussed, lost consciousness momentarily, and then recovered (common). B's brain was seriously contused; he stayed deeply unconscious and remained so (common). C was concussed & contused, and became deeply unconscious, after which he steadily improved (common). *None of these patients (A-C) deteriorated, so would not benefit from surgery.* D was concussed, then had a lucid interval before becoming unconscious again (rare but important). E was concussed, his consciousness improved but then deteriorated (not so rare). F did not lose consciousness at the time of the injury, but progressively lost it afterwards (rare). *These patients (D-F) all had cerebral compression and needed decompression to prevent further deterioration.* *Kindly contributed by Peter Bewes.*

AIRWAY *is critically important.*

(1) Place the patient in the recovery position (42-1).

(2) Clear the mouth and pharynx.

(3) Perform the jaw thrust manoeuvre (42-2C)

(4) Insert a Guedel oral (42-4), nasopharyngeal (42-5) or laryngeal mask airway (42-6), as tolerated.

N.B. The airway may be compromised by a cervical collar!

BREATHING
(1) Check the tracheal position.
(2) Assess pulmonary air entry.
(3) Insert an intercostal drain, if necessary.

A TRACHEOSTOMY MAY SAVE A LIFE

CIRCULATION
Insert an IV line and replace lost fluids with saline, to keep the systolic BP >90 mmHg.

N.B. An adult with a pure head injury and no other injury does not need IV fluids! They may worsen the intracranial pressure by increasing cerebral oedema.

ESTIMATE THE CONSCIOUS LEVEL (45.1) according either to the Glasgow Coma scale (45-1); write, *e.g.*, as E3,V4,M4:

Eye opening (E)	Spontaneous To speech To pain None	**4** **3** **2** **1**
Best verbal response (V)	Oriented Confused (disoriented) Inappropriate words Sounds only (Grunts) None	**5** **4** **3** **2** **1**
Best motor response (M)	Obeying commands Localizing pain Withdrawal to pain Flexing arms, extending legs to pain Extending 4 limbs to pain None	**6** **5** **4** **3** **2** **1**

N.B. M3 is the decorticate response; M2 the decerebrate. M1 the limbs are flaccid, as in a spinal injury.

N.B. V4: A child who has not yet learned to talk may grimace instead.

N.B. A mentally disabled or alcoholic person may have a normal baseline GCS <15.

Alternatively, use the AVPU method (which is useful in a case of polytrauma, or if there are many casualties to assess:

A	**Alert**	(not necessarily oriented, usually with spontaneously open eyes, responding to voice & able to move some part of the body).
V	**Verbal**	**(**some kind of response to speech)
P	**Pain**	(some response to severe pain, such as sternal pressure or pressing the fingernails)
U	**Unresponsive**	

DECORTICATE & DECEREBRATE SIGNS

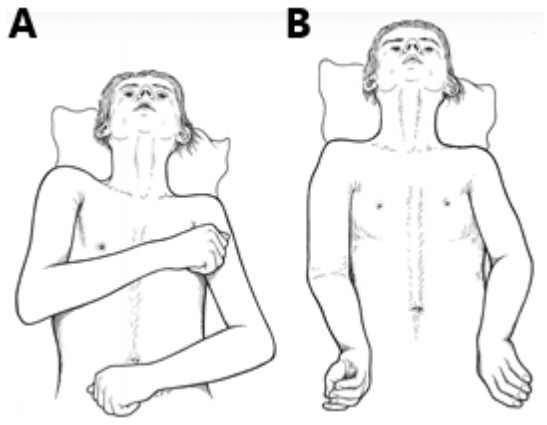

Fig. 51-3 SEVERE HEAD INJURY may result in A, decorticate or B, decerebrate positions. *After Hamilton Bailey's Emergency Surgery, ed. Dudley HAF Wright Bristol 11th ed. 1986.*

If there is no cough reflex, (GCS usually <5), intubate the trachea *before you pass a stomach or nasogastric tube.*

If intubation is impossible, and the airway is inadequate, perform a tracheostomy (42.3). This may be necessary later anyway, especially if coma is prolonged.

If unconsciousness is profound but the head injury relatively minor, *think of consumption of drugs, particularly alcohol!*

N.B. Remember: patients on anticoagulant therapy are at high risk of bleeding.

Don't however assume that because someone is drunk & unconscious, he has not also had a severe head injury! A state of confusion or agitation may be a sign of increasing intracranial pressure.

EMPTY THE STOMACH
Many patients vomit and aspirate their stomach contents after admission to hospital. *If the stomach was full at the time of injury, it will still be full!*
Pass an oro- or naso-gastric tube after endo-tracheal intubation, or you may stimulate a vomiting reflex, resulting in massive aspiration of gastric contents. If intubation is not possible, pass the tube *only while the patient is in the recovery position*.

HISTORY
What exactly happened? Try to gauge the violence of impact to the head. Try to assess the level of consciousness immediately after the injury. *A patient cannot know by himself how long he was unconscious!* Try to find this out from reliable witnesses.

If a patient is stable enough for you to consider an invasive diagnostic intervention, then you certainly have enough time to interview the next of kin thoroughly!

Did the patient take alcohol or drugs? Did anyone witness a seizure? If so, was it generalized, or affecting which side only? Is there full recovery from the seizure or not? Find out if the patient had a lucid interval (a period of consciousness before becoming comatose) following the injury. This is a classic feature of an extradural haematoma.

Enquire how much loss of memory there is for events following the injury. The duration of pre– and post–traumatic amnesia are good indicators of the severity of a past head injury.

EXAMINATION
Look at the patient in a good light, examine the body and limbs first, and then the head and neck. Smell the breath for alcohol and acetone, and *don't forget the other causes of coma*, including epilepsy, diabetes, liver failure, meningitis, drugs, malaria, & trypanosomiasis.
Check the pupil sizes & their reaction to light: *N.B. size is more important than reaction! Never use atropine!*

PUPIL REACTIONS AFTER HEAD INJURY

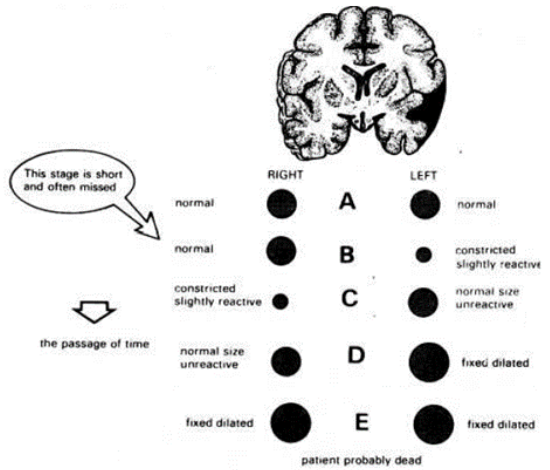

Fig. 51-4 PUPIL CHANGES AFTER A HEAD INJURY. Testing reaction to light stimulus: A, normal. B, the ipsilateral pupil constricts first and then dilates. The ipsilateral constriction usually lasts only a short time and is often missed. C, later the ipsilateral pupil returns to normal size, but is unreactive. D, then a fixed dilated ipsilateral pupil is accompanied by an unreactive normal-sized contralateral pupil. E, both pupils are dilated & fixed. Surgical intervention at this stage is futile. *Kindly contributed by Peter Bewes & Gerishom Sande.*

THE PUPIL ON THE SIDE OF THE LESION DILATES FIRST

NEUROLOGICAL EXAMINATION
If the patient is sufficiently conscious, test the motor power of all 4 limbs. Look especially for lateralization signs (weakness on one side of the body, relative to the other).
This is not easy to determine in a patient who is not fully cooperative.

If the patient is restless, observe the frequency & periodicity how each side of the body moves.
Look at the eyes & eye movement to check spontaneity of movement & the reactions of a 'curiously conscious' patient

If the patient is unconscious, see if there is any difference one side versus the other & the response to (strong) sternal pressure. *The signs may only be minimal.* Examine the knee, ankle, abdominal & especially, the plantar reflexes.

If peripheral reflexes are absent, assume a spinal injury (54.2)

CAUTION! Don't perform a diagnostic lumbar puncture! Sudden drop in intracranial pressure may be fatal. However, if you suspect meningitis or subarachnoid haemorrhage, it is indicated.

OCULAR EXAMINATION
Examination of the pupils is fundamental. Even if the eyelids are swollen, you can usually gently pull the lids apart to look at the pupils.
Get an assistant to help you to shine a torch into the eye. A 'black eye' is the result of bleeding into the eyelids and is of little significance by itself.

Conjunctival haemorrhage is, likewise, in most cases merely local bruising. This only indicates an orbital fracture (usually of the orbital plate of the frontal bone) if:
(1) The conjunctiva is oedematous.
(2) The posterior edge of the haemorrhage is not visible.
(3) Eye movement is restricted.

SCALP EXAMINATION
Look for cuts and bruises. This is especially important if the patient is drunk, and you are not sure there is also a head injury. Palpate such a laceration with a sterile gloved hand to feel for the edges of a depressed fracture.

Most often, a pad and bandage will control scalp bleeding, but if it does not, close it, even if only temporarily, with a continuous suture, or if the hair is long and strong, approximate the skin edges by tying the hair together firmly. *Don't attempt to explore a wound outside the theatre!*

EARS AND NOSE EXAMINATION
Blood from the nose is usually a sign of a nasal fracture (53.4), rather than something more serious (which will be quite obvious).

However, CSF leak from the nose or ear signifies a skull fracture (51.3). If there is only a trace of blood from the ear, it is worth examining the auditory canal with an auroscope to see if there are signs of damage. Blood behind the eardrum confirms a fractured skull base, as does bruising behind the mastoid appearing a few days after the injury.

N.B. You can reliably check for CSF by using glucose uristix (provided the blood glucose level is >6mM): CSF [glucose] is usually $^2/_3$ blood [glucose]. CSF makes a gauze dry & stiff.

NECK EXAMINATION (54.1)
Look especially for injuries of the neck and back that may indicate spine fractures, especially the cervical spine (41.3). Carefully log roll the patient onto the side while maintaining gentle head traction (54-4). Palpate every spinous process. Look for even a small *kyphus* or an abrupt misalignment.

If you suspect a fracture of the cervical spine, fit a *firm* cervical collar. If there are signs of limb paralysis (54.3), protect the pressure areas, and make sure no movement is allowed in the neck, which may make the deficit worse.

N.B. Beware of the dangers to the neck at endo-tracheal intubation!
Get AP & lateral cervical spine radiographs.

CAUTION! **If the patient is shocked**, look for severe injuries at other sites, especially in the thorax and abdomen. *Cerebral injuries do not cause hypovolaemic shock in adults,* though they may do so in small children. Serious abdominal or thoracic injuries must anyway take precedence over the head injury (44.1).

RECORDS
Always record the state of consciousness on a coma chart (51-5). Careful notes are most important. Note the exact times at which all observations are made: *this is important for medico-legal reasons*!

Completion of a chart (51-2) is vital; every head injury patient admitted *must* have one.

The purpose is to *monitor* changes, so regular completion of the chart is imperative. If your nursing staff are not familiar with such charts, it is worthwhile spending time teaching how to complete them properly. Encourage them to have faith in their own observations!

You should always re-examine a serious head injury patient 1h after your first examination fully; remember that the *trend* is more important than the *status.*
A fully conscious patient may deteriorate & die! Never use subjective evaluations such as 'partially conscious'.

INVESTIGATIONS
Plain radiographs are of little help. They may be difficult to interpret, may fail to show the seriousness of the situation and *anyway not all serious head injuries have fractures!*
However, if you have palpated an open or suspect a closed depressed skull fracture, a radiograph is useful.

CAROTID ARTERIOGRAM (38.1)
Any X-ray machine that can take a skull radiograph can take a carotid arteriogram. You need a long fine needle, and IV contrast.
Particular indications are when GCS <8 with:
(1) Basilar skull fracture
(2) Le Fort I or II maxillary fracture (53.2)
(3) Near-hanging or strangling (54.7)

OPTIC NERVE SHEATH ULTRASOUND (45.1)
Place the probe over the closed eye. At a distance of 3mm from the posterior border of the globe, a measure >5.2mm is a significant indicator of raised intracranial pressure >20mmHg. You can carry out this examination repeatedly as it is non-invasive. *Don't press hard or take a long time* or else you may damage the eye.
You may also detect papilloedema with a simple ophthalmoscope.

NURSING A HEAD INJURY

POSITION
Provided there are no other injuries which might prevent it, nurse the patient in the recovery position (42-1) & turn him 2hrly. If agitated, it may be best to place the patient on a mattress on the floor.

PAIN AND SEDATION
Pain is obviously only described by a patient whose conscious level is near normal. However, it may be manifested by confusion or violence. Use haloperidol (1mg adult, 0.5mg child) to calm someone who becomes a danger to himself and other people. Avoid stronger sedatives, especially morphine, because they depress respiration & interfere with the assessment of consciousness.

N.B. Monitor a restless child very carefully, as deterioration may be dramatically rapid.

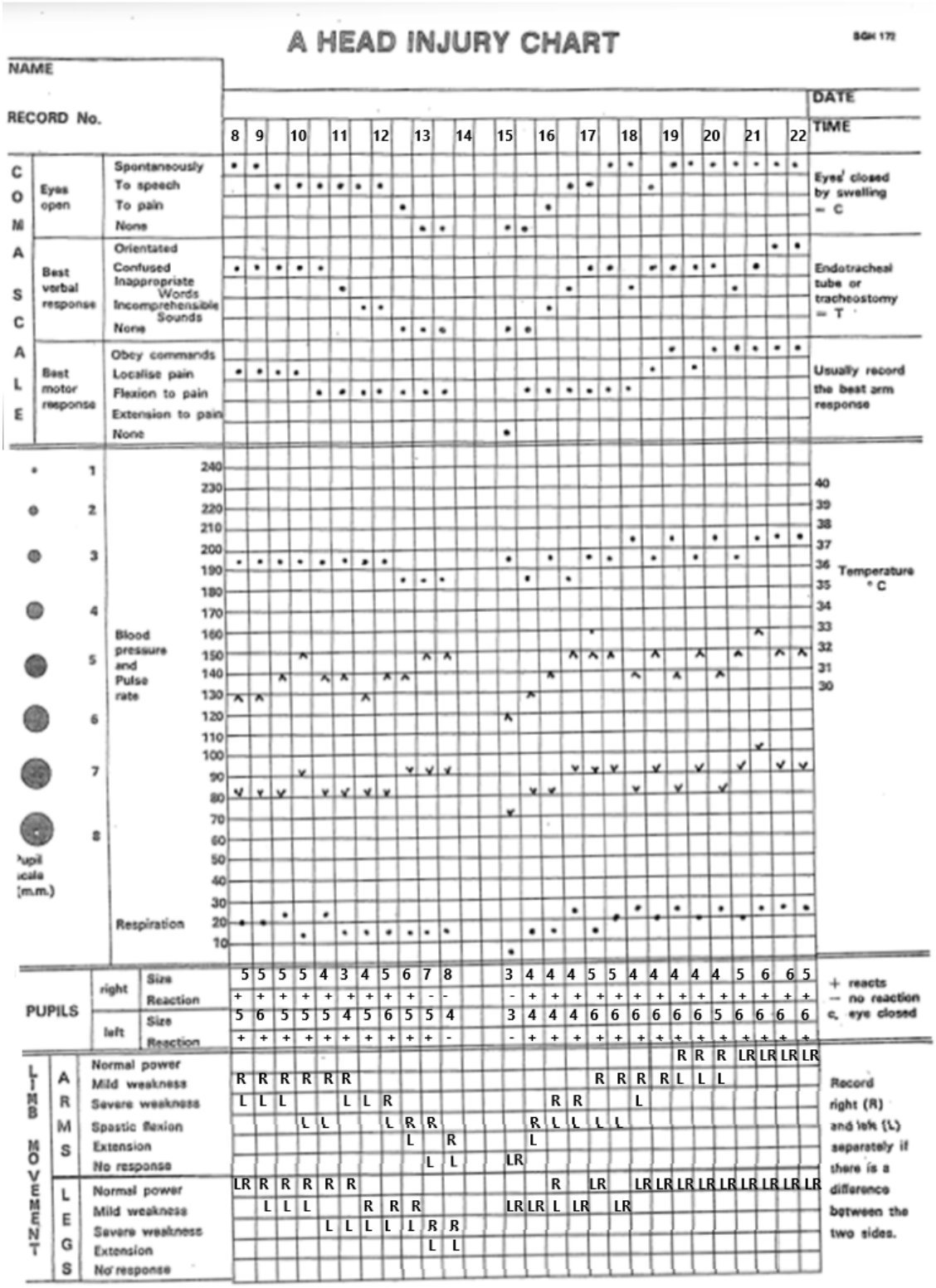

Fig. 51-5 COMA CHART. Make sure you complete this diligently $^{1}/_{2}$hrly. Note the progressive neurological decline (an extradural haemorrhage often produces more rapid deterioration than a subdural); as central function fails, so does peripheral; eye signs are key. The pupil dilation occurs first on the affected side, with contralateral limb signs. Here, the patient should have gone to theatre 1h earlier (at least!) Note the *trend is more important than the actual readings!* *Kindly contributed by Gerishom Sande.*

Moderate restlessness may be useful as it provides good lung limb exercise and prevents pressure sores. Make sure overactivity is not caused by a full bladder, constipation or a missed injury.

MONITORING
Apart from the coma chart, record the temperature, if possible, rectally bd.
Watch for hyperthermia (45.3); start cooling at 39°C.

Complete both coma & fluid balance charts.
N.B. Consider other causes of drop in conscious level:
(1) Haemorrhage elsewhere
(2) Seizure (especially in a child)
(3) Fat embolism
(4) Sepsis (particularly, meningitis)
(5) Pulmonary embolism
(6) Hypothermia & hyperthermia

INTRACRANIAL PRESSURE (ICP)
Monitoring ICP may be helpful in difficult cases, especially where there is considerable brain swelling. To do this, you need to make a small burr hole, and perforate the dura, & advance a cannula into the lateral ventricle *with all aseptic precautions*. This is not as difficult as it sounds (33.12). Make sure you tunnel the cannula under the scalp, and connect it to a pressure monitor.

FEEDING
If a patient is likely to be in hospital for a while, IV fluids alone will not supply the calories. Obviously initially maintenance fluids are needed *(though even this does not provide sufficient glucose)* but at least by 72h, pass a nasogastric feeding tube.

N.B. Both hypoglycaemia & hyperglcaemia are bad for the brain!

An adult needs up to 4x as much energy as a normal conscious adult, and especially protein; 4KJ (9cal)/kg in 3L fluid, with 1.5g/kg protein, and 4g/kg glucose daily. If the input gives less energy than needed, try to increase the protein content, *e.g.* with peanut butter.
(Note 1 egg = c. 6g protein.)
Try to keep the glucose level between 3-8mM. A patient may be unconscious for many days but eventually recover fully, *so allow starvation meanwhile*.

CUSHING'S ULCERATION
Prevent this with 40mg omeprazole or double if there is upper GI bleeding (half in children).

If you see the muscles wasting, *it is due to lack of protein and lack of exercise!* (In-bed physiotherapy is important not only in maintaining muscle tone but preventing DVT)

SPECIAL NURSING FEATURES
(1) Cornea
If the blinking or corneal reflexes are absent, and the eyes remain open, put adhesive strapping across the closed eyelids to protect the corneas from drying out.

(2) Bladder
Examine this to make sure it does not distend; most males can manage with a condom catheter, but females need catheterization.
Releasing the stopcock 4hrly is better than letting it drain continuously, and allows bladder tone to survive.

(3) Bed sores
Care for the skin from the start, as for paraplegics (54.3).

(4) Stimulation
Apart from physiotherapy, mental stimulation is vital. Play music through earphones, show pictures (of family & friends, and scenes familiar), talk or sing, and don't forget to touch the patient. Allow the patient also to touch, hear & smell you!

51.3 Complications of head injury

HYPERTHERMIA (45.6)
This may occur especially during the 1st 12h after an injury, even rising alarmingly rapidly to 42°C. When this is not due to infection *(remember endemic disease such as malaria, dengue, scrub typhus)*, it is known as neurogenic fever. It is associated, especially in children, with seizures. This puts a severe demand for increased metabolism on the brain, and leads to worse outcomes. So, it is worthwhile cooling a patient with a head injury.
N.B. Don't use NSAIDs or antipyretics!

Expose such a patient, apply cool sponging, use a fan to cool the air, and if this fails to lower the temperature <38°C, infuse IV saline at 4°C.

CONVULSIONS
These can occur at any time, and may be focal or general. They are usually associated with sudden deterioration of consciousness.

Use prophylactic anticonvulsants for:
(1) children with severe head injuries
(2) known epileptics
(3) depressed fractures (especially compound)

(4) gunshot injuries
Adjust a dose of 2.5mg/kg bd phenytoin for children or 3-4mg/kg od for adults to 4-8mg/kg od according to the response.

N.B. Status epilepticus may be fatal.

When a convulsion does occur, make sure the airway is patent. **If the convulsion continues despite correcting the hypoxia,** administer 0.3-0.4mg/kg (max 10mg) diazepam IV, and repeat this slowly after 10mins if convulsions continue.

If there is no IV line, administer the same dose rectally.

Such patients need anticonvulsant therapy on discharge.

CSF LEAKAGE
This is the result of a fracture of the skull base Where there is communication with the nose & ears. *Don't plug them*.
Advise against blowing the nose, as this may push bacteria into the meninges.

Start a 3rd generation cephalosporin as prophylaxis. Nurse the patient in a sitting position, if possible.

Make a lumbar puncture and repeat this 48h later if necessary. If the leak continues, the dura needs repair.

If the patient starts to sneeze, there may be a pneumatocoele, an air sac within the meninges, which connect with a sinus, usually the frontal. This requires neurosurgical attention.

CRANIAL NERVE PALSIES
These are usually the result of skull base fractures. No specific treatment helps.

LIMB PARALYSIS
During deep unconsciousness, you may observe no movements in all 4 limbs, and only realize this is permanent when the patient wakes up, or when you try to wean off the ventilator! If this is the case, you have missed a catastrophic cervical spine injury! By this time it will be far too late to remedy the situation*, so always remember to check the neck!*

AIR EMBOLISM (44.5)
If air is sucked into large veins (such as the venous sinuses), the risk of air embolism is high. A 200mL bolus may be fatal. There is a sudden hypotension & tachycardia, which may make you think of sudden bleeding. Pre-cordial US Doppler may pick up air in the right side of the heart.

Administer 100% oxygen at 10L or more, and noradrenaline if necessary.

FEW HEAD INJURIES ARE
SO SEVERE AS TO BE HOPELESS

NO HEAD INJURY IS SO TRIVIAL
AS TO BE TAKEN LIGHTLY

OTHER INJURIES
If a patient with a head injury has fractures elsewhere, at least splint them temporarily in the reduced position, even if you cannot treat them definitively.

LOOK FOR ANOTHER INJURY
IF A HEAD INJURY PATIENT IS IN SHOCK
ALL HEAD INJURY PATIENTS
MUST HAVE A COMA CHART

MANJI 40yrs
One Christmas Day a missionary doctor was called 40km to see a patient who had been beaten over the head with an axe, only to find him with such a severe degree of cerebral compression that he appeared lifeless apart from his pulse. It seemed that each breath he took would be his last. Unfortunately, the primitive operating theatre had collapsed, but the doctor decided to use a little laboratory barely 4m^2 in size. Light was provided by an electric torch and some hurricane lamps. No anaesthesia was required, as the patient was so limp, but after the removal of some bone and a large haematoma, blood clot, he had to be held down for skin suturing. LESSON: While there is life there is hope

51.4 The need for imaging

Try to become proficient in checking optic nerve sheath diameter by ultrasound (45.1) as this is relatively easy and non-invasive indicator of raised intracranial pressure. You can repeat it as many times and as frequently as you like.

Remember that a head injury is a dynamic event; no patient's status remains static initially. *So, if you wait till signs of deterioration are obvious, it might be too late; conversely any scan images taken too soon after an injury may not show the development of complications!*

Therefore, make a great effort to examine your patients extensively, carefully & repeatedly!
Where there is a deterioration, there is almost always some sign!

Look out for such deterioration especially in these patients with this history:
(1) Fall over 1m onto the head
(2) High speed impact (especially cyclist-car)
(3) Penetrating head injury
(4) Non-accidental injury
(5) Skull deformity or previous injury or surgery
(5) Patients using anticoagulants
or these symptoms:

(1) Vomiting more than once (esp. in children)
(2) >30 mins retrograde amnesia
(3) seizure without full neurological recovery

or these signs:-
(1) Depressed skull fracture
(2) CSF leak/bleeding ear/raccoon eyes
(3) Focal neurological deficit
(especially of the pupils & limbs)
(4) Persisting coma
(5) Hypertension with bradycardia

Where the signs are present on arrival in hospital, you have to presume they developed since the injury, and *you should not necessarily wait for further deterioration to act!*

Deterioration may be quite subtle and you will only pick this up if the coma chart is diligently filled in!
Occasionally, deterioration may be so rapid that you need to act without wasting time getting an image. *Don't insist on this, even if you have some doubt about your diagnosis.* The penalty of delay is death or serious neurological disability to the patient! *Time lost is brain lost.*
A skull radiograph will not guide you (except in rare instances) for surgery.
The carotid arteriogram will give just as much information as a CT scan, so it is worthwhile to become good at the former if you can't do the latter!

51.5 Open head injury

What may look like a simple scalp wound may conceal a dural laceration. The dura protects the brain from infection, so any dural tear may lead to meningitis, or a brain abscess.

RADIOGRAPHS are useful in open wounds of the skull vault (much more than in fractures of the base), especially in:
(1) An open fracture under a penetrating wound.
(2) A depressed fracture
(3) A retained foreign body.

The main problems with head wounds are:
(1) they may be deeper than you think,
(2) they may bleed profusely.

ARE YOU ABSOLUTELY SURE THERE IS NO PENETRATING SKULL WOUND?

OPEN HEAD WOUNDS
N.B. **If the patient has more serious wounds elsewhere**, the head wound can usually wait 12-18h, unless it is bleeding. Get control of the bleeding as a 1st priority (51.7).

You can easily confuse unconsciousness or severity of injury with instability where attention to ABC is paramount. It is wiser to proceed with any intervention in the OT.

Explore a deep small head wound with a sterile glove under LA. Feel for a gap in the skull bone. *Otherwise explore it in theatre*, because it may be deeper than it looks. Torrential bleeding may occur, so you may need theatre facilities in a hurry.
N.B. You can use a LA ring block of the scalp.

WOUND TOILET
Shave the scalp around the wound, and clean it with detergent. Be prepared to use several razor blades, because any grit in the scalp will blunt them. Protect the wound meanwhile with a sterile swab or towel.

If the wound is clean, and its edges are healthy and bleeding, *don't excise them*.

SURGICAL ANATOMY OF THE SCALP

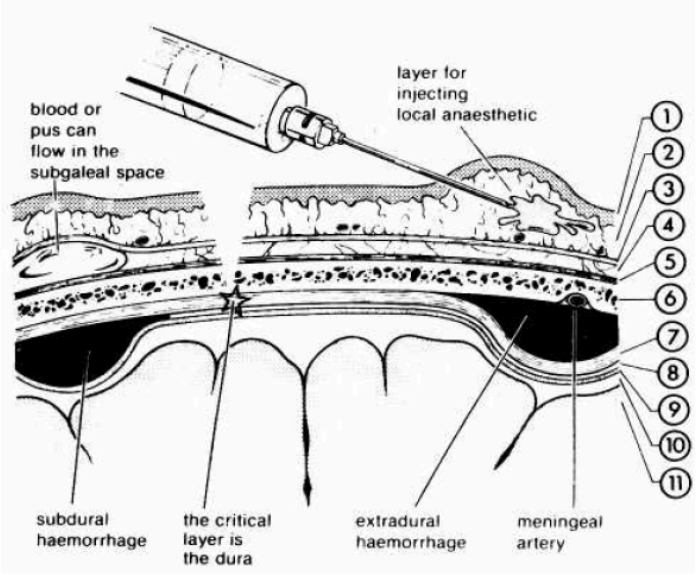

Fig. 51-6 THE ANATOMY OF THE SCALP AND SOME IMPORTANT LESIONS. The epidermis (1) is separated by a fibro–fatty layer of dermis (2), from the strong fibrous *galea* (3). These three layers are firmly united to one another to form the scalp. Under the *galea* there is a potential space, the subgaleal space (4), which enables the scalp to slide over the pericranium (5). Under the pericranium lies the skull (6), the dura (7), the subdural space (8), the arachnoid (9) the subarachnoid space (10), and the brain (11).
N.B. LA injection should go into the fibro-fatty layer, not under the galea. **Blood or pus sometimes collects in the subgaleal space and may perforate superficially or spread into the bone. An extradural haematoma lies between the skull & dura, and a subdural haematoma between the dura & brain.**

If the wound is dirty and ragged (63-19C), excise the skin edges all round it as little as necessary in one clean sweep right down to the pericranium. *Take care not to cut away excess scalp*, or then the wound will be difficult to close.

Insert a self-retaining retractor, and explore the wound cautiously with your gloved finger.
This is safer and provides more information than a metal probe. Palpate & look for a depressed skull fracture.

Remove all debris and dead tissue, and flush it out with sterile water.

If you feel any sharp bony edges, expose the surface of the skull widely (63.7)

CLOSURE
A wound which only cuts through skin does not gape, but one which cuts the *galea* gapes widely. Close this, if possible, with a large square vertical mattress suture of stout monofilament (51-7), taken through *galea* & skin. *Avoid inverting sutures.*

CLOSING A DEEP SCALP WOUND

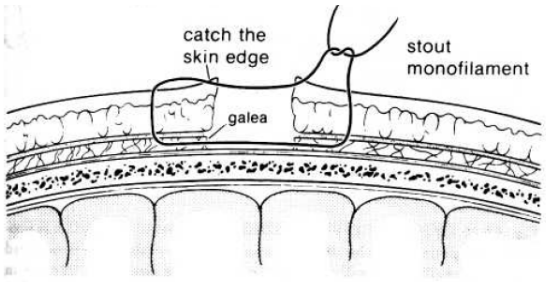

Fig. 51-7 CLOSING A DEEP SCALP WOUND. Make sure you pick up the *galea* with a large curved needle. *Kindly contributed by Peter Bewes*

Bleeding scalp vessels are difficult to pick up in haemostats, because they are held by the fibro–fatty tissue. Use LA with adrenaline, and swab the wound with hydrogen peroxide *(provided the dura is not torn).* A continuous locked deep suture (51-7) will control the bleeding: get an assistant to press on the wound edges.
Apply a series of artery clips to the *galea,* pushing them inwards to get good traction. (Special right-angled clips are very useful here.) Try to get proper haemostasis; leaving blood below the *galea* is inviting infection.
N.B. Don't use diathermy!

SCALP LOSS
Try to bring the skin edges together without tension, or the scalp may necrose. *Don't leave bare bone exposed*, or it will slough.

If there is comparatively little loss of scalp, you may be able to free it from the pericranium round the wound, so as to mobilize it over the subgaleal space. Mobilize the scalp in the layer between the *galea* and the pericranium (51-7).

If the defect is larger, use a flap (46.5). A long curved 'S' is a typical advancement flap (51-8B-D). The flaps need to be big, because the skin is quite tight on the skull.
If possible, design the flap to be based on one of the arteries supplying the scalp (46-16).
These are:
(1) The temporal arteries ascending in front of the ears.
(2) The supraorbital arteries which ascend over the forehead from the medial ends of the eyebrows.
(3) The occipital arteries behind the mastoid processes.

If the scalp hangs loose from the head, trim it, wash it with an antiseptic, such as hydrogen peroxide, and suture it back. Its excellent blood supply will probably allow it to survive, even if it has a narrow base.
N.B. Beware: such a patient has usually lost much blood and may well need a transfusion.

JABIT, 25yrs, was brought from 2h away having been attacked by a machete several times on the head. He was brought in comatose with a weak pulse. On primary examination there were no fractures but the scalp had been chopped off in multiple slices. He had lost a lot of blood and died within minutes of arrival, even before an IV line could be set up. There were no other injuries at all: the victim exsanguinated from his scalp alone. LESSON: Don't underestimate surface bleeding from the head!

FLAPS TO CLOSE SCALP DEFECTS

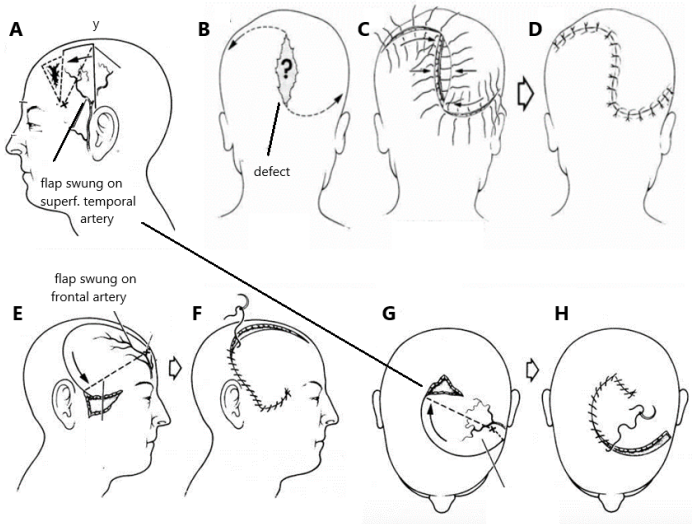

Fig. 51-8 FLAPS TO COVER SCALP DEFECTS. Because the scalp skin is tight, you need a large rotation flap to cover a relatively small area without tension. A, the pivot point is in front of the ear, based on the superficial temporal artery, and rotates on the axis xy. BCD, the flaps needs to be large. EF, here the pivot is frontal, based on the frontal artery. GH, based once more on the superficial temporal artery. *With the kind permission of Hugh Dudley & A Rowbotham.*

If the exposed skull is covered by epicranium, skin graft it immediately (46.2).

DON'T HESITATE TO EXPLORE A HEAD WOUND

DIFFICULTIES WITH OPEN HEAD WOUNDS
If blood collects under the *galea*, *don't drain the swelling*, as you may infect it, or cause it to bleed again. The haematoma will subside spontaneously, just as a cephalhaematoma does in a newborn child. Use 3rd generation cephalosporin prophylaxis.

N.B. **If a patient has more serious injuries elsewhere**, you may have to deal with vital bleeding first (or arrange 2 surgeons to operate simultaneously).

51.6 Skull vault fracture

When you discover a patient has a skull vault fracture, determine if:

(1) the fracture is not depressed, the chances are that the dura is not torn, so you can ignore the fracture, sand concentrate on the brain.

(2) there is an overlying skin wound, debride in theatre.

(3) the fracture is depressed, the dura is likely to have been torn, and needs repair.

(4) there is a foreign body in the wound or in the brain, remove it if superficial & readily accessible. *Don't try to extract a bullet or other object deep in the cerebral tissue! Never explore where you cannot see!*

Try to repair the torn dura. This might need pericranial tissue or *fascia lata* graft (51-11) Replacing pieces of skull is rather simpler.

FRACTURES OF THE VAULT
Be sure you are familiar with the methods of controlling bleeding.

INDICATIONS FOR RAISING DEPRESSED FRACTURES IN ADULTS
(1) Coma, or other signs of cerebral compression.
(2) Local neurological signs such as hemiplegia or aphasia, if most likely caused by the fracture.
(3) Fragments of bone or foreign body in the brain.
(5) Penetration of the dura.
(6) Leaking CSF (51.3).
(7) A compound (open) fracture.

CONTRAINDICATIONS
(1) Depressed fractures over a sinus (63.9).
(2) Very large closed depressed fractures.

RADIOGRAPHS
Examine these carefully to check if the sagittal or lateral sinuses are near the fracture. *These can bleed torrentially.*

PREPARATION
Shave the scalp hair generously from around the fracture, and preferably the whole head. Use a 3rd generation cephalosporin prophylaxis. Mark the side to be operated upon.

ANAESTHESIA
GA is preferable, although using LA in a comatose patient is acceptable. The skull, most of the dura, and the brain are insensitive to pain, so you need only anaesthetize the skin.
Before injecting LA with adrenaline deep to the *galea*, test the mobility of the scalp to plan any flaps.
Arrange to minimize venous bleeding by adjusting the slope of the table, and carefully positioning the head and neck (51-9).

PREPARING THE THIGH
Always prepare and towel the lateral aspect of the thigh, so that you can quickly raise a *fascia lata* flap if necessary (51-11). Be sure to take it from the lateral aspect: there is little fascia anteriorly.

METHOD
Paint the whole head with betadine, and get an assistant with sterile gloves to hold it up. Position the head so that the plane of your craniotomy will be as horizontal as possible. If your operating table does not angulate at the head, place a double-folded towel under the head to flex the neck accordingly.

Turn the head to one side and place it on a head ring (so it doesn't move about, 51-9A), and the surface you wish to operate on is uppermost. Close the eyes, pad them and seal them with strapping. Cover the nose and eyes but not the ears with a sterile towel, and clip this to the first sterile towel. *Make sure the whole scalp & ears are visible.* Put a sterile towel *under the head* after you have shaved and sterilized the scalp (51-9B). Make sure the eyes (strapped closed with ophthalmic ointment) are covered with a gauze, taped onto the nose.

Get a gowned assistant wearing two pairs of sterile gloves to raise the patient's head, using 2 fingers at the occiput and 2 at the bridge of the nose.

Now sterilze the head from frontal to occipital, from beyond the sagittal plane down to the neck, suprasternal notch and shoulders.

Draping: three small square towels and one long towel. If an extra long drape with a hole in it is available, so much the better.

POSITIONING & DRAPING THE SKULL

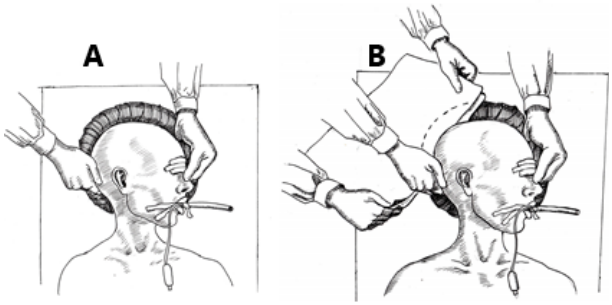

Fig. 51-9 POSITIONING & DRAPING THE SKULL. Make sure the face & ears are covered*, and the part you want to operate upon is uppermost.* A, turn the head to one side on a head ring. B, place a double sterile towel under the head, so you can fold the upper towel to cover the face.

ELEVATING A SKULL FRACTURE

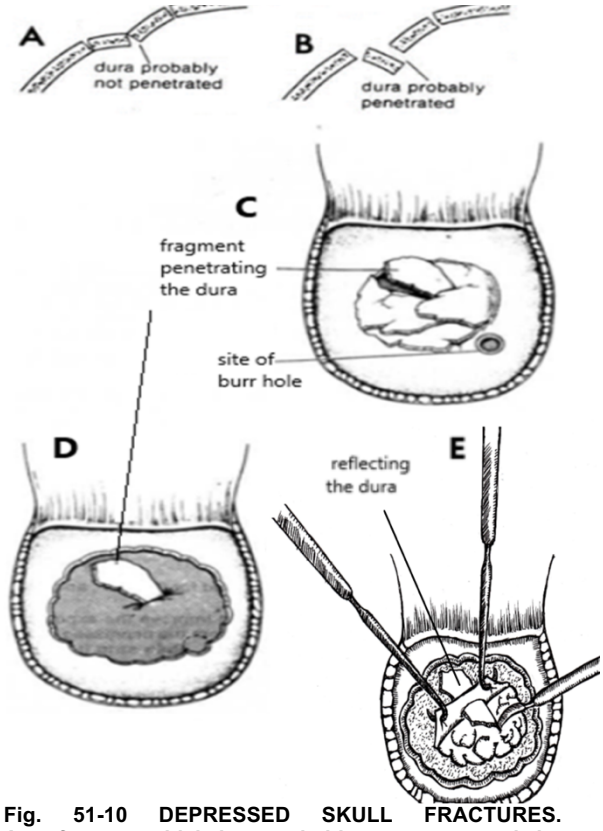

Fig. 51-10 DEPRESSED SKULL FRACTURES. A, a fracture which has probably not penetrated the dura. B, one which probably has penetrated it. C, reflect the base of the scalp flap caudally. *Don't try to pull out fragments which may have penetrated the dura.* Drill an adjacent burr hole. D, a fragment penetrating into the dura. E, reflecting a dural flap to enable you to remove the fragment under direct vision. *Kindly contributed by Peter Bewes, Gerishom Sande & A Rowbotham.*

Get another assistant to put 2 sterile towels *under* the head, pushing them down as far as the shoulders. The 1st assistant then gently lowers the head onto the now covered headring, adjusting its position.

The 2nd assistant can now remove the top layer of gloves, whilst you fold the top layer of sterile towels onto the head exposing the central part where you want to make the craniotomy.

Endeavour to reduce venous bleeding by:
(1) Positioning the head tilt-up 10° to raise it 5cm above the heart, and the head so the wound is uppermost.
(2) Use relaxant GA if possible, with slight hyperventilation. This will reduce the intracranial pressure. *If GA is unlikely to be perfect, LA may be better.*
(3) *Make sure that nothing obstructs the veins of the neck*. Raise the shoulders on sandbags.

N.B. Don't raise the head too much because air may be sucked into the veins, causing an air embolism. The first sign of this is sudden weakening of the pulse and tachycardia. Embolism will be less likely if there is fluid over the surface of the wound, so keep syringing it with saline.
(4) Irrigate the wound with 3% H_2O_2.

Make a generous incision, and if making a flap, turn this caudally (51-10C), grasping the edge of the *galea aponeurotica* with toothed forceps& then rotate these 180°; this kinks the blood vessels and stops haemorrhage.

Use a fresh set of instruments once you have debrided the scalp. Insert a self-retaining retractor to maximize the exposure.

If the fragments are loose, strip off the pericranium off the bone, starting at the edge of the depressed segment and save it as a flap. Gently lift out individual bone fragments.
(Ask your scrub nurse to clean the pieces in sterile saline and save them).

Some fragments may be wedged together. *Don't try to pull on impacted fragments!* You can usually find a gap to insert a bone nibbler, and so gently work a wedged fragment free. Scrape the pericranium off first. Nibble away badly contaminated bone. (*You don't usually destroy too much bone having to do this.*) Once the fragments are disimpacted, lift them all out and wash them thoroughly.

N.B. Don't make the burr hole in the depressed fragment. It may be loose and allow your burr to slide straight into the brain!
Alternatively, drill a burr hole adjacent to the impacted fragment (51-10C), so you can lever it out from underneath.
This is not as easy as it sounds, and you may cause damage if the dura is torn in an area which is not visible.

If a fragment has clearly penetrated the dura, and pulling it out might disrupt the dura further, lift a dural flap (51-10E) using skin hooks, in order to extract the fragment under direct vision.

Treat foreign bodies in the same fashion. *Don't search for one deeply embedded in the brain!*

If the fragments are too numerous or disimpaction is impossible, perform a standard craniotomy (51.8) around the fracture. Lift off the bone around the fragments in the normal way. This is an elegant way of removing the broken skull from the dura, but needs care if there are bone fragments penetrating the dura.

N.B. **If there are any fragments in or near a venous sinus**, *don't dislodge them:* the sinus bleeds torrentially if torn.

Remove any extradural haematoma present. Check if the dura is intact.

If there is contaminated brain tissue, handle it gently. Remove all dead tissue, clot, bone fragments, and foreign bodies that you can reach. Use a soft jet of warm saline & gentle suction from a syringe with a rubber squeezer.

N.B. Don't use H_2O_2 inside the brain: the release of gas may cause raised intracranial pressure.

If CSF is leaking out, there must be a dural tear. Expose the whole fracture area by nibbling away more bone to expose 2cm of intact dura all round it.

If the dural tear has ragged edges, trim them.

CLOSURE

If the dura is purple and bulging, open its surface with the point of no.11 scalpel blade. Then enlarge the opening with fine scissors to expose the haematoma, and drain it.

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If there remains a dural defect which you cannot close directly, simply suture in a matching piece of pericranium (for small gaps), *temporalis* fascia or *fascia lata* (for larger gaps) with fine continuous monofilament. Make sure the closure is watertight.

JULIUS, 50yrs, was walking about quite fit, smiling and gesticulating, but quite unable to speak since the previous week when he had been hit on the head in a fight. Palpation showed him to have a depressed fracture of the skull. As this was being elevated under LA, a sepulchral voice from under the drapes called out, "Shikamoo" ("I am holding your feet", a local term of subservience and indebtedness). The patient went home talking volubly and everyone was happy. LESSON Aphasia is one of the indications for raising a depressed fracture.

TAKING A *FASCIA LATA* GRAFT

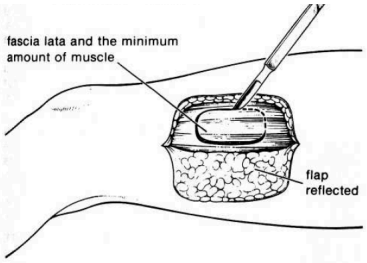

Fig. 51-11 TAKING A *FASCIA LATA* GRAFT. Prepare and towel the lateral aspect of the thigh, so that you can quickly take a piece of *fascia lata* to repair a gap in the dura. *Kindly contributed by Peter Bewes.*

The wound should be perfectly dry before you close the skull, especially after an extradural haemorrhage, and when the brain has not completely expanded. If it is not dry, a haematoma will form postoperatively, and bleeding will not stop until intracranial tension rises sufficiently to cause undesirable pressure on the brain.

CAUTION! Keep the exposed brain wet with saline.

Replace fragments of skull over the dura., and cover them with pericranium. Close the scalp as before (51.5)

DIFFICULTIES WITH A SKULL VAULT FRACTURE

If a wound has left a gap in the skull, suggest wearing a helmet. Cranioplastic repair may be necessary for cosmesis.

If a fracture enters the frontal or ethmoid sinus, rhinorrhea implies CSF leak and so danger of meningitis, brain abscess, or a pneumatocoele. Treat with 3rd generation cephalosporin. A pneumatocoele needs expert neurosurgery..

If there is a penetrating injury presenting late with contra-lateral motor weakness, there is probably now has an intra-cerebral abscess or haematoma. Perform a carotid arteriogram to locate the lesion. Then with a suitably place burr hole, open the dura and suck out the collection through a fine long blunt-ended probe.

Then syringe out the cavity gently with a jet of saline, and close his wound as above.

If there is severe bleeding, it may be arising from: (1) the middle meningeal artery, (2) the venous sinuses, or (3) the dural vessels (51.7)

FILIMON'S scalp was split and torn, the brains were pouring out of the head and dripping slowly to the ground. This is the literal truth. A tree had fallen on it, smashing it like an egg. On the operating table it became clear that the skull was in five pieces. As these were manoeuvred into position more brain kept oozing out. At last the jigsaw was complete, the dura closed and the scalp was sutured. To everyone's surprise he made a quick recovery and walked home.
He did seem to have a rather simple and euphoric personality, but his family said that he had always been like that.
LESSON Few patients are so severely injured that they must be given up as hopeless.

51.7 Burr holes

It is quite likely that when you have to make burr holes, you will not have time to read these lines immediately before operating! So, prepare yourself now! The decision to make a burr hole will be because you need to decompress the pressure on the brain. Site the burr holes according to the clinical symptoms & signs, or as more precisely indicated by a carotid arteriogram. There are standard anatomical sites (51-12).

SITES FOR BURR HOLES

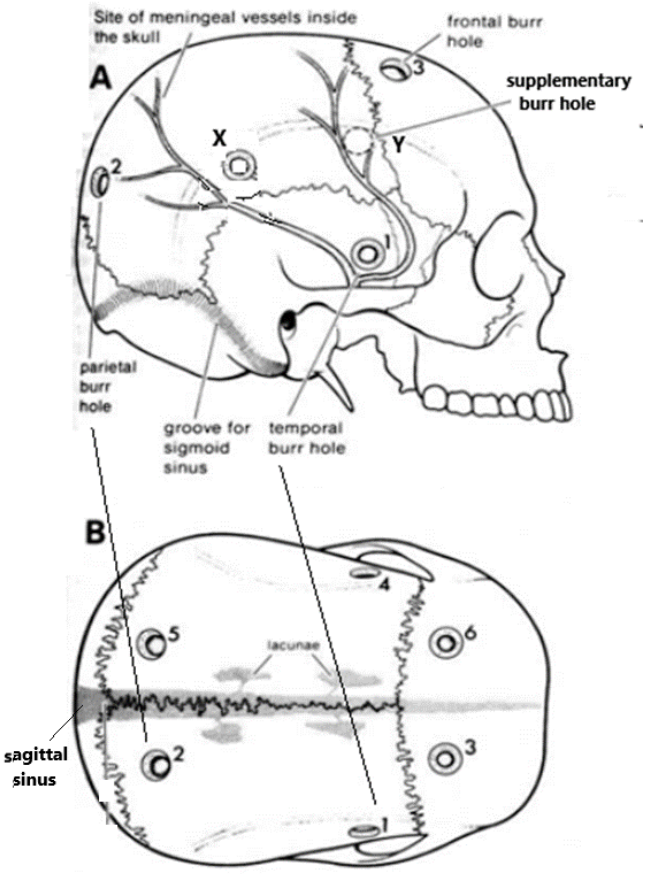

Fig. 51-12 SITES FOR BURR HOLES are standardized. You may need to make an additional hole over a fracture. *Avoid the sagittal sinus!* A, temporal, B, frontal, C, occipital sites. X, Y supplementary sites.
N.B. Don't place a burr hole over a major sinus, the orbit, the posterior fossa or the frontal sinus!

JAQUES (10yrs) was discharged following a minor head injury. He was brought back in again the following day deeply unconscious, with one fixed dilated pupil. He was rushed to the theatre, still in the out–door clothes. Within 20mins burr holes were being made. A large extradural haematoma was found and washed out. The next day, he was up and walking.
LESSON: This is what we mean by a real emergency: rush these patients to theatre, every minute matters! *Time lost is brain lost!*

NEUROSURGICAL EQUIPMENT

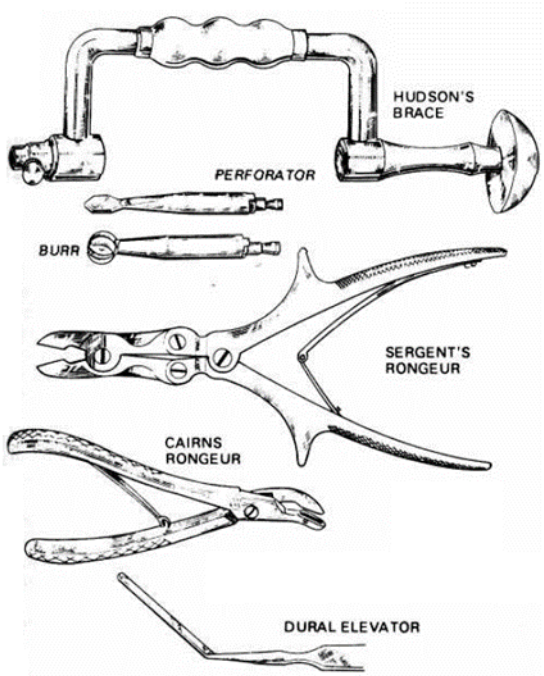

Fig. 51-13 ESSENTIAL NEUROSURGICAL EQUIPMENT. This should be in every hospital and every doctor should know how to use it.

DON'T BE AFRAID TO DO BURR HOLES: YOU CAN SAVE MANY A LIFE THEREBY!

EQUIPMENT

HUDSON'S BRACE, standard 25.4 cm is the neurosurgical equivalent of a carpenter's brace. *(You make be lucky to have an electric drill: make sure this has an automatic guard to prevent rapid penetration through the skull!)*
PERFORATOR, with standard fittings, 12 mm. Use this to start making a hole in the skull and continue immediately with burrs.
BURR, spherical, Hudson pattern, 11mm, 13mm, 16mm, 19mm, one of each size. Use these to enlarge the hole made by the perforator. *Avoid conical burrs as they are more likely suddenly to plunge through the dura and enter the brain.*
N.B. Make sure the perforator & burrs are kept well sharpened!
RONGEURS, (bone nibbler), Cairns, with fine angled-on-flat jaws and curved handles, 152mm. Use this to enlarge the burr hole. Sergent's, larger with flat jaws are for cutting bone.
ELEVATOR, skull, Penfield, double ended. Use this to elevate depressed skull fragments.
BONE WAX
LARGE SYRINGE (low pressure).
PERIOSTEAL ELEVATOR Adson's for separating the dura.
MALLEABLE GUIDES to pass over the dura between Burr holes.
GIGLI WIRE SAWS to cut through skull bone. You need several of these as they quickly go blunt or break.

Start on the side where the pupil first dilated, or the side opposite to where there is weakness or absent reflex. If a fracture crosses the route of an artery, make a burr hole relative for that artery (51-12A-C). Occasionally you need a burr hole to help elevate a wedged vault fracture (51.6)

TEMPORAL BURR HOLE

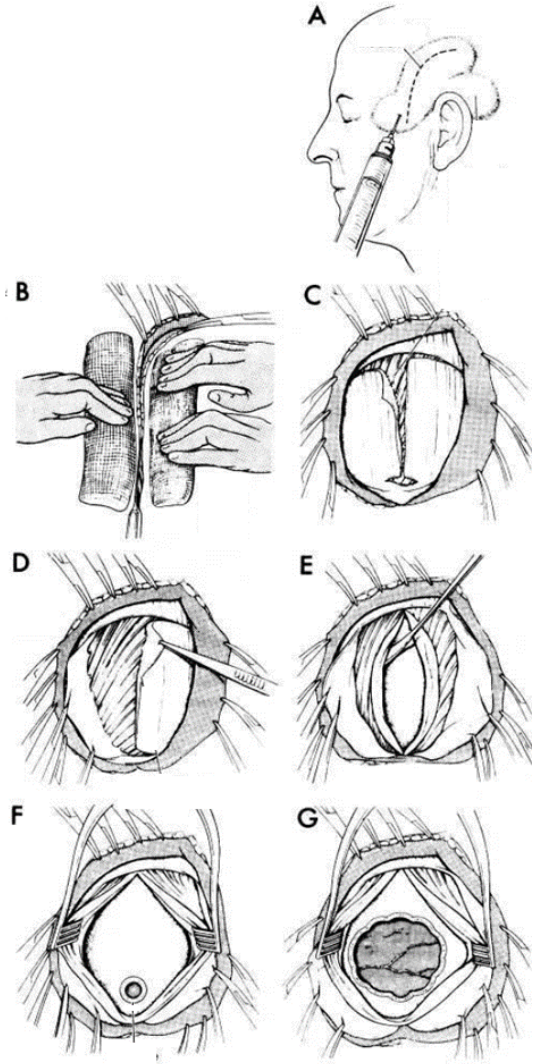

Fig. 51-14 TEMPORAL BURR HOLE. A, infiltrate the temporal muscle, including its inferior part & make a 'hockey-stick j-shaped incision. B, get an assistant to press firmly either side of your incision. C, make a T-shaped incision in the *temporalis fascia* D, reflect it. E, separate the *fascia* from the skull. F, drill the burr hole. G, enlarge it with bone nibblers. *After Rowbotham GF. Acute Injuries of the Head, E&S Livingstone, Edinburgh 4th ed. 1964 with kind permission..*

CLASSICAL TEMPORAL BURR HOLE (GRADE 2.5)

After infiltrating the temporal muscle with LA & adrenaline, make a J-shaped incision midway between the posterior margin of the orbit & the external auditory meatus, 2cm above the zygomatic arch, and 1cm in front of the ear (51-12).

N.B. Alternatively, you can make the incision more superiorly to enter the skull *above* the *temporalis* muscle: this is faster.

Control bleeding by asking your assistants to press the edges of the wound (51-14B). Pick up the edges of the *galea* in haemostats, preferably right-angled ones, and evert them. When you remove them at the end of the operation bleeding will have stopped.

Insert a self-retraining retractor, which will also stop bleeding. Make a T–shaped incision in the *temporalis fascia* (51-14C), and turn it back as 2 short flaps (51-14D).

A small horizontal incision above the zygomatic arch makes access to the inferior surface of the brain easier.

Split the *temporalis* muscle from top to bottom, in the line of its fibres, and separate it from the skull with a curved dissector or raspatory (51-14E). Reposition the self–retaining retractor, to expose c.4cm of the skull (51-14F).

DRILLING

You are now ready to start drilling a hole.

We assume you don't have electric drills. If you do, make sure they have a catch to prevent you drilling too fast right through the skull & inadvertently damaging the brain!

Ask the assistant to hold the head steady. Place the knob at the top of the brace in the palm of your left hand; take its handle in your right hand. With the perforator vertically in position at the desired site, make a backward & forward rotation to establish purchase of the perforator. Then press hard with your left hand and slowly drill a funnel shaped hole in the bone (51-15A).

Drip sterile water onto the bone as you drill to stop it overheating. When you reach the pale blue colour of the normal dura, or the dark purple of an extradural clot, stop drilling!

N.B. Don't go on any further, because you may pierce the dura and lacerate the cortex. This is very easily done. The squamous temporal bone is often thin, so *don't press too hard*!

Replace the perforator with a burr slightly larger than the size of the perforator (51-15B) and enlarge the hole. *Avoid using smaller burrs! Don't push too hard so the burr suddenly penetrates through the skull into the brain* (51-15F)! Lift the burr from time to time to check when you reach the dura. *Stop turning when the bite on the burr increases suddenly,* because this mean that you are now through the inner table.

TECHNIQUE OF DRILLING THE SKULL

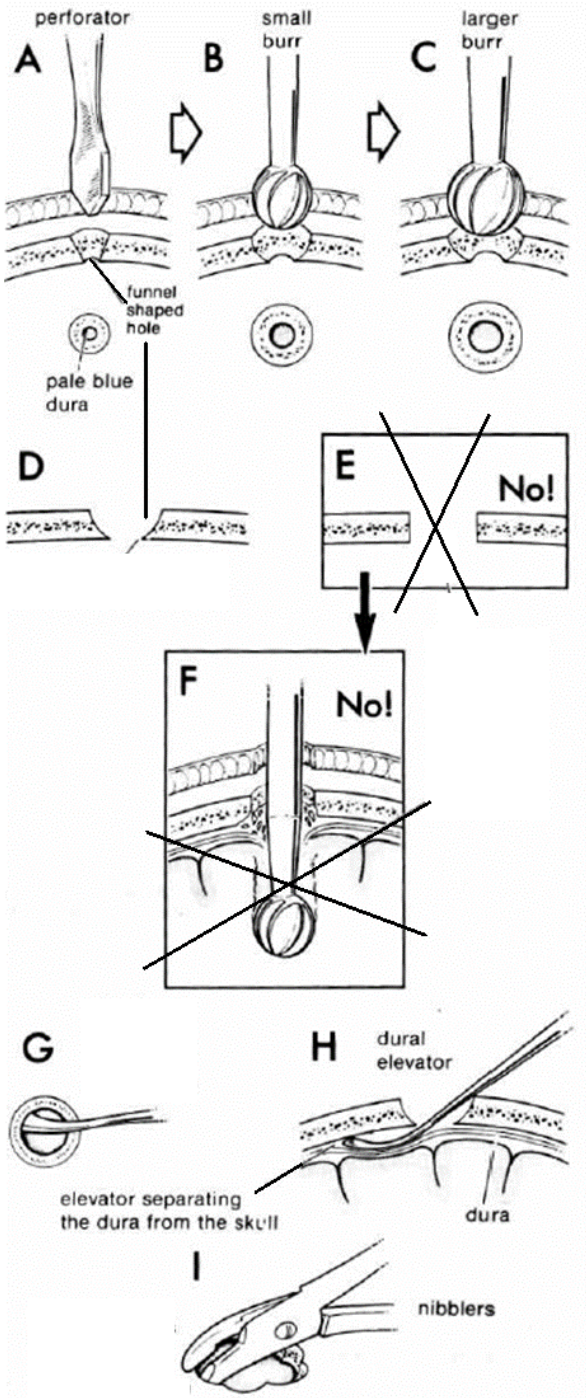

Fig. 51-15 TECHNIQUE OF DRILLING THE SKULL. A, Use a perforator initially to make a funnel-shaped hole. Stop when you see dura. B, then use a larger burr. C,D stop when you reach the inner table. E *don't make a cylindrical hole* as F, you will perforate the brain. G,H insert a dural elevator. I, increase the hole size by nibbling the edges of the burr hole in the skull bone.

Stop while there is still a rim of inner table round the edge of the burr hole (51-15D) *Don't go on until you have made a cylindrical hole* (51-15E), as the risk that the burr will slip through into the brain is high. If you have to replace a burr, choose a *larger* one.

Now nibble at the edges of the hole to give you a good view. Push the dura gently away from the inner table with a dural elevator (51-15G, H), so that it is not torn when you insert the nibbler to enlarge the edge of the hole (I).

The cut edges of the bone will bleed. Suck away the blood but *don't apply wax until you are about to close the wound*.

If you have lacerated a branch of the middle meningeal artery that runs in small bony grooves of the inner table of the skull, stop this arterial bleeding by coagulation or ligation. This means an extradural haematoma is *not* present.

EXAMINATION OF THE DURA

Make sure you have a good light. The normal brain is pink and the dura should pulsate; if they do not, suspect that there is raised intracranial pressure. If you don't see anything, enlarge the burr hole a little.

N.B. Always make burr holes away from the line of the middle meningeal artery, not over it.

If there is visible haematoma immediately under the hole, there is an extradural haematoma. You will not see the dura or the middle meningeal artery because these will have been displaced inwards.

If the dura looks purple, there is a subdural haematoma.

If the dura is torn, it needs repair (51.6)

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EXTRADURAL HAEMATOMA (51-1A)

Once you have seen the clotted blood, nibble at the edge of the burr hole to make it larger. Retract the tissues widely, so that you get a good look into the hole. Nibble away the bone in the direction of the clot; this is usually towards the base of the skull. A common error is to remove too little bone. Use a curved dissector to separate the dura from the skull each time you nibble more bone.

N.B. Don't put your finger into the wound to try to remove the haematoma, because this may increase intracranial pressure!

Instead, remove the haematoma, a little at a time with a teaspoon, curved dissector, suction or syringe of warm saline.

You may well need to make another burr hole in the direction where the haematoma seems to be spreading, in order to flush out all the clotted haematoma.

If the haematoma is coagulated and solid, as it often is, you will really need a formal craniotomy (51.8) to remove it adequately.

If there is any active arterial bleeding, nibble towards it (the middle meningeal artery, probably) or make another burr hole; this is very important, *so don't worry about how much bone you remove*. Make a dural hole, with a sharp hook, beside the bleeding vessel, and pass a needle round it, so that *you don't damage any cortical veins*. *Don't try using diathermy!*

If there is no further bleeding, after you have removed the haematoma, *don't hunt for the injured artery*.

N.B. Extradural haematoma is rare in the elderly as the dura becomes adherent to the skull bone.

If the dura is slack, fluid may accumulate again outside the dura, so pull it up with tacking sutures attaching the dura to surrounding pericranium or *temporalis* muscle

SUBDURAL HAEMATOMA (51-1B)
A purplish colour of the dura signifies the presence of haematoma under it. Extend the skin incision, and enlarge the hole a little with nibblers. It is usually not necessary to make a big hole.

Use a #11 blade on a holder to scratch an X–shaped incision in the dura. *Don't stab into the dura!* The blood will squirt out if it is an acute haematoma. The brain may be contused and lacerated, with some clots present. Remove a haematoma by rinsing it out.

If the bleeding is venous, it is coming from the veins of the dura. Push muscle grafts or pieces of surgical gauze between the dura and the skull. Keep these in place by passing a few interrupted sutures between the epicranium and the dura over the nibbled edge of the bone. These sutures will hitch up the dura, and help to keep the muscle patch in place.

If blood pours out as a dark venous stream from the sagittal sinus or lacunae, it can be very severe.

N.B. Don't apply haemostats to the sinus, because they will tear out and make bleeding worse. *Don't try to suture a torn sinus*. This will usually increase bleeding.

The sagittal sinus runs in the midline on the inner surface of the skull from the forehead to the occiput. Several irregular venous spaces (lacunae) join it on the top of the head (51-12). It is injured either from a blow to the top of the head or by a surgical mishap. *Often, a sinus only bleeds if you begin raising a depressed fracture near it!*

The transverse sinuses in the occipital region are still less vulnerable, but when they are injured, bleeding is even harder to control.
Plug the torn sagittal sinus with haemostatic gauze, a piece of muscle flattened by a hammer into a thin piece of tissue, or thin bone wax.

N.B. The muscle will be dead but its presence will promote clotting.

ALPHONSE (22yrs) fell out of a truck. Six weeks later, he went to a local clinic complaining of a severe headache. Fortunately, they had a radio, and the pilot from the local mission hospital was in the area, so he was ableto pick up the patient. By the time the pilot brought the patient to hospital, he was in a coma, but a medical student on elective, and who met the plane, obtained the relevant history of a head injury. The signs of cerebral compression were classical. He was on the operating table within 2h, burr holes were made, and he was sitting up conscious the following day.
LESSON: A chronic extradural haematoma can follow a head injury incurred weeks, or even months, before.

If there is a venous ooze from everywhere, check the clotting time.

If you have secured the main bleeding point, but there is much persistent bleeding, *don't hurry*. Perform several dural tack-up sutures at the bony edges of your craniotomy and elevate the head.

If the clot extends backwards under the parietal bone, the posterior branch of the middle meningeal artery is probably torn. You cannot tie this from your present incision. So try to tie its main trunk. If this is impossible make another burr hole 4cm superior & posterior to the ear.
This is the burr hole marked (51-12X). Fortunately, you rarely need it.

If the vessels in a bone groove or tunnel are bleeding, apply Horsley's bone wax, or plug them with muscle.

If the surface of the brain is bleeding, place a warm pack on the brain and wait 5mins; then if bleeding continues, place a muscle patch on the surface of the brain and cover it with dura. *Don't use diathermy as it is likely to be too strong! Don't use gauze, or clips!*

If you cannot find the bleeding vessel, pack pieces of haemostatic gauze, or *temporalis* muscle, between the dura and the bone where the bleeding is coming from. Hold this in place by suturing the dura to the pericranium over the edges of the hole in the skull (63-19). Insert a suction drain and raise the head.

If arterial bleeding comes from the under surface of the brain, the middle meningeal artery may have ruptured at or close to the foramen spinosum. Try to stop it by performing dural tack-up sutures in the direction of the bleeding.

N.B. **If bleeding is uncontrollable,** it is probably coming from a torn sagittal sinus.

If torrential bleeding occurs from deep in the brain, its source may be impossible to find, or repair.

If there is pale yellow fluid under tension, suction this all out gently. It is a decomposed haematoma. Decompression is still necessary.

If you find no haematoma, consider making some more burr holes. Obviously you should not be in this situation if your pre-operative imaging has clearly demonstrated an extradural or subdural haematoma. In this case, study the images again carefully to check if you have drilled at the correct site!
Make sure you have not drilled on the wrong side (*e.g.* by inverting the pictures)!
Likewise, if you decided to proceed on the basis of a dilated pupil or limb weakness, check if you have made the burr hole on the side of the dilated pupil or on the opposite side to the limb weakness!

More commonly, you have to choose another site for a 2nd burr hole (51-12). Make a parietal hole through a separate longitudinal incision over the point of maximum convexity of the skull, above and behind the ear.
If this is also unsuccessful, make a 3rd burr hole: a frontal hole in the line of the pupil 2cm behind the hair line.

If you still find no haematoma, and you have checked the side you are operating on, and you have no images, start again on the opposite side, first with a temporal burr hole, and then a parietal and frontal.

N.B. A *contre-coup* injury (where the haematoma is opposite to the side of the injury) is rare, but may occur. However, there should still be signs of an ipsilateral dilated pupil or contralateral limb weakness.

N.B. Extradural haematoma is rarely bilateral, but subdural haematomata may be.

If the brain bulges into the wound after a craniotomy, and opening of the dura**,** or open skull fracture, there is either deep intracerebral bleeding or oedema. You would need to compress the brain further to close the dura, so use a periosteal or *fascia lata* graft (51-11).

Continue hyperventilation, and administer 500mL 10% mannitol (*i.e.* 50g) IV over 1h. Repeat this every 6-8h if the consciousness improves, but *don't exceed 200g in 24h*. Insert a catheter to collect the ensuing diuresis.

From the 2nd day onwards for 3-4 days add frusemide 40-80 mg IV od.

N.B. Steroids are of no help, except maybe in children.

If your burr goes straight through the dura into the brain, this is not as dangerous as you might suppose, and recovery is usually straightforward. *It should never, however, happen* (63-10F), so beware this possibility especially in a child or in the elderly.

CLOSURE
Once you have controlled all the bleeding**,** close the dura without a drain. Otherwise, leave a suction drain in when you close the wound. Suture it to the skin, take great care with asepsis and remove it after 24h.

Control bleeding from the cut skull bone by pushing bone wax, autoclaved beeswax, paraffin (candle) wax, or chewing gum into the bleeding cut surface of the skull.
Don't use too much bone wax or else the bone will not close over the gap.

METHODS OF HEAMOSTASIS IN THE HEAD

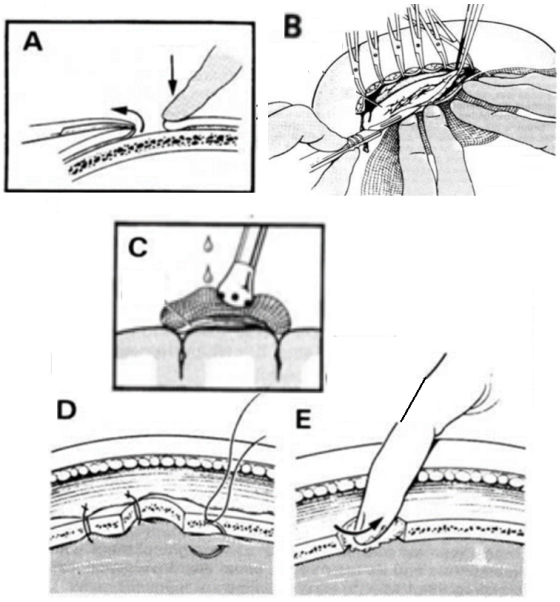

Fig. 51-16 WAYS TO CONTROL BLEEDING IN A HEAD INJURY. A, B, press on the everted edges of the scalp; apply haemostats, or clips, to the underside of the skin. C, press a flattened muscle patch on the bleeding brain, cover it with gauze, drip saline onto it, and apply suction. D, tack the pericranium to the dura. E, fill the diploe with bone wax. *By kind permission of Hugh Dudley & Gerishom Sande.*

ALWAYS OPERATE WITH THE HEAD ABOVE THE HEART

51.8 Craniotomy

INDICATIONS FOR CRANIOTOMY
(1) A solid clotted extradural haematoma.
(2) Fractured skull bones impossible to disimpact.
(3) Multiple open skull fractures.

METHOD (GRADE 3.1)
Preparation is as for open head injuries (51.5)

Make a bone flap centred on the lesion and big enough to give you good access (51-17A). You can make either a semicircular or rectangular skin incision, usually within the hair line.
Make sure the width of the base of the flap is less than its length or radius.
N.B. Don't let your flap reach the midline where the sagittal sinus lies (51-12).

Cut the skin and control haemorrhage from the scalp (51-16A,B; 51-17C): right-angled haemostats or clips are ideal.
Once you have gone round the length of the semicircular or rectangular flap, lift it off the pericranium by gentle sharp dissection, and cover it with damp gauze.

Then incise the pericranium and muscle (if necessary) except at the base of the flap; this base is usually at the same place as the skin flap base, but need not be.

Drill 5-6 burr holes around the edge of the flap c.6-7cm apart (51-17D) or nearer together if the bone is thick or the dura adherent.

Then insert a periosteal elevator gently under the bone to separate off the dura between one burr hole and the next: *take care in elderlypatients not to tear the dura if it is adherent to the bone!* In this way, go round between all the burr holes.

Now put a malleable guide along the surface of the dura through adjacent burr holes (51-17E), and pass a Gigli wire over the guide (51-17F). Attach hooked handles to the ends of the wire and saw upwards through the bone by a long firm slow jigsaw motion, beveling the angle the cut outwards, so that the bone flap will rest on the skull when put back.

N.B. Press firmly on the bone when you make the last cut, or else it may fly off! Alternatively, cut through the bony base with bone cutters, and lever it gently up, still connected by skin to the head.

CRANIOTOMY

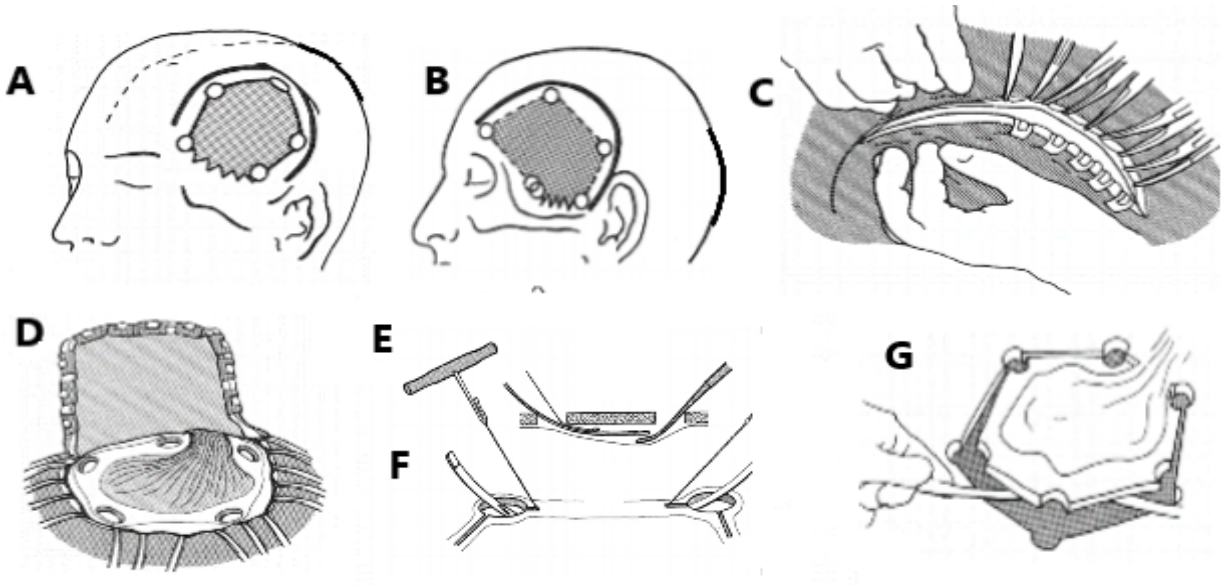

Fig.51-17 CRANIOTOMY (depending on the nature & site of the injury): make this big enough, *but avoid the midline.* A,B, possible sites for the bone flap. C, cut the skin and control bleeding by pressure & applying forceps or clips. D with the skin flap lifted up, drill burr holes 6-7cm apart. E, pass dural elevators under the skull bone to lift off the dura. F, gently insinuate a guide wire between adjacent burr holes, and glide the Gigli saw over it below the bone; saw obliquely outwards. G, you can then lift the bone flap up gently when you have divided or cracked open the last part, and put it back at the end of the operation.

You may need to use bone wax to stop bleeding from the bone edges.

If you have power tools, these are very useful for cutting bone, and have a stop to prevent drilling the skull too deeply.

After you have completed the intended cerebral procedure, you can replace the flap (51-17G) and close the wound.

Make sure that you have good haemostasis, that you have closed the dura water-tight, and if the brain is bulging because of oedema, you don't force the flap down: you can suture the skin closed later.

If there is oedema, think of putting in an intracranial pressure monitoring catheter (33.12)

If a child needs burr holes, fit the perforator into the handle for it, and open the skull with this. Then use the nibbler, without using burrs.

A child's skull is thin with no distinct inner and outer table, *so a brace and burrs, and especially a drill, can be dangerous*.

N.B. You may be able to remove the blood from a haematoma in a baby with a large needle without using a perforator.

One type of projectile wound is a bullet striking the skull tangentially (51-18). This is like hitting the head with a hammer. The bone may or may not be fractured, and bone fragments may or may not enter the brain. The underlying brain damage is a contusion with petechial haemorrhage.

Perforation of the skull with direct injury to the brain comes in several forms. The most common, because most survivable, is a low-kinetic energy projectile that penetrates the brain for several cms, and then stops.

This represents either a bullet at the end of its trajectory or shrapnel at a great distance from an explosion. The damaged area will form a cone of tissue destruction (46.39-44). The skull wound resembles an irregular burr hole (51-19). The patient is often lucid, even walking into the emergency recept

The basic rules for management of bullet or fragment wounds of the head are the same for open wounds (51.5). There are some differences, however, due to various ballistic effects.

51.9 Projectile head wounds

The patients you will see in the hospital are a self-selected group: they are the survivors. The results of projectile head wounds are similar to brain tumours; any deficit depends on which particular part of the brain has been damaged.

TANGENTIAL SKULL BULLET INJURY

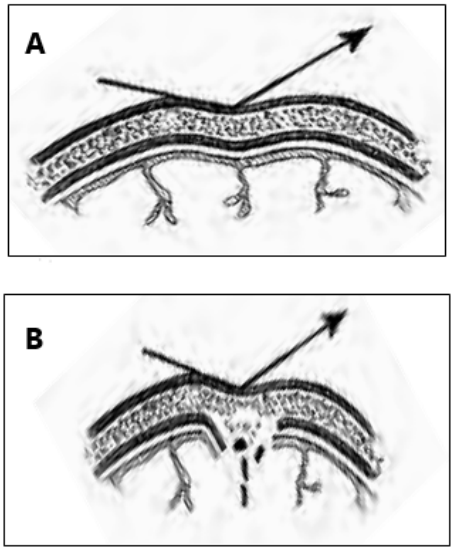

Fig. 51-18 TANGENTIAL BULLET INJURY OF THE SKULL. A, without & B, with bone fracture and penetration of the brain. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

LIMITED HEAD BULLET WOUND

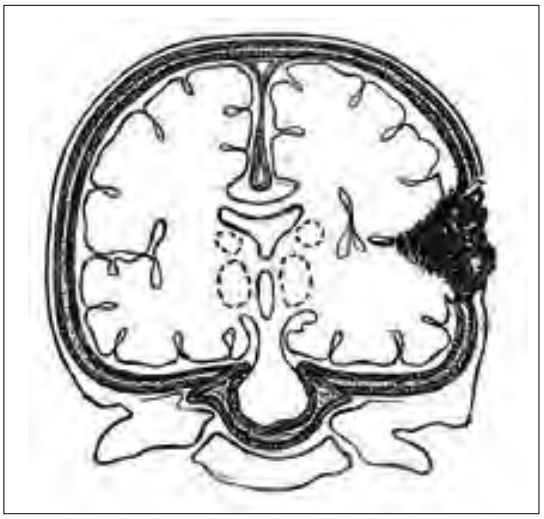

Fig. 51-19 BURR HOLE WOUND OF THE HEAD. A low-energy bullet has penetrated a few cms, and then stopped. *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

Less often, you may encounter a transfixing through-and-through injury, where the bullet passes through one entire hemisphere of the brain, with a long track. These injuries are not usually survivable and if the patient does survive, the disability is significant.

Even rarer in a surviving patient is a bilateral hemispheric wound; the bullet passes through both hemispheres from side to side. Very few of these patients survive and disability is extreme.

In both these transfixing wounds, the patient is in a deep coma.

Finally, but not rarely, is a bullet stuck in the skull. In some societies, people celebrate a wedding, baptism, circumcision, or a funeral, by shooting rifles into the air. As usual, what goes up must come down, and not infrequently the bullet coming down strikes someone in the head, although the shoulders, back and chest are not exempt.

MANAGEMENT OF BULLET INJURY
Follow preparations as for depressed skull fractures (51.6); make a horseshoe or inverted "U" flap (51-20) around the bullet wound.

Debride the scalp wound, but perform an immediate 1° closure since the scalp has such a good blood supply.
The loss of tissue may make the closure of the flap difficult. A small lateral incision at the edge of the inverted U will allow you to rotate the flap slightly to make closure easier.

HORSESHOE SCALP INCISION

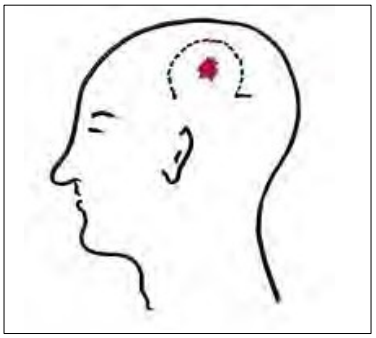

Fig. 51-20 INVERTED 'U' SCALP INCISION *After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013*

Turn the flap down (51-17C), twisting the toothed forceps holding the flap to stop the bleeding. Examine the hole in the bone; it will bey filled with blood clot, torn skin, hair, dirt, cloth, bone fragments, & damaged brain tissue. Carefully remove these with a bone nibbler (rongeur), till you can see the intact dura all the way around.

Using *very low pressure* suction, aspirate the haematoma and injured brain tissue. Irrigate with normal saline and aspirate again and again until you have removed all the devitalised tissue, foreign matter, loose bone & damaged brain tissue. Carefully use your finger to search for any bone fragments.

N.B. Damaged non-viable brain tissue looks like yoghurt or porridge and is a semi-liquid; living brain resembles jelly and holds firm.
It is the organic introduced into the wound matter that causes infection, not the bullet or metal fragment

If you find the bullet or fragment, remove it. *Don't blindly poke around searching for it! Don't pull or tug at anything!*

A bullet has an aerodynamic shape and, at the very end of its trajectory within the brain, can easily glide between neurons without injuring them. It will then be beyond the cone of tissue destruction.
A metal fragment, however, has an irregular shape and cannot glide; it will always be inside the cone of tissue damage.

Once you have aspirated away all the damaged brain, you will see a pulsating wall of brain tissue, which may ooze blood. Pack the wound for 5 mins with a compress of warm saline, dilute adrenaline solution or hydrogen peroxide.
N.B. You can use H_2O_2 here without worrying about any increase in intracranial pressure as the skull is no longer a closed box, so gas bubbles can escape. Also loss of brain volume will allow for some cerebral oedema.

Freshen the edges of the injured dura, but *don't try to close the defect directly*: use a piece of *temporalis* muscle or *frontalis* fascia to suture into the defect. If the hole is too big, use a *fascia lata* graft (51-11).

Make sure the dural closure is watertight by using a continuous interlocking monofilament suture of 3/0 or 4/0. Then check for haemostasis and close the scalp in the usual manner. If there was much oozing, leave a suction drain under the skin flap for 24h.
N.B. The brain will swell, so don't make closure or dressings too tight!

HOPE, (9yrs) sustained a gunshot wound to the right parietal lobe, and arrived within 1h, with a GCS of 3/15, but haemodynamically stable. The range of shot or its velocity could not be determined. The defect in the skull was 4cm in size and its depth c. 10cm. No ventilators, radiographs or scans were available.
After suggesting a poor prognosis to the next of kin, with a laryngeal tube in situ, and an anesthetic assistant bagging his airway extremely patiently, the wound was irrigated gently, taking out chips of fracture, dirt, débris and even necrosed brain matter that came out spontaneously. The patient survived and so, the dura was closed with fascia lata 2days later, and the skin with an advancement flap.
Thanks to extensive physiotherapy and dedicated nursing care, the patient was discharged, ambulant with support as he had residual weakness in his contra-lateral leg. He was advised to wear a helmet outside and to not sit under any fruit-bearing tree!
LESSON: The minimum in surgery is often the maximum in results.

MANAGEMENT OF TRANSFIXING SKULL WOUNDS

Both for unilateral & bilateral wounds, the best policy is conservativee. Make an S-shaped incision over both entry and exit wounds, insert a thin catheter into the track and gently aspirate while withdrawing the catheter. Close the dura and then the scalp, but don't introduce a drain.

JANNY (24yrs) had a gunshot to the left half of face and forehead. He was fully conscious and had normal vital signs but was bleeding profusely from the entire bullet trajectory which involved the left maxillary antrum, the zygomatic arch, the left orbit, the nasal bridge and the right eyebrow. The entire eye globe was ruptured.
The wounds were irrigated in the OT under GA. The globe was completely ruptured and had to be eviscerated. The rest of the wound was debrided simply and packed. No CSF leak was found. Subsequently, primary closure was achieved, and the patient was discharged, ambulant, without any neurological deficit except for the loss of his left eye.
LESSON: *Don't be overwhelmed by the grossness of an injury!*

MANAGING A BULLET STUCK IN THE SKULL

Usually, these patients also often come walking and talking, perfectly conscious, but *never try to remove the bullet outside the operating theatre*!

Look at the skull radiograph. There are 3 possibilities where the bullet has gone:
(1) it has penetrated only the outer diploe or the entire thickness of the skull, without penetrating the dura.
(2) it has penetrated the dura and gone into the brain, away from the sagittal sinus.
(3) it has penetrated the sagittal sinus.

In the 1st case, slit open the scalp with the bullet in the centre of your incision and retract the edges. Pull out the bullet, debride the scalp wound, and close the skin.

In the 2nd case, make a cruciform incision with the bullet at its centre and one arm long enough to perform a burr hole right next to the bullet. Then nibble the bone until you have isolated it. Remove it, aspirate any damaged brain, irrigate, and close the dura and scalp.

The 3rd case is a difficult problem with several pitfalls, but you can still proceed if you take certain precautions.

Perform a formal horseshoe scalp flap (51-10C) to allow good access. Slit the flap from the bullet to its edge so that you do not push it in further. Now, perform a burr hole next to the bullet and nibble away the bone edges as necessary (51-21).

The hole in the sagittal sinus is usually too large to close directly, so you will need a graft to close it. The easiest way is to make a pedunculated flap of dura mater next to the site of the bullet with its base parallel to the edge of the sinus and long enough to cover the hole comfortably when it is flipped over.

CRANIOTOMY FLAP AROUND A BULLET

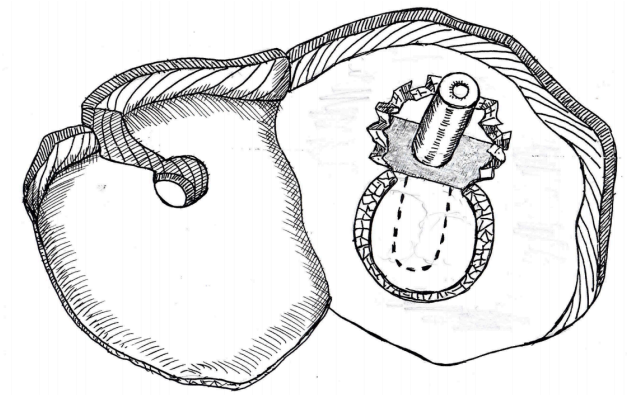

Fig.51-21 CRANIOTOMY FLAP AROUND A BULLET. Slit a flap from the bullet and nibble around it to prevent it from pushing it in further.

If you try removing the bullet while the patient is lying flat, you will cause torrential haemorrhage!
The superior sagittal sinus has a triangular cross-section with each angle tethered to keep it open. Like all intracranial venous sinuses, the sagittal sinus has no valves and ultimately drains into the jugular and brachio-cephalic veins, superior vena cava and right auricle, with only one valve in the lower jugular vein to stop backflow of blood during auricular systole.

This is the only valve in the venous drainage of the head. As a result, the pressure in the right auricle is reflected in the sinus.

Raising the head above the level of the heart decreases the pressure in the sinus. But, raising it too high decreases the pressure so much that, if you remove the bullet, air will rush in creating a massive embolus.

So, your anaesthetist should raise the patient's head slowly bit by bit, while an assistant fills the wound with normal saline. Carefully jiggle the bullet a little; blood will come out.
As you lift the head higher, the less blood flows out. At some height, c.25-30° of elevation, you will reach an equilibrium where blood no longer flows out, and saline is not sucked in.

You can now safely remove the bullet.

To close the hole in the sinus, flip over a dural flap and suture it over the hole in the sinus with continuous interlocking monofilament 5/0 or 6/0 suture. Cover the wound with a gauze compress and wait 5mins.

If bleeding from the needle holes has not stopped, repeat for 5 more mins. Now lower the head.

Debride the skin wound and close the scalp without a drain.

POST-OPERATIVE MANAGEMENT
Note that raised intracranial pressure in projectile wounds is rare. Primary blast injury, however, which may accompany a shrapnel wound or exist on its own, may cause increased intracranial pressure.

A projectile wound is dirty so administer antibiotic cover with high-dose penicillin-G plus chloramphenicol or a cephalosporin plus metronidazole for at least 10days.

51.10 Child 'ping–pong' skull fracture

A blunt object, which causes a large depressed fracture in an adult, causes a ping–pong ball fracture in a child, whose skull is soft and dents instead of fracturing. The indications for not operating on a child are even stronger than in an adult, because these fractures rarely cause trouble. If a child has a single fit, disregard it. The dent will disappear as he grows.

If fits persist, you can try to reduce the fracture with a vacuum extractor. Apply one of the vacuum cups, as you would during delivery. Pull, and hold the surrounding skull with your other hand.

If this fails or there are signs of depressed consciousness, make a hole with a perforator at the edge of the depression and elevate the fracture with a skull elevator: *don't use burrs*.