The skeletal system of children is anatomically, biomechanically, and physiologically different from that in adults. The presence of growth plates (or physes) in the pediatric skeleton is one major difference. The growth plate is composed of cartilage. It can be thought of as the "weakest link" in the pediatric bone. It may separate before an adjacent joint ligament tears. Injuries to the growth plate may result in deformities.

Another difference seen in children is a thicker periosteum surrounding the bones. As a consequence, fractures in children tend to be more stable and less displaced than those seen in adults. The greater bone-forming potential of the pediatric periosteum results in faster bone healing in children. Non-unions are rare in pediatric fractures.

A third difference is the increased porosity, due to larger, more abundant Haversian canals, and decreased density of pediatric bones. This feature makes children's bones more prone to buckling when compressed, or bowing when bent.

Finally, remodelling is more rapid in children than in adults. Imperfect reductions have been known to remodel into satisfactory alignment. The differences between pediatric and adult fractures result in different fracture patterns, problems of diagnosis, and management techniques.

Description of a pediatric fracture includes the anatomic location and configuration of the fracture, as well as, the relationship of the fracture fragments to each other and to the adjacent tissue. The anatomic location of the fracture can be described as diaphyseal (involving the central shaft of a long bone), metaphyseal (involving the ends of the shaft of a long bone), physeal (involving the growth plate), or epiphyseal (involving the ends of a long bone).

There are several configurations unique to pediatrics that may describe the fracture. A plastic deformation occurs when the bone is bowed beyond elastic recoil, without an actual fracture. This is called a bowing fracture (most common in the ulna) when the bone appears to be bent without any fracture line evident. A buckle fracture (or torus fracture) occurs due to axial compression of bone at the metaphyseal-diaphyseal junction.
These fractures are inherently stable and heal within 2-3 weeks with immobilization. A greenstick fracture occurs when a bone is angulated beyond the limits of plastic deformity. The force of impact was insufficient to cause a complete fracture. Instead, there is a fracture on the tension side and plastic deformity with an intact cortex and periosteum on the compression side. A complete fracture describes a fracture in which both sides of the bone are fractured. Complete fractures may be sub classified according to the direction of the fracture line. A transverse fracture line is at 90 degree angle to the long axis. A spiral fracture line encircles a portion of the shaft and is oblique in orientation. Oblique fracture lines are 30-40 degrees to the long axis. A fracture site revealing multiple fragments is comminuted and is unusual in children.

The relationship of fracture fragments to each other can be classified by the extent of displacement. Angulation describes the angle of deviation between the pieces of bone at the fracture site. Translocation describes transposition of segments of bone. Impaction occurs when one fracture surface is driven into the opposing fracture surface. Overriding describes the slipping/overlapping of either part of a fractured bone past the other.

The relationship of the fracture fragments to the surrounding tissue can be classified as open or closed. In an open fracture (also called compound fracture), a break in the skin is present due to penetration of the skin by a fracture fragment from within or because a sharp object has penetrated the skin to fracture the bone. An open fracture increases the risk of infection. The skin is intact over the fracture site in a closed fracture.

The *Salter and Harris system* is used to classify growth plate injuries. Physeal injuries are classified into five groups:

**Type I:** Fracture through the physis without involvement of the metaphysis or epiphysis. A non-displaced type I fracture is not visible on X-ray, but a displaced type I fracture can be identified because the epiphysis and metaphysis will not be aligned.

**Type II:** A fracture through the physis and metaphysis, with a fragment of the metaphysis remaining attached to the physis.

**Type III:** A fracture involving the epiphysis and the physis.

**Type IV:** A fracture involving the epiphysis, physis, and metaphysis.
**Type V:** The physis is crushed (compressed) without fracture of the epiphysis or metaphysis.

Generalized prognostic information regarding risk for premature physeal closure and indications for treatment can be determined according to the Salter and Harris classification. Type I and type II fractures can be treated with cast or splint immobilization. They do not require perfect alignment and have an excellent prognosis. Type II fractures of the distal femur are an exception, however. Unless anatomic alignment is attained by closed or open techniques, these fractures have a poor prognosis. Type III and type IV require precise anatomic reduction to minimize future joint or growth abnormalities. Type V fractures are usually recognized in retrospect as a consequence of premature physeal closure. Prognosis is poor due to premature growth cessation.

With knowledge of the most common types of injury for a child's developmental level, a physician may predict the type of injury sustained. Fractures in the newborn and infant are frequently the result of child abuse. In young children, falling onto an outstretched hand is a common mechanism of fracture. As a consequence, upper extremity and clavicle fractures have a greater incidence than lower extremity fractures.

Operative treatment under general anaesthesia is required for approximately 4-5% of pediatric fractures (1). Indications for surgical stabilization include displaced epiphyseal fractures, displaced intra-articular fractures, unstable fractures, fractures in the multiply injured child, and open fractures. Three basic techniques are used in the surgical management of pediatric fractures: open reduction and internal fixation (ORIF), closed reduction and internal fixation, and external fixation. Open reduction refers to intraoperative surgical reduction of the fracture ends, while closed reduction refers to manipulating the fracture externally to achieve reduction. Internal fixation refers to the insertion of metal pins, screws, plates or other hardware to stabilize or fixate the fracture once reduction is achieved, while external fixation refers to fixation of bones by splints, plastic dressings, or transfixion pins. Casts are sometimes considered external fixation but they are usually referred to as external support.

Open reduction and internal fixation may be required for displaced epiphyseal fractures (especially Salter-Harris types III and IV fractures, intra-articular fractures, and unstable fractures). Other indications include neurovascular injuries requiring repair, failure to obtain anatomic alignment, and occasionally, open fractures of the femur and tibia.
Closed reduction and internal fixation is indicated for specific displaced epiphyseal, intra-articular, and unstable metaphyseal and diaphyseal fractures. Common indications include supracondylar fractures of the distal humerus, phalangeal, and femoral neck fractures. Multiple closed reductions of epiphyseal fractures may cause repetitive damage to the physeal germinal cells, and are therefore contraindicated.

**UPPER LIMB #s**

The clavicle is the most frequently fractured bone in children (4). The most common site of fracture is between the middle and outer thirds. Clavicle fractures can be the result of birth injuries in newborns but are more typically the result of a fall on an outstretched arm in older children. The diagnosis is easily made by physical and radiographic evaluation. The patient will have pain with shoulder and neck movement. Crepitus and local swelling may be present. Neurovascular injury is rare. An AP radiograph of the clavicle is usually sufficient for diagnosis. Clavicle fractures in the newborn require no further treatment. A palpable callus can be detected several weeks later. In older children, a sling or shoulder immobilizer (a sling with another strap holding the horizontal forearm portion against the torso) is used to elevate the upper extremity to reduce downward pull on the distal clavicle. Figure-of-eight clavicle straps which extend the shoulders to minimize the overlap of fracture fragments, may also be used, but most patients find this uncomfortable and there is no clinical advantage over a sling or shoulder immobilizer. A palpable callus can be detected several weeks later which remodels in 6-12 months. Clavicle fractures usually heal rapidly in 3-6 weeks.

Proximal humerus fractures are usually the result of a fall backwards onto an extended arm. Neurovascular injury is rare. However, axillary nerve damage should be suspected if the patient experiences abnormal deltoid function and paresthesia or anaesthesia over the lateral aspect shoulder. Treatment includes immobilization by a broad elastic bandage holding the humerus against the body for 3-4 weeks. Because of the significant remodelling potential of this area, a certain amount of deformity is acceptable. Fractures with extreme angulation (greater than 90 degrees) may require surgical reduction.

Supracondylar fractures (distal humeral metaphyseal region proximal to the elbow) are the most common elbow fracture in children (4). They occur most frequently between the ages of 3 to 10 years old. This fracture is often the result of a fall onto an extended arm. The patient will hold the arm in pronation and resist flexion because of pain. Neurovascular injury is common in severe displacement. Because flow through the brachial artery can be
affected, this injury should be treated as an acute emergency. Swelling, if severe, can block venous and arterial structures. A careful neurovascular examination is necessary. Compartment syndrome of the volar forearm can develop within 12-24 hours. Volkmann's contracture due to intracompartmental ischemia may follow (5). Pins are often used to fix the fracture after closed or open reduction. The more common less severe supracondylar fractures without neurovascular compromise can be splinted with the elbow in a position of comfort flexed at 90 degrees, and the forearm splinted in pronation or neutral position.

Lateral humeral condyle fractures are the result of falls in which the radial head drives into the capitellum of the humerus. An oblique shearing fracture of the lateral joint surface occurs. There is usually severe swelling even though the fracture appears small on X-ray. There is a high risk of malunion and nonunion in these fractures. Because both the growth plate and the joint surface are displaced, open reduction and fixation with percutaneous pins may be required. A cast without pinning may be satisfactory for non-displaced fractures.

Radial head (proximal radius) fracture is often associated with other elbow injuries. Radial head fractures are common and can often be diagnosed clinically since they may be difficult to see on X-rays. Patients with radial head fractures have most pain with supination/pronation while having mild pain with flexion/extension of the elbow. The radial neck may angulate as much as 70-80 degrees. Angulation of 45 degrees or less usually remodels spontaneously. Closed manipulation is required in larger degrees of angulation.

Forearm fractures are a common result of falls. If both bones are involved, one bone may be completely displaced with the other bone only suffering a greenstick fracture. Closed reduction and casting are used in the treatment of stable fractures. Closed intramedullary pinning and open reduction and internal fixation are operative options for unstable fractures.

Torus (or buckle) fractures of distal radial metaphysis are common. They are usually the result of a minor fall onto the hand with wrist in dorsiflexion. The fracture is impacted and there is minimal soft tissue swelling or haemorrhage. There is usually a minor distal ulna fracture associated with these distal radius fractures. Treatment is by a short-arm cast. Fractures typically heal in 3-4 weeks.

A Salter-Harris type I fracture frequently occurs through the distal radial physis. Unless the epiphysis is displaced, it will not be visible on X-ray. Thus, it must be diagnosed clinically.
Any patient with a suspected distal radius fracture, presenting with tenderness over the distal radial physis should be presumed to have a non-displaced Salter-Harris type I fracture. They should be placed in a splint and followed clinically 2-3 days later. These injuries are commonly mistaken for wrist sprains. If at follow-up, the distal radius is non-tender, then a fracture is unlikely. However, if tenderness over the physis persists, then a fracture is likely and immobilization should be continued and referral to an orthopedic surgeon is appropriate.

The Monteggia injury is a fracture of the mid or proximal ulna associated with a dislocated radial head. The radial head should be pointing at the capitellum in all views. Such ulna fractures are often large, obvious and distracting making it easy to miss the dislocated radial head. Whenever a mid or proximal ulna fracture is noted (including olecranon fractures), critically inspect the alignment of the radial head with the capitellum. It is likely that a Monteggia injury occurs with many mid and proximal ulna fractures. Closed reduction of the radial head dislocation is necessary in addition to reduction and casting of the ulna fracture. Chronic elbow motion may be lost if the radial head dislocation is not properly reduced.

Phalangeal fractures in children are usually the result of crush injuries, such as slamming a finger in the door or a hyperextension injury from a basketball. If the distal phalanx is involved there may be a painful subungual hematoma which can be drained for pain relief. Occasionally, the growth plate is involved (Salter-Harris type II). Treatment is usually by splint immobilization. Closed reduction is rarely necessary; however, if there is angulation or malrotation, it may be required.

Carpal bone fractures are uncommon in children. As in adults, scaphoid fractures may be occult and difficult to identify on X-rays. Tenderness over the scaphoid (the floor of the anatomic snuff box) should indicate the possible presence of a scaphoid fracture even if X-rays fail to demonstrate a fracture. A thumb spica splint should be applied so that the thumb and wrist are immobilized. The blood supply to the scaphoid is injury prone, which puts the patient at risk for avascular necrosis and chronic pain. Scaphoid tenderness should be splinted aggressively. If the scaphoid is non-tender in a few days, then a fracture is not likely; however, persistent tenderness suggests the possibility of a fracture and referral to an orthopedic surgeon is appropriate.
Pelvic fractures are the result of major blunt trauma. Treatment is usually symptomatic due to the thick periosteum which confers stability. The patient should be assessed for intra-abdominal injuries.

Hip fractures are usually due to motor vehicle crashes, bicycle crashes, or falls from heights (4). Patients present with pain on gentle hip movement. There is a greater risk in children for avascular necrosis and growth cessation or deformity due to the vascularity and presence of a physis. Femoral neck fractures are unstable. They are treated with open or closed reduction and internal fixation to stabilize the fracture.

Femoral shaft fractures are the result of high-energy trauma. In younger children, the possibility of abuse must be considered. In children under 3 years old, approximately 70% of femur fractures are non-accidental (i.e., inflicted) (4). Although most femur fractures are closed, bleeding into soft tissues of the thigh may result in significant blood loss. Femoral shaft fractures may shorten and angulate due to longitudinal muscle pull and spasm. Length restoration and alignment are attained by longitudinal traction. Overgrowth of approximately 1.0 to 2.5 cm is commonly seen in femur fractures in children between 2-10 years old. Casts are used in this age group to allow for some shortening. Perfect reduction is unnecessary because remodelling is so rapid. A solid union is usually attained within 6 weeks.

Non-displaced oblique tibial fractures can occur in children less than 3-4 years old (toddler fracture) as the result of a rotational injury sustained while running or playing. Clinical features include pain, unwillingness to bear weight, and refusal to walk. Physical exam may be difficult to locate the site of the injury except for a refusal to bear weight on the affected lower extremity. The fracture may be radiographically subtle. Evidence of new bone formation may be seen radiographically within 1-2 weeks, and requires an additional 2 weeks of immobilization. Large distal tibia fractures (as opposed to small subtle ones as in the toddler's fracture) in young children are more likely to be associated with intentional injuries as in child abuse.

Ankle fractures may involve the medial or lateral malleolus. Medial malleolus fractures are uncommon. In children, a Salter-Harris type I fracture of the distal fibular physis cannot be confirmed radiographically so it must be suspected clinically based on tenderness over the physis. These fractures are difficult to distinguish from ankle sprains. If a fracture is
suspected, they should be placed in a splint. Ankle sprains are far more common than fractures in older children and adolescents.

Foot fractures can occur in the tarsal bones, metatarsals and/or the phalanges. Fractures of the metatarsal shaft are usually the result of direct trauma to the foot resulting from a fall, bicycle, or sledding injury. Injury is followed by soft tissue swelling and, sometimes, ecchymosis. Palpation reveals tenderness directly over the fracture. Fifth metatarsal tuberosity fractures (dancer's fracture) are also common and consist of an apophyseal avulsion fracture at the peroneus brevis tendon insertion. Swelling, ecchymosis, and localized tenderness to the fifth metatarsal tuberosity suggest a fracture. Contraction of the peroneal musculature increases the tenderness.

Toe phalangeal fractures are common and are usually the result of direct blows. They usually occur when the child is barefoot. The toes are swollen, ecchymotic, and tender. Mild deformity may be present. Closed reduction is not indicated unless the toe is significantly displaced. Casting is not usually necessary. Adequate alignment can be achieved by "buddy" taping the fractured toe to an adjacent stable toe.

References


