WAR WOUNDS WITH FRACTURES: A GUIDE TO SURGICAL MANAGEMENT

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FOREWORD

The International Committee of the Red Cross (ICRC) was founded in response to the absence of treatment and care for those wounded on the battlefield. This led to the signing of the original Geneva Convention in 1863. Today the ICRC promotes the 1949 Geneva Conventions and their 1977 Additional Protocol which afford protection for all victims of war be they wounded, shipwrecked, prisoners or civilians.

The hospitals of the ICRC have treated more than 50,000 war wounded in the last ten years. This experience has been gained mostly in developing countries where modern wars are fought and where the majority of casualties are civilian. These circumstances have led the Medical Division of the ICRC to recognise how effective treatment can reach the victims of war with neither specialist surgery nor dependence on high technology. This book approaches the difficult problem of fractures in this context. It is offered in the spirit of sharing to improve the treatment for all people wounded in wars.

Robin Coupland
Co-ordinator of surgical activities.
Medical Division, ICRC.

PREFACE

This book addresses the management of war wounds by non-specialist surgeons in situations where resources and expertise are limited. It is intended to be a practical guide whether or not the surgeon has a special training in orthopaedic trauma.

In time of war, the high-technology facilities and specialist surgeons that are taken for granted in peace time may not be available. However, in writing this book, it has been presumed that x-ray is available. This is not always the case.

A surgeon dealing with wounded people has to work with a basic level of technology applying certain basic principles of wound management. Surgeons working for the International Committee of the Red Cross (ICRC) manage all types of war wounds without the possibility of onward referral; because limb wounds are so common, all surgeons must have knowledge of fracture management. Orthopaedic trauma specialists must also change their approach in a war situation; for bone wounds, they must have lower expectations and adapt to lower levels of technology, with less reliance on metallic implants. They must also ensure that, should complications arise after a sophisticated procedure, there is an easy remedy for the next surgeon who sees the patient.

David Rowley.

CHAPTER 1

THE FRACTURE AS PART OF THE WOUND

It is important to remember that the fracture as seen on the x-ray is only one aspect of the wound complex. The objectives of the management of war wounds involving bone are to:

- remove all foreign material, dead tissue and bone fragments (wound excision)
- achieve skin cover
- achieve bone healing
- restore function (physiotherapy and rehabilitation)

When bone is injured by energy transfer, the blood supply to the bone is reduced in proportion to the degree of surrounding soft tissue damage. However well bone continuity is restored, healing only follows if the blood supply is restored. Therefore, the first step to recovering function is correct treatment of the whole wound.

The placing of fractured bones in correct alignment is termed *reduction*. Maintenance of that position until bony union is known as *holding*. When managing war wounds, reduction is usually part of the wound excision when the patient or affected limb is under anaesthesia. The methods of holding include traction, plaster and external fixation. The ultimate way in which a fracture is held depends on many factors, including the state of the soft-tissue wound and damage to major nerves and vessels.

The need to explore a fracture in order to excise a wound does not imply that a rigid holding technique is necessary. Internal fixation methods with metallic plates, screws or nails need not be used for holding.

The general condition of the patient is important. Anaemia and a poor nutritional state both contribute to slow wound healing, so a routine policy of iron and vitamin supplements is advisable with regular checks of the haemoglobin level.

''War wounds: Basic surgical management'' by R. Gray, published by the ICRC and ''War wounds of limbs'' by R. Coupland, published by Butterworth Heinmann are recommended.

TREAT THE WOUND, NOT THE X-RAY

WHAT TO DO AT THE FIRST OPERATION

Before the patient is given an anaesthetic for wound surgery he must receive an adequate volume of intravenous fluids to replace lost blood. Benzyl penicillin and tetanus prophylaxis are also essential elements of preoperative treatment.

The objectives of the first operation are:

- elimination of the culture medium from the wound (wound excision)
- reduction of the fracture
- initial holding of the fracture

Ninety per cent of the surgeon's thoughts should be concentrated on excision of the wound of soft tissues and bone and only ten per cent on the method of holding the fracture.

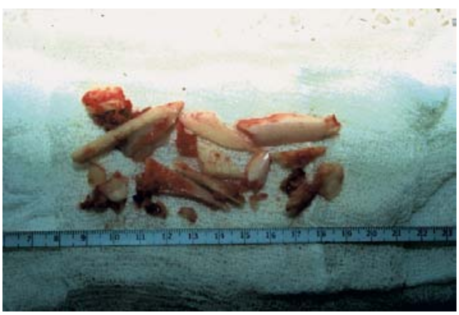
Wound excision

The soft-tissue wound. The first operation includes excision of a minimum of skin, muscle which does not bleed or contract and any damaged subcutaneous fat, i.e. removal of the bacterial culture medium. Extension of skin wounds by incision should be in the axis of the limb, and obliquely or transversely across joints. The wound excision should not be influenced by the risk of exposing bone, as leaving dead muscle and fat do not protect underlying bone and do not preserve function in the long term. This applies in particular to the arm and thigh, where fractures exposed by wound excision are surrounded by a large volume of surrounding muscle; such wounds granulate rapidly and readily accept a skin graft.

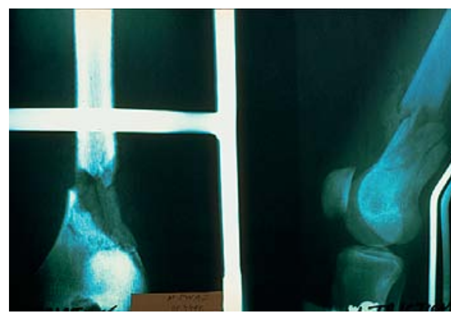
The bone wound. All unattached bone fragments should be removed however large; these are all dead. The periosteum should be retained if possible. *Any fragments still firmly attached to periosteum should not be removed.* It is usually possible to retain some semblance of the bony architecture and the majority of the periosteum. Great care should be taken to avoid creating unnecessary bone gaps. Any periosteum that is left has the capacity to generate new bone.

A left thigh with two parallel bullet wounds.

The radiographs show bony comminution. After wound excision the skeletal traction over-distracted the bone ends. This was corrected by adjusting the weights.



The bone fragments were loose with no periosteal attachments and so were removed.



Five weeks after wound excision, bone healing has occurred from the intact periosteum; callus can be seen.

Look at the ends of the major fragments (the bone ends) : are they *dirty*? Are they *stripped* of periosteum and soft tissue? If they are dirty and not stripped of periosteum, scraping of contaminated bone is all that is required. If they are clean and stripped they should not be resected but laid back down in the periosteal and soft tissue bed. If they are dirty *and* stripped, this presents a real difficulty. Gently scrape the medullary cavity until fresh bleeding bone is reached and remove the dirty cortical bone with bone nibblers.

Correct bone wound excision is difficult. If bone gaps are created unnecessarily in pursuit of a clean wound one risks later loss of function.

Late presenting wounds. In wounds that present after days or weeks, the ''culture medium'' is already infected and must be excised along with dead bone. The problems specific to the management of bone infection are discussed in detail later (page 50). Large bone fragments which are obviously dead should not be left. Dead bone is white. The argument that leaving some residual dead bone will retain overall bony shape and architecture is not valid because infection is probable and will persist until the dead bone is removed. It has to be accepted that a bone defect may be created; this defect will be larger if the removal of dead bone is delayed further. With old wounds a more aggressive approach usually pays.

Take the opportunity to align the fragments

It is possible in all but very extensive bony destruction to roughly align the major fragments. *The time to achieve good alignment is at the first operation;* this becomes more difficult with time as soft tissues adhere to bone as part of the early healing process. This happens irrespective of how the fracture is held.

Holding the initial position

Most fractures can be safely held between the first and second operations (a period of four or five days) by a plaster of Paris (POP) slab or, in the case of a femoral fracture, by means of skeletal traction. Access to the wound is not necessary when the wound excision has been correctly performed, so it is possible to follow a policy of no dressing changes between the first operation and delayed primary closure. The limb must be elevated during this period.

Excessive bone excision along with the periosteum leaves no healing potential for the bone. Inappropriate use of a free fibular graft will never compensate for this. *Do not attempt this.*

A DECISION ABOUT THE DEFINITIVE HOLDING TECHNIQUE CAN WAIT UNTIL THE SECOND OPERATION

Wounds involving joints

Articular cartilage obtains its nutrition from synovial fluid, which is produced by synovium. As joints move, synovial fluid is encouraged to circulate, thus lubricating, feeding and protecting cartilage. Therefore an intact synovium which has a good blood supply is very important.

Excision of penetrating joint injuries is subject to the same principles as those that apply to long bones. Unattached bone and cartilage should be removed and every effort made to preserve synovium.

If penetrating injuries are small, open the joint through a separate incision and wash out the joint with saline to remove any foreign material and loose bone or cartilage fragments. Put in a suction drain and close the hole and incision in the synovium with an absorbable suture. The rest of the wound should be left open for delayed closure.

With large wounds of joints, the excision can be done through the wound itself. As much synovium as possible should be left. The joint should be washed with saline and the synovial defect closed by adapting capsule or muscle around the wound if necessary.

Resist the temptation at the first operation to remove large osteochondral fragments. A ''bag of bones'' held by the damaged capsule may gain some joint congruity, especially if early active movement is encouraged. Movement helps cartilage nutrition and permits some moulding of osteochondral fragments. Useful function may be restored. Internal fixation of such wounds should be avoided: it is very dangerous.

Joint capsule and ligaments should be sutured at the second operation as part of the delayed primary closure.

CLOSE THE SYNOVIUM OR COVER THE JOINT

Dressing the wound

At the end of the first operation the wound should be washed with saline and dressed with large quantities of loose, dry gauze and cotton wool. In the period between the first and second operation there is no need routinely to change the dressing. Vaseline gauze and antiseptics should not be used. A plaster slab may be placed over the dressing (page 27); this also helps keep inquisitive hands and eyes off the wound!

The policy of leaving operative dressings undisturbed until delayed closure requires the use of bulky dry dressings. Outer dressings can be changed if dirty but the dressing which is in contact with the wound surface should be left. Routine examination of wounds is unnecessary, is painful for the patient and contributes to the spread of infection.

Should the patient's general condition deteriorate after the first operation with tenderness or visible skin redness proximal to the wound this indicates incomplete excision of the wound. In this case *the patient should be taken back to the operating theatre and given an anaesthetic* for reassessment of the wound and re-operation.

THE FIRST OPERATION: IS THE WOUND EXCISION COMPLETE? WHAT IS THE SAFEST AND EASIEST WAY TO HOLD THE FRACTURE?

WHAT TO DO AT THE SECOND OPERATION (4th to 6th day)

Closure

When the wound is clean, close by sutures or skin graft. In rare cases a reconstructive procedure may be necessary (page 54). Small cavity wounds may be left to heal by themselves (granulation).

When the wound is infected or there is further necrotic tissue, it should be excised again, any more loose bone fragments should be removed and the wound left open for delayed closure.

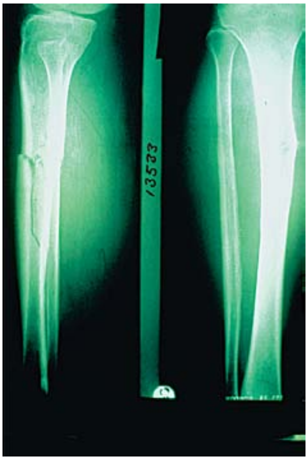
In both cases, assess the bone and periosteal defect and reconsider the method of fracture holding.

THE SECOND OPERATION: CLOSE A CLEAN WOUND; IF IN DOUBT LEAVE IT OPEN.

Assessing the bone defect

When inspecting the wound, feel and observe the periosteal tube: some continuity should remain in all but the worst injuries. Bone continuity and an intact periosteum permit fracture healing.

The degree of bone damage may be classified according to the Red Cross Wound Classification; this makes a distinction between two fragments and many fragments as well as indicating the extent of soft-tissue damage. However, it does not apply to the bone defect left after the first operation. The following is a guide to assessing the bone defect.



This tibia is fractured but the bone has no defect. Following excision of the soft-tissue wound accompanying such a fracture, healing will progress smoothly.

A. Small and circumferentially incomplete bone defects

These defects heal well if the wound excision is correctly carried out.

A type A defect in a child's tibia - there is overall continuity of the bone despite the incomplete defect.

B. Small and circumferentially complete bone defect (<3 cm)

These defects may be retained or permitted to shorten. In the lower limb any slight shortening is usually adapted to by the patient.

This bullet wound includes circumferential bone loss but the defect is small. All the periosteum is usually present in such wounds and must be retained during surgery.

C. Large and circumferentially complete bone defect (>3 cm)

With such defects there may be some callus formation from the remaining periosteum. If the progress of callus formation is slow on the radiograph, it may be corrected by a bone graft later.

There is gross comminution and bone loss; this will lead to a type C defect. Many of the fragments will be loose but some will still have good periosteal attachments and should be retained.

D. Large defect associated with circumferential loss of bone and periosteum

The osteogenic potential in such gaps is very small. Even with a subsequent bone graft, healing may take months or years. Management decisions will depend on the site of the fracture and other injuries. There is no easy answer to such problems.

A severe tibial wound with this kind of defect might raise the question of below-knee amputation, depending on locally available prosthetic facilities. However, in severe femoral fractures the greater degree of disability following an above-knee amputation means that a more prolonged and challenging plan of treatment may be justified in order to preserve the limb.

The choice of holding is then made according to which bone is fractured, the wound itself, its position and the bone defect.

CHAPTER 2

HOLDING FRACTURES: THE CHOICE

There is no single, ideal method of holding a fracture in its reduced position. Any method has its advantages and disadvantages. The most appropriate method is determined taking into account the bone injured, the nature of the fracture and the soft-tissue wound. The method chosen is also influenced by the experience of the surgeon, his expertise and the quality of postoperative nursing and physiotherapy. The principal methods for treating fractures associated with war wounds are plaster of Paris (POP), skeletal traction and external fixation.

An operative method (external fixation) permits early mobilization and discharge of the patient. These advantages and the higher risk of complications must be weighed against the safety and simplicity of other methods (traction or POP) which offer a better chance of union and acceptable function. *Avoiding complications has higher priority than rapid mobilization, especially where severe wounds are treated by non-specialist surgeons.* Simple methods of treatment are best: the more complicated the method the more complicated the complications!

Two phases of holding may be considered:

Initial holding - between the first and second operation. This should be confined to traction and POP techniques.

Definitive holding - when the decision is made after the second or subsequent operations. Definitive holding may be a continuation of initial holding or a new technique. For instance, initial holding of a tibia fracture may be by a POP slab and the definitive holding for reasons of wound access and mobilization of joints may be external fixation.

PLASTER

The use of plaster of Paris (POP) is a cheap and effective way of constructing a shaped splint for a limb. It may be applied as a slab (''backslab'' or ''splint'') or as a complete cylinder (''circular'' or ''circumferential'' POP). In addition, POP may be used to construct simple functional braces.

POP slabs are used as a temporary means of holding in the initial management of open fractures after wound excision. They provide support and maintain alignment and thus reduce pain; they allow for some limb swelling. POP cylinders can be used as the definitive method of holding when the wound is closed or requires only dressing. Functional braces are used later when mobilisation with load-bearing is desirable.

The effective use of POP, whether in the form of slabs, cylinders or functional braces is a clinical skill which must be learnt and practised.

Principles

POP slabs function by providing a well-fitting support which is bandaged onto the limb over the wound dressing with minimal risk to the circulation through constriction. The bandages can be slackened or tightened easily.

A POP cylinder or functional brace works in two ways. First, it is moulded to the limb so that there are three applied forces, one on one side and two on the other side, providing counter-forces which splint the injured limb in three-point fixation. The single point is positioned at the fracture site on the side most deformed by the injury. This method of *three-point holding* is particularly suitable for low-energy injuries when there is soft-tissue continuity - the so-called ''soft-tissue hinge''. Second, it gives general support to soft tissues by providing a *rigid exoskeleton* of strong material to compensate for the loss of bony continuity. This in turn supports the fracture through a hydraulic effect permitting positional control and weight-bearing. A functional brace works in the same way (see below).

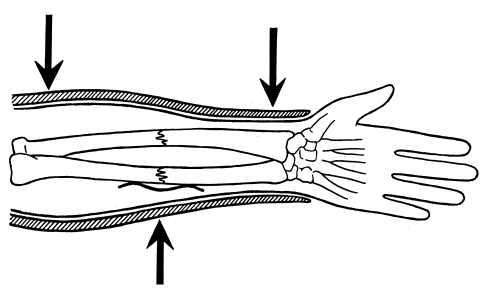
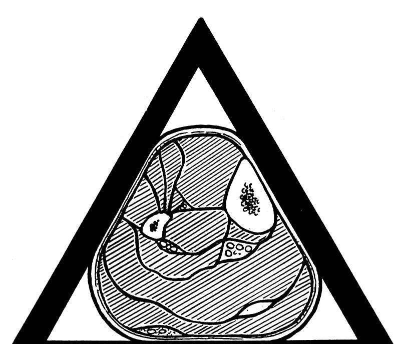


Diagram showing how a fracture is subjected to a three point force applied through a moulded cast.



Moulding also helps to prevent rotation and the rigid form of the cast will exert an even hydraulic support around the fracture site.

Indications

POP may be used:

- as the initial holding method of open fractures
- as a later holding method after soft tissue healing
- in the management of nerve palsies
- as primary treatment of closed, low-energy injuries. (This is not considered in this booklet. Please refer other texts such as ''Apley's System of Orthopaedics'' (Apley AG and Solomon L) or ''Primary Surgery, volume 2: Trauma'' (King M).

Conclusion

POP slabs are the best choice for initial holding after the first operation (exception - the femur). Whatever method of holding is chosen, the injured limb should be put in a POP cylinder as soon as the soft tissues permit so that controlled weight-bearing can commence. The principal disadvantage of using plaster for definitive holding is that limbs and joints are immobilized for long periods. POP is the first choice for holding all closed fractures.

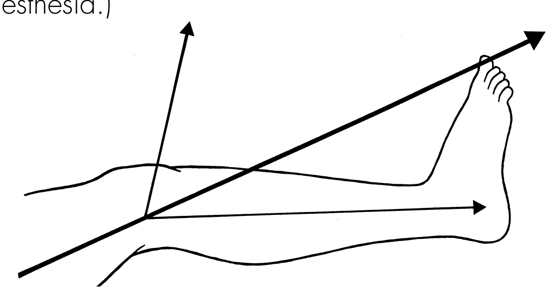
USE POP SLABS FOR INITIAL HOLDING. EXCEPTION – THE FEMUR

TRACTION

Traction is a simple way of managing most lower limb and humeral fractures. It is safe, with few complications, provided it is carefully supervised by the surgeon. It allows for the substitution of other techniques in the event of complications.

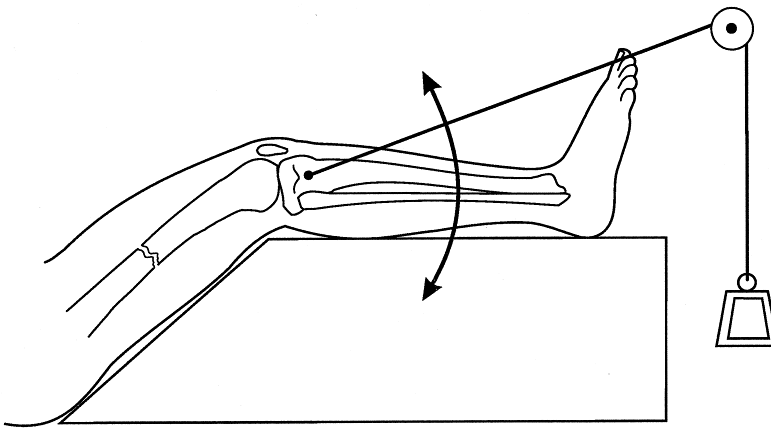
Principles

Traction is a holding method whereby a force is applied to a limb so as to resist the tone in the muscles surrounding the fracture; this enables the fracture to be held in alignment. (This should not be confused with the ''traction'' required to reduce a fracture and which needs anaesthesia.)



Traction is applied to a limb through a skeletal pin which acts as a focus for the force applied by a weight. There is always some force exerted along the axis of the limb irrespective of the position of the limb.

Larger forces are applied along the axis of the limb via skeletal pins, pulleys and weights (skeletal traction). When lesser forces are required these may be transmitted via adhesive tape (skin traction). The direction can be altered by adjusting the position of the pulleys.



Traction applied for a femur fracture with the knee in almost full extension. The position of the traction pin is such that the force is applied in a uniform direction and is not affected by the position of the knee. The knee can therefore be flexed through 90 degrees in traction.

Indications

Traction may be used:

- as an initial method of immobilisation after the first operation (femoral, tibial and humeral fractures)
- as a definitive holding technique in femoral and some tibial fractures;
- to hold some humeral fractures (especially difficult fractures near the elbow) after the second operation.

Conclusion

Traction is simple and safe; it leaves all options open for alternative methods of holding. The principal disadvantage is prolonged confinement of the patient to bed.

Non-specialist surgeons should ask themselves the question: why not use traction?

TRACTION IS SAFE FOR FEMORAL FRACTURES

EXTERNAL FIXATION

In an era of high-technology wars it is easy to think that the management of war wounds must also use high technology. External fixation is favoured by military medical services of developed countries to facilitate evacuation of the wounded soldier away from the war zone. This gives the patient access to definitive high-technology surgery by specialists in bone and soft-tissue reconstructive surgery under optimal conditions in referral hospitals. Outside a modern military environment, the surgical management of wounds requires a basic level of technology for surgeons who in civilian practice have no special interest in trauma orthopaedics. High-technology equipment and the surgical skills required to use it are not easily transferable.

The concept of external fixation is deceptively simple – metal frames mounted across the fracture and attached to the bone via pins – but this hides many practical difficulties of application; the technique may not be the best choice for the definitive care of the whole limb.

Principles

External fixation stabilizes long bone fractures, gives access to the wound and permits mobilization of joints adjacent to the fracture. These advantages are offset by inhibition of callus formation due to the rigidity of holding and complications related to the pins in the bone. Therefore it is best to remove fixators as soon as possible and replace them by a POP cylinder or functional brace.

The technique requires considerable skill on the part of the surgeon. If the fixator is left in place for a long period it requires a frame which can later be partially destabilized along the axis of the bone to stimulate callus formation – a process described as ''dynamization''. Movement of a broken bone held by a fixator places great demands on the bone/pin interface and, unless the technique is skilfully applied, the pins work loose and the fixator fails.

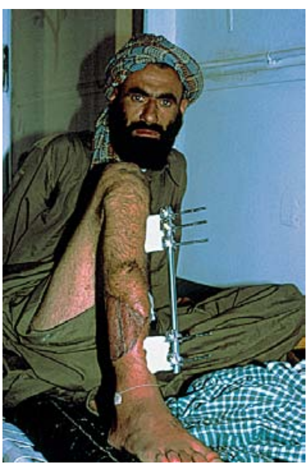
Physiotherapy encourages the patient to mobilize himself and the injured limb.

Indications

In the context of ICRC hospitals, the role of external fixators is limited to severe injury where there would be difficulty in holding the fracture by any other means. There is rarely an advantage in applying external fixation as a method of initial holding. It is important to realize that if the wound management is correct there is less need for access to the wound and therefore less need for external fixation. The surgeon should use the simplest and safest technique available and not assume that external fixation is always the best option.

Examples of cases where the use of external fixators is valuable are:

- Type C and D tibial wounds (page 18) where there is considerable soft-tissue and bone loss. The fixator should not be applied at the first operation – calcaneal traction or a POP slab are safe and simple options until the wound is assessed at the second operation. The only exception is in severe upper tibial fractures with vascular damage.
- Humeral fractures with extensive soft-tissue loss and where stability cannot be achieved by any other means. However, the axillary and radial nerves are at risk because they are close to potential pin sites. When there is bone loss, prolonged procedures to maintain humeral length are inappropriate; external fixation can be used to close the bone gap and so shorten the bone. Restoration of humeral length is not essential in salvaging useful arm function.



An external fixator has permitted use of a fasciocutaneous flap to be used to cover an exposed tibial fracture.

The fracture has no defect of bone but the fixator has facilitated access to the soft tissues.

Conclusion

External fixation is not an easy option. The application is difficult and there are many potential complications even with the best expertise. The question is always: is this really the simplest and safest way to hold the fracture? There is rarely a need to apply external fixation at the first operation, when the wound excision has priority over the method of holding.

EXTERNAL FIXATION IS NOT EASY AND CAN BE COMPLICATED

INTERNAL FIXATION

When managing people wounded in war, internal fixation may be successful in selected cases evacuated to specialized facilities where the surgeon is experienced in such techniques in civilian practice and has the proper equipment and operative facilities. Otherwise, no metal should be implanted in the wound because of the high risk of dangerous bone infection. Internal fixation should never be used for initial holding. In the context of ICRC hospitals it is not an option to be considered at any stage.

DO NOT USE ANY FORM OF INTERNAL FIXATION

CHAPTER 3

PLASTER OF PARIS (POP) TECHNIQUES

INITIAL HOLDING OF OPEN FRACTURES WITH POP SLABS

The stability of a fracture relies on its bony architecture and the degree of residual soft tissue support. For most wounds, POP slabs provide adequate stability for initial holding of the accompanying fracture. They are effective as long as the principles of wound management are understood and applied. POP cylinders should not be used for initial holding unless they are split down to the skin and levered open.

Injuries for which POP is unsuitable after the first operation include all femoral fractures, because of the difficulty of immobilizing the hip.

The key to making effective slabs is to apply POP strips at points of maximum stress and to ensure smooth, finished edges that are not bulky and do not dig into the skin. The joint above and below the fracture must be incorporated. This is most effectively achieved by using the ''figure of eight'' technique. The POP strips are applied over the wound dressing. An example for the lower limb is shown below – the principles and basic technique can also be applied to the upper limb.

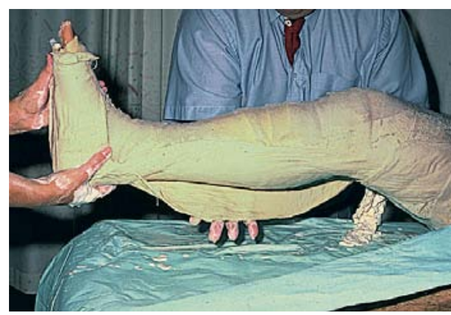
1. Prepare your materials before you start. You need two slabs of POP (6 inches or 15 cm), each being eight layers thick. Measure them on the good limb, from the tip of the toes to just below the greater trochanter. You will also require stockinet and padding to cover the leg and bandages to hold the cast in place.

2. The stockinet is applied over any wound dressing from the toe tips to the greater trochanter.

3. Apply padding over the stockinet paying particular attention to points at risk from pressure, including the malleoli, heel, patella and head of the fibula.

4. Apply the first slab so that it encloses the little toe and lateral border of the foot, passes posteriorly at the heel and is moulded over the medial side of the calf and knee to end on the medial aspect of the thigh.

5. the slab should take the configuration shown.



6. Apply the second slab in the same way as the first but starting over the big toe and finishing postero-laterally on the thigh so that it overlaps slightly with the first slab.

7. Trim off any excess plaster; folding it back results in an uncomfortable, lumpy cast.

8. Gently but firmly bandage the cast into position.

9. Hold the cast until set with the knee flexed to 30 degrees; this will prevent the cast slipping down and help maintain the position with respect to rotation. Keep the foot at 90 degrees to the leg. Elevate the finished cast on pillows.

POP AS A SECONDARY (LATER) METHOD OF HOLDING

As a general rule, the patient's limb should be moved from traction or external fixation to a light POP cylinder as soon as possible. This permits load-bearing on the fracture which is a potent stimulus to bone healing. Joints should be as mobile as possible before being enclosed in POP.

For the **tibia**, the Sarmiento cast is ideal because it permits knee movement. For the **femur** there are two choices. The simpler method is to construct two simple plaster shells which do not overlap and are held on the leg by bandages. These "Chinese splints" – named after bamboo splints – provide good support to soft tissue and also provide the contracting muscles with feedback during exercises. The alternative is a femoral cast brace with hinges at the knee. This permits movement of the knee, controls rotation and angle of the fracture and provides vertical support. The use of femoral braces is determined by the availability of suitable hinges and the skills needed for their application. The advantages are earlier mobilization and the ability to treat joint-associated injuries. Hip spicas are a third possibility, but are uncomfortable and immobilize the knee. They should not be used except in particularly difficult upper-third femoral fractures where other methods have failed. They are better tolerated by children.

The "Sarmiento" tibial brace

The important feature of a Sarmiento brace is that it is moulded around the upper third of the tibia, shaped to the tibial condyles at the front and slightly flattened at the back to produce a generally triangular cross-section.

1. Prepare five six-inch (15cm) and two four-inch (10 cm) plaster bandages, two rolls of padding and stockinet.

2. Sit the patient on the end of a couch or bed so that the leg hangs vertically. Cover it with a single layer of stockinet from the toes to six inches (15cm) above the knee.

3. Cover the stockinet with padding, paying attention to vulnerable bony points.

4. Make the central cylinder by applying two six-inch (15cm) plaster bandages.

5. Mould the cylinder so that the upper third is flattened at the back and shaped around the tibia at the front.

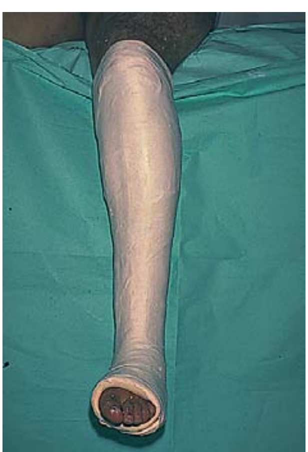
6. Ensure the foot is kept at 90 degrees to the leg whilst the foot piece is constructed.

7. Once the cast has set enough to retain the moulded shape apply the upper part of the cast by forming a plaster shape up around the knee using the four-inch (10cm) plaster bandages.

8. While the plaster is still wet turn down the stockinet so the patella remains covered; the cast must be low enough behind the knee to allow the knee to flex. The finished shape should encompass the femoral condyles when the knee is flexed.


9. Let the plaster set.


10. Reinforce the sole to permit walking.


11. The finished POP cylinder from the front.


12. The finished POP cylinder from the side. The knee should flex to 90 degrees and fully extend. The foot must be in a neutral position to permit comfortable standing and to prevent late ankle stiffness.

Chinese splints

Originally "Chinese splints" were made of bamboo wands which were bound onto the limb, making a fairly conforming but rigid splint. The use of moulded plaster slabs held with bandage is a way of adapting the idea of bamboo to the principles of a functional brace.

The Chinese splints are worn until the fracture becomes immovable on firm stressing. Besides providing comfort and a small degree of positional control, the splints also give useful proprioceptive feedback to exercising muscles, thus making physiotherapy more effective.

Chinese splints

1. Make sure the limb is clean and then place the thigh in two layers of stockinet.
2. Cut two slabs as long as the thigh and eight layers thick.
3. Wet the slabs and apply to the inner and outer aspects of the thigh, moulding them until they set smoothly following the contours of the soft tissues. As the plaster sets, turn up the edges to provide a smooth finish.
4. Ensure that the two slabs do not overlap and then remove the slabs from the limb by cutting the outer of the two layers of stockinet.
5. Trim the two slabs to ensure that the edges will not dig into the skin especially around the knee during flexion.
6. Replace the two slabs on the inner layer of stockinet and maintain in place with a crêpe bandage.


These simple slabs are moulded while the plaster is setting.


They should fit the thigh exactly and are held in place by bandages.

The femoral brace

There are two components to a femoral brace – the cast pieces and the hinges. The shaping of the plaster is the most important part of the procedure.

Hinges may be bought (usually plastic) or made locally from aluminium or plastic. The bi-pivotal hinge has the advantage of permitting normal knee movement.

The femoral brace may be constructed using plaster of Paris. A standard below-knee cast and a well-moulded plaster thigh piece are constructed; the latter is then anchored to the below- knee walking cast by means of simple hinges which can usually be made locally following the design shown in the photographs.

To construct the thigh piece:

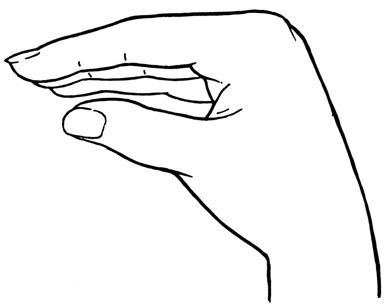
1. Cover the thigh in two layers of stockinet.
2. Apply the plaster directly to the stockinet without padding, making a well-moulded cylinder from the greater trochanter to two fingers breadth above the patella.
3. As the plaster dries, gently flatten the upper third on the soft medial part of the thigh with the palm. This helps control rotation.
4. Apply the hinges as indicated in the diagram to join the thigh piece to the below-knee walking cast.

A knee hinge made locally is used here to join a simple below-knee walking POP cylinder to a thigh cylinder to allow early mobilization of a patient with a femur fracture.

POP IN THE MANAGEMENT OF NERVE PALSIES

When external fixation or traction is used, supplementary support by POP slabs may be needed to prevent deformity from nerve palsies. One example is a night splint for the ankle when there is associated sciatic or peroneal nerve injury; this prevents the joint becoming stiff in an equinus position. Similarly, a wrist drop secondary to a radial nerve palsy should be held in dorsiflexion by a POP slab.

POP SLABS FOR HAND INJURIES



The correct position for a hand to be splinted. The interphalangeal joints are extended and the metacarpophalangeal joints are flexed to 90 degrees.

An injured hand should be elevated and immobilized with the metacarpophalangeal joints in 90 degrees of flexion and the interphalangeal joints in full extension. In this position, the capsule and collateral ligaments of these joints are maximally stretched and cannot contract. This facilitates subsequent restoration of function. The presence of open wounds of the hand does not prevent the use of this ideal position. It can be achieved by fully extending the wrist and applying a slab. Bulky dressings in the palm help maintain the hand in the correct position. A hand splinted flat or with the fingers fully flexed can result in permanent loss of normal function.

MANAGING PATIENTS IN POP

After any POP cast is applied the state of the limb must be carefully monitored with a view to detecting problems of constriction of circulation. Any complaint of pain or numbness should be taken seriously. Examine the distal limb for swelling, cyanosis and presence of pulses. The limb can look normal and have normal pulses and yet still have a compartment syndrome. A sensitive indicator is to dorsiflex gently the toes or fingers; in the presence of compartment syndrome this elicits extreme pain. If there is any suspicion of circulatory problems the plaster and lining must be split down to the skin and levered open.

CHECK THE CIRCULATION

Patients should be encouraged to bear weight with crutches as soon as possible in all lower limb injuries: this will not ''overload'' their fractures. Pain mediation feedback between injured limbs and the weight-bearing upper limbs, through the crutches, leads to progressive weight-bearing as the fracture unites. (This subtle biofeedback mechanism is inhibited by internal and external fixation.) Weight-bearing is good for lower limb fractures and should start after the POP is completely dry, which takes 40 hours.

Any complaints from patients of burning or rubbing under the POP might indicate that a sore is developing . In such cases the POP should be removed, the limb inspected and the POP reapplied. Sores can be avoided by correct technique with adequate padding over pressure points such as the heel, malleoli and fibular head. Excessive padding does not compensate for poor technique.

A limb may be put into a POP cylinder before the wound has completely healed. In this case a window can be cut in the POP for the purpose of dressing. The problem of windows is that the soft tissues bulge out and can rub on the edges of the window. If the wound is small and there is little discharge, it can be enclosed in the POP without any need for dressing changes.

A below-knee cast with windows cut out so that wounds can be dressed.

After the application of POP, an x-ray should be taken to check the alignment of the fracture. If satisfactory, this should be followed by a weekly x-ray for two weeks and then monthly films to union. Union is defined as x-ray evidence of progressive callus formation supported by clinical examination indicating that healing is taking place. Malposition must be corrected early in order to avoid malunion. If a fracture is malpositioned in traction or external fixation a secondary cast will not correct that position.

Non-union is not caused by the use of POP; it results from bone and periosteal loss in the wound and wound infection.

After removal of the plaster the patient must be encouraged to move the joints actively and passively. Without motivated physiotherapy the rehabilitation of an injured limb is very slow.

MOVE THE PATIENT AND THE JOINTS AS SOON AS POSSIBLE

COMPLICATIONS OF POP

''Plaster disease''

When a limb is put into POP and the joints immobilized, joint stiffness, muscle wasting and osteoporosis are unavoidable. This syndrome can be reduced to a minimum by the early use of functional braces, isometric exercise and early weight-bearing. These in turn promote a rapid retrieval of function.

Compartment syndrome

Ischaemia of individual muscle compartments of a limb can be produced by the injury, a period of ischaemia secondary to vessel injury, an incorrectly applied tourniquet or a POP cast that is too tight. Symptoms and signs of compartment syndrome include: pain out of proportion to the injury; increased pain on passive stretching of muscles; complaints of paraesthesia. The peripheral pulse may be present if only one muscle compartment is affected.

If compartment syndrome is suspected, first split the POP, bandage and any dressings down to the skin surface and lever the POP apart – even a dressing stiff with dried blood may be sufficient to restrict the circulation. If there is no improvement in signs and symptoms do not hesitate to operate. The operation involves open fasciotomy and decompression of all the compartments (see ''War wounds of limbs'', page 78).

Conclusion

Plaster is a very effective holding technique. Although it is a simple concept, like any other method it requires practice and close attention to detail. Surgeons are well advised to seek instruction in the basics of this technique as they would with any other procedure.

CHAPTER 4

APPLICATION OF TRACTION

FEMUR FRACTURES

For all femur fractures, the best site for the pin is the upper tibia; it should be placed 2.5 cm distal to and 2.5 cm posterior to the tibial tubercle. There is minimal muscle tethering at this site and the knee can be bent without distorting the traction force. A traction pin in the distal femur always tethers muscle and joint capsule, thus inhibiting knee movement. This site should be avoided if possible.

It is very important that the pin be at right angles to the long axis of the tibia; otherwise the distal fragment of the fracture is difficult to align along the traction frame. The pin should also be angulated backwards on the medial side by 10 degrees posterior to the coronal plane of the femur. This exerts a slight external rotation which counteracts the tendency of the leg and with it the distal fragment of the femur to turn inwards.

As a general rule, 1 kg per 10 kg body weight should be applied for femoral traction (see diagram). A counterforce must be applied; otherwise the weight simply pulls the patient down the bed. This counterforce is achieved by tilting the bed backwards so that friction and gravity resist the pull of the weight.

Inserting the traction pin in the tibia.

1. Make skin incisions 1.5 cm long, on the lateral side, and then medially where you wish the pin to emerge.
2. Gently open the muscles on the lateral side down to the bone with an artery forceps.
3. Using a guarded hand drill, make a 3.2 mm hole across the tibia from lateral to medial. Excessive vigour in inserting pins produces heat and compression which damage soft tissue and bone, making the pin site prone to infection. Therefore power drilling should not be used.
4. Using a 4.0 mm Steinman pin on a T-handle, slowly insert the pin down the pre-drilled hole until it emerges symmetrically. Ensure that there is no tension around the pin and skin – extend the incision if necessary to relieve tension. Never suture pin holes.

5. Place a loop or ''stirrup'' and pin guards on the ends of the pin to protect both patient and staff from injury. The loop is important as it permits motion between the applied load and the limb. The loop should rotate freely on an oiled bearing which is clamped to the pin. Any rotation of the pin in the bone leads to loosening and subsequent infection.
6. Dress the pin site with gauze impregnated with diluted antiseptic solution. The gauze should not be allowed to adhere to the pin or skin. Cover the gauze with a wide bandage to prevent interference by the patient.
7. Change the dressing every two or three days unless the gauze becomes soaked with exudate from the pin site.

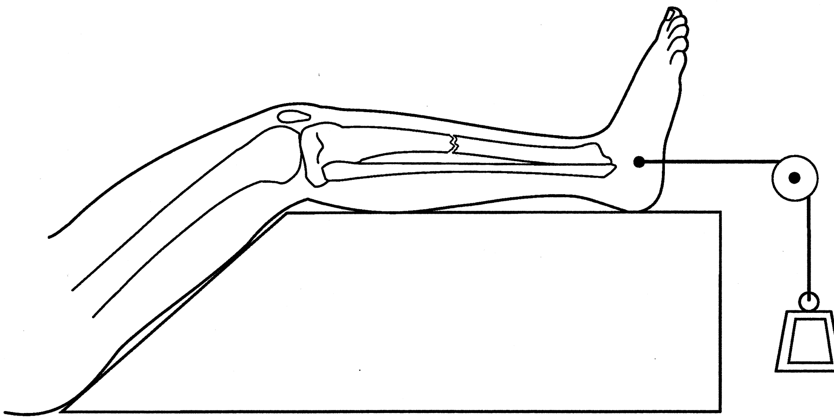
Position of the lower limb in traction

In any fracture the proximal fragment takes up a position that is determined by the balance of forces of the muscles remaining attached to that fragment. The distal fragment, if not held, takes up a position determined by gravity. Successful reduction and holding with traction involves aligning the distal fragment (the whole limb) with the position taken up by the proximal fragment and holding the two in this position.

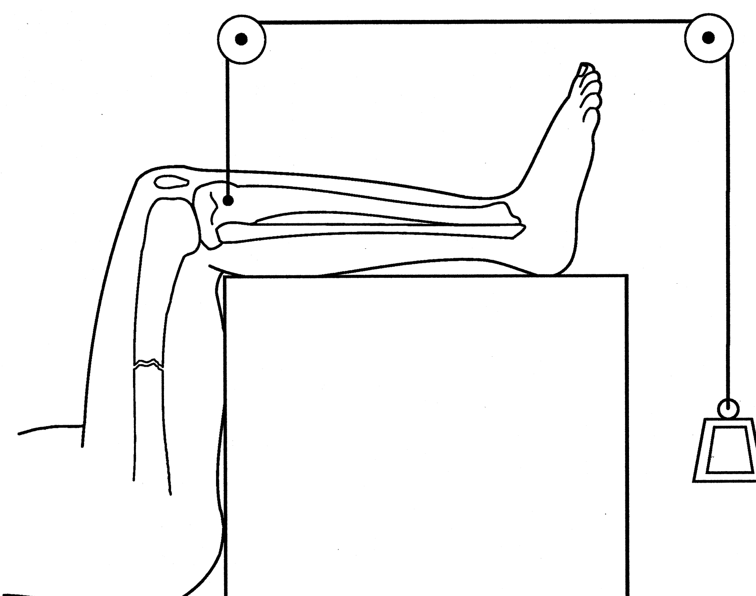
For fractures of the lower two-thirds of the femur, the position in traction can be held by using an adapted Braun frame. This permits variation of the traction cord position through pulleys to ensure that the force is maintained along the axis of the limb. It also elevates the limb. Fine adjustments can be made by padding the frame under the thigh. It is especially important to compensate for posterior sag, which is common with lower femoral shaft fractures. Foam pads can be used; they are versatile, cheap and washable.

This method may not hold a fracture of the upper third of the femur in a good position. In such fractures, the proximal fragment tends to flex and abduct due to the action of the psoas and the gluteal muscles. To align the distal fragment with this flexed proximal fragment a ''90/90'' position in traction is required. This involves flexing both the hip and knee to 90 degrees as shown; the effect of the muscles on the proximal fragment is minimized. This position needs to be maintained only for four to six weeks and has the advantage of ease of mobilization of knee and hip as the limb is lowered onto a standard traction frame.

For all fractures of the lower limb observe the overall alignment. Looking from the end of the bed you should check that the mid-inguinal point, the second toe, and the knee and ankle joints all lie in the same plane.



A tibial fracture being treated on a traction frame. Note how the pulleys ensure that the line of pull is along the axis of the limb.



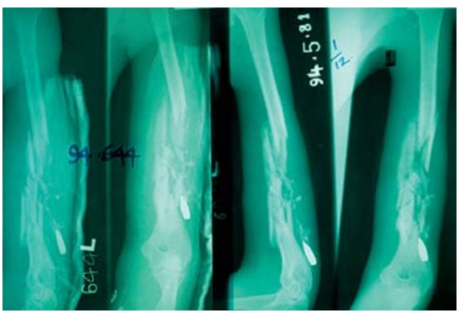
A special traction frame being used to treat a high femoral fracture. The position of the hip in a 90-degree position permits the distal fragment to be held in line with the flexed proximal fracture fragment. The 90-degree knee position allows the joint to be fully exercised during traction management.

TIBIAL FRACTURES

A pin can be inserted through the calcaneum to hold a tibial fracture in traction. The entry site for the pin lies 2.5 cm vertically beneath the lateral malleolus. This is a good site for a pin as there is no tethering of muscle and the ankle can move. It is very important to use the technique described for inserting the pin (page 38). Infection in the calcaneum is difficult to eradicate. The weight required is 0.5 kg per 10 kg body weight.

HUMERUS FRACTURES

A force can be applied along the axis of the arm by using its own weight; the suspended arm in a collar-and-cuff sling is a form of traction which allows the fracture to lie in an anatomically acceptable position parallel to the chest wall.



X-rays of a humeral fracture managed in sling traction. A small slab was used initially only for patient comfort. The bone is healing in good alignment.

MANAGING THE PATIENT ON TRACTION

Checking the fracture position

The position of the patient and the limb in traction should be reviewed twice a day, as it is easy for the position to alter.

Management on traction is an active process. Besides checking alignment, movement of the joints should be encouraged as soon as it is comfortable to do so. A nurse or physiotherapist who understands what traction achieves is essential for successful fracture management.

X-rays should be taken of the position of the fracture within 24 hours of the operation and weekly for the first three weeks. Traction patients should have easy access to the x-ray facilities without altering the position of the fracture. It is important to get a good position as early as possible because as the wound heals the soft tissues adhere to the bone, preventing later adjustment of the fracture position. The position should be checked and adjusted repeatedly until a good position is achieved and then x-rays should be taken monthly until union.

Care of the pin site

Each day the pin site should be checked for tenderness, firmness in the bone and inflammation of the surrounding skin. It should be cleaned with normal saline or a diluted antiseptic and kept free of any encrustation that prevents exudation around the pin.

When can joints be moved?

Early movement of joints is important. However, if the soft-tissue wound is large, active physiotherapy is painful and may hinder wound healing. For most fractures in traction, adjacent joints can be moved after a week. Movement earlier than this is painful and may interfere with early wound healing; however, further delay slows rehabilitation unnecessarily.

When does union occur?

There is no simple answer to this question. The monthly radiographs usually show progressive callus formation from four weeks onwards. It is surprising how well fractures do unite, despite extensive soft tissue damage, when the wound is carefully and completely excised and no infection occurs.

Delayed union (impending non-union) is defined as undue fracture mobility after eight weeks in the lower limb, and six weeks in the upper limb, associated with lack of progressive callus on the x-ray. If the fracture is ''sticky'' but not progressing, consider early mobilization perhaps in a functional brace or cast. No callus on the x-ray after eight weeks is a bad sign.

The most effective method of assessing union is to take off the weight, feel the fracture and stress it gently. If there is palpable callus formation at the fracture which is relatively immobile and pain-free and there is angulation but no shortening on stressing, the term ''sticky'' can be applied. A fracture is usually ''sticky'' after four weeks. Full union before ten weeks in the lower limb is unusual.

When can traction be removed?

Removal of traction and mobilization of the patient can start when the fracture is ''sticky''. This may be as early as four or six weeks even in the lower limb. It is not necessary to wait for union before starting mobilization.

The decision is made on clinical grounds. Remove the weight temporarily from the traction cord. Rotate the limb and see if it all moves simultaneously. For example with a femur fracture: does the greater trochanter move when the leg is moved or rotated? Does it hurt to stress the fracture? Healing fractures are generally less painful on stressing than those which are slow to heal and freely mobile. The x-rays show progressive callus formation but it is not necessary to see full continuity before mobilization. The clinical features are more important than the x-ray, provided that the radiograph shows a general trend towards callus formation.

After removal of traction, a period of one week in bed should follow so joints can be moved and muscles strengthened. When muscle tone is recovered, mobilization on crutches is possible. Some support for the fracture by POP may be needed (page 33). Early mobilization is more likely to make an external support in the form of POP necessary.

COMPLICATIONS OF TRACTION

Infection of pin tracks

Pain around the pin often indicates infection; it should be taken seriously. By contrast a firm and painless pin is not deeply infected.

If the pin is firm but the skin around it is red, tender and adherent to the pin, the pin site should be opened with a knife and forceps and then irrigated daily with a diluted antiseptic solution. The pin must be kept free from the skin. Antibiotics may help the soft tissue element of pin site infection.

If the pin is loose, it is infected and must be removed. Under anaesthesia in the operating room, the pin should be removed and any pus released. The track should be overdrilled if there is evidence of a ring sequestrum; this is indicated by a circle of white bone on the x-ray. If dead bone is retained, chronic infection follows.

A new pin may have to be inserted. If the upper tibial pin is lost, a calcaneal pin is the next choice. As a last resort a pin can be inserted through the distal tibia but care should taken to avoid the fibula and pass behind the tibialis anterior tendon, which can be felt.

Muscle wasting and bed sores

After trauma patients inevitably go into negative nitrogen balance and lean body mass is lost, even if they are already malnourished. This is made worse by immobility.

Management of these problems must start on the day after the first operation if the benefits of improved nutrition in hospital are to be maximized.

Bed sores are caused by prolonged immobility coupled with shearing forces between skin, fat and bone. Pulling of the patient down the bed by the traction weight can be prevented by raising the bottom end of the bed on blocks; the shearing forces are thus avoided. An overhead handle (a ''monkey pole'') encourages patients to pull themselves up off the bed. Patients should also be encouraged to push their bodies up from the bed on straightened arms. Severe bed sores may indicate a need to change the method of fracture holding

Active physiotherapy is a vital part of the treatment of a patient in traction.

Malunion

The most common cases of malunion with traction occur with either lower femur fractures where the fracture sags into the traction frame or proximal femur fractures where the flexion of the proximal fragment by the psoas muscle has not been overcome. Such malunion is usually avoidable as long as the traction is carefully supervised and regular check x-rays are taken. In general a 10 degree angulation in any direction is acceptable, although it is usually possible to obtain a better result than that. Valgus deformity (pointing outwards in the coronal plane) in the lower limb is more serious than varus (pointing inwards in the coronal plane) because the leg is normally oriented in a varus direction.

Conclusion

The key to effective traction is frequent checking of the position of the limb. In the early days after injury this may mean at least twice a day. It is essential to have nurses and other helpers who understand how your traction system works. Take time to explain to people.

CHAPTER 5

APPLICATION OF EXTERNAL FIXATION

Before applying an external fixator make sure that the necessary equipment and components are available and in good order. It is particularly important that drills and pins are sharp, and that their size and that of any drill guides match the manufacturer's specification. Familiarity with the equipment and its application is essential: consult colleagues and manuals before starting. Without taking all these precautions, the procedure is likely to fail.

The best system is one which allows free placing of the pins. The pin positions should not be determined by the frame.

A number of commercial systems are available and simple ones can be created using wood or metal components joined with plaster bandages or bone cement. However, ''home-made'' systems tend to be only of short-term value as they fail when the patient is mobilized. A simple but versatile commercial system should be available which allows application of the pins, manipulation and holding of the fracture by the surgeon and *then* tightening of the components of the frame by an assistant.

APPLYING AN EXTERNAL FIXATOR FOR A TIBIAL FRACTURE

Placing the pins.

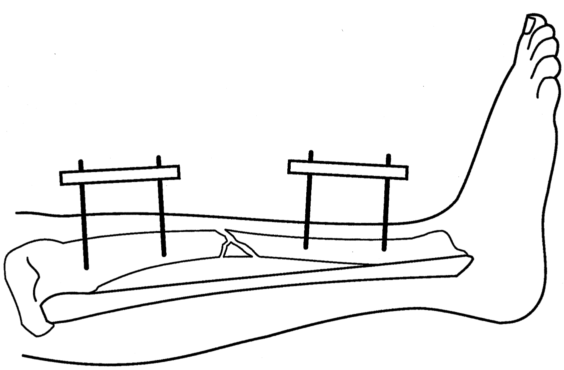
Decide where the pins are going to be put before the operation starts. At least four pins are required; two above the fracture and two below. A single pin on one side of the fracture never provides adequate stability and if there is not room for two then external fixation should not be applied and an alternative method used.

Pins should be placed where they do not pierce muscle or tendons and they must not prevent joint movement. The anterior crest of the tibia is ideal. There is little soft tissue and the fixator does not catch the other leg during walking; try to avoid applying the fixator to the medial surface. Do not apply the fixator from the lateral side.

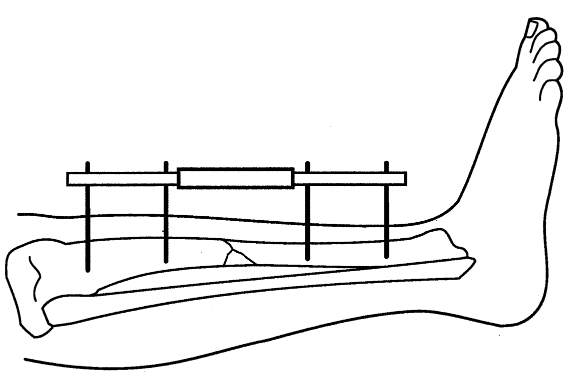
Each pin must cross both cortices of the bone; otherwise the fixator is not stable. If they penetrate too far beyond the distal cortex they may damage nerves, cause muscle tethering and even create a false aneurysm.

For each pin:

1. A 1.5 cm incision in the skin is made longitudinally, parallel to the long axis of the limb.
2. Both cortices are drilled using hand power with a soft-tissue guard. The depth of the pin hole can be measured using a gauge.
3. A pin of larger diameter is screwed into the bone by hand until the measured depth has been reached.
   The pin should be at right angles to the long axis of the bone.
4. The procedure should be repeated at each of the minimum of four sites. If possible, pins should be parallel to each other in each segment.
5. Join the two principal segments with an external fixation device.



1. Attach two pins to each major fragment and join the pins with short rods.



2. Join the two short rods together with a crossbar to align the long axis of the bone. Universal joints between the segment bars and the crossbar makes the system very versatile.

External fixation is useful in very extensive wounds to permit access for further surgery - here skin grafts have been applied whilst the external fixator holds the alignment of the fracture.

External fixation used to treat a relatively simple fracture because mechanical stability of the fracture permits patient mobility on his remaining limb.

MANAGING A PATIENT WITH AN EXTERNAL FIXATOR

After surgery the limb should be elevated.

A check x-ray must be taken as soon as possible. It may be necessary to adjust the position under anaesthetic. Malunion can be avoided by early adjustment. Late adjustment is much less effective because of soft-tissue swelling and early adhesions around the fracture. Accepting poor alignment defeats much of the purpose of applying an external fixator.

The pin sites should be cared for as described in the section on traction (page 42).

Mobilization of joints should start as soon as possible after the operation – soft-tissue wound permitting. Weight-bearing is usually painful but should be encouraged.

As a general rule, once the skin and soft tissues have healed, the fixator should be removed and a POP cylinder applied. This should be done within five weeks.

COMPLICATIONS

Infection of pin tracks and pin loosening

Most early infections of pin tracks are secondary to residual infection in the wound; this underlines the importance of correct wound management. Another cause of infection of pin tracks is poor technique used in the application. Any unnecessary damage to bone and soft tissue when placing the pins is likely to promote later infection and loosening. Signs of loosening include discharge and pain at the pin site and undue discomfort on weight-bearing. On x-ray there is lucency of bone around the pin, this is a late sign.

All four of these bone pins are loose as shown by the bone resorption around them. Note the periosteal reaction around the lowermost pin which indicates the high probability of associated infection.

Infection of a pin track must be managed according to whether the soft tissues are inflamed and the pin is firm or whether the pin is loose. A loose and infected pin should be repositioned. Whether this is possible depends on the fracture site and the design of the fixator. The whole fixator may have to be reapplied; if there are multiple infected and loose pins a different method of holding should be used.

All pins eventually loosen and become infected. Weight-bearing on a fixator may speed up the process of pin loosening, so the fixator should be removed as soon as possible.

Delayed union and non-union

The most important factor contributing to non-union is the extent of loss of bone and periosteum. However, the method of holding may influence the speed of bone healing. Healing of fractures from missiles depends on new bone formation from the periosteum. A potent stimulus for this is multi-axial movement. Any method of fracture holding that inhibits movement at the fracture site also inhibits callus formation. A rigid system of external fixation, therefore may facilitate the management of the soft tissue wound but prolong the time of bone healing. External fixators which are left in place for a long period are usually associated with delayed union or non-union. This again highlights the importance of early removal of a fixator whenever possible; later weight-bearing in POP may stimulate bone healing.

Wounds with fractures for which external fixation is most useful are those where non-union is likely anyway, i.e. comminuted tibial fractures with large soft-tissue wounds with loss of bone and periosteum (page 18). Such fractures often require a bone graft eventually (page 54).

Conclusion

The decision to use an external fixator need not be made at the first operation; it can usually wait until the second operation. Do not use it if you do not know how. Reserve its use for where there is no reasonable alternative. For the non-specialist *routine* use of external fixation makes management of difficult fractures more complicated.

CHAPTER 6

BONE INFECTION

War wounds become infected because they present late, because of incorrect wound management or because dead bone remains in the wound. The difficulty of controlling chronic post-traumatic infective osteitis (often loosely referred to as chronic osteomyelitis) should not be underestimated.

The well-established principles of wound management also apply to bone infection, whatever the cause:

- Surgery is required to remove all foreign material and dead tissue, including devascularized bone.
- Antibiotics alone do not eradicate bone infection.
- Recurrence of infection after initial surgery means that dead tissue, often bone, remains in the wound.

Immobilization of the limb is important but no method of fracture holding promotes nor inhibits wound infection.

ANTIBIOTICS FOR ESTABLISHED BONE INFECTION

When considering antibiotics for established bone infection a distinction must be made between protecting surrounding soft tissues from, principally, streptococcal and clostridial invasion in conjunction with wound excision (page 12) in neglected, late presenting wounds which are already infected and, on the other hand, special antibiotics which *may* prevent recurrent infection of bone. In both cases, antibiotics are a supplement to surgery; if there is dead bone antibiotics alone do not help. In the absence of bacteriological services, a combination of benzyl penicillin plus metronidazole (1.5 g daily in three divided doses) is best. If infection persists, despite the apparent removal of all dead and foreign material, or if the patient first presents with systemic signs of spreading sepsis, then a good combination is cloxacillin (1 g every six hours), metronidazole, and gentamicin (80 mg every eight hours).

Neither antiseptics, locally applied antibiotics nor antibiotic-impregnated beads are of proven value; they are not recommended.

SURGICAL MANAGEMENT

Infected bone wounds need surgical exploration to remove the dead bone; this may involve making a partially healed wound bigger. However, it shortens the overall time to healing. The procedure may have to be repeated before all dead bone is removed.

Prepare the patient

Check the haemoglobin; the wounds of anaemic patients do not heal well and blood is always lost in the operation. Give thought to the nutritional status of the patient; an antihelminthic may be indicated in addition to a high protein diet and iron and vitamin supplements.

X-rays and sinograms

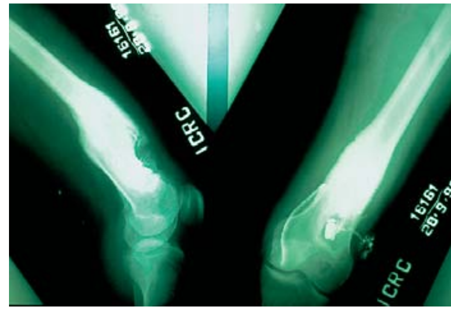
Make sure you have adequate x-rays of the fracture in two planes. Dead bone (sequestra) is whiter than living bone.

Bone infection often presents as a discharging sinus which has dead bone at the bottom. A sinogram adds valuable information as it often outlines the cavity which contains the fragment of dead bone. The sinus is often surprisingly long.

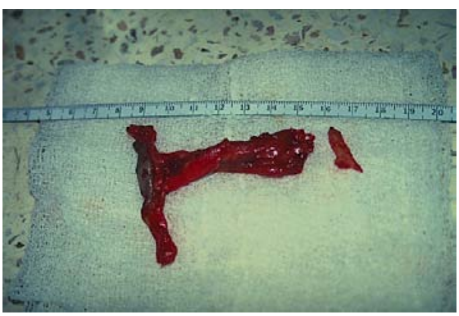
Performing a sinogram

1. Ensure you have two new x-ray cassettes for the anteroposterior and lateral planes.
2. Position the patient and the appropriate x-ray cassette under the limb and ask the radiographer to set the exposure appropriately – once the contrast medium is inserted there may not be time to make adjustments.
3. Using a sterile technique prepare a 50% diluted solution of a urological contrast medium, according to the instructions supplied with the radio-opaque solution.
4. Use a 8- or 10-gauge Foley catheter with a 10 cc balloon. Have a syringe of water ready to inflate the balloon.
5. After cleaning the wound insert the Foley catheter into the sinus for a few cm. Inflate the retaining balloon to prevent back-flow of contrast medium.
6. Gently but firmly inject a few cc of dilute contrast medium. Make sure this does not leak out onto the skin, dressings or x-ray cassette.
7. Ask the radiographer to take a picture.
8. Inspect the radiograph; if it does not show a sinus adequately inject a little more contrast and take another film. If a sinus is shown, take a lateral film.

This young man has a sinus in his lower femur.



A sinogram shows that this is associated with a cavity within the bone in which there is a piece of dead bone.



The sinus tract was excised and the bone fragment was located and removed.

Resolution of the infection and consolidation of the fracture followed.

Procedure for excision of dead bone

The removal of dead bone cannot be achieved by simply scraping the sinus with a curette. The dead bone must be found and removed.

Plan the operation using the sinogram. Injection of methylene blue into the sinus helps to find and follow the track. A pneumatic tourniquet on the limb reduces blood loss and makes the operation easier.

The bottom of the sinus and bone fragments can usually be reached by following the track. It may be necessary to make a secondary incision to reach and remove the bone fragments. If possible, the sinus tract should be completely excised. Adjacent major nerves and vessels should be identified first.

When the sinus communicates with a joint, a formal arthrotomy combined with sinus track excision may be necessary. The joint capsule must be closed at the end of the procedure.

Always leave the wounds open. They granulate and subsequently accept a skin graft or close spontaneously.

Dressing the wound

The ideal ward dressing for cavities left after excision of dead bone is cheap, non-toxic, antibacterial and easy to apply. All these criteria are met by a daily sugar dressing. Filling the wound with sugar after washing with saline provides an environment of high osmotic pressure in which bacteria cannot thrive. Repeated every day, this method can effectively clean wounds and promotes the formation of granulation tissue. When the exudate has stopped and the wound is clean, only a simple dry dressing is needed every three or four days.

Follow-up

A wound that continues to discharge large volumes of pus almost certainly has dead bone remaining. Another attempt to remove the dead bone should be considered before changing to other antibiotics.

When infection is eliminated around an unhealed fracture, there may be rapid ingrowth of callus, especially around small defects. Therefore it is wise to wait for four to six weeks before deciding whether or not bone union has to be stimulated by a bone graft. In any event the wound must be completely clean before a bone graft is done (page 54).

Conclusion

Treating bone infection is never easy and there are no short cuts. Surgical removal of dead bone is the only method of eradicating deep bone infection and antibiotics should be seen as a supplementary treatment. Careful planning using x-rays and sinograms increases the chances of success of the operation.

CHAPTER 7

BONE GRAFTS AND OTHER PROCEDURES

The surgeon's objective, when managing a patient with a fractured long bone, is to restore function to the limb. In most cases this is achieved by correct wound management and the encouragement of natural bone healing. Occasionally, a bone graft or other reconstructive procedure is needed. However, the severity and site of the wound may make it impossible to recover full function. In attempting to retrieve function the surgeon should avoid sophisticated and specialist procedures because the risk of failure is higher and the complications more serious. Only simple and safe procedures should be attempted.

SOFT-TISSUE RECONSTRUCTION

Skin cover of a fracture can usually be achieved by delayed primary closure, split-skin graft or permitting defects to heal by secondary intention. Occasionally, more complex procedures are useful provided that the surgeon has adequate expertise and experience. Reconstruction of soft tissue both covers the fracture and brings a new blood supply thus promoting the healing of the fracture. The most useful procedures are soleus and gastrocnemius muscle flaps to cover fractures of the upper tibia and knee joint. For forearm wounds abdominal skin flaps may prove useful. (See ''War wounds of limbs'' page 82.)

Muscle flaps are also valuable in treating exposed and infected bone.

BONE GRAFTS

The use of bone grafts should be limited to a number of well-defined situations. The simplest method should be attempted first; this involves taking cancellous bone chips from the pelvis and packing them in and around a bone defect. This gives reliable results if the correct technique is used.

The indications for bone grafting are:

- Long bone defects left after wound surgery or after eradication of infection. Some type C defects and many type D defects require a bone graft to achieve bone union.
- Non-union. This is defined as delayed union for more than 16 weeks in the lower limb and 12 weeks in the upper limb. If union is delayed the fracture may require a bone graft in association with weight-bearing mobilization.

The timing is important. For many type D defects, it is obvious that a bone graft will be required at some stage; this can be done as soon as the soft tissue wound is well healed. The cleaning of an infected bone wound and a subsequent bone graft is a prolonged exercise. Short cuts are not forgiven by nature and may make the situation worse. After eradication of infection, it is wise to wait at least six weeks before doing a bone graft.

For success a bone graft requires an adequate local blood supply, a clean wound and some stability. Ideally, the skin should be healed although an open technique (Papineau - page 58) may be used for a clean and granulating wound.

Cancellous bone chips are made of cells and hydroxyapatite and protein; they stimulate bone formation around them but exactly how is not known. Cortical bone grafts do not have the same effect.

Techniques

Harvesting graft: The site depends on how much bone is required. Each cancellous chip should be the size of a fingernail.

Where *large quantities* are needed, for example where there is a tibial defect greater than 4 cm, the best site is the posterior pelvic rim.

Taking a bone graft

1. Place the patient laterally or prone.
2. Locate the posterior iliac spine and incise forwards along the crest.
3. Separate the muscles on the external surface of the crest with a knife; then, using a periosteal elevator, gently scrape the first few mm of muscle from the bone.
4. Insert a sharp osteotome parallel to the crest and cut through the outer cortex. Cut through the central area and crack the inner table.
5. Work the osteotome cut from posterior to anterior and cut across both tables at both ends. This creates a small flap of bone which can be elevated to give access to the space between the two bony tables of the pelvic brim. The total length of exposed crest may be about 6 cm.
6. With a curette or a narrow osteotome remove the cancellous bone between the two tables of the pelvis. Smaller bits are usually curetted. Do no use too much force or the sacroiliac joint may be breached.

7. Keep the harvested bone in a swab soaked with blood from the initial incision – do not immerse it in saline as this kills the bone cells and may remove unrecognized humoral stimulating factors.
8. Close the crest by ''shutting the flap'' and suture the lid back to the periosteum.
9. Place a suction drain in the subcutaneous layer and leave for 24 hours. This clean wound can be closed primarily.

This wound is always painful postoperatively.

If a very large quantity of bone is required, both sides of the pelvis can be used.

For smaller grafts

1. For defects smaller than 3 cm, use the anterior crest of the pelvis.
2. Place the patient supine so that both harvesting and placing of the graft can be done with the patient in one position.
3. Make the incision from the anterior superior iliac spine backwards.
4. Repeat stages 5 to 9 described above.

Closed wounds

The operation is best started where possible with a pneumatic tourniquet on the limb. This should be released before placing the graft.

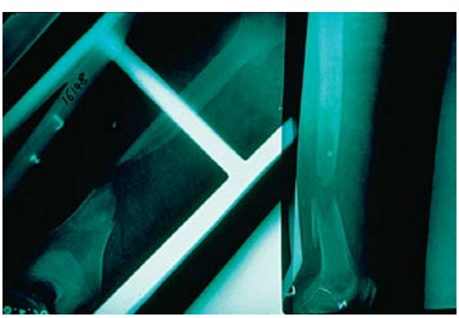
The incision for access to the fracture usually goes through the old wound, with longitudinal extension incisions if necessary. If possible, the incision should be at the edge of but not across a healed skin graft. There may be an advantage in approaching the fracture through a new wound. This carries less chance of infection.

After the fracture is exposed, the bone ends should be freshened by removal of adherent fibrous tissue. The bone chips should be firmly packed in and around the defect.

The wound should be closed over a suction drain which should not be left for more than 24 hours.

X-ray showing a comminuted bullet wound of the femur.

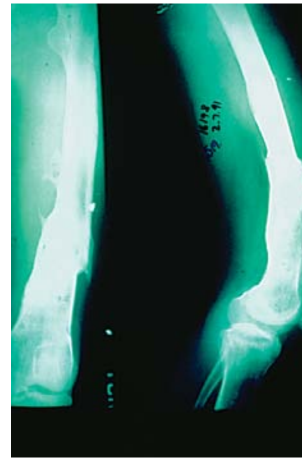
At the first operation loose fragments were excised but the periosteum was retained.



Overall alignment was achieved on traction. The patient had an accompanying abdominal wound.

Eternal fixation was applied to mobilize the patient out of bed and because of the bone defect a bone graft was put into the defect via a separate incision after six weeks.

The pins of the external fixator became infected and had to be removed; the patient's limb was put back into traction.



The fracture went on to unite in a functionally acceptable position. X-ray taken after 15 months.

Open wounds (Papineau technique)

The same basic technique applies but the wound is left open and the graft is exposed. The graft will ''take'' provided it is kept clean and moist and regularly cleared of encrustation and rejected chips. It may be covered by a muscle flap if the skills are available. As the wound granulates, the bone chips are incorporated and eventually the surface may close spontaneously or accept a skin graft.

Whether an open or a closed technique is used, the fracture must be held by an appropriate method for at least four weeks.

Follow up

An x-ray taken soon after grafting gives a baseline of radiodensity compared with preoperative films. A successful graft shows no change on the x-ray for the first two weeks and then becomes increasingly dense. Loss of radiodensity indicates resorption or infection of the graft. The overall time for bone union is variable and should be judged clinically and on x- ray.

Complications

Infection is the most serious and common complication of a bone graft. Pure cancellous bone grafts are safe and can easily be removed if they become infected. Pieces of cortical bone can become the nidus of later infection. Donor site infection is more dangerous; if this is suspected do not hesitate to open the site, washing it thoroughly and leaving it to heal by granulation.

Some weeks after a bone graft the x-ray may show that all the graft has simply resorbed without exerting its stimulatory effect on bone healing. The procedure may have to be repeated.

ARTHRODESIS

Following a severe joint wound, normal limb function might be irretrievable. The joint might be too unstable or too painful to use. Arthrodesis (surgical fusion) is an effective way of providing stability and freedom from pain.

The decision to fuse the joint should not be made at the first operation because the full extent of the bone and soft tissue loss cannot be established at this stage. It is best to wait until wounds are healed and remaining bone has consolidated.

The operation involves opening the remains of the joint, removing any cartilage, trimming incongruent residual surfaces so that two flat bony surfaces oppose each other and providing enough stability for the joint to fuse. The most effective way of holding the joint to be fused in position is with an external fixator applied over the joint and compressing the bone ends together. This technique is known as compression arthrodesis; it takes about eight weeks.

Arthrodesis works very well at the knee and for joints of the fingers. It is technically very difficult at the shoulder, elbow and hip.

ARTHROPLASTY

Arthroplasty is the surgical reshaping of a joint so that movement is maintained between adjacent bones. In civilian practice in developed countries this is usually synonymous with artificial joint replacement. *Excision* arthroplasty involves removal of the joint; this may be the only way of achieving healing of a severely infected joint wound and may be life-saving when large joints are affected.

The procedure is a valuable last resort for difficult wounds of the hip, shoulder and elbow. Surprisingly good function is possible. It is not appropriate at the knee, where stability is of paramount importance.

Conclusion

All the techniques described in this chapter are related to specialized areas of orthopaedic and reconstructive surgery. Before embarking on them, ask yourself if there is any alternative. Read and plan before such an operation. Take the opportunity to watch others with experience. Be humble rather than overambitious - surgical adventures do not help the patient.

CHAPTER 8

MANAGEMENT OF REGIONAL FRACTURES: A SUMMARY

The protocols set out below for femoral, tibial and humeral fractures utilize the principles described in this book. The most important element, it must be remembered, is the wound excision at the first operation.

FEMORAL FRACTURES

First operation

Excise the wound (page 12).

Insert a pin through the upper tibia (page 38).

Place the limb on a Braun frame and apply 1 kg weight per 10 kg body weight.

Align the distal fragment of the fracture with the proximal fragments. The position of the limb will depend on the level of the fracture. The higher the fracture the more flexed the position of the hip and knee on the frame must be (page 40).

In the immediate post-operative period take a check x-ray and make adjustments to correct the alignment if necessary.

Second operation (after four or five days)

Inspect the wound and either carry out further wound excision or, if the wound is clean, close by direct suture or skin graft. If in doubt leave the wound open and allow it to heal by secondary intention.

In the postoperative period, continue with the traction. Take radiographs regularly and adjust the traction if necessary until a satisfactory position is obtained.

Continue traction for three to four weeks, taking a weekly x-ray until callus appears.

Remove the traction as soon as the fracture is ''sticky'' (page 43).

Leave the patient on strict bed rest for one further week to exercise the affected limb and its joints.

Apply a functional brace if possible and mobilize the patient on crutches bearing as much weight as possible.

TIBIAL FRACTURES

First operation

Excise the wound (page 12).

Put the leg in an above-knee POP slab applied over the wound dressing (page 27).

Elevate the limb on pillows or a traction frame.

Second operation

Inspect the wound and either carry out further wound excision or, if the wound is clean, close by direct suture or skin graft. If in doubt leave the wound open and allow it to heal by secondary intention. If the wound is clean, large and complex, consider using a simple muscle flap such as gastrocnemius or soleus if you know how.

Consider whether amputation may be a safer option. (Only perform the amputation if the patient has been warned of its possibility and has given permission.)

Decide whether to use POP, calcaneal traction or external fixation (page 20). The decision is based on the size and site of the wound. Apply the method of holding according to the instructions given on pages 27, 38 and 45 respectively.

In the postoperative period check the position of the fracture by x-rays and make appropriate adjustments. X rays should be taken at least every month.

Once the wound has healed, replace the method of holding by a POP cylinder, preferably in the from of a tibial functional brace (Sarmiento, page 29)

Commence weight-bearing walking with the aid of crutches.

HUMERAL FRACTURES

First operation

Excise the wound (page 12).

Place the arm in a collar-and-cuff sling. A POP slab helps pain relief in the first few days. Nurse the patient sitting up with the elbow flexed at 90 degrees.

Encourage the patient to move the fingers and wrist.

Second operation

Inspect the wound and either carry out further wound excision or, if the wound is clean, close by direct suture or skin graft. If in doubt leave the wound open and allow it to heal by secondary intention.

Continue nursing in a collar-and-cuff sling until the skin has healed, encouraging movement of the fingers, elbow and shoulder.

In the postoperative period, take regular x-rays every two to four weeks.

When soft-tissue wounds permit, put the arm in a brace comprising a simple cylinder of plaster and start movement without a sling and with some load-bearing.

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