Childhood fractures
a guide to management

Childhood fractures are extremely common. The risk of sustaining a fracture during childhood is said to be 42% for a boy and 27% for a girl. A working knowledge of management is therefore paramount.

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The management of any fracture must follow:
- the immediate and appropriate management of any coexistent life-threatening injuries – that is, attention to ABC (airway, breathing, circulation)
- cervical spine stabilisation, if required.

Fracture management can, broadly speaking, be broken down into three components:
- reduction and stabilisation
- maintenance of reduction
- rehabilitation.

These components remain the same whether we are dealing with a fracture in an adult or in a child. However, children cannot be simply thought of as small adults. There are anatomical, physiological and biomechanical differences, making the principles governing fracture management in children vary from those in adults. This article aims to review and illustrate some of these principles.

How the skeleton grows

In order to understand the principles governing fracture management in children it is important to have a basic understanding of how the skeleton grows.

Bone formation

Bony growth is achieved chiefly by appositional growth at the growth plates (that is, the cartilaginous physes) of long bones by a process termed 'endochondral ossification'.

Growth also occurs circumferentially at the periosteum of bones. 'Intramembranous ossification' describes this process of bone formation and also that occurring at flat bones of the skeleton, such as in the skull, the scapula and the clavicle.

The growth plate

The growth plate, or cartilaginous physis, forms

IN SUMMARY

- **Assess the child as a whole – are there injuries other than the fracture? Could the injuries be life-threatening? Attend to: airway, breathing and circulation (ABC) plus cervical spine stabilisation first. Does the fracture itself warrant immediate attention in theatre or by a specialist?**
- **Children are not small adults – anatomical, physiological and biomechanical differences govern the principles of fracture management.**
- **A number of fractures are specific to childhood, e.g. greenstick, torus, physeal. Each fracture is individual to a patient (and the parents!).**
- **Do not rely solely on plain radiographs for fracture diagnosis; there is no substitute for a well taken history and an accurate clinical examination. Comparison radiographs of the uninjured side can prove extremely helpful, especially around difficult sites (such as the elbow).**
- **Complications secondary to childhood fractures are rare, but can have devastating long term and progressive functional and cosmetic effects for the patient when they occur.**
- **If you are in doubt about the best management for an individual fracture, seek the help of an orthopaedic surgeon – preferably one with a special interest in paediatric fractures.**

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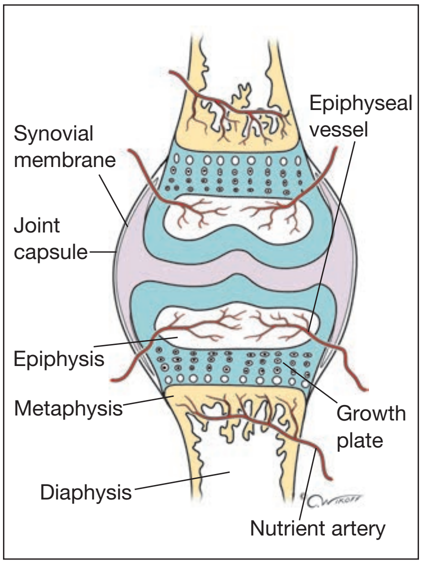

Figure 1. Growth plate relationships.

within the epiphysis (secondary ossification centre) of a bone (Figure 1). Growth plates are radiolucent; therefore, they can be mistaken for a fracture by the uninitiated, and particularly by anxious parents. Although they have well described sites and patterns of appearance, variability can lead to diagnostic difficulty when assessing radiographs. Comparison views of the uninjured side can prove extremely helpful in these circumstances. The best example of this is at the elbow where multiple secondary ossification centres make fracture diagnosis notoriously difficult.

A physis (growth plate) must not be confused with an apophysis. Apophyses are specialised growth centres occurring around joints and to which major muscle groups insert or take origin. Examples are the greater trochanter and the tip of the olecranon. They are found in the immature skeleton. Following maturity, these may occasionally be seen as bony outcrops.

Table 1. Fractures specific to childhood

- Greenstick fracture
- Torus or 'buckle' fracture
- Plastic deformation
- Corner or bucket-handle fracture
- Growth plate or physeal (Salter–Harris) fracture
- Apophyseal fracture

Bone in children

A child's bone is less dense and more porous than adult bone. It is made up of wider Haversian canals and can withstand a greater degree of deformation. The periosteum is much thicker, stronger and more vascular than adult periosteum.

Importantly, child bone is biologically much more active, producing much greater amounts of callus (new immature bone) compared with that of an adult. It also has an inherent ability to remodel.

From a biomechanical point of view, it is important to remember that ligaments in children are stronger than in adults. Sprains and tears are less common. More likely are epiphyseal separations at bony attachments. When assessing radiographs, these need to be looked for actively.

Fracture diagnosis

History

As in any other sphere of medicine there is no substitute for a thorough history and examination. The history will provide major clues as to the energy with which the injury was sustained and the mechanism of the injury.

Examination

Accurate examination will direct appropriate radiography. Examination should always include:

- an assessment of neurovascular structures
- the joint above and the joint below the site of an injury.

The examination findings must always be thoroughly documented.

Investigation

Radiographs should always include two orthogonal views, commonly an anteroposterior and a lateral view (Figure 2). The role of comparison radiographs of the uninjured side has already been mentioned.

Further views may be warranted, as may further investigations (e.g. ultrasound, CT, MRI and isotope bone scan),

Figures 2a (above) and b (right). The importance of two orthogonal radiographic views: this greenstick fracture of the distal radius looks undisplaced on the anteroposterior (AP) view but is clearly angulated on the lateral view.

in cases where fracture diagnosis is unclear or where more accurate information about fracture configuration is required. Such investigations are usually requested following specialist orthopaedic consultation.

Specific childhood fractures

A number of fractures are specific to childhood (Table 1).

Greenstick fracture

A greenstick fracture (Figure 3) can be thought of as a fracture of 'one' cortex, with plastic deformation of the 'other' cortex. It occurs when a bone is bent beyond its limits such that the tension side of the bone fails and the compression side bends but does not fail.

These fractures can be very subtle to the eye radiographically unless guided by an accurate examination of bony tenderness.

Treatment will depend upon the degree of angulation at the fracture site. Simply because the fracture is a greenstick does not mean that it does not require careful treatment and/or observation. A number will displace further, for example when the splinting effects of oedema settle 5 to 10 days after the injury.

Figures 3a to d (left to right). Greenstick fracture of the distal radius with 20° to 30° of angulation and obvious clinical deformity. Manipulation under anaesthesia was performed with long-arm backslabs applied.

Torus fracture

A torus or 'buckle' fracture (Figure 4) is caused by a compressive force mechanism and is usually found close to the metaphysis of a long bone, especially in younger children.

Radiographically the bone appears to buckle, hence the term 'buckle' fracture.

Buckle fractures are probably greatly overtreated and on the whole require little more than protection and observation.

Plastic deformation

Plastic deformation of a bone relates to the deformability of children's bones.

Plastic deformation may present with radiographic bowing but no clear evidence of an acute cortical breach, as would be seen in a greenstick fracture for example.

The deformation can occasionally be severe enough to warrant manipulation under anaesthesia. Clinical appearance is again paramount; if there is visible deformity, the bowing may require treatment.

Corner fracture

A corner fracture occurs at the metaphyseal–physeal junction of a long bone. Periosteum is firmly attached at this point and can be stretched by a tensile or pulling force, leading to a small avulsion-type fracture. Such fractures should raise suspicions of nonaccidental injury.

Growth plate, or physeal, fracture

A fracture involving the growth plate, or physis (Figures 5 and 6), has the potential to arrest or alter growth of the bone involved. The major prognostic factors governing this possibility relate to:

- the energy of the injury
- the age of the patient
- the degree of displacement and site of the fracture
- the specific type of growth plate fracture suffered.

Types of growth plate fracture

A number of classifications of growth plate fracture types exist. The most commonly used classification is the Salter–Harris, which describes five main patterns of physeal fracture (see the box on page 42):

Figures 4a (left) and b (right). Torus fracture of the distal radius, AP and lateral views.

Figures 5a (left) and b (right). Displaced Salter–Harris II distal radius fracture that required closed reduction by manipulation under anaesthesia.

• **Type I** fractures are when the epiphysis separates completely from the metaphysis.
• **Type II** fractures are the most frequently seen (approximately 70%).
• **Type III and IV** fractures have an intra-articular component. They have the most potential to alter or arrest growth and can lead to premature osteoarthritis within a joint. Displacement in these fractures requires anatomical reduction to restore articular congruity.
• **Type V** fractures are often only diagnosed retrospectively, because initial radiographs are commonly reported as normal.

Risk of arrested growth

The risk of physeal growth arrest is greater:

- in high-energy injuries
- in type III and IV fractures
- if anatomical reduction is not attained
- in fractures involving the physes about the knee.

Younger patients have more growing to do; therefore, potentially they can have a greater functional disability and limb-length discrepancy as a result of such fractures.

Apophyseal fracture

Apophyseal fractures occur most commonly in children participating in vigorous athletic activities. Tension forces can be high in such circumstances and can lead to 'pull-off' or avulsion-type lesions at the apophysis. Common sites of injury are listed in Table 2. The periosteum usually remains in continuity.

Management is commonly conservative unless there is substantial displacement, neurovascular compromise or a marked functional deficit. Activity limitation and modification are required until healing is complete, usually at 6 to 12 weeks. Early return to sports is associated with symptom chronicity.

Figures 6a (left) and b (right). Displaced Salter–Harris II fracture of the distal femoral physis that required reduction and internal fixation. Note that the screw does not cross the growth plate.

Factors that affect healing of fractures

Children have a distinct advantage over adults in terms of the duration of fracture healing. For example, a femoral fracture will heal within 3 to 4 weeks in a neonate and within 10 to 14 weeks in an adolescent, compared with 14 to 24 weeks in an adult.

Remodelling

Not only do children's fractures heal at a much quicker rate than those of adults but there is also a greatly enhanced ability in children to remodel bone both during and after fracture repair. This ability is greater the younger the child. It is also greater when the fracture sustained is:

- close to a growth plate (in the metaphysis)
- angulated or displaced in the same plane of motion as the adjacent joint.

Fractures unlikely to remodel

The ability to remodel can be considered virtually nonexistent in the final two years before skeletal maturity (approximately age 14 years in girls and 16 in boys). Intra-articular fractures, diaphyseal fractures with gross angulation, shortening or rotation, and fractures with deformity at right angles to the plane of adjacent joint movement are also unlikely to remodel to an acceptable position and may result in significant functional and cosmetic deformity. Fractures unlikely to remodel usually require intervention (Table 3).

Fracture angulation and displacement

The amount of angulation and displacement that is acceptable when managing childhood fractures is a constant source of discussion among healthcare professionals involved in this field. Such discussion should always include the child's parents from the outset. It is important to realise that views differ and that, as always in medicine, each case should be assessed on its individual presentation by all those concerned.

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Table 2. Common sites of apophyseal injury

Apophysis	Origin or insertion
Greater trochanter	Gluteus medius
Lesser trochanter	Iliopsoas
Anterior superior iliac spine	Sartorius
Anterior inferior iliac spine	Rectus femoris (direct head)
Iliac crest	External oblique
Ischial tuberosity	Hamstrings

Table 3. Fractures unlikely to remodel*

- Intra-articular fractures
- Diaphyseal fractures with gross angulation
- Diaphyseal fractures with significant shortening
- Diaphyseal or metaphyseal fractures with rotation
- Deformity at right angles to the plane of adjacent joint movement
- Fractures occurring within two years of skeletal maturity (approximately 14 years in girls, 16 in boys)

* Such fractures usually require intervention.

Generally speaking, the presence of a clinically – as opposed to radiographically – apparent deformity will dictate that at least a manipulation of that fracture be performed. This is usually done under anaesthesia.

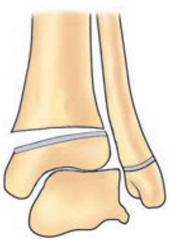
Growth plate fractures require accurate anatomical reduction unless they are only minimally displaced or are nondisplaced. If reduction is not achieved within a few days, the fracture may be difficult or impossible to reduce as physeal fractures are usually well healed within three weeks of the injury. Indeed latent attempts at reduction are likely to cause more harm than good.

Management overview

Reduction and stabilisation

The goal of fracture management is to return to the premorbid functional state. Anatomical reduction and stabilisation of fractures is often the ideal way to achieve this goal, particularly if the fracture has disrupted articular or physeal congruity.

Salter-Harris classification of growth plate (physeal) fractures

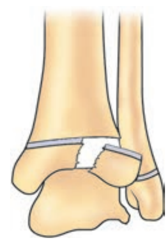


Type I fracture

The epiphysis separates completely from the metaphysis.

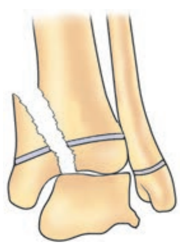
Type II fracture

The fracture plane passes through much of the physis before travelling out through the metaphysis.



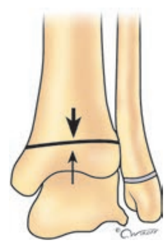
Type III fracture

The fracture plane passes along the physis before travelling out through the epiphysis into the joint; it is therefore an intra-articular fracture.



Type IV fracture

The fracture plane passes from the joint surface, across the epiphysis and physis before travelling into the metaphysis; it is therefore an intra-articular fracture.



Type V fracture

This is most simply thought of as a crush fracture of the physis or a ‘bridge’ fracture and is often not recognised at the time of the injury; the diagnosis is more commonly entertained with the benefit of hindsight.

The remodelling ability of younger children's bones is so great that anatomical reduction is not always necessary.

Maintaining a reduction or an acceptable position can be achieved by different methods. Traction and plaster techniques are used to prevent further displacement or angulation of a fracture, and to maintain closed reductions.

It is important to remember that in the initial days subsequent to a fracture and the application of plaster, there is a gradual resolution of swelling within limb compartments. This can allow for further displacement or angulation of a fracture that may then require reduction. Following manipulation under anaesthesia, the incidence of remanipulation approaches 10%. Therefore, it is advisable to warn parents of this possibility.

Complications

Pain and loss of function seemingly out of proportion to an injury must be viewed with caution because compartment syndrome and ischaemic contracture can be a devastating complication of fracture.

Cardinal signs to watch for are: pain to passive stretch, paraesthesia, diminished perfusion and coolness. Tight plasters or bandages must be split in such cases. The use of plaster back slabs, as opposed to potentially tight circumferential plasters, will help to reduce the incidence of this complication. If there is a suspicion of compartment syndrome, urgent specialist review is essential because fasciotomy may be required.

Unstable fractures

Unstable fractures (Figure 7) may require internal or external fixation to maintain reduction. Kirschner wires ('K wires') are commonly used in children for this purpose and, if left protruding from the skin, have the advantage of being removable in clinic.

Other methods include the use of intramedullary wires and rods, or extramedullary plate fixations. External fixation devices are particularly helpful in some open fractures.

Figure 7. Grade III extension supracondylar fracture. These are highly unstable fractures that require urgent reduction and stabilisation in theatre. Significant neurovascular compromise may be present, leading to Volkmann's ischaemic contracture if not dealt with promptly. This case was an open fracture with division of the brachial artery that required a vein graft to repair. Clearly this constituted an orthopaedic and vascular emergency. Fracture stabilisation was achieved by a standard crossed K-wire technique.

Open fractures

As a general rule, all open fractures require thorough debridement within six hours of the event (see the Case history on this page). Initially, major contaminants should be removed, a polaroid photograph taken and a sterile dressing applied. This should ideally be left undisturbed until theatre. Intravenous antibiotics should be commenced as soon as possible. Tetanus toxoid may also be required.

Urgent orthopaedic referral is mandatory (Table 4) in all open fractures and in any fracture with evidence of neurovascular compromise.

Complications of childhood fractures

On the whole, complications are less frequent in childhood fractures than in their adult counterparts.

Partial or complete growth arrest can lead to progressive deformity and limb-length discrepancy. Overgrowth can also

Case history

Open fracture of the midshaft radius and ulna in a 14-year-old boy, sustained on a fall from a mountain bike. Debridement and open reduction and internal fixation were performed within six hours of the injury. Plate fixation was employed and the wound left open to heal by secondary intention.

Figure A. Open fracture of the radius and ulna in a 14-year-old boy.

Figures B and C. Preoperative radiographs of the open fracture.

Figures D and E. Postoperative radiographs of the injury.

Table 4. Fractures requiring emergency or immediate specialist management

- Associated life-threatening injuries
- Open fractures
- Neurovascular compromise (limb at risk)
- Associated compartment syndrome (limb at risk)
- Fracture dislocation
- Skin at risk
- Unstable fractures

Table 5. Complications of childhood fracture

Specific to childhood

- Growth arrest:
  partial
  complete
- Progressive deformity
- Overgrowth (e.g. of the femur)

General to any fracture

- Delayed union
- Nonunion
- Malunion
- Infection
- Neurovascular problems
- Degeneration (intra-articular)

occur. Limb-length discrepancy is most commonly seen in femoral fractures, where shortening of 1 to 2 cm is often accepted during the initial management.

Nonunion, although rare, does sometimes occur. Soft tissue interposition or synovial fluid dispersion between fracture surfaces can be a cause, such as in a nonunion of a lateral condylar fracture of the elbow. Complications of childhood fracture are summarised in Table 5.

Nonaccidental injury

Nonaccidental injury is life threatening to a child. In the Western world, approximately 25% of all fractures in children under the age of 3 years are the result of physical abuse.

Certain fracture patterns will raise suspicions of physical abuse. These include multiple fractures, fractures of different ages of healing, corner fractures, skull fractures, and vertebral and rib fractures. Spiral fractures in long bones should also raise alarm. In Australia, any such fracture in a child who is less than 1 year of age must be reported to the Department of Community Services.

Osteogenesis imperfecta and pathological fractures

Commonly referred to as brittle bone disease, osteogenesis imperfecta is a disorder of collagen leading to frequent and multiple fractures. A number of different types have been recognised. The management of these children is best placed in the hands of paediatric orthopaedic surgeons and physicians with a special interest.

Other pathological fractures result from 'normal forces on abnormal bone'. Examples include fractures through infected bone, benign neoplastic (e.g. unicameral or simple bone cyst) and malignant neoplastic processes (e.g. Ewing's sarcoma), and metabolic and endocrine disorders.

Summary

The three main components of fracture management in children are the same as those in adults:

- reduction and stabilisation
- maintenance of reduction
- rehabilitation.

Complications are less frequent in childhood fractures than in their adult counterparts. However, partial or complete growth arrest can lead to progressive functional and cosmetic deformity, with devastating effects for the child. If there is any doubt about management, the help of an orthopaedic surgeon should be sought. MT