Abstract

Upper-extremity fractures account for more than half of childhood bony injuries. The frequency of injury increases with increasing mobility. The most common mechanism is a fall on an outstretched hand while playing. Optimal management requires knowledge of the normal anatomy and variants unique to pediatric bones. The physician needs to maintain a high level of suspicion for growth plate injuries because if unrecognized, these may result in growth arrest. Although the vast majority of pediatric upper-extremity fractures will heal rapidly with minimal intervention, physicians should be aware of the complications that can arise from these injuries.
Children injuries account for more than 10 million annual visits and are the second leading cause for visits to primary care offices and the emergency department.\textsuperscript{1,2} Fractures make up around 10% to 25% of these musculoskeletal injuries. Almost two-thirds of all boys and nearly half of all girls will have had sustained a fracture by 15 years of age, with a peak incidence for fractures of age 14 years for boys and 11 years for girls.\textsuperscript{3,4} In children, fractures tend to occur more frequently in the upper extremity in comparison to the lower extremity.\textsuperscript{5} The distal radius is the most frequently fractured bone. This, along with fracture of metacarpals and phalanges, accounts for 50% of all fractures.\textsuperscript{3,6}

With children and adolescents’ ever-increasing participation in sports, it is likely that primary care physicians will increasingly encounter patients with upper-extremity injuries. This article discusses the commonly encountered upper-extremity fractures in children. Common mechanisms of injury, fracture type and classification, possible complications, and current principles of their management are reviewed.

**KEY ASPECTS OF PEDIATRIC BONE**

The skeletal anatomy of a child varies considerably from that of an adult in several important ways. The pediatric bone is less dense, more porous, and has a lower mineral content. Being more elastic and pliable, it can undergo a greater degree of deformation before breaking. Hence, both greenstick and torus fractures are seen almost exclusively in the pediatric population. Increased porosity prevents fracture propagation, thereby resulting in a lower incidence of comminuted fractures in children. However, since the tensile strength of pediatric bone is lower than that of the ligaments, fractures are more common than sprains.

The two key attributes of immature skeleton are presence of growth plate and thick periosteum. The growth plates are located at the ends of the long bones and are responsible for continued longitudinal growth. In younger children, fractures closer to a growth plate have great remodeling potential, as the physis of a bent bone will grow eccentrically to help restore alignment over time. Depending upon age, remodeling can correct varying degrees of displacement and angulation but not axial malrotation. The periosteum in children is much thicker, stronger, and has a greater osteogenic potential. It provides stability, acts as a restraint to displacement, preserves the vascular supply, maintains reduction, and allows for faster fracture healing.

**CLASSIFICATION OF PEDIATRIC FRACTURES**

Pediatric fractures can be broadly classified into five types: plastic deformation, buckle fracture, greenstick fracture, complete fracture, and physeal injury (Figure 1). Plastic deformation is essentially unique to children and most commonly involves the ulna. Plastic deformity occurs from longitudinal stress and results in bowing of the bones, with a completely intact periosteum. No fracture line is visible radiographically. Buckle or torus fracture, also a primary childhood injury, results from axial loading on an extremity and occurs at the junction of the metaphysis and diaphysis. Acute angulation of the cortex is noted as opposed to the usual curved surface, resembling the torus or base of a classical Greek pillar. This is best seen on the antero-posterior view and not on the lateral view of a radiograph. Greenstick fractures are incomplete fractures that result from a bending force perpendicular to the shaft of a long bone, much like a green twig when it is bent. The side under the force remains intact but gets bent, whereas the cortex opposite the bending force fractures completely. Complete fractures are those that propagate completely through a bone. They can be spiral, oblique, or transverse fractures.

The physis, also known as the “growth plate,” is an area unique to pediatric bone. The physis is the transition zone at the end of the long bones in the body between the metaphysis and the epiphysis. Physeal fractures make up 15% to 25% of the pediatric fractures, with a peak incidence in the adolescent age group.\textsuperscript{7} The distal radial physis is the most frequently injured physis.\textsuperscript{8} Growth plate injury should be suspected if point tenderness is noted over a physis regardless of presence or absence of radiographic findings. Depending upon the pattern, the physeal injuries are usually classified into five categories by the

![Figure 1](https://example.com/figure1.png)
Salter and Harris classification system.\(^9\) Type I injuries extend through the physis. Type II fractures extend through the physis and exit through the metaphysis. They are the most common and represent approximately 50% of all growth-plate fractures in children.\(^10\) Type III begins in the physis and exits through the epiphysis intra-articularly. Type IV injury traverses through the physis, metaphysis, and epiphysis. Type V involves crush injury to the physis and carries the worst prognosis. Salter-Harris III to V fractures have a higher incidence of growth disturbance, as the likelihood of growth arrest is directly related to the severity of physeal injury. Usually the growth plate repairs well and rapidly but it is important to recognize physeal fractures as any damage to the growth plate can result in progressive angular deformity, limb-length discrepancy, or joint incongruity.

## RISK FACTORS

In otherwise healthy children, skeletal fragility is often attributed to low peak bone mass. Several independent risk factors like genetic constitution, birth weight, poor nutrition, and low socio-economic status may influence fracture risk in children. Whiting\(^11\) and Goulding et al.\(^12\) showed that obesity in childhood and adolescence reduces bone mineral density with an increased propensity for fractures. Furthermore, obese and overweight children tend to fall more during daily activities as a result of difficulty with balance. Environmental modifications have not been shown to lower the risk of fractures in obese children, and the only reduction in fracture risk was achieved by attaining a healthy body weight.\(^13\)

The role of vitamin D in maintaining patients’ bone health, as well as fracture healing and prevention of future fractures, is well known. In a recent study by James et al.,\(^14\) hypovitaminosis D was common among children with upper-extremity fractures. In their study cohort of 181 patients, 64% had low vitamin D levels, with African-American children being more likely to have an insufficient or deficient level.

Repetitive stress may result in fractures due to overuse and fatigue of the surrounding musculature. Though less prevalent than lower-extremity stress fractures, upper-extremity stress fractures are now being more frequently recognized. Common examples include “Little Leaguer shoulder” and “gymnast wrist,” which are a chronic Salter-Harris type I injury to the physis of the proximal humerus and distal radius, respectively. Pediatricians should offer nutritional counseling and discuss the importance of appropriate training and conditioning prior to and during sports participation to avoid these fractures.

### INITIAL ASSESSMENT

Accurate diagnosis of musculoskeletal injuries in children warrants a systematic approach. A detailed history, comprehensive physical examination, and a good understanding of sport biomechanics are vital adjuncts in making the correct diagnosis and planning appropriate management. A pertinent history should include mechanism of injury, direction and magnitude of the force, prior injuries, or any associated symptoms. All splints and bandages must be removed to ensure a thorough

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**TABLE 1.**

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Sensory</th>
<th>Motor</th>
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<tbody>
<tr>
<td>Radial</td>
<td>Dorsum of first web space</td>
<td>Thumbs-up sign</td>
</tr>
<tr>
<td>Ulnar</td>
<td>Volar aspect of little finger</td>
<td>Make a star (Spread fingers wide)</td>
</tr>
<tr>
<td>Median</td>
<td>Volar aspect of index finger</td>
<td>Make a fist with thumb flexion</td>
</tr>
<tr>
<td>Anterior Interosseus</td>
<td>No sensory function</td>
<td>“OK” sign (Making a circle with the thumb and index finger)</td>
</tr>
</tbody>
</table>

**TABLE 2.**

<table>
<thead>
<tr>
<th>Splint</th>
<th>Indications</th>
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<tbody>
<tr>
<td>Volar/Dorsal</td>
<td>Soft tissue injuries to hand and wrist, carpal bone fractures (excluding scaphoid/trapezium), and distal radius buckle fracture.</td>
</tr>
<tr>
<td>Thumb Spica</td>
<td>Scaphoid, non-displaced first metacarpal, and stable thumb fracture.</td>
</tr>
<tr>
<td>Radial Gutter</td>
<td>Non-displaced/non-rotated fractures of second and third metacarpal or corresponding proximal/middle phalangeal shaft fractures.</td>
</tr>
<tr>
<td>Ulnar Gutter</td>
<td>Non-displaced/non-rotated fractures of fourth and fifth metacarpal or corresponding proximal/middle phalangeal shaft fractures.</td>
</tr>
<tr>
<td>Sugar Tong</td>
<td>Acute distal radial and ulnar fractures.</td>
</tr>
<tr>
<td>Long Arm Posterior</td>
<td>Distal humeral, proximal/midshaft forearm fractures, and non-buckle wrist fractures.</td>
</tr>
<tr>
<td>Aluminum U-Shaped Splint</td>
<td>Distal phalangeal fractures.</td>
</tr>
<tr>
<td>Buddy Taping</td>
<td>Stable, non-displaced, non-angled shaft fractures of the proximal or middle phalanx.</td>
</tr>
</tbody>
</table>
examination of the injured extremity. Ensure appropriate analgesia, as it will make the child comfortable and comply with the examination. It is imperative to examine the entire limb as well as assess the joint above and below the injury for range of motion, stability, or concomitant injuries.

While performing an upper-extremity examination, attention should be paid to the clavicle, scapula, and shoulder. One should assess for any swelling, deformity, open wound, area of maximal tenderness, and active and passive range of motion. Finally, it is important to assess the distal neurovascular status of the limb. In younger children, motor and sensory assessment can be done by asking them to copy simple movements and touching areas reliably supplied by each nerve (Table 1). Plain radiographs are the mainstay of the diagnosis. Fractures should be described in terms of location, displacement, separation, shortening, and presence of angular or rotational deformities. Further imaging, such as computed tomography (CT) scans, may be necessary to plan operative intervention for intra-articular displacements. A bone scan or magnetic resonance imaging (MRI) may be needed occasionally to confirm the diagnosis of a stress fracture.

**BASIC PRINCIPLES OF FRACTURE MANAGEMENT IN CHILDREN**

Bone healing in children is usually rapid and inversely related to the age of the patient. Further, greater remodeling potential and abundant callus formation lessens the likelihood of long-term complications in childhood fractures. Therefore, conservative treatment including pain control, immobilization in a splint or cast, and return of activity in accordance with the patient’s symptoms suffices in the majority of common upper-extremity fractures.

Splinting may be accomplished using plaster, pre-padded casting material, or prefabricated and over-the-counter splints. In general, six to 10 sheets of plaster material over appropriate padding — especially over bony prominences — are recommended for upper-extremity injuries. Splints should be non-circumferential, somewhat loose, and applied in a position of function. Commonly used upper-extremity splints and their indications are listed in Table 2. Although some angulation is acceptable depending upon patient’s age, the fracture should not be malaligned or malrotated. In most cases, 15 to 20 degrees of volar/dorsal angulation in the sagittal plane in a skeletally immature child is deemed acceptable.15,16 Marked bowing should usually be corrected by completing the fracture and restoring alignment. For displaced fractures, closed reduction and immobilization in a cast can be achieved under procedural sedation. Open fracture warrants broad-spectrum antibiotics and tetanus vaccination. Immediate orthopedic evaluation is indicated for fractures that are unstable, open, or associated with neurovascular compromise.

**CLAVICLE FRACTURES**

Clavicle fractures are the most common of all pediatric fractures. They may be seen in newborns as a result of birth trauma, or in children and adolescents following a fall on an outstretched hand (FOOSH) or shoulder, or a direct blow to the bone. An overwhelming majority (80% to 85%) occur in the middle one-third of the bone (Figure 2). In younger children, these fractures are typically greenstick and may go unnoticed until a large callus forms.17 In older children, the fracture is usually displaced and associated with lowering of the affected shoulder, point tenderness, swelling, obvious deformity, and/or ecchymosis at the fracture site. Shoulder movements across different planes usually exacerbate the pain. X-rays with dedicated clavicle views can accurately diagnose most clavicle fractures. However, one should be aware that clavicle views are different from routine shoulder films.

The majority of clavicle fractures will heal uneventfully and are managed using a simple sling for 2 to 3 weeks, primarily for pain control. When compared to a figure-of-eight splint, a sling is more comfortable, less cumbersome to put on, causes fewer skin problems, and has similar outcomes. Indications for operative intervention include open fractures, complicated comminuted fractures, and fractures with neurovascular compromise or greater than 100% displacement (width of the clavicle) where skin is tented or its integrity is threatened.18 Parents should be informed that a callus bump at the fracture site is part of the natural healing process and will become less distinct as the bone remolds over the next 6 to 12 months. Complications, though rare, may include brachial plexus injury, pnumothorax, and airway compromise. Healing usually happens over 6 to 18 weeks, with average return to non-contact sports in 4 to 6 weeks followed by return to contact sports when there is no pain over the fracture site, full pain-free range of movements, and normal strength.

**Figure 2.** (A) Midshaft clavicle fracture with overriding. (B) Healing clavicle fracture with surrounding callous.
HUMERUS FRACTURES

Proximal humerus fractures are a common injury in children that peaks during adolescence secondary to increased sports participation. It comprises both physeal and metaphyseal fractures (Figure 3A). The most common mechanism of injury is a FOOSH or a hit directly at the proximal humerus. Although less common than clavicle fractures, this type of fracture may be seen in neonates secondary to birth trauma. The patient usually presents with pain localized to the proximal humerus and/or anterior shoulder or, in newborn cases, pseudoparalysis. Physical findings could be subtle or absent and may include swelling, bruising, and/or an obvious deformity in more severe injuries. Injury to the axillary nerve should be excluded by carefully assessing deltoid function and sensation over the lateral aspect of the proximal humerus. Standard shoulder radiographs are diagnostic. These fractures carry an excellent prognosis as a result of the abundant remodeling potential of the proximal humerus. Most can be managed by immobilization with a simple sling, or a coaptation splint for the more severely displaced fractures, for approximately 3 to 4 weeks. Surgical intervention is required for associated neurovascular injuries, open, and/or intra-articular fractures, or severely angulated fractures in older children and adolescents. Complications are quiet rare and include axillary nerve/brachial plexus injury (typically neuropraxia), avascular necrosis, and malunion.

Humeral metaphyseal/shaft fractures in the absence of significant trauma (eg, motor vehicle accident, fall from height) should raise the suspicion of abuse, although neither age nor fracture pattern is pathognomonic of abuse (Figure 3B). Physicians should also consider pathologic fracture, as the humerus is a common site for bone cysts and other benign lesions (Figure 3C). These fractures also have an enormous remodeling potential; hence, the majority are treated with immobilization in a coaptation splint for 3 to 4 weeks and rarely require surgical intervention. Complications are rare, with radial nerve injury being the most common.

ELBOW FRACTURES

Elbow fractures in children are quite common and represent approximately 10% to 12% of all pediatric fractures. Unlike fractures of the clavicle or proximal humerus, elbow fractures are more likely to require precise, often surgical, reduction.

Diagnosis of pediatric elbow fractures can be challenging, as this requires distinguishing normal ossification centers from fractures in a radiograph. Applying the mnemonic CRITOE, which refers to the sequence of appearance of six secondary ossification centers at the elbow (Table 3), can help pediatric providers with this. However, one should be aware that these ages are approximations, and these injuries often occur somewhat earlier in girls.

**Supracondylar Fractures**

Supracondylar fractures account for 60% to 80% of all pediatric elbow fractures. They occur primarily during the

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**Figure 3.** (A) Displaced fracture through the neck of humerus. (B) Humerus shaft fracture with overriding. (C) Pathologic proximal humerus fracture through a bone cyst.
first decade of life, with a peak incidence at around 5 to 7 years of age. The most common mechanism is a FOOSH injury with hyperextension of the elbow (eg, a fall off the monkey bars). The child usually presents with a swollen painful elbow and limited range of motion and may have an obvious deformity. Significant ecchymosis is considered a risk factor for forearm compartment syndrome. Due to its potential to injure the brachial artery, as well as the radial, median, and/or ulnar nerve, a thorough neurovascular assessment should be performed in all patients with a suspected or known elbow fracture. Standard elbow radiographs, including an anteroposterior (AP) view in extension and a lateral view at 90-degree flexion, are sufficient in making the diagnosis. On a lateral radiograph, the classic figure-of-eight appearance of the distal humerus and the anterior humeral line should always be assessed. In a normal elbow, a line drawn along the anterior cortex of the humerus should bisect the middle third of the capitellum, whereas in the case of a supracondylar fracture, the capitellum is generally displaced posterior to this line. In absence of a clear fracture line, subtle signs like presence of a posterior fat pad or a large, triangular sail-shaped anterior fat pad are indicative of an intra-articular joint effusion with an associated fracture. Supracondylar fractures are classified on the basis of the degree of displacement of the fractured distal fragment (Figure 4, Table 4).24

Type I non-displaced supracondylar fractures can be treated in a long-arm cast for approximately 3 to 4 weeks. Type II and Type III fractures are mostly managed surgically with closed reduction and percutaneous pin fixation. In case of suspected vascular compromise, the patient should be taken immediately to the operating room for fracture reduction. Supracondylar fracture carries one of the highest complication rates of any pediatric fracture.25 Complications include neurovascular injuries, compartment syndrome, Volkmann’s ischemic contractures (contracture deformities of the fingers, hand, and wrists), and cubitus varus (angular gunstock deformity).

OTHER ELBOW FRACTURES

Lateral Condyle

The lateral condyle is the second most common elbow fracture and results from a FOOSH mechanism. Examination findings reveal a swollen elbow, possible localized lateral tenderness, and decreased range of movement. The fracture may not always be appreciated on initial radiographs, as it occurs through an area that may be only partially ossified. Radiographic findings may include the presence of a posteriorly displaced metaphyseal fragment or disruption of the radial head alignment with the capitellum (Figure 5A). Treatment is usually surgical. The articular nature of the fracture and often delayed diagnosis result in a high incidence of malunion and nonunion with this injury.

Medial Epicondyle

Medial epicondyle is the third most common pediatric elbow fracture. It is usually seen in children between the ages of 9 and 14 years and frequently encountered in baseball pitchers. The mechanism of injury is a valgus stress, and about half of cases are associated with dislocation of elbow. Examination findings include a swelling and tenderness over the medial epicondyle and weakness in the flexor-pronator muscle group. Imaging for epicondylar fractures includes AP and lateral radiographs (Figure 5B). Non-displaced and
stress fractures are treated conservatively in a long arm posterior splint or cast for 3 weeks. Displacement of greater than 3 mm to 5 mm or presence of intrarticular loose bodies require surgical fixation. The most common complications are stiffness, ulnar nerve injury, and symptomatic non-union.

RADIAL HEAD/NECK FRACTURES

Children usually sustain radial neck fractures, whereas fractures of the radial head occur primarily in adults. Most fractures result from a FOOSH mechanism with the elbow in extension and valgus. Upon examination, there may be local tenderness over the radial head with pain accentuation on pronation/supination of the forearm. At times, patients may present with referred pain at the wrist. Most cases are Salter-Harris type II fractures and are revealed on standard elbow radiographs (Figure 6C). At times, radiographic findings can be subtle and only demonstrate the presence of a posterior fat pad sign. Undisplaced fractures, or those with less than 30-degree angulation, are managed in a long arm posterior splint or cast. Displaced or more angulated fractures are treated surgically. Complications include decreased range of motion, avascular necrosis of the radial head, and posterior interosseous nerve injury.

FOREARM FRACTURES

Forearm fractures typically result from a FOOSH injury or, occasionally, due to direct blow, as in the case of a both-bone forearm fracture. Physical exam may reveal swelling, tenderness, and decreased motion, and gross deformity may or may not be present. While evaluating forearm fractures, if only one bone appears to be fractured, the clinician should check the proximal and distal joints for injury. Although rare, compartment syndrome should be ruled out in both-bone forearm fractures. Plain radiographs of the forearm can provide the diagnosis.

Treatment depends on the type of fracture and the degree of displacement. Most pediatric forearm fractures can be treated without surgery. Buckle fractures may simply need the support of a splint or cast for 2 to 3 weeks until they heal. Closed reduction and immobilization for 6 to 12 weeks in a long arm cast is needed for greenstick fracture with more than 10 degrees of angulation, both-bone fracture in children younger than age 10 years, fracture dislocations, distal radius fractures, and Salter-Harris type I

OLECRANON FRACTURES

Olecranon fractures occur rarely in children. If present, they are commonly associated with other elbow injuries. The common mechanism is a fall onto the elbow or a direct blow to the olecranon process. Examination may reveal swelling and tenderness over the olecranon process, and the patient will resist extension at the elbow. If nondisplaced, these fractures can be treated in a long arm cast; however, operative intervention is required for displaced fractures.

10 years of age, buckle and greenstick fractures occur most frequently, whereas growth plate and complete fractures are more likely in patients older than 10 years of age and adolescents, respectively. Fractures of both bones of the forearm are mostly distal in location, as well (Figure 6B). Imaging may reveal plastic deformation, greenstick, or complete injuries with varying degrees of displacement. Fracture dislocations of the forearm can also happen, in which there is a fracture with shortening of one of the two bones with dislocation of the other bone. Monteggia fracture comprises radial head dislocation plus proximal ulna fracture or plastic deformation of the ulna without obvious fracture (Figure 6C). Galeazzi fracture is a relatively rare injury characterized by fracture of the distal radial shaft with disruption of the distal radioulnar joint (Figure 6D).

Figure 6. (A) Transverse fracture of the radial metadiaphysis. (B) Fracture of both bones of the forearm. (C) Monteggia fracture characterized by proximal ulnar fracture with radial head dislocation. (D) Galeazzi fracture depicted by distal radial fracture with disrupted distal radioulnar joint.

Figure 7. (A) Fracture through waist of the scaphoid bone. (B) Fracture through shaft of the 5th metacarpal (“boxer’s fracture”).

Figure 6A
and II injuries. There is great potential for remodeling, and outcomes are quite good. Surgical indications include open fractures, Salter-Harris type III and IV fractures of the distal radial physis, failed or unstable reductions, associated vascular injuries, and fractures in skeletally mature individuals.

**WRIST AND HAND FRACTURES**

Carpal bones are predominately cartilaginous until late childhood. Therefore, mechanisms that would produce bony wrist injuries in adults would produce fracture of the forearm in young children. Acute injuries to the wrist usually result from a FOOSH or blunt trauma. The scaphoid bone is the most common carpal bone to be fractured (Figure 7A). Clinically, there is radial-sided wrist pain and swelling, with tenderness that is often localized to the anatomic snuffbox. Scaphoid fractures can be difficult to diagnose on plain films, with reported sensitivities between 70% and 86%. Hence in an acute setting, any suspected scaphoid injury should be managed with a splint. CT or MRI may be needed to make the diagnosis of subtle or stress fractures. Treatment and prognosis is dependent on the location of the fracture. Distal and middle one-third scaphoid fractures are often non-displaced and treated with a short arm thumb spica cast for 4 to 8 weeks. Since they have a good vascular supply, distal and middle third scaphoid fractures heal well without complications. Proximal or displaced scaphoid fractures often require surgery as they have a more precarious blood supply and, hence, a higher incidence of nonunion.

Hand injuries in children are common but seldom complicated. Metacarpal fractures are the second most common type of upper extremity fracture. They can result from a direct blow or trauma to a clenched fist, such as punching a wall. The most common site of injury is neck of the fifth metacarpal, known as a “boxer’s” fracture (Figure 7B). The phalanges too are frequently fractured, with distal phalanx being the most common. The usual mechanism of injury to the distal phalanx is a crush or axial load injury. Often there is associated finger-tip or nail bed injury. The assessment for hand injury should include finger alignment, as any rotational deformity is unacceptable. The radiographs should be thoroughly examined for rotation, shortening, and angulation. Pediatric hand injuries are mostly managed non-operatively. Non-displaced metacarpal fractures can be immobilized in a radial or ulnar gutter splint. Most phalangeal fractures can be treated with splinting or buddy taping for 3 to 4 weeks. Antibiotic therapy should be prescribed for distal phalangeal fractures with associated nail trauma, as they are technically open fractures. Fractures associated with open injury, rotational deformity, unacceptable angulation, and intraarticular displacement require surgical management.

**CONCLUSION**

Upper-extremity fractures occur frequently in the pediatric and adolescent patient population. It is important for the primary care physician to be cognizant of the key skeletal differences and unique fracture patterns in children, as they can directly impact patient management and outcome. A thorough, systematic approach will enable providers to accurately identify these injuries, institute the initial treatment, and offer appropriate anticipatory guidance for a positive outcome.

**REFERENCES**


