73 Child orthopaedic injury

73.1 Fractures in children

Play is the occupation of children and sometimes, they do not play safely. They are not exempt from road traffic injuries, assault, and abuse. Children living with disabilities that impair movement or who are malnourished may have osteoporotic bones that render them soft and more prone to breaking.

A child's bones differ from those of an adult. Instead of fracturing completely, they often bend like a stick (incomplete or greenstick fractures), or there may only be a small swelling of the cortex (buckle fractures).

This chapter deals with issues specific to children, and where treatment differs from that for adults.

The child's long bone has two ends, proximal and distal, linked by an intervening shaft, the diaphysis. Between the ends and the shaft, there is a growth plate, the physis, where which the bone increases in length. The physis is a layer of radiolucent cartilage and is weaker than the bone. The epiphysis is the bony region beyond the physis and adjacent to the joint surface, while the metaphysis is the flared part of the bone that blends with the diaphysis.

There are 2 types of epiphyses: (1) pressure (compression) epiphyses at the ends of long bones near joints, and (2) traction (tensile) epiphyses where muscles are inserted. These are called apophyses and are often prone to displacement. Apophyseal injuries are usually only a minor nuisance, with the exception of the important medial epicondyle injuries of the humerus (73-13).

Injuries to long bones often affect the growth plate more than the adjacent bone. The epiphyses are sites where cartilage is converted into bone and growth in length occurs. When poorly managed, epiphyseal injuries lead to deformities (asymmetric growth, growth arrest or length discrepancies).

Fractures in children unite quickly and rarely need surgery; they need immobilization for a shorter time, and you can almost always manage them by closed methods.

BONY INJURIES IN CHILDREN

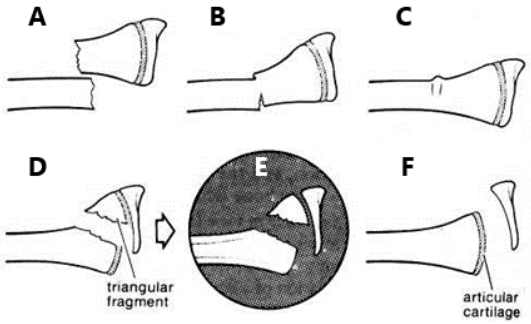

Fig.73-1 BONY INJURIES IN CHILDREN. A child's bones are different from those of an adult; instead of breaking, they often bend like a stick. A, complete fracture. B, greenstick fracture. C, buckle fracture. D, epiphyseal fracture Type II. E, Xray view of D. F, epiphyseal fracture Type I. *Kindly contributed by Peter Bewes*

The periosteum is a membranous tissue covering the bone surfaces where there is no cartilage nor attachment of tendons & ligaments. It has an outer fibrous layer that lends structural integrity and an inner *cambium* that has significant osteoblastic potential. This contains blood vessels and nerves and is important in bone repair and appositional growth. The periosteum is generally thicker in children than adults, and limits displacement of bone fragments after fracture and provides a hinge which might either help or hinder reduction..

SIGNS
Examination normally reveals the site of injury, with swelling, tenderness, deformity or abnormal movement. Angular deformity and length discrepancy may be a feature of late presentation.

Although some severe malunion slowly disappears as a child grows, other apparently mild malunion becomes steadily worse. *So, you must know which positions you can accept, and which you cannot.* Here are some general principles. *Note a child's fracture becomes 'sticky' within 1wk.*

(1) Try to get the fragments into line. They don't necessarily have to be end to end. In younger children, especially, side to side alignment may also be acceptable.

(2) Try to stop them from rotating, because growth will not correct a rotation deformity.

(3) Be cautious about how much angulation you accept. This depends on:
(a) The age & gender of the child, and particularly on whether the epiphyses have united or not. The younger the child the higher the remodelling potential. The epiphyses remain open longer in boys than in girls.
(b) The distance in a long bone fracture from the knee or elbow. Remodelling potential increases the further away from the elbow and the closer to the knee. The younger the child, the greater the angulation you can accept. Uncorrected angulation, shortening or rotation in the middle of a long bone causes severe deformity, especially in the forearm, but also in the femur and tibia. Angulation is likely to be permanent.

(4) Overlap and moderate shortening are unimportant. In fractures of the femur and humerus in younger children, *overlap is even desirable*, because these bones show overgrowth after a fracture. So you can leave a fractured long bone to unite with its fragments side to side up to the age of 10 in girls, and 12 in boys. The fragments unite rapidly, and the bone soon remodels.

(5) Beware displaced intra-articular fracture displacement with the axis at right angles to the plane of movement, and displaced fractures crossing the growth plate at right angles: these need reduction.

Children may be difficult to manage in an emergency and whenever possible and safe, they should have their fracture reduction and immobilization done under GA in the OT, especially if fluoroscopy is available. You may decide to admit or discharge a child once awake according to the type of fracture and procedure, and the risk of neurovascular complications. We mention here special instances where childhood injuries require a different approach than adult injuries.

73.2 Epiphyseal injury in children

At the end of this book you will see charts showing the epiphyses, and stating both the time they appear and when they unite.

N.B. A rural African child's epiphyses may remain open almost to the age of 20yrs, rather than 14 in a girl and 16 in a boy as in Western countries. This is probably a genetic difference. Some epiphyses are much more often injured than others.

The cartilage joining epiphyses and apophyses to the shaft of a bone is weak, and is often the site of displacement.
Suspect an epiphyseal injury whenever a child has an injury near the end of a long bone, even if it seems only to be a sprain.

On rare occasions, an epiphyseal injury may reduce spontaneously. This kind of epiphyseal injury cannot be diagnosed on a radiograph, since the bone will appear normal, but you can visualize the epiphysis with ultrasound, and the child will be in pain.

Fortunately, most epiphyseal injures cause no harm to bone-producing cells. However, if these they are injured, partial or complete growth arrest can occur. If injury is unilateral, or if injury is greater in one bone in a parallel pair, such as the radius and ulna, progressive angular deformity may occur slowly over several years, and then needs an osteotomy for correction.

There are 5 types of epiphyseal injury, each requiring different management, with a different prognosis.

EPIPHYSEAL INJURIES

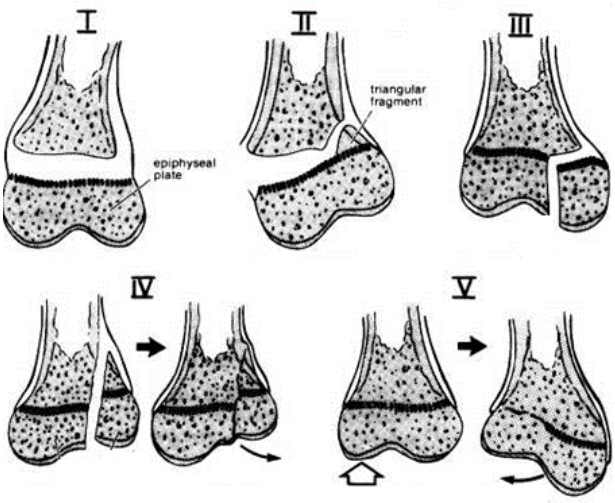

Fig. 73-2 EPIPHYSEAL INJURIES. Type I, a slipped epiphysis. Type II, epiphyseal separation which takes a triangular piece off the shaft. Type III, partial epiphyseal separation with fracture of a distal fragment, involving the joint. Type IV, a lateral condylar fracture through the epiphyseal plate into the joint. Type V, a crushed epiphyseal plate, leading to deformity later. *After Salter RB, Harris RW, Injuries involving the epiphyseal plate. J Bone Joint Surg Am 1963; 45(3): 587-622 with kind permission.*

Type I: The epiphysis slips completely off the end of the shaft, without a fracture. These injuries are common at birth and in early childhood. Reduction is usually not difficult, and the prognosis is good, *except at the upper end of the femur* (73.12).

Type II: The line of separation runs through **a** part of the epiphyseal plate and then out through the shaft, where it produces a characteristic triangular fragment (73-1D). This is a common epiphyseal injury, particularly at the distal end of the radius.

Type III: The fracture extends from the joint surface into the epiphyseal line and then along into the periphery. These are rare injuries, usually at the ends of the tibia. Accurate reduction is essential to restore a smooth joint surface and align the epiphyseal plates. An open operation may be necessary.

Type IV: The epiphysis and part of the shaft split, particularly at the lateral condyle of the humerus (72.13). Perfect reduction is essential, and open reduction is often necessary.

Type V: This is another rare injury, usually of the ankle or knee, with a poor prognosis. The epiphyseal plate is crushed and at least part of it subsequently closes early, resulting in severe shortening & deformity. The 1st radiograph may look almost normal, and you may think the child has a sprain. Suspect an injury of this kind if there is a history of a crush injury, and don`t allow weight bearing for at least 3wks. Inform the parents about this potential devastating result right at the beginning.

Treat epiphyseal injuries with splinting to minimize swelling and discomfort. Gentle, timely and appropriate reduction may be necessary as well as further immobilization. Close, repeated follow-up is important during the growth of the child.

RADIOGRAPHS
Take 2 views of the child`s injured limb at 90° to each other; always include proximal & distal joints not to miss Monteggia (63.3) or Galeazzi (63.4) fractures, for example. Take care to position the limb correctly.

If you find the radiographs difficult to interpret, you may have to compare them with exactly the same views of the opposite limb, *although this exposes a child to extra radiation! Failure to do this is, however, responsible for most of the errors in treating children's fractures.*
Diagnosing an epiphyseal separation is difficult before the centres of ossification have appeared. Suspect epiphyseal separation if there is displacement of the shaft and soft tissue swelling.

REDUCTION
An epiphyseal plate is easily damaged, so reduce the displacement gently. If a Type I or II injury is >10 days old, leave it. The epiphysis will probably have started healing in this position already. *An attempt to reduce the epiphysis at this time may actually damage it permanently*.

If the displacement is too big to ignore, an osteotomy will be necessary at a later point in time.
CAUTION! Reduce these injuries immediately, especially in the lower limbs. Any delay will make reduction more difficult.

IMMOBILIZATION
Immobilize epiphyseal injuries for the same time as for a shaft fracture for a child of the same age.

FOLLOW UP
See the child regularly. You may have to compare radiographs of the injured side with the opposite side. If there has been little growth, review every 3-6 months.

PROGNOSIS
This is good for injuries of Types I & II and poor for Types III-V, particularly Type IV if there is gross displacement needing internal fixation. The younger the child, the more growth ahead, and the worse the deformity that may follow a given injury involving bone-producing cells. An injury in the last year of growth is likely to cause little disability.

REDUCE EPIPHYSEAL INJURIES IMMEDIATELY

73.3 History in child trauma

OF UTMOST IMPORTANCE IN PAEDIATRIC TRAUMA: ASKING HOW DID IT HAPPEN?

The history of trauma/accident must reveal an adequate explanation for the injury. This is of utmost importance, especially in younger children, to distinguish accidents from non-accidental injuries (47.1), particularly pathological fractures or child abuse.
If trivial trauma results in broken bones, a pathological fracture in the presence of a juvenile bone cyst could still be the cause.

Delayed presentation, unmentioned secrets, inconsistent or contradictory history in front of an 'extraordinary looking' fracture *will point to child abuse*.

Typical patterns are metaphyseal fractures or bony fragments, subperiostal haematomas, and fractures of different ages. Last but not least, *beware spiral shaft fractures in infants who are yet not walking themselves!*

N.B. If a child has pain in a bone or joint, especially at night, think of infection or tumour!

A CHILD COMPLAINING ABOUT A CAST ALWAYS HAS A GOOD REASON!

Tell the guardians the same!

Take the opportunity to teach the family after any accident regarding child safety protection means (*i.e.* wearing helmets on motorcycles, or safety belts in cars).

For children, the guardians are of utmost importance in encouraging exercises, getting acute pain relief and providing encouragement!

SHANTI (8yrs) had an undisplaced fracture of the distal end of her radius. There was almost no swelling. A circular cast was applied. She returned the next day crying in pain. She was given aspirin and sent home. Three days later she returned with a gangrenous hand and sloughing forearm muscles. Her forearm was amputated. LESSONS (1) *Never treat a painful cast with analgesics only!* (2) Pain, numbness, and paralysis are signs of impending compartment syndrome.

ABDULLAH (8yrs) had a supracondylar fracture. It was successfully reduced within 1h and a skin tight cast was applied. He returned the following day saying that the fingers hurt, but was sent home without removal of the cast. A mere 5 days later he returned. This time all the fingers and thumb were black and gangrenous, and had to be amputated. LESSONS (1) A closed cast is *not* the treatment for this fracture; a posterior plaster slab is preferred. (2) *Take any complaint of pain seriously and split or remove a cast immediately*.

N.B. Always demonstrate the equipment for removing a cast to a child beforehand, & apply ear plugs (if possible) when using an electric saw.

N.B. Treat girls after their first menses and boys after their growth spurt as adults.

73.4 Fracture immobilization

PLASTER OF PARIS PoP CASTS
Casts are frequently used in children, and unsplit circular casts pose little risk in children compared to adults when used correctly.

Use PoP, since it is cheap, easy to apply, very malleable and can be taken off by parents themselves by submerging the plaster in water in case of emergency.

Explain to parents what the alarm symptoms for a compartment syndrome are: increased pain, change of colour of fingers or toes, complaints of tingling, numbness or paralysis and explain how to take of the cast at home for every cast you apply.

N.B. In small children a compartment syndrome may present with agitation and anxiety instead of the classic 6 P's (49.2).

N.B. Never use an unsplit cast:
(1) for an elbow fracture
(2) for a swollen joint
(3) where there is a distal neurological deficit.

Keep in mind that the patient in the cast still needs to go to toilet and attend to personal hygiene. So tape exchangeable plastic onto the edges of the cast near to the body orifices

SKIN TRACTION

Skin traction is much more satisfactory in children than it is in adults, and, because a child`s joint does not become stiff permanently, it seldom needs physiotherapy.

This is particularly useful for treating elbow and femoral fractures in children.

(a) Gallows traction
Suspend the legs of a small child with a fractured femur from a bar with adhesive strapping.

(b) Extension traction
Use adhesive strapping to treat femoral fractures in an older child or teenager with the knee extended. This is also useful for some femoral neck fractures (67.3, 73-10A).

(c) Forearm (Dunlop) **traction**
Apply adhesive strapping to a child's forearm when the elbow is so swollen from a supracondylar fracture that it cannot be reduced immediately. (73-10B)

CAUTION! *Don't let the strapping interfere with the circulation of the hand.*

N.B. Don't use skeletal traction across joints in children. It may damage the growth plate and/or ligaments.

For TRACTION WEIGHTS, use bottles filled with water. *Don't exceed 10% of the child's body weight!*

FIXATION
It is essential in children to cover *ALL* external wiring safely, because at a certain age, children put everything in their mouth and therefore might ingest your K-wire etc.

EXERCISES
When the time is right, encourage exercises; active physiotherapy is rarely needed, but parental encouragement is ideal. Mostly, all a child needs is to play outside! *Active movements are safer than forced passive manipulation!*

73.5 Shoulder injury in children

(a) Clavicular fracture
Fracture of the clavicle is common in a child, who cries on moving the arm, but there may be little to suggest that the clavicle is broken. Feel carefully, and you will find an area of tenderness but no swelling.
The fracture may be a greenstick and difficult to see on a radiograph (easier on ultrasound), but is not really necessary unless there are unusual symptoms. Rarely there is an acromio-clavicular dislocation or brachial plexus injury. A young child may resolutely refuse to use the arm.
A figure-of-8 shoulder strapping eases the pain. The fracture heals easily, but if there is gross displacement or serious tenting of the skin, reduction & internal fixation is necessary.

N.B. Sometimes there is a swelling without any history of injury, so always consider child abuse (47.3)!

N.B. A congenital pseudo-arthrosis may occur in the absence of trauma, especially associated with dextrocardia, if on the right.

(b) Humeral neck fracture

Fractures of the surgical neck are relatively common in children; more commonly metaphyseal <11yrs and epiphyseal >11yrs. Some children are in great pain and are quite unable to move the arm; others have little pain and a surprising range of shoulder movement.

If a child is in pain, don't try to examine the shoulder; get a radiograph. Take 2 views to determine the position of the fragments.

In young children, the fracture is transverse and is 2cm below the epiphyseal line. When the fracture is complete, the shaft rides up in front of the upper fragment, and overlaps it.

Epiphyseal fractures are sometimes associated with a slowly evolving brachial plexus palsy, especially if axial reduction is delayed. Try to get as correct reduction as possible. In severe cases external fixation is advisable.

Fractures of the proximal metaphysis are more common between 5-11yrs. Greenstick fractures are common in the youngest, but seldom occur with significant angular deformity. Pathological fractures, *e.g.* from a juvenile bone cyst, are quite frequently found in this area.

The neck of the humerus breaks, either at the time of the accident, or while a simple dislocation is being reduced with excessive force. The head of the humerus lies in front of the glenoid, or it may be displaced into the axilla. The axillary vessels and the brachial plexus are sometimes injured at the same time.

In children 5-15yrs, the head of the humerus sometimes becomes detached from the shaft, and may take a piece of the shaft with it. The head of the humerus is very mobile, so reduction can be difficult. Perfect reduction is not necessary because the head readily remodels. Check for any involvement of the brachial plexus: check the radial pulse and the axillary nerve (48.1).

TREATMENT
If the fragments are not widely separated, put the arm in a sling and encourage the child to move it.

If the fragments are widely separated, try to get them to hitch (61.12). Use GA with full relaxation.

Ask an assistant to pull the arm into abduction, (61-14). As he does so, use both your thumbs to press the humeral head towards its socket.
If possible, get radiographs to check reduction whilst the child is still anaesthetized. Maintain traction in bed for 2wks. Then protect it in a sling for another week.

If you succeed in reducing the humeral head, treat this as an uncomplicated fracture of the humeral neck (61.12).

If you cannot reduce the head the first time, try only once more. If you fail again, it will need open reduction.

If you fail to get the humeral fragments to hitch, use traction for 2wks, using overhead suspension (73-10), a pulley, and enough weight to keep the arm raised: 2kg will probably suffice. *Don't tie the arm to a pole*, because on sitting up, reduction is lost. Continue until the fragments are 'sticky'. Then start pendulum exercises.

Acceptable alignment and angulation per age group are:

Age	Varus/Valgus Angulation	Displacement	Shortening
<5yrs	60°/10°	100%	2cm
5-12yrs	30-60°/10°	50-100%	2cm
>12yrs	<30°/10°	<50%	2cm

DIFFICULTIES WITH HUMERAL NECK FRACTURES IN CHILDREN

If the sharp end of the distal fragment has perforated the shoulder muscles, and you can feel it under the skin, use GA and manipulate the broken end of the humerus back through the muscles.

Use a combination of pulling and twisting movements, and get it to hitch with the proximal fragment. Sometimes the distal fragment goes right through the skin.

N.B. Treat this as a compound fracture!

73.6 Upper arm injury in babies

A baby's humerus is often fractured during a difficult delivery, or in a non-accidental injury. It heals rapidly with massive callus formation and needs no treatment, unless there is >30° angulation or >2cm shortening. Bind the arm loosely to the chest wall with a crepe bandage for 1wk to prevent further injury.
At the end of 1yr there will be no trace of the fracture.

N.B. **A brachial plexus injury** may also occur from vigorous pulling of the arm, or from an obstetric injury to a neonate.

73.7 Elbow injury in children

AGE INCIDENCE OF CHILD ELBOW INJURIES

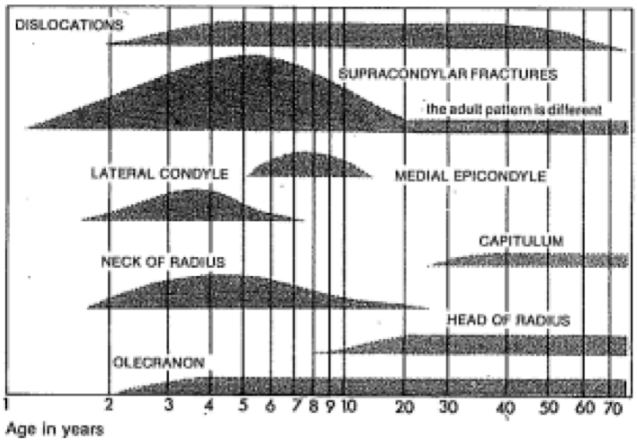

Fig. 73-3 INJURIES AROUND THE ELBOW have a characteristic age incidence. Dislocations occur at all ages. Supracondylar fractures are the most common elbow injuries with a modal age c. 7yrs. The medial epicondyle is injured in teenagers, and the lateral condyle in young children. The neck of the radius fractures in children, and its head in adults.

Feel the bony anatomy of the child's elbow carefully; this may be difficult if it is very swollen. Note especially the position of the olecranon in relation to the humeral axis. This is a useful guide to satisfactory reduction. Feel how much external rotation of the flexed elbow is possible on the normal side.

FEATURES OF ELBOW INJURIES:
Dislocation
(1) Any age.
(2) Contour normal.
(3) Severe swelling.
(4) Elbow fixed at 45°.
(5) 3 Bony points misaligned.

Supracondylar fracture
(1) Common in children.
(2) Contour abnormal.
(3) Severe swelling.
(4) Some movement possible.
(5) 3 Bony points aligned but displaced posteriorly relative to the humeral shaft.
(6) Lower humeral fragment mobile + crepitus

Fractured medial epicondyle
(1) Older children & adolescents.
(2) Contour normal.
(3) Medial epicondyle tender and swollen.
(4) Some flexion and extension possible.
(5) Rotation painful but possible.

Fractured lateral condyle
(1) Children.
(2) Contour normal.
(3) Lateral condyle tender and swollen.

Fractured radial neck
(1) Children <4yrs.
(2) Contour normal.
(3) Flexion and extension possible.
(4) No rotation.
(5) Radial head tender.

Pulled elbow
(1) Young child.
(2) Contour normal.
(3) Child refuses to use the arm.
(4) No rotation.
(5) *The arm hangs straight down with the forearm in pronation*

Fractured olecranon
(1) All ages.
(2) Contour normal.
(3) Moderate swelling.
(4) Olecranon tender, with palpable gap.
(5) 2 varieties: active extension or not.

ELBOW RADIOGRAPH: 10-YR OLD CHIILD

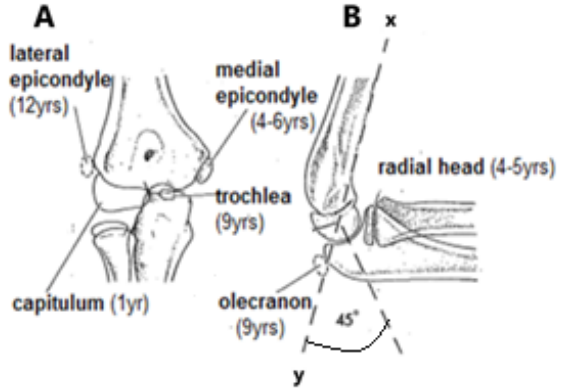

Fig. 73-4 10YR OLD CHILD'S ELBOW RADIOGRAPH. A, find 6 centres of ossification in the AP view, but they are not always present at the same time. A large centre for the capitulum appears in the 1st yr. A smaller one for the medial part of the trochlea appears at c.9yrs. A centre for the medial epicondyle appears about the 5th yr. It is entirely outside the capsule and unites with the shaft at 20yrs. The lateral epicondyle starts to ossify at about 12yrs. The centres for the capitulum, trochlea and lateral condyle join one another and the shaft at puberty. A centre for the head of the radius appears in the 4th or 5th yr, and unites with the shaft at puberty. There is also a centre of ossification for the olecranon, and another centre for the trochlea (not shown). These appear at c.9yrs and unite at puberty. B, in a lateral view, the shaft of the humerus and its lower epiphysis overlap one another and obscure most of the epiphyseal space, which is wider behind than in front. A normal epiphysis lies in front of the lower end of the shaft, so a line xy drawn down the anterior border of the shaft meets the epiphysis at its middle. A supracondylar fracture disturbs these relationships. *After Perkins G. Fractures and Disclocations,. Athlone, London, 1958, with kind permission.*

ELBOW DISLOCATION
A child may fracture the medial epicondyle which may become trapped inside the dislocated elbow.
Reduce an elbow dislocation in the same way as in adults. Always get a radiograph after reduction to check for additional fractures. Put on a posterior plaster slab for 2wks for protection.

If you cannot reduce an elbow dislocation, the medial epicondyle may have broken off and be inside the joint. If in doubt, compare with the other elbow, and look for a small centre of ossification in an abnormal position.

ELBOW FRACTURES
A child falls on the outstretched arm, and breaks the lower end of the shaft of the humerus just above the epiphyseal line in one of four ways:
(1) In $^{1}/_{3}$ of cases, there is no displacement, or the fracture is incomplete, so that the child needs no treatment except for a collar-and-cuff.
(2) In the remaining $^{2}/_{3,}$ the distal fragment is diplaced posteriorly (62-10A). There is tenderness just above the elbow, which swells rapidly and obscures the bones around the fracture
(3) Occasionally, the lower fragment is displaced anteriorly (73-6C).
(4) Occasionally, separation takes place at the epiphyseal line and displaces the epiphysis. Treat these epiphyseal displacements exactly as if they were supracondylar fractures, and reduce them immediately. Like all epiphyseal injuries, they unite rapidly.

Supracondylar humeral fractures are very common in children. They may be complicated by radial or median nerve as well as vascular injuries. Malunion, with a consequent restriction of function, follows if the fracture is not well reduced.

The history is usually of a fall during play followed by a painful, swollen elbow with marked limitation of movement. Antecubital ecchymosis is a sign of subcutaneous bone fragments with soft tissue interposition. It often results in severe swelling and reduction will be difficult.

Check the colour of the skin of the hand on that side, for warmth and capillary refill.
N.B. The radial pulse may still be palpable with a severe vascular injury!

Rule out nerve injuries by asking the child to cross the index and middle fingers of the affected limb (73-5A), make an 'O' sign (73-5B) and give a 'thumb's up' (73-5C) sign.

HAND SIGNS FOR ELBOW INJURY

Fig. 73-5 CHECKING FOR NERVE INJURY. A, ask the child to cross the index & middle fingers. B, make an 'O'. C, give a 'thumbs up'

The lower end of the humeral shaft break may be undisplaced or incomplete. Commonly there is a posterior (73-6A) or more rarely, an anterior (73-6C) displacement of the distal fragment.
Bony landmarks are the radial & ulnar epicondyles and the olecranon. *If these are tender or can be moved*, a fracture may be present.

Check the ulnar and radial collateral ligament stability in extended elbow position; pronate and supinate the forearm in 90° of flexion: you will be able to feel the radial head moving.

If the 3 bony points are in their correct relation to one another but are displaced in relation to the lower end of the humerus (62-1), there may be a supracondylar fracture. *This is a critically important sign in very young children before much ossification has taken place in the lower end* of *the humerus.*

You can only make a safe and correct diagnosis of any elbow fracture or dislocation by x-ray of the elbow in AP & lateral planes. The films of a child's elbow are difficult to interpret; sometimes it is helpful to x-ray the other elbow and compare both films. If you are in doubt, apply a posterior plaster slab and re-evaluate after 1wk.

N.B. (1) in children a mildly oblique radiograph can both resemble and disguise a dislocation, and (2) the radial read and medial & lateral epicondyles can be displaced before their centres of ossification appear. This makes diagnosis difficult.

If the radiograph of a child's injured elbow looks normal, & the 3 bony points are in their normal places, consider a 'pulled elbow' (actually a subluxation of the radial head).

(a) Posteriorly displaced supracondylar humeral fracture
This is a particularly important fracture as the wrong treatment can easily result in a useless elbow. They are common, arising from a fall on the outstretched arm, between the ages of 3-11yrs, and are rare >18yrs,
The radial nerve and brachial artery are in danger.
A child falls on the outstretched arm, and breaks the lower end of the shaft of the humerus just above the epiphyseal line in one of 4 ways:
(1) In $^1/_3$ of cases, there is no displacement, or the fracture is incomplete, so that the child needs no treatment except for a collar-and-cuff.
(2) In the remaining $^2/_3$, the distal fragment is diplaced posteriorly. There is tenderness just above the elbow, which swells rapidly and obscures the bones around the fracture
(3) Occasionally, the lower fragment displaces anteriorly (73-6C).
(4) Occasionally, separation takes place at the epiphyseal line and displaces the epiphysis.

DISPLACED SUPRACONDYLAR FRACTURES

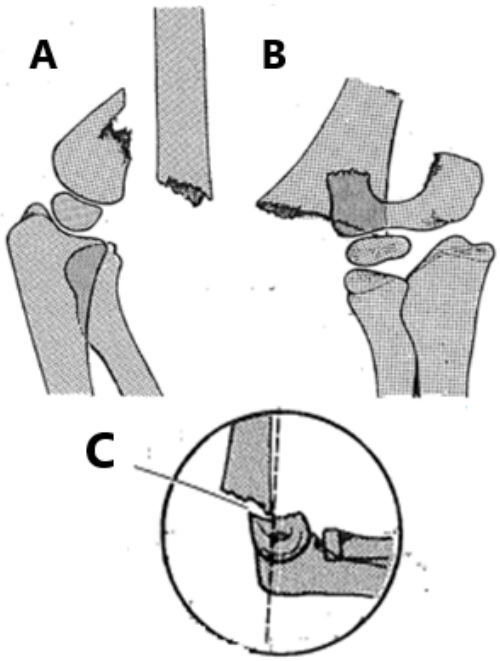

Fig. 73-6 SUPRACONDYLAR FRACTURES. A, lateral view of posterior displacement. B, anterior view. C, lateral view of an anterior displacement: the anterior humeral line should pass through the middle $^1/_3$ of the ossification centre of the capitulum

Treat these epiphyseal displacements exactly as if they were supracondylar fractures, and reduce them immediately. Like all epiphyseal injuries, they unite rapidly.

The force causing the injury pushes the distal fragment posteriorly and proximally, and the proximal fragment anteriorly and distally. The sharp proximal fragment pierces the periosteum, and comes to lie under *brachialis*. If the force continues the proximal fragment goes straight through *brachialis* into the antecubital fossa, and may even penetrate the skin.

As it moves forwards it may tear the brachial artery, or make cause spasm of the artery, or injure the median, or occasionally, the radial nerve. The artery and the nerve may also come to lie between the proximal and distal fragments, and so prevent reduction. Worse, the antecubital fossa fills with blood. This obstructs the collateral vessels which impairs the venous return from the forearm. The ischaemic forearm muscles swell and the compartment syndrome develops (49-6). *Bending such an acutely swollen elbow is like trying to bend a balloon.*

COMPLICATIONS

(1) **A rare immediate danger**, both with this fracture and with posterior dislocations of the elbow, is that the fracture can impair the blood supply to the lower arm, and cause a compartment syndrome. If the forearm remains warm, splint & watch. *If it is cool & pale, explore!*

N.B. Contracture from a supracondylar fracture is much rarer than from *failing to split a circular cast* on a fracture of the forearm.

(2) **The most common later danger** is a very stiff, or fixed elbow. This is caused by the post-traumatic ossification that may follow repeated manipulation or early aggressive physiotherapy. *So reduce the fracture with a maximum of 2 attempts.* Your 1st attempt is the most likely to succeed, and later tries will be more and more difficult.

(3) **The other common late disability** is a deformed elbow.

The displacements which remodel are:

(a) Minimal angulation of the lower fragment in the axial plane of the elbow

(b) Minimal displacement of the lower fragment; growth of the epiphysis corrects this.

(4) **If there is a neurological deficit distally,** consider exploration if there is poor reduction or after 6months.

UNCORRECTED ANGULATION IN A SUPRACONDYLAR FRACTURE

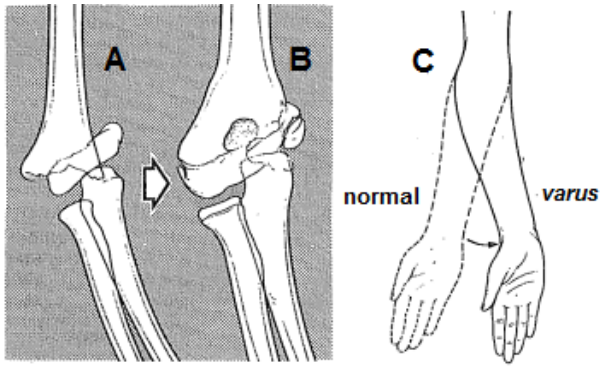

Fig 73-7 UNCORRECTED ANGULATION IN A SUPRACONDYLAR FRACTURE. C, *varus* angulation is common and results in a loss of carrying angle in mild cases, or in an ugly deformity in more severe cases, as in this child. It does not affect flexion and extension, so that disability is mild, but it does not look good. *After Perkins G. Fractures and Disclocations. Athlone, London, 1958, with kind permission*.

The displacements which don't remodel are:

(a) Severe angulation of the lower fragment in the plane of the elbow. If you leave this unreduced, or reduce it badly, the child will be left with permanent hyperextension and severe loss of flexion

(b) *Valgus* & *varus* angulation, however mild it is or young the child. *Varus* angulation is common and is usually accompanied by internal rotation and medial displacement. The result is a loss of the normal carrying angle in mild cases, or an ugly *varus* deformity in more severe ones, (73-7). This is common, and although it does not affect flexion or extension, so that disability is mild, it does not look good, and makes it difficult for the patient to carry a basket.

The fragment may also injure the median or occasionally the radial nerve. Soft tissue may also come to lie between proximal and distal fragments, and so prevent proper reduction.

A later complication is post-traumatic ossification following repeated manipulation, as with elbow dislocation (62.3).

N.B. Never treat these fractures with a circular cast. The risk of Volkmann`s ischaemic contracture is great. If you do apply plaster, it *must* be a backslab.

NEVER PUT A CIRCULAR CAST ON A SUPRACONDYLAR FRACTURE

This description is of reduction of a fracture on the *right side*, (73-8).

Flex the child`s normal elbow, feel its bony anatomy carefully, and compare it with the injured elbow. Feeling the bony parts of the injured elbow may be impossible if it is very swollen. Note especially the position of the olecranon in relation to the axis of the humerus. This is a useful guide to satisfactory reduction.

Feel how much external rotation of the flexed elbow is possible on the normal side. Later, when you come to reduce a medially displaced fragment, you will need to rotate the injured forearm externally to the limit of what is possible on the normal side, and a bit more. This external rotation may be critical. Sideways displacements either corrects itself, or is easily corrected.

Note what happens to the pulse if you flex and exert gentle traction on the arm. If the pulse disappears and only reappears when the arm is nearly straight, it may merely be due to the swelling round the elbow, or there may be a brachial artery lesion.
Try to check with an ultrasound Doppler.

If possible, reduce the fracture immediately. If there are signs of ischaemia this is urgent.

If immediate reduction is impossible because the arm is swollen like a balloon, apply forearm traction (73-9), and reduce the fracture as soon as the swelling has subsided sufficiently for you to feel the fragments.

Reduction is possible up to 7days after the injury, but not more.

If the fracture is >7days old, manipulation is very difficult, so leave it. Six months later, if there is a severe deformity, refer for a corrective osteotomy. Check the median, ulna, and radial nerves (65-3).

REDUCTION OF A POSTERIORLY DISPLACED SUPRACONDYLAR FRACTURE (GRADE 1.3)

The principles of reduction are:
(1) To exert traction on the elbow, and while doing this to correct the sideways displacement of the distal fragment.
(2) Then to flex the arm while still exerting traction, so as to use *triceps* tendon action to hold the lower fragment in place.
A common error is to try to correct sideways displacement *after you have flexed the arm*.
(3) Finally to flex the wrist maximally and keep everything fixed by taping the lower and upper arm in this position with a figure-of-8 adhesive.

N.B. If you have fluoroscopy, supinate or pronate gently, until you see exact anatomic reduction.

SUPRACONDYLAR FRACTURE REDUCTION

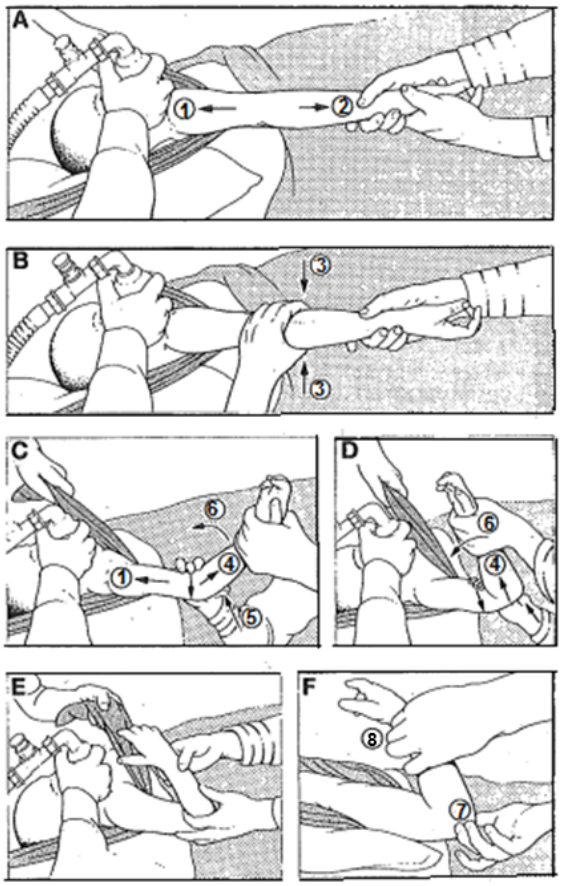

Fig. 73-8 RIGHT SUPRACONDYLAR FRACTURE REDUCTION. A, an assistant steadies the shoulder (1), and keeps the elbow slightly flexed; you disimpact the fracture by pulling on the forearm (2) for ≥1min. B, feel for the distal fragment and push it to the middle if displaced medially or laterally (3). C, keep pulling on the forearm with your left hand (4), and press the olecranon fragment with your right thumb (5), and start flexing the elbow to 90^0 (6). D, keep pressing on the olecranon & externally rotate the forearm a little more than the left side can. E, continue flexing past 90^0 pushing posteriorly on the humerus & pulling on the forearm. F, check the position of the olecranon (7) & feel the radial pulse (8). *Kindly contributed by Peter Bewes.*

Get an assistant to exert traction with a towel in the axilla. Pull to disimpact the fracture and correct the angulation. Extend the elbow gently, gripping the wrist and distal forearm. Pull hard in a longitudinal direction *for a full minute* (73-9A).

As you feel the fragments disimpacting, check that the lower humeral fragment is free. Correct medial and lateral displacement of the distal fragment now (73-9B).

Whilst exerting longitudinal traction with your left hand, press on the olecranon with your right thumb, starting to flex the elbow to 90º (73-9C). Keep pressing the olecranon & externally rotate the forearm a little more than was possible on the normal side (73-9D). (This helps to restore the normal carrying angle).

Continue flexing the elbow past 90°, push posteriorly on the humerus, and pulling on the forearm (73-9E).

CAUTION! Use only moderate tension as the arm reaches 90°. If you pull too hard at this stage, you can pull the distal fragment in front of the end of the humerus. (Fortunately, this is rare!) Now complete the flexing.

N.B. Beyond 90°, further flexion does not improve reduction, but does stabilize reduction by wrapping the *triceps* tendon round the distal fragment and fixing it. This also impacts the fragments. *You cannot now correct lateral displacement of the distal fragment.*

Check the position of the point of the olecranon (73-8F). It should be in line with the axis of the humerus or perhaps little anterior to it.
You should also be able to feel both epicondyles forming, with the tip of the olecranon, the 3 bony points of the elbow (73-4)

Check the child`s pulse. This may be difficult because of oedema. If the pulse disappears when you flex the arm, extend the elbow until it reappears.

Check the function of the median and ulnar nerves (65-3). They may be injured, but function usually recovers eventually.

ELEVATION WITH A STOCKINETTE

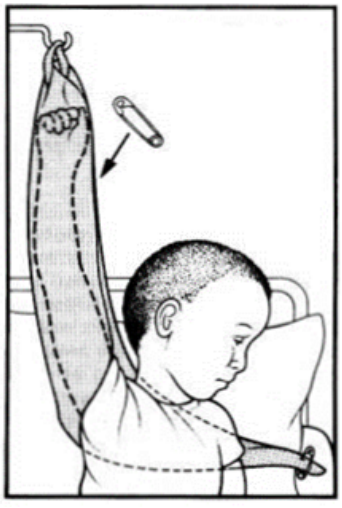

Fig. 73-9 SIMPLE EFFECTIVE ELEVATION

If there is a good radial pulse, put the elbow in a posterior plaster slab with sufficient padding to allow for swelling. Check the neurovascular status frequently during the 1st 24h. Remove the posterior plaster slab after 3wks and let the child move the elbow freely.

If you cannot get the arm beyond 70° without the pulse disappearing, use forearm traction (73-10).

If you are not sure if you can feel the pulse or not, put a warm towel for some time around the elbow to increase the perfusion.

Once the anaesthetic has worn off, ask him to flex the fingers. If this is not possible, follow instructions (73.10).

FOREARM TRACTION

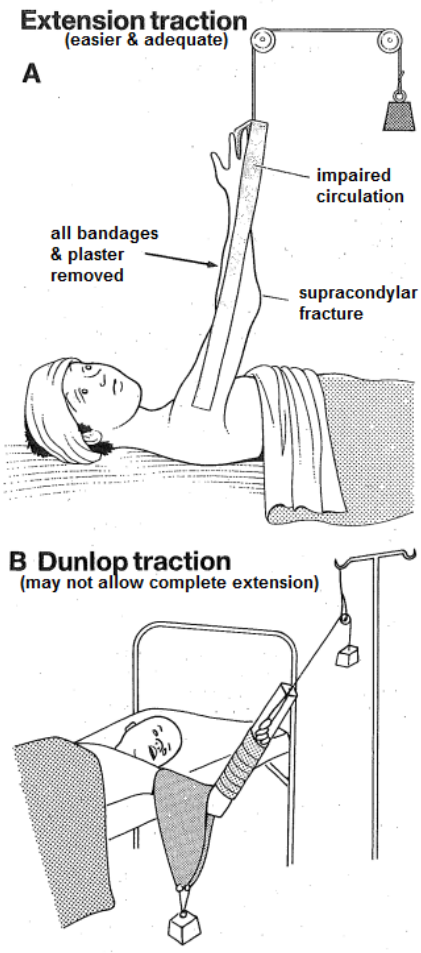

Fig. 73-10 FOREARM TRACTION is useful first treatment for ischaemia following a supracondylar fracture. If this fails to restore the circulation you need to explore the arm. A, traction in extension *(not a method of reduction)*: use a pulley, so the traction is maintained even if the child moves about in bed. B, Dunlop traction (more widely used). *After Rang M, Children's Fractures, Lippincott Williams & Wilkins, Philadelphia 1973, with kind permission.*

CHECK REDUCTION
The post reduction radiographs are of not much help in seeing if you have successfully corrected any angulation because: (1) you must keep the child`s arm flexed after reduction, and (2) the centres of ossification in the lower fragment may still be small.

There should be no angulation of the lower fragment in the AP view, no significant forward bowing in the lateral view, and the fragments must be in contact. Pay also attention to the lateral view: *there must be no step in the anterior cortex*, as this would be a typical sign of malrotation instability.

GETTING A GOOD RADIOGRAPH TO CHECK REDUCTION

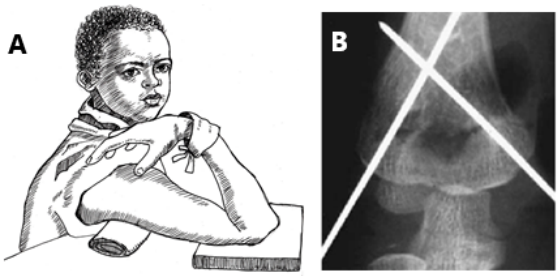

Fig. 73-11 CHECKING SUPRACONDYLAR FRACTURE REDUCTION. A, positioning the arm and the film to take the radiograph. *Don't let an assistant remove the collar & cuff to X-ray the arm. Make sure it is held in place without safety pins!* B, the post reduction radiograph. B, take a lateral and an AP view through the point of the elbow as shown. *Note the K-wires in place.*

If the reduction is unsatisfactory, have *only one further attempt at reduction*, not more, *or you will damage the elbow,* and increase the chances of post-traumatic ossification. Refer for internal fixation with K-wires in case reduction remains unsatisfactory after 2 attempts.

POSTOPERATIVE CARE AFTER REDUCTION
Make sure the child can flex and extend the fingers. Check the function of the median and ulnar nerves.

Monitor the circulation in the hand carefully for 36h. Watch for early signs of ischaemia. Check the pulse, and then assess capillary refill (which should be <2sec).

The first signs of ischaemic paralysis are: (1) pain on passive extension of the fingers, (2) paraesthesia, (3) pallor, and (4) finally the inability to use the fingers. In smaller children, anxiety & agitation may be the only signs.

N.B. Make sure all ward staff know why they are monitoring the pulse and what signs they should watch for. Otherwise, they may be quite content to feel the pulse in the normal arm!

If you have to reduce the flexion of the elbow because of impaired circulation, flex it again as the swelling decreases. Then, put a new posterior plaster slab & a repeat radiograph.

CAUTION! (1) *Forceful passive movements after removal of the cast will make the stiffness worse.* (2) *Don`t try to straighten the elbow by suggesting carrying weights.*

(b) Anteriorly displaced supra-condylar fracture of the humerus

Anterior displacement of the distal fragment of a supracondylar fracture is rare, and the signs are milder than a posterior displacement. *The ulnar nerve is in danger*.

A lateral radiograph (73-6C) may be difficult to interpret because the lower end of the diaphysis overlaps the epiphysis, especially in a young child, so that the epiphysis may appear to be displaced when it is not. Check the anterior humeral line's relationship to the epiphysis (73-4)

ANTERIORLY DISPLACED SUPRA-CONDYLAR FRACTURE REDUCTION (GRADE 1.3)

Under GA, extend the forearm. Ask an assistant to exert steady traction in the line of the arm with the forearm supinated. Steady the lower end of the humerus with one hand, and correct the sideways displacement of the lower fragment with your other hand.
Either, use traction (73-9), or apply a 10cm plaster slab along the back of the arm and forearm with the elbow extended. Keep this in place with a posterior plaster slab.

Confirm reduction with a radiograph. Remove the posterior plaster slab in 3wks and then put the arm in a sling.

Follow postoperative care as above (73.8)

DIFFICULTIES WITH SUPRACONDYLAR FRACTURES

(1) ISCHAEMIA
Early warning symptoms are pain or paraesthesiae and an early sign is difficulty to move the fingers after the reduction of a supracondylar fracture (49.2).
Be vigilant for ischaemia, quick and decisive.
If symptoms or signs are getting worse, decompression is urgent.
You have no time to refer the child. You must act immediately:

(1) Remove all bandages & any plaster cast.
(2) Apply longitudinal traction to the forearm (73-10).

If the pain disappears, the circulation improves, and the fingers start to move, maintain the traction till most of the swelling has gone, usually in c.7days.
Then reduce the fracture as well as you can, accepting a malposition, and put the arm in a posterior plaster slab.

If pain, paraesthesia, pallor, or paralysis persist for >1h, explore the antecubital fossa and, if necessary, decompress the volar aspect of the forearm if there is a compartment syndrome (49.6). *You need to do this within 3h!* Wrap the elbow in a warm towel to reduce vascular spasm whilst you prepare theatre.

N.B. Don`t explore the antecubital fossa until you have tried to reduce the fracture, because this may itself be enough to improve the circulation in the forearm.

EXPLORING THE ANTECUBITAL FOSSA

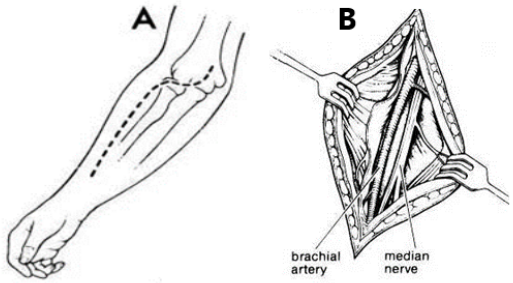

Fig. 73-12 EXPLORING THE ANTECUBITAL FOSSA. *Don't explore the antecubital fossa until you have tried to reduce the fracture*, because this may itself be enough to improve the circulation in the arm. A, incision (extended in the forearm if needed for decompressing a compartment syndrome) B, the median nerve lies medial to the brachial artery. *After Grenshaw AH, Campbell's Operative Orthopaedics Mosby 8th ed. 1961, permission requested.*

OPENING THE ANTECUBITAL FOSSA (GRADE 2.4)

Make a lazy 'S' incision (73-12A), beginning above the flexor crease & the inner border of the *biceps* tendon. Pull back the flaps, incise the tight deep fascia and the bicipital aponeurosis. Pale or blue-black muscle will bulge from the wound.

There may be a tight hematoma. Remove it. This may be enough to relieve the obstruction and restore the circulation. Carefully expose the brachial artery and the median nerve medially.

CAUTION! Don`t meddle with the artery or try to resect the spastic section.

Soak the wound with warm swabs, and dilute lidocaine or glycerine trinitrate spray.

If this fails, and the forearm is swollen, extend the incision down the forearm (73-12A). Slit the deep fascia the length of the incision. Decompress the superficial and deep volar compartments.

Leave the flaps open, and dress the wound.
If the fracture is not reasonably reduced, apply forearm traction. If it is reduced, apply a collar- and-cuff.

Close tissue over the artery & nerve; skin graft the defect after 4 days.
You may need to deal with a contracture later (34.2).

TREAT THE EARLIEST SIGNS OF ISCHAEMIC PARALYSIS IMMEDIATELY

(2) NERVE INJURIES
These are more common than vascular injuries but are less serious. Alone, *they are not an indication for an immediate operation*. Refer for exploration if there is no recovery after a month.

(3) POST-TRAUMATIC OSSIFICATION.
This occurs after 3wks, when the collar-and-cuff are removed; the elbow doesn't move, or if there is some little movement, this gradually decreases.
The anterior elbow is tender; there is muscle spasm and the *biceps* tendon stands out as a taut band. Radiographs may show a vague shadow like callus, or it may be so dense that it looks like bone. Sometimes a stiff painful elbow with new bone around it is the presenting symptom.
Put the injured elbow through several 15min periods of gentle active movements each day, both flexion and rotation. You must be patient, persistent and gentle. *Forced movements and even too vigorous passive movements will make the elbow worse.* Explain this to the child.

If the movements of the arm are diminishing, put the arm in a collar-and-cuff until muscle spasm has disappeared, which may take a month.

If the child cannot flex the elbow enough to get the hand to the mouth, put it in a loose collar-and-cuff and gradually tighten it until he can. After prolonged rest the spasm disappears and movement returns, but there is usually some permanent loss of movement.

Unfortunately, post-traumatic ossification is common, and is a major disability, especially when pronation is lost. Osteotomy followed by an arthrodesis in the position of function (c. 90°) may be necessary.

(4) SEVERE PERSISTENT *VARUS* DEFORMITY
Refer the child for corrective osteotomy, after the growth spurt. Explain to parents that remodelling is possible.

(5) MALUNION
If the fracture was never properly reduced, with only ≤30° flexion, an osteotomy may improve the range if it is around full extension,

NEVER MOVE AN ELBOW CONTRACTURE FORCEFULLY

(c) Medial humeral condylar fracture

A medial condylar fracture is a rare type of intra-articular fracture involving the trochlea and the medial part of the distal humerus.
A high level of clinical suspicion is necessary not to miss this type of injury, especially in the really young. An elbow dislocation in combination with a medial condylar fracture is rare. However, the elbow may subluxate posteriorly because of loss of stability due to the fracture.

After a fall, an older child or youth may complain of a painful elbow. The contour of the arm is normal, but the medial epicondyle is tender and swollen. Rotation is possible but painful and some flexion and extension is usually possible. Compare the radiographs of both elbows.

From 5-20yrs, the centre of ossification of the medial epicondyle is a separate piece of bone. The flexor muscles of the forearm are attached to it, and if pulled hard enough by a fall on an outstretched hand, they can pull it away from the humerus. The detached medial epicondyle may remain outside the elbow joint or enter it and lock it. Closed methods may succeed in removing it, but if they fail, an open operation is necessary. Often the elbow is dislocated also.

Test for *varus* and *valgus* instability in the elbow. A medial epicondylar fracture will only have valgus instability, while a medial condylar fracture will show both *valgus* & *varus* instability. Any suspicion of identifying ossified metaphyseal bone attached to the epicondylar fragment on a radiograph is a reason for further examination.

You can easily misclassify a medial condylar fracture as a medial epicondylar fracture. Careful clinical examination and history of the fall will help to differentiate between them.

If the medial condylar fragment displaces <4mm, treat the fracture with a posterior plaster slab for 4-6wks. Regular follow-up radiographs are necessary to monitor for secondary displacement.

If the medial condylar fragment displaces >4mm, refer for an open reduction and internal fixation to preserve elbow function. Put the elbow in a posterior plaster slab for comfort during transport.

MEDIAL CONDYLAR FRACTURE

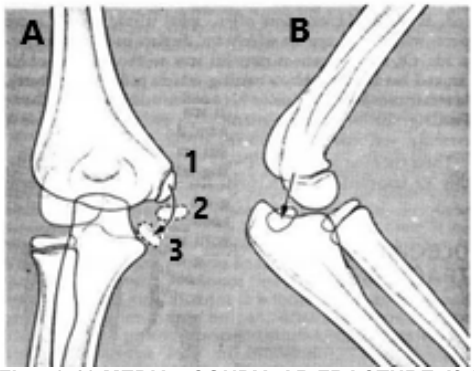

Fig. 73-13 MEDIAL CONDYLAR FRACTURE. If the child is >5yrs, the age at which the centre of ossification appears, you will be able to see if it is in its normal position A or not. If it is displaced, it may not prevent the elbow moving (B), or it may be inside the elbow and locking it (C). *After Perkins G. Fractures and Dislocations. Athlone, London, 1958, with kind permission*.

If the elbow moves adequately & the fragment displaces <2mm, put the arm in a posterior plaster slab for 2-3wks. Encourage active movements after removing the cast. Full movements may not return for 1yr.

If the elbow does not move adequately, **or the fragment displaces >2mm,** extend the wrist under GA to tense the flexor muscles. Flex, abduct, and supinate the elbow, then suddenly extend it. The fragment may reduce with a sudden clunk. Xray the elbow, and repeat the manoeuvre twice if necessary.

If then you can move the elbow through its full range of movement and it is stable, check that a radiograph shows good reduction and apply a posterior plaster slab as above.

If you cannot move the elbow through most of its full range, and you cannot reduce the medial epicondyle, an open reduction is necessary.

This is not an operation for the beginner, because the ulnar nerve will not be in its normal position and may be kinked into the joint with the medial epicondyle.

Make all incisions in the line of the nerve, *not across it.* Make a 5 cm longitudinal incision 1cm anterior to the medial epicondyle. Find the ulnar nerve and take care not to injure it. You will see the fibres of the common flexor origin emerging from the joint cavity. Pull on these fibres with a hook or forceps, and pull the epicondyle out of the joint. Find the rough place on the medial side of the elbow from which the epicondyle broke off. Fix it with two short K-wires or, if possible, with sutures. Apply a posterior plaster slab for 3wks. Remove the wires 4-6wks later.

DIFFICULTIES WITH MEDIAL CONDYLAR FRACTURES

If the ulnar nerve is injured, paralysis may be due to stretching and only be temporary. If recovery is delayed >6wks, a nerve transposition is needed.

If the fragment has been left inside the joint, and you discover it some time later, arrange for its removal. Warn that full movement may not return.

(d) Lateral condylar fracture of the humerus

The elbow is swollen and will not move. The posteromedial side of the arm is not tender, showing that there is probably no supracondylar fracture.
Sometimes the elbow is dislocated also.

This is a serious, but rare, Type IV epiphyseal injury (73-2). It occurs at a younger age than an injury to the medial epicondyle, and the displaced fragment is larger. The fracture line runs from the middle of the articular surface of the elbow upwards and laterally, isolating part of the trochlea, the whole of the capitulum, and often a small part of the shaft of the humerus (62-15).

Sometimes, there is only a little lateral shift which need not be reduced. More often, the lower fragment turns over completely inside the joint.

If this type of fracture is not reduced, it unites to the shaft with fibrous tissue, and growth in the lateral half of the epiphysis stops. The result is a severe valgus deformity of the elbow which increases until growth ceases.

Distortion of the path of the ulnar nerve round the severely deformed elbow causes a late ulnar paralysis with wasting of the small muscles of the hand.

The radiographs of the elbow are difficult to interpret, because a large part of the fragment is cartilage and casts no shadow.
Ultrasound may be more helpful. An AP view shows that the epiphysis of the capitulum is missing; instead, there is an abnormal mass of bone on the outer side of the elbow. In a lateral view this may hide behind the humerus, but usually displaces anteriorly.

In young children the flake of metaphyseal bone attached to the lateral condylar fragment can be very small and difficult to identify on a radiograph. If in doubt, compare the image of the injured side with that of the normal one. Look at the relationship between the olecranon and the distal humerus (ask yourself if there a lateral shift of the ulna) and the relationship between the radial head and the capitulum (does the articulation look congruent or not?) *Don't mistake this injury for a supracondylar fracture!*

LATERAL CONDYLE FRACTURE

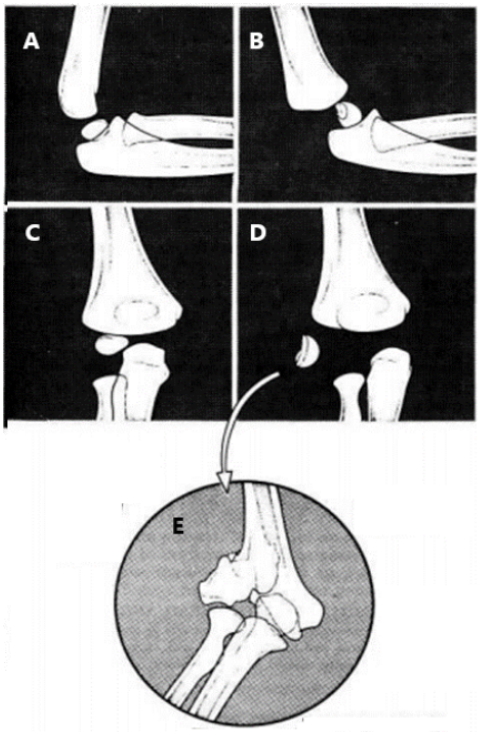

Fig. 73-14 LATERAL CONDYLAR FRACTURE is a serious Salter Harris Type IV epiphyseal injury; it occurs at a younger age than injuries of the medial condyle, and the fragment is larger. A, normal. B, displaced epiphysis. C, the lateral condyle did not take a piece of the shaft with it. D, late result of displacement, resulting in E, severe valgus deformity & probably an ulnar nerve palsy. *Kindly contributed by John Stewart.*

If there is <2mm displacement, apply a posterior plaster slab; after 5days get a control radiograph. If there is no secondary displacement, treat with the backslab for 4-6wks.
If there is 2-4mm displacement, try reducing and fixating it percutaneously. Introduce a 1st K-wire into the lateral condyle and use that to reduce the fracture. Add a 2nd and maybe a 3rd for additional rotational stability.

If the fracture is clearly unstable or cannot be reduced, an internal fixation is necessary: perform a 5cm longitudinal incision over the epicondyles, dissect bluntly to the bone, reduce the fragment and fix it with 2 K-wires putting pressure on the fracture line. If available, take a small screw to fix it. Apply a posterior plaster slab also for 4-6wks.

CONSEQUENCES OF LATERAL CONDYLAR FRACTURE

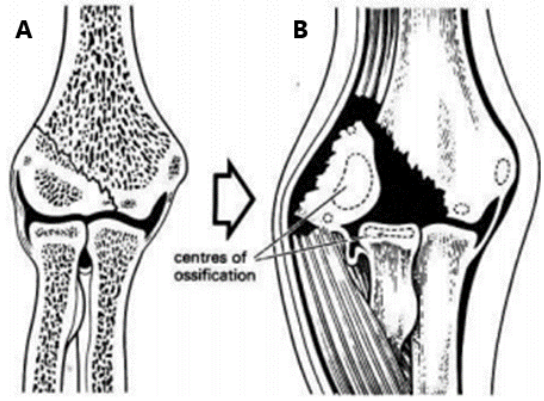

Fig. 73-15 LATERAL CONDYLAR FRACTURE CONSEQUENCES. If this injury is not treated correctly, it will be followed by a severe valgus deformity which increases until growth ceases. *After Watson Jones R, Fracture & Joint injuries, 4th ed. Churchill Livingstone 1976 with kind permission.*

.

DIFFICULTIES WITH FRACTURES OF THE LATERAL CONDYLE

If 10-30yrs later, there is numbness and tingling in the ulnar side of the hand, followed by wasting of the small muscles of the hand, there is an ulnar nerve paralysis. Warn that this may follow the progressive valgus deformity of the elbow many years later, because the patient may not connect it with the injury. The ulnar nerve should be moved anteriorly in the elbow *before* the small muscles of the hand start to waste.

N.B. Fracture-separation at the epiphysis, especially if the child is <18months, suggests child abuse (47.1).

This needs reduction, holding at 90º, with the forearm pronated, in a posterior plaster backslab for 3wks.

DISTAL HUMERAL EPIPHYSEAL INJURIES

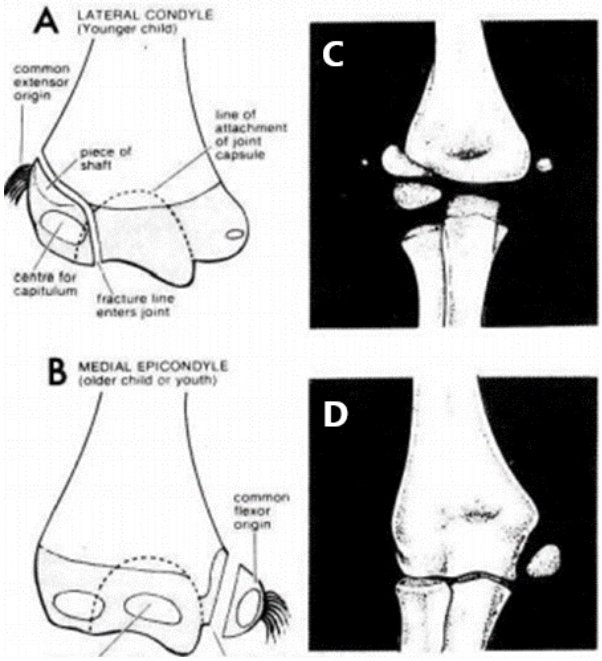

Fig. 73-16 DISTAL HUMERAL EPIPHYSEAL INJURIES. The medial & lateral condyle differ considerably. A, the lateral condyle is a pressure epiphysis to which the common extensor origin is attached. It is fractured in young children. The fracture line enters the joint displacing the centre for the capitulum and sometimes part of the shaft. You must accurately replace the displaced fragment (B). C, the medial epicondyle is a traction epiphysis outside the elbow joint to which the common flexor origin is attached. It is displaced in teenagers, and D, unless it happens to enter the elbow joint, it need not be removed or reattached.

(e) Pulled elbow

This common injury is the result of lifting up a child by one arm, or swinging him around on it. Many minor and otherwise undiagnosed injuries are probably pulled elbows. The head of the radius slips out partially from the annular ligament and subluxes. The injury is very rare after 5yrs, because of changing physiology in the child's elbow.

A child with a pulled elbow holds the hand in pronation, refuses to use the arm, and cannot rotate the wrist, but generally will not complain of pain. Sometimes, the head of the radius is tender. Radiographs are normal. The differential diagnosis is a fracture of the radial neck.

If the clinical presentation and history match with the diagnosis of a pulled elbow, there is no need for a radiograph. Continue immediately with the reduction manoeuvre.

PULLED ELBOW

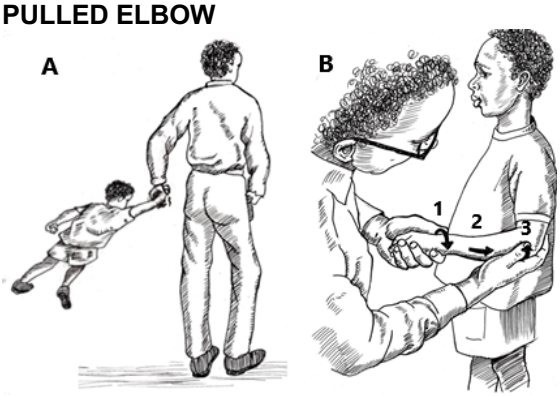

Fig. 73-17 PULLED ELBOW. A, the mechanism of the pulled elbow: all the child's weight is transmitted to the elbow! B, Reduce it this way: cup the elbow, apply slight traction on the forearm, and then suddenly supinate (1) and drive it elbow-wards (2), whilst pushing the head of the radius with your thumb (3).

Treatment is usually easy (73-17). Rotate the forearm in extreme pronation while holding the elbow joint. If this does not work, follow the manoeuvre using supination (73-17). Keep the child for evaluation for 30mins after reduction. If the arm moves normally at that point, the problem is solved.

If the arm still doesn't move correctly obtain radiographs of the elbow to exclude a fracture or dislocation. Otherwise, apply a sling and reassess in 5-10 days. This will usually free the head of the radius from the annular ligament. Sometimes, just extending the elbow will do the same.
The child may cry loudly, but then will usually be able to move the arm. In this case, apply a backslab in full supination for 3days.

(f) Radial neck fracture

In this common injury, a force travelling up the arm drives the head of the radius against the capitulum. In a child, the neck of the radius bends displacing its head anteriorly and laterally, but the head itself almost never fractures.

A child falls on the outstretched hand and breaks the neck of the radius just distal to the epiphyseal plate, proximal to the attachment of the biceps. The head of the radius angulates anteriorly and laterally on its broken neck, and usually remains attached to the shaft.

The same injury may fracture the medial epicondyle, strain or rupture the medial ligament of the elbow, or fracture the upper third of the ulna.

RADIAL NECK FRACTURE

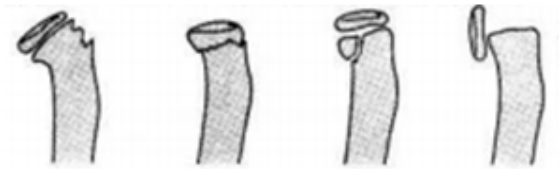

Fig.73-18 RADIAL NECK FRACTURE Treat this conservatively. *Never excise the head!* *Kindly contributed by Peter Bewes*

The contour of the elbow is normal, and flexion and extension are less painful than rotation. The posterior interosseous nerve (PIN) may be injured; check extension of the wrist, fingers and thumb.
As a child may complain only of wrist pain because of referred nerve pain, *always get a radiograph of both elbow & wrist.*

If this injury occurs before the centre of ossification appears in the head of the radius at 10yrs, the only radiological sign is an irregularity in the metaphyseal margin.

Treatment depends on the degree of angulation and on the child's age. Mild angulation needs no treatment. You must correct moderate and severe angulation, because the head may grow abnormally and ultimately dislocate, particularly after severe displacement in an older child. In very young children, the head may grow almost normally, even after severe displacement. *Never excise the head*, because this is sure to cause a severe growth deformity.

TREATMENT
For a child >10yrs, with the head angulated <30°, a posterior plaster slab for 10days.
With the head angulated >30°, try a closed reduction, even if the head is severely displaced

For a child <10yrs, with the head angulated <45°, a posterior plaster slab for 10days.
With the head angulated >45°, try a closed reduction.

If the child's elbow Is also dislocated, reduce it and then treat the radial head.

If the radial head is completely separated, an open reduction is needed.

CLOSED REDUCTION (GRADE 1.3)
If the child's elbow is very swollen, suspend the arm in extension traction (73-10), until the swelling has reduced. Then try reduction under GA (73-19)

If this fails to reduce the angulation to 30° (child>10yrs) or 45°(child< 10yrs) or less, an open reduction is necessary.

POST REDUCTION RADIOGRAPHS
In both AP & lateral views, the surface of the radial head should be parallel to the capitulum.

POSTOPERATIVE CARE
Apply a posterior plaster slab for 2wks.

REDUCTION OF DISPLACED RADIAL NECK

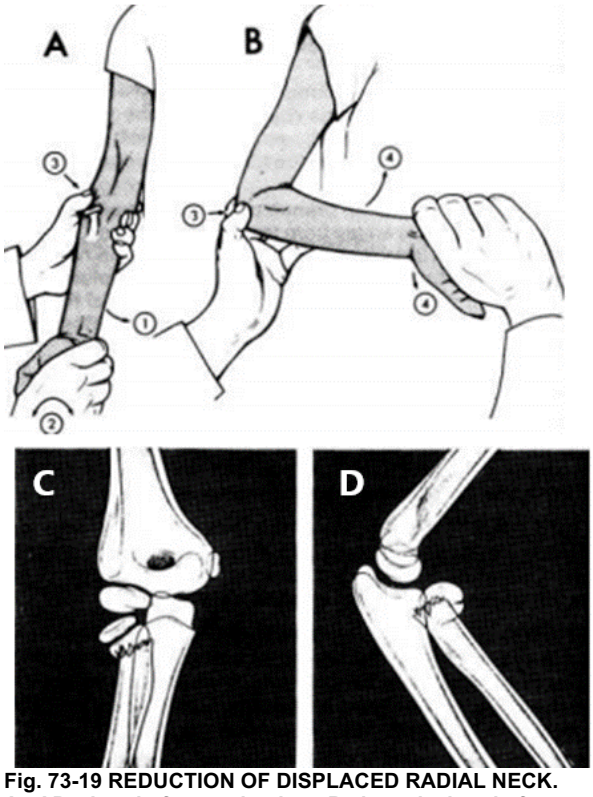

Fig. 73-19 REDUCTION OF DISPLACED RADIAL NECK. A, AP view before reduction. B, lateral view before reduction. C, with an assistant to steady the upper arm, extend the elbow, grasping the wrist with one hand and the elbow with the other, adduct the forearm at the elbow (3), so as to open the joint between the capitulum and the head of the radius a little. Rotate the forearm (2) into the position in which the most prominent part of the displaced head lies laterally and superficially. D, put your thumb over the displaced head of the radius. While you adduct the forearm, press the head of the radius proximally and medially (3). Now flex the forearm and supinate it sharply (4).

(g) Olecranon injuries

The child of 10-16yrs will present with the elbow flexed and with a swelling over the olecranon. Extension of the elbow will be difficult and painful.

A child may have several centres of ossification in the olecranon, so you may have difficulty deciding if there is a fracture or not. If in doubt, x-ray the other elbow.

The apophysis of the olecranon occasionally separates from the shaft of the ulna because the *triceps* tendon pulls it off during a fall. This fracture can occur before the centre of ossification of the olecranon appears. Treat with a posterior plaster slab for 3-4wks.

If the olecranon fracture displaces <4mm and shows adequate joint congruence, treat with a posterior plaster slab for 3-4wks.

If the olecranon fracture displaces >4mm or if there is clear joint discongruity, treat it as an adult olecranon fracture.

73.8 Forearm injury in children

The child will present with a very painful arm, usually supporting it with the other arm. He will refuse almost any clinical examination out of fear and pain and will refuse active mobilization of any part of the affected arm. Usually, the diagnosis is apparent immediately because of a gross forearm deformity.

Although adult forearm fractures are difficult, you can, however, treat most forearm fractures of children (<10yrs) conservatively, because the bones remodel.

It is important to take strict AP & lateral views, because otherwise you cannot assess the true angulation of the fracture.

Keep in mind that the wrist and elbow, also need radiographs, to exclude associated injuries. Assess the extent of deformation in terms of lateral displacement, angulation, and shortening or distraction.

The key goals of treatment are: (1) maintaining correct length of radius and ulna, (2) maintaining correct radial angulation for proper pronation & supination, & (3) maintaining the function of the proximal and distal radio-ulnar joints.

You can assess acceptable degrees of angulation and displacement by age as below:

	Location	Angulation	Displacement
<9yrs	Distal $^1/_3$	20°	50-100% without overlap
	Mid $^1/_3$	15°	50-100% without overlap
	Proximal $^1/_3$	10°	50-100% without overlap
>9yrs	All parts of the forearm	10°	0-50°

Forearm fractures in children present in 4 different patterns: bowing, greenstick, complete and comminuted fractures. All 4 patterns have their own specifics that require attention.

Bowing fractures have no one clear radiological fracture line, but are actually a combination of multiple micro-fractures across the shaft of the ulna or radius. Reduction of radial or ulnar bowing may be necessary in children >9yrs, where limited potential for remodelling remains. Cut-offs in the table above apply here as well.

Greenstick fractures pose specific challenges for treatment. If the fracture of the ulna and the radius are not at the same level, this indicates that there is a rotational component in the deformity that you need to take into consideration when reducing the fracture.

Complete and comminuted fractures are inherently unstable and will need at least a closed reduction. If this is insufficient, an internal fixation will be necessary.

If the fracture is only minimally displaced (see table above for age and location specific cut-offs), put on a well-moulded circular cast from the knuckles to the middle of the upper arm with the forearm in mid-pronation. While the cast is still soft, straighten the forearm.
Get a check radiograph at 2wks to make sure no secondary displacement has occurred. If it has, reduce the fracture under GA and re-apply the well-moulded above elbow circular cast.

ALWAYS MONITOR A CHILD FOR POTENTIAL COMPARTMENT SYNDROME FOR 24h AFTER REDUCTION AND APPLICATION OF A CIRCULAR CAST

We recommend the following positions for a child's forearm in a cast, if the child permits:
(1) distal $^1/_3$ radial fracture: pronation
(2) middle $^1/_3$ radial fracture: neutral
(3) proximal $^1/_3$ radial fracture: supination.
In this way the pull of *pronator quadratus, teres & biceps* will be neutralized; there will be less risk of permanent rotational deformity.
Otherwise place the cast in a position acceptable to the child.

If the fracture is displaced beyond the cut-offs described in the table above, reduce the fracture, and treat as above.

Correct angulation carefully, especially in the lateral (coronal) plane, which remodels even less readily than angulation in the antero-posterior (sagittal) plane.

If the fracture is higher up in the middle or proximal $^1/_3$ of the child's radius, remodelling is less rapid and less complete, especially if the child is older. So under GA, bend the radius back.

Greenstick midshaft fractures of the middle $^1/_3$ of both forearm bones cause an obvious bowing of the child's forearm. Correct angulation carefully, because the fracture has only limited potential for remodelling later in life. You will have to decide whether you will completely break the greenstick fracture to facilitate reduction or not. The remaining periosteal connection however gives stability to the fracture which is useful during the healing process. However, its pull also makes it more difficult to maintain a full reduction of the fracture. Breaking this periosteal bridge will facilitate reduction but will make the fracture more unstable, potentially risking secondary displacement. Therefore try to maintain the periosteal bridge if possible for the sake of stability, but don't be afraid to break it to obtain an adequate reduction.

CAUTION! If you fail to correct the angular or rotational deformity, loss of pronation and supination may follow.

Put on a well-moulded above elbow circular cast for 6wks. Start active movements of the shoulder and fingers as soon as possible. Repeat radiographs during the 1st 3wks, looking for angulation, and if necessary, correct it under GA.

Explain to parents that there is an increased risk of refracturing in the first 4months after the accident. The child should refrain from sports and any activity with risk of falling on the arm again.
N.B. There is no need for additional protective measures such as a sling or keeping the child longer in a cast.

If angulation in one plane persists or more compression on the site of the greenstick fracture is needed, wedge the cast after 7days. A secondary dislocation of the fragments, resulting in an angulation >10° in the check radiograph 7days later, should make you re-assessment your treatment.

Break the bones with a sharp bending force, and slightly overcorrect the deformity if reduction is not possible. Then suspend the forearm as for a complete fracture, apply a long arm cast.

If you cannot reduce the fracture adequately after 2 attempts or there is persistent secondary displacement after reduction, an internal fixation with K-wires will be necessary. Refer the child for internal fixation if you do not have the adequate equipment or skills at hand.

SPECIFIC FRACTURE PATTERNS THAT REQUIRE SPECIFIC ATTENTION

(a) The Monteggia fracture (63.3), a displaced proximal ⅓ ulnar fracture with a radial head dislocation, is commoner in children than in adults. In younger children it can also present with bowing of the ulna instead of a fracture. Unless you reduce the dislocation of the radial head (63-5), the elbow will never be able to flex again. The longer the delay, the more difficult is the reduction.

Although adult forearm fractures are difficult, you can, however, treat most forearm fractures of children <10yrs conservatively, because the bones remould.

When both forearm bones fracture in a child, the fracture is likely to be a greenstick type.

(b) Incomplete Galeazzi fractures (63.4) cause a child's lower forearm to bow forwards. There is tenderness over a greenstick fracture of the radius, usually in its distal ⅓. The distal end of the ulna is also tender. Closed reduction is usually straightforward.

(c) Fractures of the lower ¼ of the radius and ulna in young children.
In this common injury, a young child breaks both the bones transversely c.4cm above the wrist.
The fracture is usually greenstick, and the lower fragments angulate radially and anteriorly. Sometimes the ulna remains intact, and the only radiological sign is buckling of the radial cortex on one side (the buckle fracture).

If the fracture is complete, both lower fragments displace behind the shafts and produce a dinner fork deformity. The lower ¼ of the forearm bones readily remodel, particularly in very young children, so that unless there is a significant degree of angulation, no reduction is necessary. If necessary you can leave it.

The younger the child, the more the displacement you can accept.

CLOSED REDUCTION OF FRACTURES OF THE LOWER ¼ OF THE RADIUS AND ULNA

If the lower fragment of the radius is angulated, straighten it. Disregard the ulna.

REDUCING OVERLAP

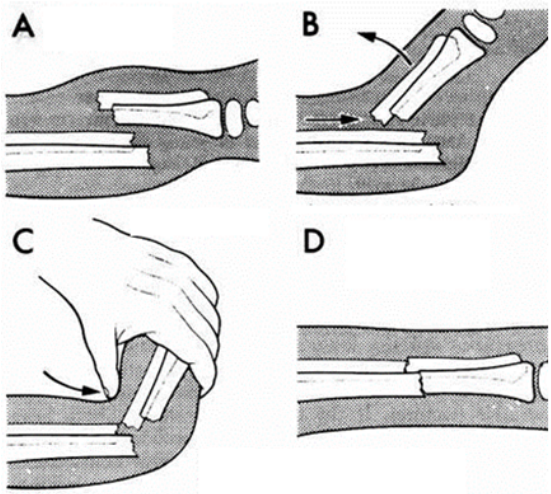

Fig. 73-20 REDUCING OVERLAP. A, before reduction. B, start by increasing the angulation. C, then get the ends of the bones to hitch by pushing as shown. D, finally, straighten them. *Kindly contributed by Peter Bewes.*

If you decide to reduce the overlap, increase the angulation as far as possible, press on the base of the distal fragments when they are fully angulated, get the ends to hitch, and then straighten and distract them (73-19). Apply a long arm cast in full pronation.
Consolidation takes 6wks. Keep the cast on for the full period.
The child may fall again and refracture the arm, so in this case, re-apply a forearm cast for another 6wks. Split the cast in children after their growth spurt, and in obese children; *not otherwise!*

IF CLOSED REDUCTION FAILS, this may be because the *pronator quadratus* comes between the bone ends. Management now depends on whether the child's epiphyseal growth lines have closed or not.

If the epiphyseal growth line at the lower end of the radius is open, it is not important if the fragments are end on or not, provided the radius is reasonably straight. They will remodel themselves completely in 2yrs, so some overlap is permissible.
If you fail after 2 attempts, stop. Apply a long arm cast, and start exercises immediately.

If the epiphyseal growth line is closed, make a 2nd attempt at closed reduction. If this fails, you can attempt open reduction if you are experienced. Do this as early as you can, but before 10 days.

OPEN FOREARM FRACTURE REDUCTION (GRADE 2.4)
Incise the back of the forearm longitudinally over the fracture, separate the muscles, open the periosteum longitudinally, and lever the displaced fragments into place with any convenient instrument, such as a MacDonald's dissector. Close the wound in layers, and apply a backslab held in place with a crepe bandage. Take out the sutures 1wk later, and apply a long arm cast as for an extension fracture of the wrist (74.2), but extending above the elbow with the wrist in a neutral position. Leave the long arm cast on for 6wks, and then apply a forearm cast for 4wks more.

73.9 Wrist injury in children

AGE DIFFERENCES
0-5yrs.
A young child usually has a greenstick fracture of the lower third of the radius, and sometimes of the ulna also. If the injury is severe, both the forearm bones may break transversely just proximal to the wrist (73.8).

5-10yrs
In an older child fractures of the lower quarter of the radius and ulna are more often complete (73.8), and the fragments may overlap.

10-15yrs
A young teen typically has a fracture separation of the distal radial epiphysis.

The bony remodelling capacities after distal radial fractures in childhood depend on:
(1) the remaining growth potential, which is a function of age,
(2) the position of the fracture along the metaphysis,
(3) the extent of angulation.

You can assess acceptable degrees of angulation and displacement by age as below:
(1) Differences in boys & girls reflect different ages of puberty.
(2) Simple distal radius fractures without significant displacement or angulation simply require a below elbow cast for 4wks.

Age	Palmar/ dorsal flexion	Displacement
Girl <8yrs Boy <10yrs	20°	50-100%
Girl 9-11yrs Boy 11-13yrs	10°	0-50%
Girl >11yrs Boy >13yrs	0°	0%

A greater deformity results in unfavourable mechanical performance & poor cosmesis.

The power of growth-associated spontaneous correction is enormous and even continues beyond the age of 10yrs. Your options are: (1) conservative treatment, (2) plaster wedging, (3) reduction and percutaneous K-wire stabilization.
N.B. An open reduction of metaphyseal fractures is almost never necessary.

If displacement is not acceptable either for cosmetic reasons or growth potential, a reduction manoeuvre is mandatory. Wedging the cast without GA is, rarely, satisfactory. In the majority of cases reduction GA is necessary.

1-2 crossing K-wires are usually sufficient to avoid secondary displacement within a plaster cast.

Distinguish between the completely slipped epiphysis and fractures with shortening and the minimally angulated fractures with maintained bony contact. The 1st need a complete reduction and, most likely, fixation under anaesthesia, while you can treat the 2nd conservatively or with wedging.

(a) Fracture separation of the distal radial epiphysis (10-15yrs)

This is the most common epiphyseal injury. The fracture passes partly through the radial metaphysis, and partly through the epiphyseal line (Type II, 73-2) or only through the epiphyseal line (Type I). Its lower end usually displaces and tilts radially and posteriorly. There may also be a fracture of the styloid process of the ulna, or a separation of its epiphysis. Fortunately, if you reduce the epiphysis, subsequent disability is rare.

If the radial epiphysis is displaced dorsally, under GA, press it firmly forwards into place. There is no need to exert traction, because the epiphysis is not impacted. It will hinge forwards on its intact dorsal periosteum, which will prevent over correction.

You should feel a distinct 'clunk' when the epiphysis falls back into its correct position. Otherwise consider fixing the epiphysis with a K-wire to avoid secondary displacement.

Apply a well moulded cast with 3-point moulding extending above the elbow with the forearm in neutral position and the wrist ulnar deviated and slightly flexed. (This looks as if the arm is ready to shake someone's hand.) Leave it in place for 6wks.

The epiphysis may displace secondarily, so x-ray the wrist at 1 & 2wks after reduction. If it displaces, it needs internal fixation.

The prognosis is good, even if there is slight residual angulation after reduction.

DISPLACEMENT OF THE DISTAL RADIAL EPIPHYSIS

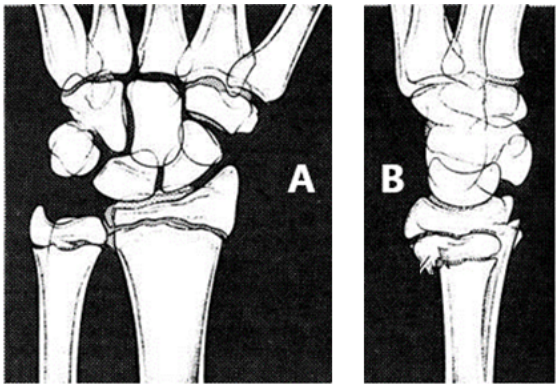

Fig. 73-21 FRACTURE SEPARATION OF THE DISTAL RADIAL EPIPHYSIS is the most common epiphyseal injury. A AP view, and B, lateral view more typical appearance is that in 73-1D,E, which show the fracture line passing partly through the radial metaphysis, and partly through the epiphyseal line (Type II), tearing the triangular ligament.

73.10 Hand injury in children

A child's epiphyses are easily displaced, especially those of a proximal phalanx close to its MP joint, sometimes with considerable rotation at the line of separation. Try to reduce these displacements as best you can.

Where you have no grip on the proximal part of the fracture or the epiphysis, put a pencil in between the fracture finger and the finger away from which the fracture finger is now pointing because of the displacement. The pencil should be perpendicular to the palm of the hand and resting in the interphalangeal web space. Now push the dislocated fracture in the direction of the pencil while stabilizing itl and the hand with your other hand.

The pencil will stabilize the proximal fragment; you can easily reduce fractures and displaced epiphysis this way.

REDUCTION OF A PROXIMAL PHALANX FRACTURE

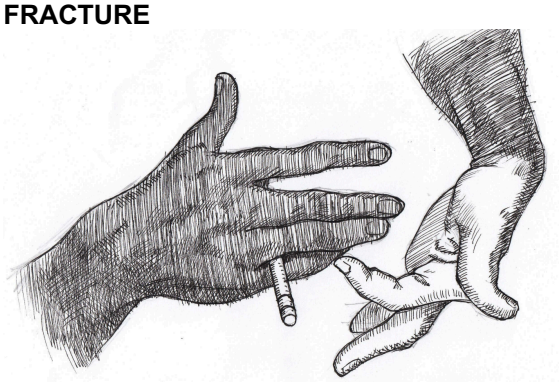

Fig. 73-22 PENCIL METHOD FOR REDUCING A DISPLACED PROXIMAL PHALANX FRACTURE.

In a child's finger, the tendon of *flexor digitorum profundus* is inserted into the phalangeal metaphysis, and the long extensor tendon into the epiphysis. A combined angulating and crushing injury (65-17C) can cause a mallet finger. Take a lateral radiograph to distinguish this from rupture of the extensor tendon, which is rare. Treat as you would treat a mallet finger in adults.

If the distal fragment of the distal phalanx is forced out through the nail bed (10 in 65-15, & 75-13)**,** re-position the distal phalanx by open reduction, and insert the proximal end of the nail into the nail fold where it will act as a splint. Splint the distal ip joint in extension (like a mallet finger) for 2wks. These are serious, difficult injuries, and a mallet deformity often follows.

If the neck or diaphysis of a phalanx is fractured, and the distal fragment is rotated (16 in 65-15)**,** you need to reduce the fracture as well as correcting the rotational deformity. Open reduction and internal fixation with a K-wire are needed when the fracture is unstable or you cannot reduce it or there is a major displacement >15° or a rotational deformity persists,.

N.B. If you fail to achieve reduction, permanent loss of flexion may result.

EPIPHYSEAL INJURIES OF A FINGER

If an epiphysis is minimally displaced (33, in 65-11), no reduction is necessary. Treat the child with a buddy tape of the afflicted finger and the adjacent larger finger for 1-2wks for comfort.

If an epiphysis is more than minimally displaced, and especially if there is any rotation deformity (34 in 65-11), be sure to correct it, so that the injured finger is in proper relation to its neighbours in both flexion and extension, and is not rotated. Then splint it, preferably with an aluminium splint. Most displaced epiphyses are in the proximal phalanx close to the mp joint. These types of injuries will remodel in the plane of flexion and extension, but lateral and rotational deformities will not correct, so accurate reduction is essential.

Metacarpal fractures are typical injuries of adolescents after hitting something with a full fist (the boxing fracture). Most are only minimally displaced and you can treat these with a boxing glove cast. This is a lower-arm cast that includes the fingers so as to stabilize both joints of the metacarpal bones. In case of gross displacements, or clear shortening of the metacarpal, reduce the fracture and keep the hand for 6wks in a boxing glove cast. In case of persistent instability refer for internal fixation.

73.11 Pelvic injury in children

Acetabular fractures in children are rare. The mechanism of accident is usually a crushing force. The child pelvis is more plastic than the adult's and can sustain more forces before breaking. Most pelvic fractures in children stem from motor vehicle accidents.

Most of the general adult pelvic trauma principles apply to children as well. Treat undisplaced and stable pelvic fractures conservatively. *Remember displaced pelvic fractures can lead to life-threatening bleeding.*

If a child presents with a pelvic fracture, examine the child fully and exclude any other potentially life-threatening injury.

As in adults, fixation is only necessary in severe dislocation. Fractures of the entire pelvic ring, such as open book fractures, cause massive haemorrhage, and therefore need emergency treatment by a pelvic binder. Always check for an associated lesion of the urethra, and other abdominal injuries.

Treat almost all undisplaced fractures of the pelvis and sacrum conservatively by bed rest and non-weight bearing until the pain subsides (c. 3wks).

Put young children in a spica cast (73-22) Isolated fractures of the iliac bone or crest, of the anterior pelvic ring are the most common.

Sometimes a child will present with an avulsion fracture of the iliac spine, most commonly after an athletic activity. Treat this conservatively with crutches and non-weight-bearing for 2wks and gradual return to weight-bearing afterwards.

73.12 Hip injury in children

Hip fractures in children are rare but can happen as part of a polytrauma or because of a fragility in the bones, *e.g.* a bone cyst or osteoporosis secondary to malnutrition. Always take a good history to understand why such a child has sustained such an injury. Treat the underlying causes if possible.

A child's femoral head receives its blood supply from the *ligamentum teres.* So, any injury to a child's hip should be treated as fast as possible to protect the blood supply to the femoral head and avoid avascular necrosis at a later stage.

Children around the age of 2yrs sometimes suddenly start to limp, complaining of pain, and have restricted movements in their hip. In most cases the pain is focused on the knee joint, but the movements there are unrestricted.

Include radiographs of the lower leg, as young children sometimes continue walking on a hairline fracture in their tibia. Otherwise consider transient synovitis, which is a painful joint effusion (visible by ultrasound) which occurs after a viral infection

Treatment is bedrest, analgesia & NSAIDs for 3days. Recovery is usually uneventful; fluid aspiration is only necessary in prolonged cases.

CAUTION! The differential diagnosis is a septic hip. If you have any clinical sign of severe infection, *e.g.* high fever, high ESR or CRP or leucocytosis, particularly with excessive pain and warmth around the joint), immediately aspirate the joint, drain the pus & flush with copious saline into the joint. Administer broad spectrum antibiotics, and later those antibiotics suggested by culture & sensitivity.

If you overlook a septic hip, necrosis will result, or even life-threatening sepsis.

HIP SPICA
You will sometimes find a plaster spica useful to immobilize the hip, or more often, the femur in young children. Unfortunately, hip spicas are expensive because they need a lot of plaster. Also, they are inconvenient, because a patient has to be lifted on to a bedpan. But, provided a family can cope, a spica can treat children with femoral fractures at home or in a near-by health centre for at least part of their illness, whereas they would otherwise need a hospital bed.

INDICATIONS
(1) Fractured femur in children, preferably after union has occurred in gallows or extension traction (73.13).
(2) Undisplaced pelvic fracture
(3) Postoperatively, following release of a flexion contracture of the hip.
(4) Septic arthritis of the hip.

EQUIPMENT
A low stool, or better, a special support;
Stockinette; Cotton wool
PoP rolls in 10,15 & 20cm breadths;
Padding material;
Crepe paper to prevent liquid PoP seeping into the wool.
[You can, alternatively use 10-20 layers of toilet paper, covered with 15cm strips of plastic from bags].

APPLYING THE SPICA
Anaesthetize the child with ketamine. Use a suitable support and pad the leg and trunk. Put extra padding over the bony points, particularly the sacrum (73-22)

If there is a femoral or pelvic fracture, continue the spica to the ankle. Otherwise, keep the knee free; you can insert a pin through the lower end of the femur and incorporate this in the cast to will allow movement of the knee but stop the femur rotating at the hip.

Remember to turn the child over, and inspect the back of the cast carefully to make sure it is comfortable and not pressing into the skin.

CAUTION!
(1) A hip spica must engage the lower ribs on each side.
(2) There must be space for the abdomen to move, otherwise respiratory difficulty or ileus may follow.
(3) Enough of the buttocks must be free to allow sitting on a bedpan.

Nursing care is not easy, and the spica soon becomes soiled; pressure sores, skin irritation, especially in the perianal area may ensue. Protect the spica with plastic in this region.

N.B. You may be able to apply gallows traction or a long leg cast first and then convert to a spica.

MAKING A HIP SPICA

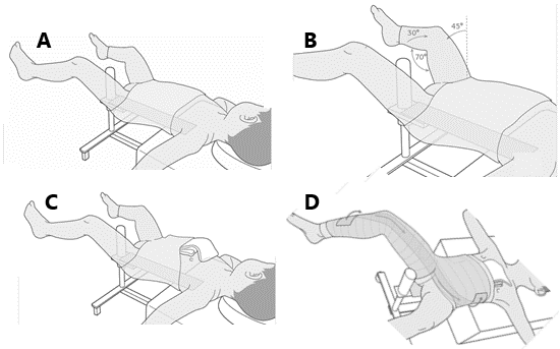

Fig. 73-22 APPLICATION OF A HIP SPICA. A, place the anaesthetized child on a suitable support which has the spine supported but the legs free. Put stockinette around the leg, hip, pelvis and chest to nipple level: it helps to sew the leg part to the trunk part so they don't separate. B, make sure there is 30^0 hip abduction, 45^0 hip flexion & 75^0 knee flexion. C, put a folded towel over the abdomen under the bandage to allow for breathing. *Keep a tail of the towel free to pull it out later.* D, apply the cast with reinforcing straps. *N.B.* Cut a hole over the central abdomen to make it more comfortable.

(a) Femoral neck fractures

Fractures of the neck of a child's femur are rare but serious. Subsequent remodelling will not correct the femur's deformities. Changes in its angle persist, so if the fracture produces *coxa vara* (lessening of the angle between the neck of the femur and its shaft), this deformity will become worse over time and be permanent.

A preferred treatment for femoral neck fractures is internal screw fixation, irrespective of stability and level of displacement. If you can, try to refer for this.

Apply extension traction and try to correct the angle of the neck of the femur correct.
Overlapping and anteroposterior angulation are less important. Correct the deformity and once callus starts to form (c. 2wks, in children <10yrs old), apply a plaster spica.
In older children continue extension traction until the hip fracture is sufficiently stable on radiographs. Continue non-weight bearing for a total of 10-12wks.
N.B. There is a high risk of aseptic bone necrosis or pseudarthrosis.

INTERTROCHANTERIC FRACTURES
Reduce the fracture using traction for c.2wks until callus appears on radiographs. Gallows traction (73-24) is suitable for children up to c.3yrs, or at the most 5yrs if the child is small.

For older children <10yrs, use extension traction. Then apply a plaster hip spica with the hip in wide abduction for 8-10wks.

Consider internal fixation for children >10yrs. If internal fixation is not possible, treat with extension traction and non-weight bearing for a total duration of 10-12wks.

Treat SUBTROCHANTERIC FRACTURES in children in the same way.

(b) Traumatic hip dislocation

Traumatic hip dislocations are rare in children and tend to reduce easily if seen early. A child's femoral head receives its blood supply from the *ligamentum teres* and therefore, there is direct correlation between the delay till reduction and the risk of avascular necrosis of the femoral head. Reduce the dislocation as you would treat an adult hip dislocation. Outcomes are generally good.

POST-REDUCTION CARE
Put the child in a hip spica (if <10yrs) or on strict bed rest if >10yrs for 4-6wks. Get a radiograph to check for an adequate position of the hip. Make sure to exclude a traumatic separation of the epiphysis of the femoral head and any fractures to the acetabulum. Just because there was no fracture to the acetabulum visible on the initial radiograph, doesn't mean that there isn't one! Check the post-op radiograph carefully as well. In case of an acetabulum fracture, treat appropriately with bedrest.

If there is a hip dislocation in combination with a femoral head, neck or pertrochanteric fracture an open reduction will almost always be necessary. Do not stall this intervention as the survival of the femoral head depends on it.

(c) Slipped upper femoral epiphysis

This is quite a common disease of obese middle to late teenagers. It is an epiphyseal injury (Type I, 73-2) in which the child's upper femoral epiphysis slips spontaneously backwards and downwards through the epiphyseal line, either gradually or suddenly, often after only a minor injury.

In 20% of cases, the other epiphysis slips too, even while the patient is in bed being treated for the first one. Try to diagnose and refer these patients for internal fixation early, because the results will be good.

If you leave an epiphysis which has started to slip, it may slip completely, so that extensive and often unsuccessful major surgery is needed.

Gradual slipping may occur; a teenager complains of pain in the hip or knee, and starts to limp. Examine especially to check if the hip externally rotates if you flex the knee (66.2), and compare the abnormal leg with the normal one, because the signs are not obvious.

Look for:
(1) limitation of abduction,
(2) loss of internal rotation, and
(3) external rotation of the hip during flexion (7-17).

Rapid slipping; the child may not have had symptoms of gradual slipping before. He falls to the ground with a severe pain in the leg, which is externally rotated and short. He cannot move the leg off the couch, cannot weight bear and finds passive movements acutely painful if it is unstable.

Although the physical signs may be minimal, a suitable 'frog leg' view radiograph (73-23) may be diagnostic, if you examine it carefully. The epiphyseal line is widened and fluffy, and the epiphysis is displaced downwards. *Include both the hips on the same film. Don't try to manipulate this under GA!*

If you cannot refer the patient, try to rest the hip in internal rotation and abduction, either in a hip spica or in extension skin traction (67-3). A hip spica needs less supervision and is more convenient, especially in younger children.

HIP SPICA
Flex the child's knee about 15°. This will enable you to rotate the leg internally and abduct it. Then apply a spica to just above the ankle. Keep it on for ≤6wks. Then keep on crutches until there are radiological signs that the epiphyses have fused, or there is no further slipping. The epiphyses may unite earlier, but crutches are still needed further.
If there are any signs of further slipping, do your best to refer him for internal fixation.
N.B. The contralateral side will probably also need treatment.

TRACTION
Apply extension traction for 8-12wks, as in (67-3), but with the leg in abduction. If neither form of treatment is practical, at least avoid further slipping by preventing him from bearing weight on the leg. Use crutches.

SLIPPED UPPER FEMORAL EPIPHYSIS

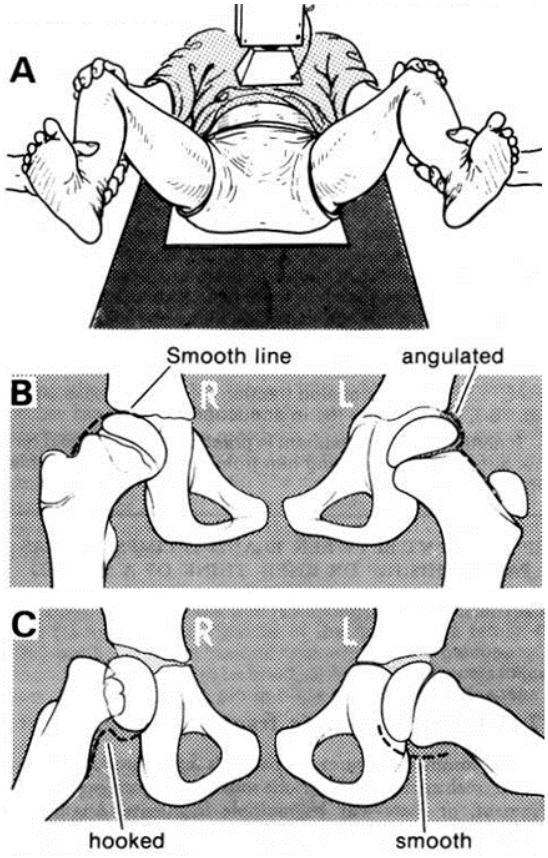

Fig. 73-23 SLIPPED UPPER FEMORAL EPIPHYSIS. A, showing a 'frog leg' view. This is essential for diagnosing a minimally slipped upper femoral epiphysis. The child's lower legs are horizontal and parallel with the edge of the table. B,C, the upper femoral epiphysis has slipped on the right. In the AP view the upper border of the neck continues on smoothly into the head whereas it normally angulates sharply. In the 'frog leg' view, the lower border of the neck is sharply hooked, instead of being smooth. *Kindly contributed by John Stewart.*

DIAGNOSE SLIPPED FEMORAL EPIPHYSES EARLY

IF A CHILD 10-15yrs OLD LIMPS, OR HAS PAIN IN THE HIP OR KNEE, THINK OF A SLIPPED EPIPHYSIS

73.13 Femoral shaft injury in children

Fractures of the central part of the shaft of the femur are common. Treatment varies with the patient's age:
(1) At birth no treatment is strictly necessary, though you may bandage the baby's thigh to the abdomen, as in the foetal position, for 10days. *Don't apply traction*.
(2) From birth to 3yrs use gallows traction or a plaster spica.
(3) Between 3-18yrs use extension traction.

In children between the ages of 0-10yrs, a shortening of up to 2cm is favourable. Because a fracture is often followed by this degree of bony overgrowth at the epiphyseal lines. This is useful in clinical practice, because it will allow you to treat a child's fractured femur in a hip spica without causing permanent shortening. From the age of 10yrs, children will not show the same degree of overgrowth: the maximum acceptable shortening then is 2cm. Minimize shortening as much as possible.

GALLOWS TRACTION
This does not need plaster and makes nursing easier. There is a risk of ischaemia in larger children. You can't send a child home with it.

LAXMAN (3yrs) fractured the shaft of his femur. He was put in gallows traction and the longitudinal strips of strapping were held in place with several circular turns. In the interests of tidiness, a sheet was put over his legs. He cried loudly during the night. Next morning both feet were cold and had later to be amputated. LESSONS. (1) *Never put circular strapping around any leg in traction*. If you want to hold longitudinal strips in place, apply figure of 8 strapping (73-24). (2) Make sure you can always see the toes.

INDICATIONS
(1) Femoral shaft fractures from 0-3yrs, provided the child weighs <15 kg. *Don`t use gallows traction in larger children:* max 3wks.
(2) Rectal prolapse (26.8): max 2wks
(3) Inguinal hernia (18.5); max 24h.

Make sure the base and the gallows are the same length. Apply skin traction to both legs. Pad the malleoli and the head of the fibulae. Apply adhesive strapping directly to his skin, *but never encircling around the legs*. Keep any knots away from the malleoli. Suspend the legs so that the pelvis is just clear of the bed, and you can slip a hand under the buttocks. The weight of the child's pelvis will reduce the fracture, and hold the fragments into position. Make sure the legs are aligned straight.

If the fracture is subtrochanteric, avoid an adduction deformity by keeping the legs well apart.

CAUTION!
(1) *Never apply circular strapping round the leg,*
(2) Make sure the strapping does not slip.
(3) Check the capillary return in both toes.
(4) *Don`t apply traction to one leg only*
(5) *Don't use in children >15kg.*

After 3wks of traction, apply a long leg cast or hip spica.

GALLOWS TRACTION

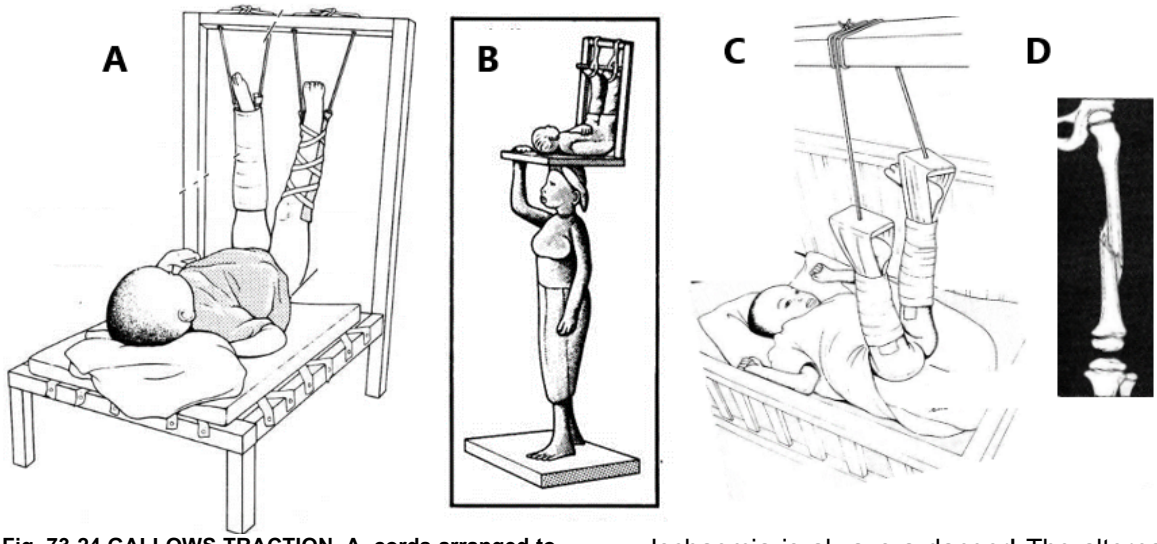

Fig. 73-24 GALLOWS TRACTION. A, cords arranged to keep knots away from the malleoli with a figure of 8 bandage on the right. B, *N.B. The statuette giving an idea of home care with a child on the head is not really recommended!* C, interrupted non-elastic bandage to hold the strapping, with a, gap under the buttocks. D, radiograph with healing callus.

MONITOR THE CIRCULATION IN HIS TOES CONSTANTLY

EXTENSION TRACTION
A child >3yrs is too heavy for gallows traction so apply traction to the extended lower leg over a pulley at the foot of the bed which is raised to apply counter-traction.

You can use this from the age of 3-18yrs, when the proximal tibial epiphysis fuses with the shaft.
N.B. If you use a pin in a child <18yrs, you may damage the epiphysis.

Extension traction keeps the leg extended so it cannot be exercised. This is less important in children and teenagers because their immobilized joints are much less apt to stiffen. Perkins traction preventing knee stiffness in older patients is thus unnecessary in children.

A femoral fracture in an older child is usually spiral. Extension traction corrects angulation, rotation, and lateral shift. It also corrects overlap, too. Actually in a child <10yrs, a certain overlap is preferable to compensate for the overgrowth that will follow.

So, subsequent growth soon corrects shortening. But avoid overlap as much as possible in children >10yrs. The shortening will not be compensated anymore.

Ischaemia is always a danger! The alternative is a hip spica. *Don`t use a Thomas splint or a Böhler-Braun frame.*

INDICATIONS
(1) Femoral shaft fractures at ages 3-18yrs
(2) Separation of the upper femoral epiphysis
(3) An unstable hip after dislocation reduction.

METHOD
Apply a long length of broad adhesive strapping from just distal to the fracture down to the lower leg. Pass it around a block of wood to act as a spreader, and then up to the outer side of the leg as far as the fracture but not beyond it.

Prevent the longer length of strapping sticking to the ankle by sticking a shorter piece to it. Pass this around the other surface of the spreader.
If necessary, make small cuts in the strapping to make it fit more closely to his leg. Pass a cord through the hole in the spreader and fix it to the foot of the bed. Raise the foot of the bed 40- 50cm, or use a weight (73-25).
Start with traction at 10% the body weight, *but not >5kg*, and compare the lengths of the legs with a tape measure to make sure you have not distracted the fragments.

Encourage the child to move about in bed.
Wait 6wks for clinical union (58.7) and then take a check radiograph or ultrasound scan. If union is satisfactory, use crutches.

CAUTION! (1) Watch carefully for signs of ischaemia, especially calf pain and pain on dorsiflexing the foot. (2) Make sure the strapping does not press on the common peroneal nerve as it winds around the head of the fibula.

EXTENSION TRACTION

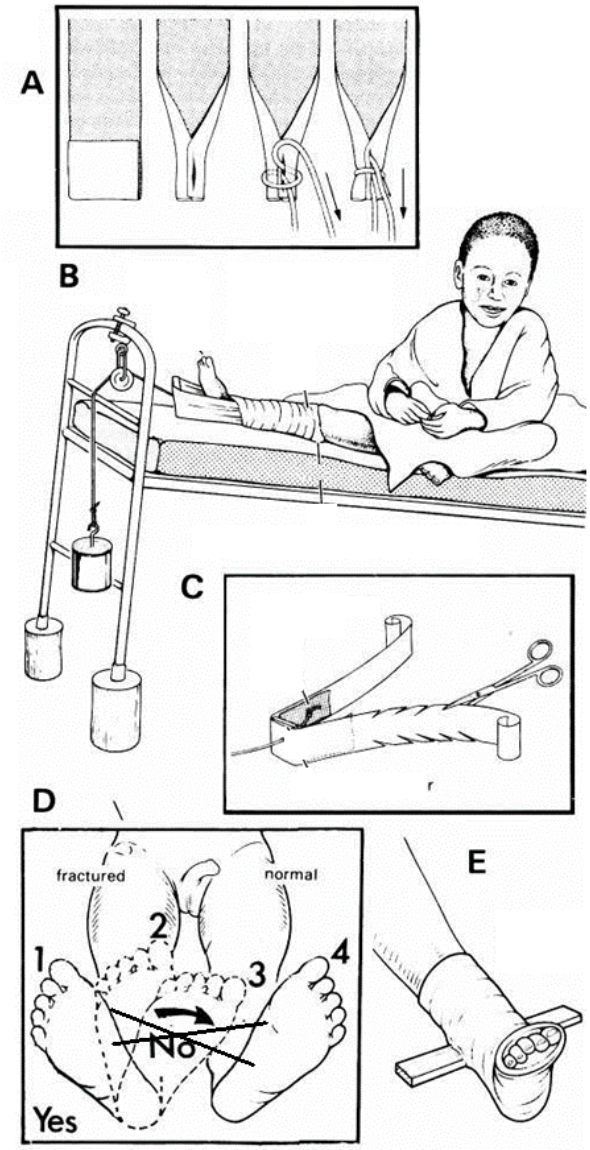

Fig. 73-25 EXTENSION TRACTION. A, one method of fixing the cord to the strapping. B, skin extension traction in action. C, fixing a spreader to the strapping. D, try to make sure the child's injured leg (1) matches his normal one (4). If you put it in position 2 it will rotate internally into position 3 when he walks (as shown by the arrow) and will cause severe disability. The anterior superior iliac spine, the patella, and the space between the 1st & 2nd toes normally lie in a straight line. E, a derotation bar in use. Note that it lies under the ankle, *not the heel. Don't fit a derotation bar to a damp cast,* or it may cause a pressure sore. *Kindly contributed by Richard Batten, Andrew Pearson & John Stewart.*

N.B. Teenagers are particularly likely to refracture their femurs. Warn teenagers and parents for this. Tell them to avoid sports and intensive activities for another 4 months after treatment.

A PLASTER SPICA FOR A FRACTURED FEMUR

After 2wks' treatment with gallows or extension traction you can change to a spica cast (73-22) in children <10yrs. The child will be able to go home with it and is no longer confined to a hospital bed.
Get a radiograph to ensure that there is sufficient callus formation and that the fracture is stable. Apply the cast for 6wks. Take care to make this strong enough. Apply extra plaster at the hip.

In children >10yrs, a spica cast becomes very unpractical and is no longer an option. If the fracture is distal enough in the femur, convert treatment to a long leg cast for another 6wks.

Check for adequate callus before stopping the traction treatment and make sure the fracture is stable. The upper border of the cast should reach at least 10cm higher than the fracture in order to ensure adequate support and stability in the cast. If this is not possible to achieve, use extension traction for full treatment.

73.14 Knee injury in children

Anterior tear on the knee in a child can displace the epiphyses and also displace the tibial spine, or the tibial tuberosity. If a child has spontaneous knee pain, examine the whole lower limb from hip to ankle. The upper femoral epiphysis may have slipped.

(a) Tibial eminence (spine) **rupture**

In this uncommon injury, a child falls on the bent knee, drives the femur posteriorly on the tibia, and pulls the anterior cruciate ligament away from its insertion into the tibia. It is the paediatric equivalent of an anterior cruciate ligament rupture (68.5) seen in adults. It is mostly seen in a knee in hyperextension during sports with a rotated knee or after a fall from a motorcycle. As it tears, a wedge-shaped piece of the tibial plateau, which is usually called the 'tibial eminence' or 'tibial spine' pulls off. The knee fills with blood, either immediately, or not until the following day; it is tender all over, and the child cannot move it.

A lateral radiograph shows a thin flake of bone anteriorly between the tibia and the femur. The AP view may look almost normal.
This injury is worse than it looks, because the small bony fragment can pull much translucent cartilage with it.

TIBIAL EMINENCE FRACTURE

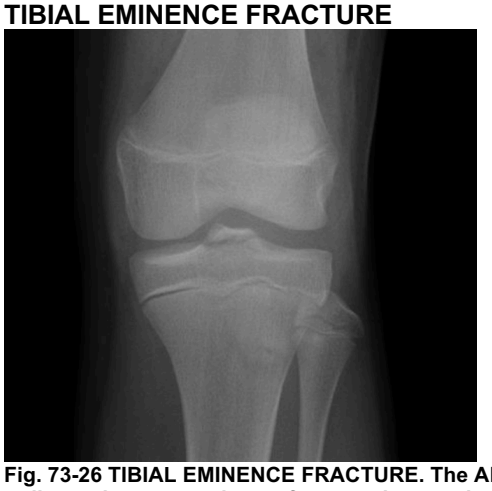

Fig. 73-26 TIBIAL EMINENCE FRACTURE. The AP knee radiograph may not show a fracture; *beware,* it usually hides a significant injury!

You can easily miss the diagnosis. If the loose fragment remains caught in the knee, the last 10° of full extension is lost.

If you can extend the knee, hold it in full extension (not overextended) and apply a plaster cylinder cast (68.2) from the upper part of the thigh to just above the heads of the metatarsals. Take a new radiograph in the cast cylinder to check the position of the fragment.

If the fragment is still displaced (>2mm from its anatomical position), or if the fracture is comminuted, fixation is needed.

Allow standing immediately, and advise walking as naturally as possible. Leave the cylinder cast on for 6wks. Knee movements will then return gradually as the leg is used.

If presentation is late, and you cannot extend the knee, even under GA, refer for open reduction.

(b) Femoral supracondylar fracture
Anaesthetize the child, manipulate the fragments into position, and apply a long leg cast from the ischial tuberosity to the toes. Apply it with the knee in the position that best reduces the fracture. If necessary, flex it to 90°.

(c) Slipped lower femoral epiphysis
Displacement of the distal femoral epiphysis typically follows a violent injury or blow to the knee in a teenager, or may occur in osteomyelitis (7.10).

A severe injury which would cause a supracondylar fracture in an adult, produces a Type I, II or IV epiphyseal injury (73-2), the commonest being Type II, in a child or teenager.

The child presents with an obvious deformity of the knee and severe pain. This may also be described as the knee "giving way" Undisplaced fractures tend to present with milder symptoms, and the child can sometimes even walk and bear weight on the affected knee. *Don't be fooled though by this presentation* and examine radiographs carefully.

The distal epiphysis usually moves anteriorly, displacing the distal end of the shaft of the femur posteriorly where it may obstruct the popliteal vessels. Make a proper distal neurovascular examination to make sure that there is no injury to the popliteal artery or the sciatic, tibial or peroneal nerves.

Replace the epiphysis under GA, and hold the knee in flexion in a cast. You can use Perkins traction if displacement is mild.

REDUCING A SLIPPED DISTAL FEMORAL EPIPHYSIS

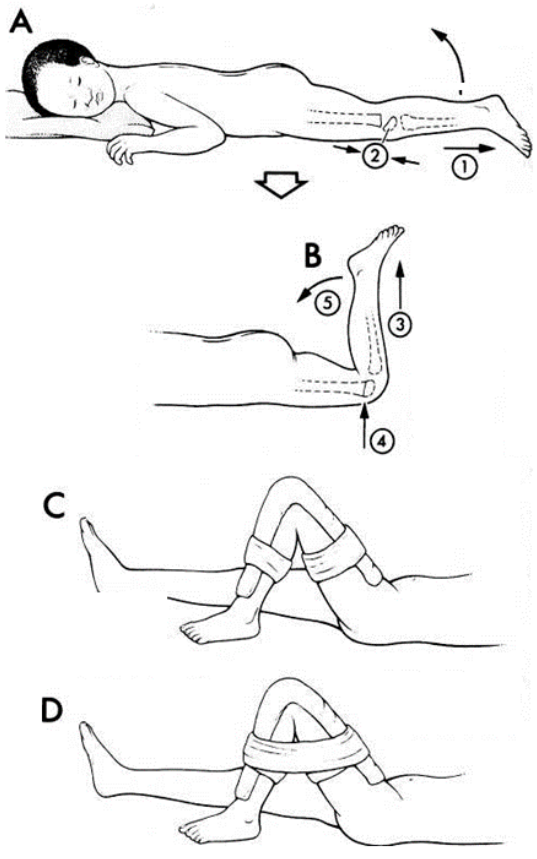

Fig. 73-27 REDUCING A SEPARATION OF THE DISTAL FEMORAL EPIPHYSIS (TYPE I). A, applying traction with the knee extended (1), try to correct lateral displacement (2). B, now bend the knee & distract the lower leg (3), and try to correct anterior displacement (4), pushing posteriorly. Finally flex the knee to 110° (5). C, monitor circulation in the toes. D, *don't continue immobilisation >3wks.* *After Rang M, Children's Fractures, JB Lippincott, 2nd ed 1983 with kind permission.*

DIAGNOSIS
If you are not sure whether a child has ruptured the medial ligament, or displaced the epiphysis, take another film with the extended knee in a *valgus* position. This will help you differentiate between them.
If the medial ligament is ruptured, the knee joint will open with *valgus* stress, but the distal femur has a normal shape and contour. If the child has a displaced distal femoral epiphysis, you will see the epiphyseal line opening up on a radiograph screening instead of the knee joint.

MILD OR NO DISPLACEMENT
Apply Perkins traction (67.3).

MODERATE DISPLACEMENT
In the more common Type I variety, with the distal fragment displaced anteriorly, the circulation in the leg may be impaired; reduction is then urgent. Under GA in a prone or lateral position (73-27A,B), manipulate the fragment and reduce the fracture.

If reduction is stable, apply an anterior plaster slab to the flexed leg (73-27C), and secure the slab to the thigh with circular plaster bandages. Then put another plaster bandage around the thigh and the lower leg (73-27D). *Don't flex the knee more than the degree of swelling will permit*.

Then, 10days later, reduce flexion to 60°. Remove the cast after a further 3wks. Movement will return slowly.

CAUTION!
(1) Monitor the circulation in the toes carefully during the early stages.
(2) *Don't prolong immobilization beyond 3wks*, because the flexion contracture that results may be very difficult to treat.
(3) Watch for loss of reduction, which may occur as late as the 3rd wk.
If reduction is unstable, refer the child.

SEVERE DISPLACEMENT
Refer the child, especially if the injury is of the rarer Type IV variety (73-2) in which the fracture line opens into the knee joint.
Long term prognosis is fair to poor. Type I fractures have the best outcomes. Types II, III and IV have a high risk of physeal growth arrest.

TOPO (14yrs) was injured in a football match, and severely displaced his lower femoral epiphysis. No attempt at reduction was made, and a cast was applied. He was referred 6wks later by which time it was too late to try to attempt reduction. The severe angulation will have to be corrected later by osteotomy. LESSONS (1) Reduce epiphyseal injuries within 3days. (2) *Casts are not universal treatment for all bony injuries*.

(d) Patellar sleeve fracture
Patella fractures typically occur in the young male adolescent following a direct blow to the knee. This type of fracture requires the same assessment and treatment as in adults.
A rarer type of patellar fracture is the sleeve fracture that only occurs in children. It typically follows after a forceful contraction of the quadriceps during a jump or a direct blow to the knee.

The *quadriceps* tendon pulls off a large osseo-cartilaginous fragment off the patella, and only cartilage and a very small bony fragment remains attached to the patellar tendon.

Patellar sleeve fractures are difficult to diagnose on radiography. Pay extra attention to the lateral view where you will find the typical findings of a high-riding patella and some small bony fragments where you would normally expect to see the patella. If the clinical presentation is very suspicious, treat the patient as if there is a sleeve fracture.

PATELLAR SLEEVE FRACTURE

Fig. 73-28 PATELLAR SLEEVE FRACTURE. Left knee radiographs. A, a small segment has detached. B, the segment is pull off completely

Treat minimally (<4mm) displaced fractures (73-28A) with a long leg cast in extension for 6-8wks.

Displacement >4mm requires an open reduction and internal fixation. In children <10yrs, you can achieve good fixation with a non-absorbent suture through the cartilaginous sleeve and the patellar tendon. In children >10yrs, a traditional tension-band wiring with K-wires (68-10) is better. Treat with a long leg cast in extension for 6-8 wks after fixation.

(e) Tibial tuberosity avulsion
During childhood, a projection of the proximal tibial epiphysis forms the tibial tuberosity & the attachment of the patellar tendon. At any age until early adult life when the epiphysis unites, sudden contraction of the quadriceps may tear the tibial tuberosity away from the tibia.

This happens most in basketball games.
Children suffering from Osgood-Schlatter disease are at higher risk of sustaining this tibial tuberosity avulsion.

TIBIAL TUBEROSITY AVULSION

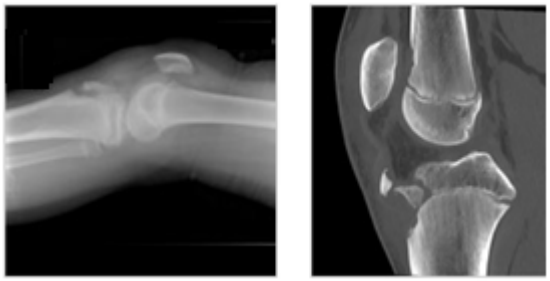

Fig. 73-29 TIBIAL TUBEROSITY AVULSION. Left knee radiographs. A, mild separation. B, severe separation affecting the joint.

Treatment depends on the degree of separation. If this is mild (73-29A), immobilize the child's knee in extension in a plaster cylinder cast for 4wks. If separation is severe (73-29B), under GA, try to push the tuberosity back into place, then apply a plaster cylinder in extension.

If closed reduction fails, open reduction & screw fixation are necessary.

(f) Slipped proximal tibial epiphysis
A Type I or II fracture of the proximal tibial epiphysis is a rare injury predominantly affecting adolescent boys. The proximal tibial epiphysis tends to displace anteriorly, in a similar way as the distal femoral epiphysis.

Study the radiograph carefully, and try to push the displaced epiphysis back into place.

Sometimes the fracture follows a Type III pattern where the fracture looks much like a tibial tuberosity avulsion. Make this distinction carefully.
N.B. Don`t miss a lesion of the peroneal nerve or a vascular lesion because of compression of the popliteal artery.

Treat minimally (<2-3 mm) displaced fractures conservatively in an extension cast for 6wks. If >2-3 mm displacement remains after 2 attempts of closed reduction, open reduction and internal fixation are needed.

If the epiphyseal line is crushed (Type V, 73-2), you should follow-up this injury by repeat radiographs until full growth is reached. Since a severe *valgus* deformity often ensues, treat this with an osteotomy when the epiphyses are closed.

73.15 Lower leg injury in children

(a) Tibia shaft fracture
A child falls, and afterwards refuses to walk. There are few signs. Radiographs usually show a long spiral or oblique fracture with little displacement, commonly in the lower $^1/_2$ of the tibia. If the fracture is transverse there is a higher risk of displacement and reduction may be necessary.
.
INCOMPLETE FRACTURES
This type of fracture, also called the 'toddler's fracture', is typical of the infant or young child. The fracture is sub-periosteal and is stable. On a radiograph you will see a very fine line the thickness of a hair in a spiral pattern. Apply a long leg walking cast for 2-3wks to relieve pain and prevent the fracture from becoming complete.

COMPLETE FRACTURES
If there is no significant displacement, apply a long leg cast (70-4) for 2wks until pain subsides. Then convert to a short leg walking cast for another 4wks.

If there is significant displacement, reduce the fracture under GA. Elevate the fracture above the level of his heart (70-1), by raising the foot off the bed on pillows.
Apply a well-padded circular long leg cast to maintain reduction. Keep the long leg cast until the fracture is adequately stable. Then convert it to a short leg walking cast.
Treat with a total of 6wks of casting. If you cannot maintain the reduction using a cast, refer for internal fixation.

CAUTION! Always split the cast in adolescents and, as soon as the swelling has gone down, renew or complete the cast by pulling its split edges together, and binding it round with a plaster bandage. Apply a walking heel, and allow crutches with full weight bearing as soon as pain allows. Leave the cast on for 6wks. When you remove it, full movements will return quickly.

(b) Fracture of both tibia & fibula
Regardless of the type of fracture of each lower leg bone, it is of utmost importance if the fibula is fractured or not. Always include the knee and ankle in your radiographs to assess the integrity of both the fibula and the tibia over their entire length.

If both the fibula & tibia are fractured in their middle segment, there is a risk for *valgus* angulation in tibia because of the muscle pull in the lower leg. You therefore should slightly overcorrect them to *varus*. Conversely, isolated fractures of the middle segment of the tibia have a tendency to slip into *varus* deformity.

These fractures tend to be unstable by definition. Put on a well-moulded long leg cast with the knee in 45° flexion to inhibit rotation at the knee level. Put the ankle in about 10-20° plantarflexion to avoid recurvatum (posterior bending) at the fracture site.

If you cannot achieve anatomical reduction because of swelling of the leg, cast it in the most acceptable position possible. Admit the patient for neurovascular monitoring and redress the cast after 1-2wks using the wedging technique.

COZEN PHENOMENON
Children between the ages of 3-6yrs who have sustained a proximal metaphyseal tibial fracture are at risk of developing the 'Cozen phenomenon'. A certain number of these children will develop a progressive *valgus* deformity in their proximal tibia after fracture consolidation. The aetiology of this phenomenon remains a mystery and in most cases it is self-limiting. The *valgus* will stabilize after about 2yrs and then remodel to a normal tibia again after about 4yrs post-fracture.

Some children however will not remodel and will need an osteotomy to correct valgus deformity. *Don't perform this too early*, as recurrence of *valgus* deformity after osteotomy may still occur.

Explain to parents that there is a risk for this deformity after a metaphyseal tibia fracture. Plan a long term follow-up of all children with these fractures with serial radiographs.

Children generally do not need any physical rehabilitation after a tibia fracture. Many children will walk with the leg in external rotation, with the toes pointing outwards for a few wks to a month after removal of the cast. This is normal, and will disappear by itself. Reassure parents about this.

73.16 Ankle & foot injury in children

(a) Slipped distal tibial epiphysis
This is a child`s equivalent of a malleolar fracture. You can usually treat a Type II epiphyseal injury (73-2) by closed reduction & cast immobilization. Type III & IV injuries, in which the fracture line opens into the joint, often need open reduction to restore a smooth joint surface, unless the articular step-off and displacement is <2mm.

The ankle is also the most common site for the Type V injuries which crush the epiphyseal plate. Because there is no displacement, you may think that a child has only sprained his ankle, until growth deformities occur years later. Under GA, exert strong traction on the foot and manipulate the ankle into position. Take great care to correct rotation. Apply a long leg walking cast for 6wks.

(b) Transitional fractures of adolescence
A triplane fracture is a fracture that only happens during a very specific time window during closure of the distal tibial epiphysis. As such, it only happens in adolescents between 12-16yrs. The fracture typically consists of an antero-lateral tibial fragment and a larger medial fragment with a posterior metaphyseal spike. The exact pattern is determined by which parts of the epiphysis is already closed and which part is still open.

TRIPLANE FRACTURE

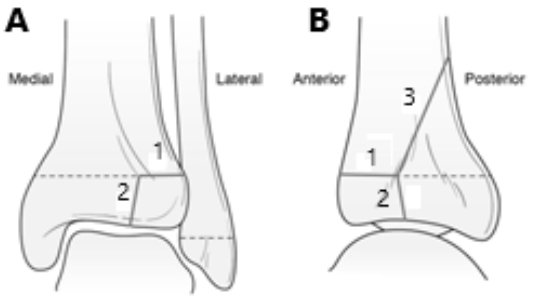

Fig. 73-30 TRIPLANE FRACTURE occurs in juveniles. Left ankle: A, A-P view, B, sagittal view. 1,2,3 typical lines of the fracture.

Because of the complex 3D nature of this type of fracture, a CT-scan is necessary to evaluate the level of displacement and need for surgical fixation. Refer this for further assessment and treatment when possible.

N.B. WALKING AIDS IN CHILDREN
Flat pieces of wood on the bottom of 2 sticks ('plonkers', 66-1F) will make them easier to use.

Serious foot fractures are rare, but *beware a missed talar fracture,* because the risk of avascular necrosis & non-union is high.