Pediatric Upper Extremity Injuries

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The pediatric musculoskeletal system differs greatly from that of an adult. Although these differences diminish with age, they present unique injury patterns and challenges in the diagnosis and treatment of pediatric orthopedic problems.

Pediatric bone is highly cellular and porous, and it contains a large amount of collagen and cartilage compared with adult bone. The larger amount of collagen leads to a reduction of tensile strength and prevents the propagation of fractures, whereas the abundance of cartilage improves resilience but makes radiologic evaluation difficult \cite{1}. The tensile strength of pediatric bone is less than that of the ligaments, so children are more likely to have bone injuries with mechanisms that would cause only ligamentous injuries in adults. The periosteum of pediatric bone is comparatively more metabolically active than the adult periosteum, leading to rapid and large callus formation, rapid union of fractures, and a higher potential for remodeling. The periosteum is also thicker and stronger in children. This difference is responsible for some of the unique fracture patterns seen in children \cite{1,2}.

The most obvious difference between the pediatric and the adult skeleton is the presence of growth plates. The physis is a transition zone between the metaphysis and epiphysis. This is a highly metabolic and rapidly changing area of bone. The germinal area of the physis rests on the epiphysis, and cartilage cells grow toward the metaphysis, forming columns of cells. These columns degenerate, undergo hypertrophy, and then calcify at the metaphysis. The growth and change that occur at a growth plate facilitate remodeling of fractures and

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contribute to rapid healing; however, damage to the physis itself can lead to deformity secondary to asymmetrical growth [3–6].

Fractures in children are less likely to propagate and become comminuted. Greenstick fractures, common in the forearm, illustrate this well. The bone bends before it breaks, but because of the thick outer portion of the bone, the periosteal sleeve maintains apposition and creates a “hinge” effect (Fig. 1A) [2,7]. In some cases, the periosteum may remain completely intact, and the bone may be bowed, which is known as a plastic deformity. It is common in the forearm as well, and it is likely seen in conjunction with another fracture (see Fig. 1B). Torus, or buckle fractures, are also a result of the high collagen content of pediatric bone. The bone is more likely to fail in both tension and compression. This fracture is commonly seen in the distal radius (see Fig. 1C) [7].

**Physeal injuries**

Physeal injuries are unique to children, and they account for approximately one fourth of all pediatric fractures. Although a majority of these fractures heal without incidence, approximately 30% of these fractures cause a growth disturbance, and 2% of them cause a functional growth deformity. A number of classification systems exist for these fractures, but the Salter-Harris classification system is the simplest and most widely used. Salter-Harris type I injury is a fracture through the hypertrophic cartilage that causes a widening of the physeal space. These fractures are difficult to diagnose radiographically and are clinically hallmarked by point tenderness at the epiphyseal plate (Fig. 2). Type II fractures are the most common. These extend through both the physis and metaphysis. Although these fractures may result in some shortening, they rarely cause functional deformities (see Fig. 2). Type III injuries extend through the physis...
and the epiphysis, disrupting the reproductive layer of the physis. These injuries may cause chronic sequelae because they disrupt the articular surface of the bone, but they rarely cause any deformity and generally have a good prognosis (see Fig. 2). Type IV injuries cross through all three areas of bone, the epiphysis, physis, and metaphysis. These fractures are also intra-articular, increasing the risk for chronic disability. They also can disrupt the proliferative zone, leading to early fusion and growth deformity. Type V fractures are the least common but most difficult to diagnosis and have the worst prognosis. The classic mechanism of injury is an axial force that compresses the epiphyseal plate without an overt fracture of the epiphysis or metaphysis. Although a type V Salter-Harris fracture may not be radiographically apparent, radiographs may demonstrate a joint effusion. This compressive mechanism results in premature closure of the physis and thereby arresting bone growth \[3,4,8\]. Type V injuries are commonly diagnosed in retrospect, secondary to the occult nature of the radiograph.

**Evaluation**

Proper injury management is contingent on the correct diagnosis. The evaluation of the child may be complicated by other injuries and the lack of cooperation on the part of the child. It is vital to obtain an accurate history, including the situation, mechanism, and timing of the injury. The orthopedic physical examination follows the standard sequence of inspection, palpation, range of motion, and neurovascular examination. First, observe the patient for any obvious deformity and watch for spontaneous movement. Lack of spontaneous movement may be true paralysis, but pseudoparalysis is common in children who have had trauma or infection. It is important to remove all splints, bandages, and obscuring clothing to perform an accurate examination. Look for any breaks in the skin, deformity, swelling, or ecchymosis. Depending on the ability of the patient to cooperate, have the patient locate the point of maximal tenderness. This is vital to the correct diagnosis in some cases because the presence of unossified bone makes some fractures difficult to diagnose. Palpate the entire limb, including the
joint above and below the obvious injury. It is also important to remember the shoulder, clavicle, and scapula when performing an upper extremity orthopedic examination. Evaluate both the passive and active ranges of motion of the entire extremity. With an uncooperative patient, this may be difficult. Finally, it is important to assess the neurovascular status of the patient. For the vascular examination, the presence of a pulse alone is not an adequate test of circulation. The capillary refill rate is a more sensitive test of perfusion. Observe while the patient passively extends the fingers. Pain with this activity may be an early sign of ischemia. A complete neurologic examination of both sensory and motor functions of the extremity is an important part of the assessment, as well.

Imaging

Although the history and physical examination are important in the correct diagnosis, a majority of orthopedic injuries are diagnosed with radiographic imaging. Conventional radiography is adequate to diagnose a majority of injuries, but some injuries may require additional views or other imaging modalities. It is necessary to obtain at least two views of the injured area, and as it is important to carefully examine the joint above and below the injury, because these areas may require imaging as well. The presence of ossification centers can make radiographic evaluation difficult, especially of the wrist and elbow. It may be helpful to obtain films of the uninjured extremity for comparison. Difficulty with radiographic evaluation can often occur in young infants, whose bones have not begun to ossify at the site of interest. In these cases, ultrasonography or CT scanning may be needed to further elucidate the injury. With these imaging modalities, cartilaginous structures and associated effusions can be better appreciated [8,9].

Consultation

It is important when consulting a specialist to accurately describe the injury, including severity, location, description of the fracture line, displacement, separation or shortening, angulation, and any complicating findings from the physical examination, including delayed capillary refill or neurologic deficits. If there is a fracture, note first whether it is open or closed. Virtually all open fractures, with the exception of open distal phalanx fractures, require urgent operative management and immediate orthopedic consultation. The location of the injury includes not only the bone involved but also whether the injury is proximal, distal, or midshaft and whether there is involvement of the articular surface. The fracture line describes the defect in the bone. The line may be linear or spiral. There also may be more than one fracture line. Fractures that have more than one line and break the bone in many pieces are comminuted. Two separate fractures that result in a free-floating segment of bone are segmental. Displace-
ment implies that the two fracture fragments are offset from each other. It may be described in measured distance or a percentage of the width of the proximal piece. The direction of displacement can be described as volar, dorsal, anterior, posterior, radial, ulnar, medial, or lateral. Separation is the distance that the distal segment is removed from the proximal segment. Shortening is the distance that the bone has been shortened as a result of either impaction or an over-riding fracture fragment. Angulation defines the angle that the distal fragment takes in relation to the proximal fragment. It is easily determined by noting the number of degrees that the distal fragment would need to be rotated to be parallel to the proximal fragment. If any neurologic deficit or vascular compromise is noted, an orthopedist should be consulted [10].

Traumatic injuries by location

Clavicle

The clavicle is one of the bones most frequently broken in children, although most fractures heal well with minimal or no treatment [11,12]. Clavicle fractures may occur in newborns, caused by compression of the shoulders during birth. In children and adolescents, fractures typically occur from a fall on an outstretched arm or shoulder. Fractures may also be the result of a direct blow, accounting for the majority of distal clavicle fractures. In infants and young children, these fractures are typically greenstick fractures and may go unnoticed until a large callus forms [12]. In older children, the fracture is usually displaced completely, resulting in a lowering of the affected shoulder, local swelling, and tenderness. Pediatric clavicle fractures rarely require operative treatment. An asymptomatic fracture in the newborn and infants may be treated with “benign neglect,” and parents are cautioned to handle the child carefully. In infants with a significant amount of pain, the arm may be splinted for 7 to 14 days. Midshaft clavicle fracture in children and adolescents are treated with a sling or a figure-of-eight bandage, which is worn for 1 to 4 weeks for comfort only. Fractures are only reduced if the integrity of the overlying skin is in jeopardy [12,13].

True dislocations of the clavicle are rare in children and are more often physeal injuries. Medial physeal injuries may be displaced anteriorly or posteriorly. The patient typically has pain and swelling at the medial end of the clavicle. Severe posterior dislocation can cause compression of the trachea, subclavian vessel, or brachial plexus [11]. Lateral physeal separation presents clinically as pain with all movements of the shoulder. Depending on the severity of the injury and degree of displacement, the skin may be tented over the acromioclavicular joint. Treatment of medial injuries is usually conservative if there is no evidence of mediastinal injury or significant cosmetic deformity, and patients are treated symptomatically with a sling or a figure-of-eight harness. A closed reduction is attempted for more serious medial injuries [11,14]. Minor
lateral physeal injuries with minimal displacement are treated symptomatically with a sling, but more severely displaced injuries typically require open reduction.

**Scapula**

Scapular fractures are rare and are usually the result of high-energy trauma. They are usually associated with other injuries, including clavicle fracture, rib fracture, pneumothoraces, thoracic vertebral fractures, and fractures of the humerus. The diagnosis of scapular fracture is often delayed because of these associated injuries. Treatment is often conservative, with patient comfort being the goal of treatment. Most patients tolerate a sling or shoulder immobilizer and are able to perform gentle range of motion exercise after 2 weeks. Complications are not common and are generally related to malunion or associated thoracic injuries.

**Shoulder**

Dislocations of the shoulder are rare in infants but more common in adolescents [15]. In the young child, proximal humeral injuries consist of a fracture at the physis. These fractures account for approximately 3% to 7% of all physeal injuries [16]. Difficulty can arise when evaluating a young infants’ shoulder because the humeral head is primarily cartilaginous. In such an event, radiography will not be able to distinguish between a physeal fracture and a dislocation. In this case, ultrasonography or MRI imaging is of benefit. Proximal physeal fractures occur in children of any age but are most common in adolescents. These fractures may result from a fall on an outstretched arm or from a direct blow, with the former being more common. Infants may sustain these fractures as a result of birth trauma or child abuse. On physical examination, there is localized swelling and tenderness, and the affected arm may be shortened and held in abduction and extension. There also may be distortion of the anterior axillary fold. Proximal humeral physeal injuries are almost exclusively Salter-Harris type I and II and have the potential for significant remodeling. The treatment of these fractures is generally nonoperative, even with significant displacement. A sling, sling and swath, or shoulder immobilizer is worn until pain subsides. Two weeks after the injury, the patient may begin pendulum exercises. Most patients resume some overhead activities within 4 to 6 weeks. Complications are rare; however, the most common complication is shortening of the humerus secondary to physeal damage and growth retardation [16–18].

**Shoulder dislocation**

The glenohumeral joint is one of the most flexible joints the body, but this flexibility is achieved at the expense of stability. There is little bony stability of the shoulder. Both static and dynamic supports are provided almost solely by muscles and ligaments. Traumatic dislocations of the shoulder are typically the result of indirect force. Greater than 90% of dislocations are anterior dislocations,
but posterior and inferior dislocations do occur. Traumatic dislocations are acutely painful. With anterior dislocations, the arm is held in abduction with external rotation. The humeral head may be palpable anteriorly, and there is a palpable defect just inferior to the acromion. Posterior dislocations are rarer, accounting for less than 3% of these injuries, and they are more commonly missed [11]. The arm is usually held in adduction with slight internal rotation. The shoulder may also appear flat anteriorly with a prominent coracoid process. Luxio erecta, or inferior dislocation, is the rarest traumatic dislocation. The arm is maximally abducted and adjacent to the head. These injuries can occur with enough force to drive the humeral head through the axilla, creating an open injury. Shoulder dislocations are commonly diagnosed by physical examination, but the diagnosis should be confirmed radiologically, along with any noted associated fractures. A thorough neurovascular examination should be performed. Special attention should be paid to the axillary nerve because it is most commonly injured with anterior dislocations. Acute shoulder dislocations should be reduced as quickly as possible. There are many techniques for reducing these injuries. Anterior shoulder dislocations are commonly reduced under procedural sedation with a traction–counter-traction technique. If an assistant is not available to provide counter-traction, there are many modifications of this technique. For instance, the patient is mildly sedated and placed in a prone position with the affected limb dangling over the edge of the bed. With enough time, the shoulder will reduce. Radiographs should be obtained after reduction to confirm anatomic placement as well as to look for any traumatic fracture. The neurovascular examination should be repeated. The patient is usually placed in a sling for comfort and can resume full activity within 2 to 3 weeks [15,19]. The most common complication of these injuries is recurrent instability. The incidence of recurrent dislocations has been reported to be as high as 70% to 90% [14]. These injuries may also be complicated by a fracture of the glenoid fossa or humeral head (the Hill-Sachs lesion), neurovascular injuries, and osteonecrosis of the humeral head [11,19,20].

**Humerus**

Fractures of the humeral metaphysis are more common in children than in adolescents, because adolescents are more likely to have a humeral physeal fracture [11]. Most of these fractures are caused by a high-energy direct blow to the metaphysis, and they are often associated with multiple traumas [21]. Any fracture to this area with a history of minimal trauma should raise the suspicion of a pathologic fracture or abuse. The humerus is a common location of bone cysts and other benign lesions [21]. These injuries typically present with localized pain, deformity, and swelling. Evaluation of the radial nerve is imperative because it is vulnerable to these fractures. Injury to this nerve will cause numbness to the dorsum of the hand between the first and second metacarpal and loss of strength with thumb and wrist extension and forearm supination. Humeral shaft fractures
are the second most common birth fracture. Neonates with this injury are treated with immobilization of the arm next to the thorax for 1 to 3 weeks, and a follow-up examination is required to exclude a brachial plexus injury. These fractures, like humeral physeal fractures, have a high potential for remodeling. Patients are treated with a coaptation splint for 2 to 3 weeks and then treated in a sling or hanging arm cast [22]. It is not necessary to achieve end-to-end alignment of these fractures. Angulation greater than $15^\circ$ to $20^\circ$ or any rotational deformity needs to be addressed by a specialist. Complications are rare, with radial nerve injury being the most frequent.

### Supracondylar fracture

#### Epidemiology

Supracondylar fractures occur most commonly between 3 and 10 years of age, with a peak incidence at age 5 to 7 and a mean age of 7.9 years [23–25]. Overall, these fractures are the most common pediatric elbow fracture, accounting for over half of all elbow fractures in children and a third of pediatric limb fractures [23]. For this reason, the following sections focus on this fracture type.

There are two major classifications of supracondylar fracture, extension and flexion. Extension fractures account for approximately 95% of supracondylar fractures. The mechanism of injury of a supracondylar extension fracture is a fall on an outstretched hand (FOOSH) with the elbow hyperextended (eg, a fall from the playground “monkey bars”). The FOOSH mechanism causes the ulna and triceps muscles to exert an unopposed force on the distal humerus, thereby resulting in posterior displacement of the fracture [25]. This extension mechanism results in a shift of the condylar complex in either the posterolateral or the posteromedial direction. Supracondylar flexion fractures account for 5% of supracondylar fractures. They occur secondary to a direct blow to the posterior aspect of the flexed elbow and result in anterolateral displacement of the condylar complex [26].

#### Clinical presentation

The child with a supracondylar fracture presents with swelling at the elbow and localized tenderness; and with a supracondylar extension fracture, the child presents with a proximal depression over the triceps. The physical examination should focus on the degree of swelling and neurovascular status. Excessive swelling and ecchymosis at the elbow are concerning signs of extensive soft tissue injury, which is a significant risk factor for compartment syndrome [27]. It is critical that the clinician perform a thorough neurovascular assessment. Neurovascular evaluation includes palpation of the distal pulses and assessment of skin color, temperature, capillary refill, and the sensory and motor aspects of the median, radial, and ulnar nerves. If a pulse is not detected by palpati,
examination by Doppler ultrasound should be undertaken. A concerning sign of ischemia is increasing pain or pain with passive extension of the fingers [24]. In the presence of ischemia, an orthopedic surgeon must be consulted immediately to evaluate and reduce the fracture. In cases of supracondylar extension fractures, the examination should focus on assessment of the brachial artery as well as the median and radial nerves.

Radiographic findings

Radiographs should be obtained in children who present with a clinical presentation suggesting a supracondylar fracture, an unclear history, or localized tenderness or swelling of the elbow. Both an anteroposterior view in extension and a lateral view at 90° of flexion should be undertaken. As the pediatric radiograph are interpreted, consideration should be given to the stages of ossification. Radiographs should be assessed for fracture lines and, if present, the degree of fracture displacement and angulation. Because fracture lines are often difficult to visualize, attention should also focused on the subtle signs of a supracondylar fracture such as the presence of fat pads, the anterior humeral line, and the absence of the figure-of-eight.

Interpretation of the pediatric elbow radiograph is challenging secondary to the different stages of ossification [25]. The first ossification center, the capitellum, appears at approximately 1 year of age followed by the radial head at roughly 3 years of age. The third site to appear is the medial or internal epicondyle at roughly 5 years of age, followed by the trochlea at roughly 7 years. The final two ossification centers are the olecranon (approximately 9 years of age) and the lateral or external epicondyle (approximately 11 years of age). A helpful memory aid for recalling the radiographic order of ossification sites of the pediatric elbow is the acronym CRITOE (capitellum, radial head, internal epicondyle, trochlea, olecranon, external epicondyle), remembering that the capitellum appears at 1 year of age and each ossification site in the mnemonic appears in a 2-year progression (ie, 1, 3, 5, 7, 9, and 11 years).

The radiograph of the elbow should be assessed for the presence of fat pads, the anterior humeral line, and the figure-of-eight at the distal humerus. Fat pads are a nonspecific marker of hemorrhage or an elbow joint effusion. Depending on the location and size of a fat pad, it may be an indicator of an occult fracture. An anterior fat pad can be a normal variant when it is seen as a narrow radiolucent strip superior to the radial head and anterior to the distal humerus. If the anterior fat pad is wide, it is known as a “sail” sign and is indicative of a fracture, but a small anterior fat pad may be normal. The posterior fat pad results from visualization of fat from the olecranon fossa. It appears radiographically as a radiolucency posterior to the distal humerus and adjacent to the olecranon fossa. The presence of a posterior fat pad is never normal and is indicative of pathology. As such, the radiographic presence of a posterior fat pad requires careful immobilization and close follow-up.
The anterior humeral line is a line drawn through the anterior cortex of the humerus that intersects the capitellum in its middle third. In the presence of a posteriorly displaced supracondylar fracture, the anterior humeral line passes through the anterior third of the capitellum, or it may entirely miss the capitellum. An assessment of the figure-of-eight requires a true lateral view. Disruption of the figure-of-eight indicates a supracondylar fracture.

**Management**

Immediate therapy consists of pain management, application of a splint for comfort, and elevation of the arm above the level of the heart. Further management is determined by the classification of supracondylar fracture based on radiographic findings. There are three classifications of supracondylar fractures. Type I is a nondisplaced fracture suspected either on clinical grounds or radiographically by the presence of the sail sign or posterior fat pad (Fig. 3). The child may be discharged home if the family is perceived as reliable, able to assess neurovascular status, and live close to the hospital. The child should be placed in a posterior splint from the wrist to the axilla, with the elbow at 90° of flexion and the forearm in its neutral position for at least 3 weeks \[24\]. It is advisable to avoid circumferential casting and extremes of flexion in an effort to decrease the incidence of compartment syndrome and vascular compromise \[25,28\]. If a child meets criteria for discharge, the family should be instructed to return immediately for signs of unmanageable pain or the child’s inability to extend his or her fingers. For the discharged child, close orthopedic follow-up (within 24 hours) must be established. Type II supracondylar fractures are angulated and displaced fractures in which the posterior cortex remains intact.
Type II fractures require a pediatric orthopedic evaluation. The choice of therapy, for example, closed ED reduction versus percutaneous pinning, is based on the degree of deformity as well as the adequacy and stability of the fracture reduction. The child should be immobilized in a noncircumferential splint at 110° of flexion. All children with type II posteriorly displaced supracondylar fractures should be admitted to the hospital for neurovascular assessment secondary to the increased probability of neurovascular compromise. Type III fractures have a disrupted posterior periosteum with a completely displaced distal fragment, without contact between fragments (Fig. 5). Type III fractures may be displaced.
in three directions: posteromedial (the most common pattern), posterolateral, or anterolateral. The direction of displacement is important in determining which neurovascular structures may be injured (see complications in the following section). All type III supracondylar fractures require orthopedic consultation for the evaluation of closed or open reduction with percutaneous pin placement, hospitalization for vigilant neurovascular assessments, and close follow-up.

The flexion type of supracondylar fracture results from a direct force to the posterior elbow, resulting in anterior displacement of the distal segment and disruption of the posterior periosteum. A pediatric orthopedist should be consulted promptly, and these children require hospitalization for frequent neurovascular assessment. Immediate reduction should be attempted in cases in which there is neurovascular compromise and orthopedic consultation is not available.

**Complications**

Complications of supracondylar fractures include nerve injury, vascular compromise (brachial artery), forearm compartment syndrome resulting in Volkmann’s ischemic contracture, and loss of range of motion.

Overall the incidence of supracondylar-associated neurovascular injury is 12% and increases with displacement to between 19% and 49% [29–31]. Nerve function before fracture reduction should be documented. The most commonly injured nerve is arguably the median (28%–60%), followed closely by the radial (26%–61%), and then the ulnar (11%–15%) nerves [30–32]. Median nerve injury occurs most commonly from posterolateral displacement and results in weakness of the flexor muscles of the hand and loss of two-point sensation in the index and middle fingers [33]. The anterior interosseous nerve is the branch of the median nerve most commonly injured [25,31,33]. Injury to the anterior interosseous nerve is difficult to detect because it lacks a superficial sensory component. Motor impairment is manifested by impairment of the flexor digitalis profundus to the index finger and the flexor pollicis longus as well as mild weakness in supination [25,34]. The motor aspect of the anterior interosseous nerve can be examined by asking the patient to flex the interphalangeal joint of the thumb against resistance or have the patient make an okay sign and assess strength [25,33]. Injury to the radial nerve occurs from posteromedial displacement of the fracture. Anterior displacement of the supracondylar flexion fracture may have an associated ulnar nerve injury. Although nerve injuries may be associated with long-term sequelae, the majority are neurapraxias and will resolve in time [25,30,33,35,36]. Most of these injuries resolve within 2 to 3 months, but in some instances, it may take up to 4 to 5 months for function to return [25,30,33,35,36].

The absence of the radial pulse is reported in 7% to 12% of all supracondylar fractures and up to 19% of displaced fractures [26]. The brachial artery is injured most commonly in posterolaterally displaced fractures [26]. Vascular injury can
lead to compartment syndrome, with associated necrosis and fibrosis of the involved musculature. Compartment syndrome of the volar forearm may develop within 12 to 24 hours [24]. Suspected compartment syndrome should indicate making compartment pressure measurements and immediate consultation with a pediatric orthopedist. When a diagnosis of compartment syndrome is confirmed by compartment measurement, a fasciotomy procedure is indicated [25]. If a compartment syndrome is untreated, the associated ischemia and infarction may progress to the feared complication of Volkmann’s ischemic contracture. Volkmann’s ischemic contracture is characterized by fixed flexion of the elbow, pronation of the forearm, flexion at the wrist, and joint extension of the metacarpal-phalangeal joint [24].

Cubitus varus or “gunstock” deformity is a common long-term complication of a supracondylar fracture [36]. Cubitus varus occurs when a supracondylar fracture heals with a varus deformity. Overall it is more of a cosmetic issue than one of function.

Transphyseal fractures

Transphyseal fractures are most common in children under 2 years of age. In younger children, these fractures are a result of rotary of shear force, whereas in older children, the fracture is usually caused by a fall on an outstretched hand. Transphyseal fractures are difficult to distinguish radiographically from elbow dislocations [37]. With transphyseal fractures, however, the relationship of the radial head and capitellum is preserved, whereas with dislocations, it is disrupted. In children under the age of 2, in whom the capitellum has not yet ossified, these fractures are even more difficult to diagnose. These fractures are managed by obtaining an acceptable reduction and maintaining it until the fractures heals. These fractures may simply be splinted after reduction, but there is an increased incidence of cubitus varus, and they may be managed by closed reduction and percutaneous pinning [37]. In patients, this fracture is the result of abuse in up to 50% of cases, and the most serious potential complication is not recognizing the abuse and returning the child to a dangerous environment [37]. In older children, the mechanism of transphyseal fractures is similar to that of supracondylar fractures, and the complications are similar, except that neuro-vascular injury is not common as it is with supracondylar fractures [37,38].

Lateral condyle fractures

Fractures of the lateral condyle of the humerus are typically the result of a fall on an outstretched arm. The lateral condyle is either avulsed by varus stress or displaced by the radial head under valgus stress [39]. Children with these fractures complain of pain and decreased range of motion. In patients with
minimally displaced fractures, localized lateral tenderness may be noted. The most common radiographic finding is the presence of a posteriorly displaced metaphyseal fragment known as the Thurston-Holland fragment. The fracture line may also extend to involve the capitellum. These fractures may be difficult to distinguish from transphyseal fractures. Lateral condyle fractures disrupt the anatomic relationship between the radial head and the capitellum, whereas with transphyseal fractures, it is maintained [39,40]. Minimally displaced fractures may not be evident, and oblique views may be helpful. Lateral condyle fractures are all transphyseal and intra-articular, and most require open reduction and internal fixation [39,40]. Complications include cubitus varus, formation of lateral spurs, delayed union, nonunion, and growth arrest [39].

Medial epicondyle fractures

Medial epicondyle fractures account for up to 12% of pediatric elbow fractures and are associated with elbow dislocations up to 50% of the time [41]. They are most common in children 7 to 15 years of age. The medial epicondyle is the insertion point of the ulnar collateral ligament and the flexor muscles of the forearm. Valgus stress produces traction on the medial epicondyle through the flexor muscles. The child typically holds the elbow in flexion, and any movement is painful. There is point tenderness over the medial epicondyle [41,42]. Ulnar nerve paresis and dysthesias may be present because of its close proximity. The medial epicondylar fragment is usually visualized on plain radiograph in older children (those over the age of 6 or 7) with this injury. The fragment may be trapped in the joint space, especially if there is an associated dislocation [42]. Comparison views may be helpful to assess for medial joint space widening in younger patients in whom the medial epicondyle has not yet ossified. Minimally displaced fractures are managed conservatively in a long arm splint or cast for 1 to 2 weeks, with early range of motion exercises to follow. Fractures displaced more than 5 mm may be managed either operatively or conservatively. If the fracture fragment is intra-articular, the fragment must be removed, and this is performed most commonly by surgery. The most common complications are stiffness, ulnar nerve injury, and symptomatic nonunion. Stiffness is avoided by short-term immobilization (less than 3 weeks) and early range of motion exercise. Ulnar nerve injuries occur in 10% to 16% of these fractures, but injury is more likely if the fracture fragment is trapped in the joint [41,42].

Elbow dislocations

Elbow dislocations are not common in the pediatric population, and there are often associated fractures about the elbow, including the medial epicondyle, proximal radius, olecranon, and coranoid process [42–44]. These injuries are seen in adolescents, and the presence of an elbow dislocation in a younger patient
should raise the suspicion for a transphyseal fracture [37]. The mechanism of injury is frequently a fall on an outstretched hand. Posterior dislocations are most common, but anterior, medial, lateral, and divergent dislocations can occur. The direction of displacement depends on the force applied. Posterior dislocations are the result of a fall onto an extended or partially flexed supinated forearm. Anterior dislocations result from a direct blow, such as a fall on the olecranon process. Medial and lateral dislocations are secondary to direct trauma or twisting of the forearm. Divergent dislocations are exceeding rare and result in the ulna and radius being displaced in opposite directions [43]. Physical findings include a painful, swollen elbow held in flexion with a seemingly shortened forearm and longer upper arm. Any attempts of movement are painful. All radiographs should be examined carefully for associated fractures. A thorough neurovascular examination is important because the anatomic relationships of the brachial artery, median nerve, and ulnar nerve make them vulnerable. These dislocations are managed generally with procedural sedation and closed reduction. For posterior dislocations, the arm is hyperextend while traction is applied to disengage the forearm and restore length. The elbow is then gently flexed while maintaining traction [43]. Anterior dislocations are frequently associated with extensive soft tissue damage. They are reduced by longitudinal traction being applied to flexed forearm. The elbow is then gently extended as firm pressure is applied distally and posteriorly. The arm is then immobilized in a long arm splint. Radiography after reduction is imperative, and these patients are typically hospitalized for observation because compartment syndrome has been reported after elbow dislocations. Patients are immobilized for 1 to 2 weeks, after which time active range of motion is encouraged to prevent stiffness. Stiffness is the most common complication of elbow dislocation but can be avoided with the appropriate immobilization and institution of range of motion activities. Myositis ossificans and heterotopic bone have also been reported. Vascular injury is not common except with open injuries. Nerve injury patterns mimic those seen with fractures about the elbow and are more common than vascular injuries. The ulnar nerve is the most commonly injured nerve and is associated with medial epicondyle fracture [42]. Median nerve injury also occurs, but it is more difficult to diagnose because of the delayed appearance of motor and sensory symptoms.

Radial head and neck fractures

In children, the radial head is composed of cartilage and is resistant to fracture. As a result, children are more likely to fracture the radial neck. These fractures are rarely isolated because they are associated with other injuries about the elbow, approximately 50% of the time [45]. The radial head or neck may be broken by a fall on an outstretched hand with the elbow in extension and valgus. This mechanism may also cause a fracture of the medial epicondyle, olecranon, proximal ulna, or lateral condyle or rupture of the medial collateral ligament. Elbow dislocation may also fracture the radial neck. With posterior dislocations,
the radial head abuts the capitellum. Force at the time of injury or the time of spontaneous reduction may fracture the radial neck. The radial head may be fractured with anterior elbow dislocations, as well [43]. These injuries do not have remarkable physical findings because there is rarely any visible deformity. Children may have some localized swelling and tenderness over the lateral aspect of the elbow. There is pain with passive flexion and extension, but patients experience more pain with pronation and supination of the forearm. Fractures of the radial head and neck may be subtle. If this fracture is suspected, radiographs of the proximal radius should be obtained in addition to elbow films. These fractures are classified by the degree of angulation. Type I injuries have less than 30° of angulation, type II have thirty to 60° of angulation, and type III injuries have more than 60° of angulation [46]. Type I injuries can be managed simply with a sling or posterior splint or long arm cast for 1 to 2 weeks. Closed reduction is attempted in children older than 10 years of age with any angulation greater than 15° because of their decrease potential for remodeling. Type II and III injuries are reduced with procedural sedation [46,47]. If a suitable closed reduction (less than 30° of angulation) cannot be obtained, percutaneous or intramedullary reduction is performed. The most common complication of these injuries is loss of joint motion, specifically rotation. This loss of motion is more likely with severely displaced fractures, other associated elbow injuries, patients older than 10 years of age, any delay in diagnosis or treatment, and substandard reductions. Avascular necrosis may develop after radial head fractures because of the unique blood supply of the radial head. It is estimated that between 10% and 20% of radial neck fractures result in avascular necrosis (AVN), resulting in a clinically significant loss of movement [47].

Olecranon fractures

Olecranon fractures account for only 5% to 7% of all elbow fractures. An association with other elbow injuries is seen in up to half of these fractures [44]. The olecranon is protected from serious injury in children because, in younger children, it is cartilaginous, and the relatively thick periosteum in older children leads to minimally displaced greenstick fractures [7]. Many mechanisms may result in this type of fracture, including hyperextension, hyperflexion, direct blow to a flexed elbow, or a shear force. Physical findings include a swollen tender elbow and possible abrasion or contusion over the olecranon. Radiographs should be examined carefully for other injuries, because these are common. Fractures with a displacement of 3 mm or less are managed conservatively with 3 to 4 weeks of cast immobilization. Fractures that are extra-articular with more than 3 mm of displacement are managed with closed reduction and cast immobilization [44,45]. The position of immobilization is dependent upon the mechanism. Hyperextension and shear injuries are usually stable if they are immobilized in flexion, whereas flexion injuries are most stable in extension. Intra-articular fractures require open reduction and internal fixation [44]. The most serious
complication of these fractures is the failure to recognize a concomitant injury, but delayed and nonunion peripheral nerve injury and compartment syndrome have all been reported [44].

**Rare elbow fractures**

T-condylar fractures are rare in children and are usually the result of a high-energy injury. With these fractures, the medial and lateral columns of the humerus separate from each other and the humeral shaft. With minimal displacement and no comminution, these fractures may be managed with closed reduction and percutaneous pinning, but more serious injuries require open reduction and internal fixation. T-condylar fractures are complicated by stiffness, nonunion and AVN of the trochlea [48].

Medial condyle fractures are not as common as lateral condyle fractures, but they mimic lateral condyle fractures radiographically and clinically. The management and the associated complications of these injuries are similar [48]. The capitellum is rarely fractured in young children because it is still cartilaginous. This injury is seen almost exclusively in adolescents. Because this fracture is intra-articular, it requires open reduction and internal fixation [48].

**Radial head subluxation**

Radial head subluxation, or “nursemaids’ elbow,” is produced by traction on the hand with the elbow extended and the forearm pronated. It is the most common upper extremity injury in children under 6 years of age, with peak incidence between 1 and 3 years of age [49,50]. The radial head is oval in shape. With the forearm in supination, the anterior aspect of the radial head is elevated. Traction causes the bony prominence to be pulled next to the annular ligament. With the forearm in pronation, the anterior aspect of the radial head is more rounded, and traction allows the radial head to slip under the annular ligament. As children age, the annular ligament becomes thicker and has stronger distal attachments, thus explaining the age distribution of this injury. The diagnosis is made by history and physical examination. Classically, the child cries immediately after having traction force applied to an outstretched arm [50]. The arm is held in slight flexion with the forearm pronated. The child usually refuses to use the arm. There is usually no visible swelling or deformity. Radiographic findings are normal and are not required with an accurate history [49]. Classically, reduction is achieved by gripping the effected elbow and, with the opposite hand, supinating the wrist and then flexing the elbow. An alternative method is to grip the effected elbow and, with the opposite hand, hyperpronating the forearm. It has been demonstrated that the success rate for reduction with supination is between 80.4% and 92%; however, the hyperpronation has been
shown to have a rate as high as 97.5% and has been successful when the supination-flexion technique failed [50]. The child will usually begin using the arm again within minutes. Parents should be cautioned that recurrence rate is as ranges from 26.7% to 39%, and they should avoid pulling on the child’s hand [50]. If the subluxation has been present for more than 24 hours, closed reduction may not bring any relief, and the child may be placed in a long arm splint. There has also been evidence that shows that reduction attempted less than 2 hours after the injury may be less effective. Without a history suggestive of subluxation of the radial head, radiographs may be obtained to exclude fracture or joint infection.

**Forearm fractures**

Fractures of the shaft of the radius or ulna account for 10% to 45% of pediatric fractures [51–55]. These injuries vary greatly because they may involve one or both bones and may be complete, and up to 50% of them are greenstick fractures [54]. Complete fractures of the forearm have the potential to be significantly displaced and angulated, with overriding fracture fragments. Plastic deformities are also commonly seen in the forearm [56]. Forearm fractures are usually treated successfully with closed reduction because of the substantial remodeling potential of pediatric bone [5,54,57]. Forearm fractures are usually the result of a fall on an outstretched hand, but direct trauma of significant force can cause both bone forearm fractures, as well [54,58]. Direct trauma to the forearm can result in an ulnar shaft fracture, known as a “nightstick” injury. Patients with fractures of the distal one third, which are more common, present with the classic “dinner fork” deformity [54]. Swelling, deformity, and point tenderness are seen with displaced fractures, but plastic deformity, greenstick, and buckle fractures may have more subtle findings on physical examination. It is not usual for these patients to present days after the original injury occurs. The skin requires careful examination for any in-to-out puncture injury because this injury requires immediate orthopedic consultation and operative treatment. It is essential that at least two radiographic views be obtained to determine an accurate measurement of displacement and angulation. If only one bone is fractured, radiographs of the wrist and elbow should be obtained to exclude a Galeazzi or Monteggia fracture (discussed below) [54].

A Monteggia fracture is a fracture of the proximal third of the ulna with an associated radial head dislocation [54,59,60]. These fractures are clinically significant because of the complications that can arise from these injuries. The radial head is in close anatomic proximity to both the radial and median nerves, causing nerve palsies with dislocation of the radial head. Compartment syndrome can also be seen [59,60]. Patients with this injury usually present with an obvious deformity of the elbow and forearm. The radial head may be palpated, displaced from its usual anatomic location. The skin should be examined carefully for any sign of an open fracture, and a thorough neurologic examination should be
performed, with special attention paid to the posterior interosseous nerve. Radiographs of the elbow should be obtained with any isolated fracture of the ulna. Fractures that are diagnosed and treated acutely can be managed successfully with closed reduction and cast immobilization. Operative intervention is required when an adequate closed reduction cannot be obtained or maintained. If the diagnosis is overlooked, the child may develop a chronic or missed Monteggia fracture [60,61]. Complications of treated fractures include recurrent radial head dislocation, malunion, posterior interosseous nerve palsy, and Volkmann’s ischemic contracture [62].

With the exception of physeal and distal metaphyseal fractures and Monteggia and Galeazzi fractures (discussed below), forearm fractures are classified according to completeness, location, and direction of angulation. Radial and ulnar shaft fractures usually have good outcomes when treated with closed reduction and cast immobilization [52,54,57]. Operative treatment is required for open fractures, arterial injuries, irreducible fractures, failed reductions, and skeletal maturity. Refracture is the most common complication of these injuries and occurs in 7% to 17% of forearm fractures [54]. It is more likely following a greenstick or open fracture. Delayed union and nonunion are rare and are associated with open injuries with significant bone or soft tissue loss [53]. Synostosis may occur as a result of high-energy trauma or surgical manipulation, but it is rare in the pediatric population. Compartment syndrome may also occur and may be caused by any casting placed [54]. If a full cast is placed at the time of injury, it should be split to allow for swelling. If there is any suspicion of compartment syndrome, including pain with extension of the digits, paresthesia, pallor, or lack of pulse, the cast should immediately be split to the skin or removed altogether. The radial, median, and ulnar nerves are all susceptible to injury with forearm fractures. Injury to the anterior interosseous nerve is seen with fractures of the radius [54]. Nerve injury can occur at the time of injury or during a closed reduction. If possible, a complete neurologic examination should be performed before reduction, although this is sometimes difficult with the pediatric patient.

Distal forearm fractures

Distal forearm fractures are common in children, and they account for 75% to 84% of pediatric forearm fractures [51,54]. They include buckle or torus, greenstick, metaphyseal, physeal, and Galeazzi fractures. These fractures are also typically the result of a fall on an outstretched hand. Displacement of the fracture depends on the position of the wrist at the time of the injury. A fall on a dorsiflexed wrist will result in a dorsally displaced fracture, with the converse being true. Buckle or torus fractures are more common with low-energy injuries, whereas displaced fractures are seen following higher energy mechanisms. The patient may have a “dinner fork” deformity, but physical findings may be subtle. A careful examination of the wrist and elbow should be performed to look for any
associated injuries. As with all fractures of the forearm, careful skin and neurologic examinations are imperative. Physeal fractures are classified according to the Salter-Harris classification system. Isolated radius fractures should raise the suspicion of a Galeazzi fracture, which is a fracture of the distal radius with associated disruption of the radioulnar joint [52,63,64].

Buckle fractures are usually managed successfully in short arm casts [51]. This provides comfort and prevents any further displacement. It is important to note the involvement of the physis as the time of injury. If the physis is involved, it must be reevaluated in 6 to 12 months.

Greenstick fractures are managed with closed reduction and long arm casting. Although there is controversy regarding the position of the forearm during immobilization, the neutral position is accepted widely as the most appropriate position [48,51]. These fractures heal quickly and well, and the cast is removed after 6 weeks. Parents must be cautioned about the possibility of reinjury [54,55,57,58].

Forearm metaphyseal fractures usually involve both bones. The radius is usually involved as a complete fracture, and the ulna may have a complete, greenstick, styloid avulsion fracture, or a plastic deformity. Typically, the goal of treatment is to ensure adequate reduction of the radius, and this in turn, usually results in good results with any involved ulnar fractures [54–57]. Nondisplaced fractures are immobilized in a cast for 4 weeks. Displaced fractures are treated with closed reduction and casting for 4 to 6 weeks. The indications for operative management include open fractures, reductions that are not adequate or cannot be maintained, fractures associated with compartment syndrome or carpal tunnel syndrome, fractures with severe swelling, and those with ipsilateral fractures requiring stabilization (usually supracondylar fractures) [48,53,54].

Fractures of the distal radial physis can be managed with closed reduction and casting. These fractures heal quickly, requiring only 3 to 4 weeks of immobilization, and have a high potential for remodeling [5,6,51] Fractures presenting more than 3 days after the original injury should not be reduced because there is an increased likelihood of damaging the physis [48]. All Salter-Harris III and IV fractures require open reduction because they are, by definition, intra-articular fractures.

The distal ulnar physis is only rarely fractured, and there is controversy regarding the optimal way to manage these fractures. Some studies indicate that growth arrest with these injuries is common; however open reduction has not been shown to decrease the incidence of growth arrest [48]. Fortunately, growth arrest of the distal ulna only rarely causes any significant clinical or cosmetic symptoms. Fractures of the ulnar styloid are common and are seen with approximately one third of distal radius fractures. An avulsed ulnar styloid typically requires no treatment and results in an asymptomatic nonunion [54].

Galeazzi fractures are fractures of the distal radius with disruption of the radioulnar joint. Children may have separation of the ulnar physis instead of true disruption of the radioulnar join [63,64]. This is known as a Galeazzi-equivalent injury. Both true Galeazzi fractures and Galeazzi-equivalent injuries can be
managed usually with closed reduction in younger children. The goal of treatment is to prevent proximal migration of the distal radial fragment and stabilization of the radioulnar joint. Older children, like adults, require an open reduction [52, 54, 62–64].

Pediatric distal forearm fractures generally have a good prognosis. Malunion is the most frequent complication, although it is not usually symptomatic for the patient. Other complications may include refracture, growth arrest, nerve injury, and compartment syndrome.

Wrist and hand

The carpus is composed entirely of cartilage at birth and remains predominantly cartilaginous until the late childhood and adolescent years. As a result, mechanisms that would produce bony wrist injuries in the mature skeleton produce fractures of the forearm bones in young children. The capitale is the first carpal bone to begin ossification at 2 to 3 months of age, and the hamate closely follows approximately 1 month later. Ossification then proceeds in a clockwise manner. The triquetrum begins to ossify at 2 years of age, the lunate ossifies at age 3, the scaphoid ossifies at age 5, and the trapezoid and trapezium ossify at age 6. The pisiform does not appear on radiographs until 9 or 10 years of age. Carpal fractures in younger children, although rare, are usually associated with other fractures [65]. Adolescents have patterns of injury similar to adults. Although not common, ligamentous injuries may be associated with carpal fractures in children [65]. These injuries can cause lasting sequelae, including stiffness and weakness, and require prompt identification and treatment.

As in adults, the scaphoid is the carpal bone most commonly fractured in children [48, 66]. The typical patient is an adolescent male who fell on an outstretched arm. These fractures may be associated with ligamentous injuries. Clinically, the patient has radial-side wrist pain, mild swelling in the anatomic “snuff box,” and tenderness directly over the scaphoid. Both swelling and tenderness should be compared with the unaffected wrist. Scaphoid fractures often have subtle findings on radiographs, and there is no imaging modality to accurately assess for any ligamentous injury. If there is suspicion of a scaphoid fracture, the wrist must be immobilized in a short thumb spica cast, and repeat radiographs should be obtained 14 to 21 days later. Plain radiographs should include a dedicated scaphoid view and comparison views. If the repeat radiographs are negative but the patient continues to be symptomatic, CT scans, bone scans, and MRI are all suitable alternative imaging modalities to visualize an occult fracture [48]. Nondisplaced fractures are treated with a short thumb spica cast for 4 to 8 weeks. Any displacement on radiographs is a sign of instability and warrants open reduction and internal fixation. Adolescent athletes may have nondisplaced fractures repaired operatively to assure stability and to allow earlier return to activity [66].
Wrist dislocation and fracture-dislocation

Wrist dislocations and subluxations are exceedingly difficult to diagnosis in children. The wrist is unossified, making radiographs difficult to interpret. A dislocation or subluxation must be ruled out when a child presents with a painful, swollen wrist that is unable to flex or extend and no forearm fracture is evident. Comparison views are essential in the diagnosis. These rare injuries usually require additional imaging with arthrography or MRI to better delineate the nature of the injury [48,65,67].

Hand fractures

Pediatric hand fractures are rarely complicated injuries and are usually treated adequately with splinting or casting. Open reduction is required for fractures that fail closed reduction. Single metacarpal fractures only require splinting and protection while healing; however multiple metacarpal fractures are usually unstable and may require pinning. Additionally, any metacarpal fracture with rotational deformity significant enough to cause finger overlap usually requires open reduction [67,68]. Severely angulated proximal and middle phalanx fractures or displaced intra-articular fractures require open reduction. All other fractures may simply be managed with closed reduction, if necessary, and splinting [67–71]. The distal phalanx is closely associated with the nail bed. A significant fracture of this bone is commonly associated with nail trauma, which requires repair. Conversely, any significant nail trauma should be imaged to look for an underlying fracture. Fractures that are not significantly displaced, although they are technically open fractures, do not require immediate orthopedic consultation. The patient may be treated with oral antibiotics, splinting, and orthopedic follow-up [68].

Hand infections

Pediatric hand infections are not as common as in adults. The most common infections are those of the fingertip, paronychia, felon, herpetic whitlow, and infections following trauma.

Paronychia is infection of the paronychial tissue. It may be either acute or chronic. It is usually the result of a pulled “hangnail,” and it is characterized by redness, swelling, and tenderness at the lateral edge of the nail plate. There is a potential for the infection to course along the bottom edge of the nail. If the infectious process continues, it may undermine the nail plate itself. Causative organisms are *Staphylococcus aureus* and oral anaerobes. Acute paronychias are treated with warm soaks, elevation, and antibiotics. Persistent paronychia with purulent tissue is elevation of the nail fold, or if the infection has already
loosened the nail plate, it is removed. Antibiotic coverage should include \textit{S aureus} and oral flora. Chronic paronychias are rarely seen in children, and mixed flora, including fungi, infection should be suspected [72,73].

A felon is an infection of the pulp space in the distal segment of the finger. Felon infections usually follow penetrating trauma. Clinically, they are characterized by intense pain, erythema, and swelling of the palmar aspect of the distal phalanx. \textit{S aureus} is the most common organism identified. Treatment includes antibiotics covering this organism and surgical drainage of the infection. The septae of the pulp space are divided, and a wick is placed for 48 hours [72,73].

Herpetic whitlow is a superficial skin infection of the herpes simplex virus. In children, it is almost exclusively caused by the oral herpesvirus, herpes simplex virus I. Prodromal symptoms are pain and tingling over the effected area. Vesicles will later appear. The vesicles are initially clear on an erythematous base, giving the typical “dewdrops on a rose petal” appearance. Vesicles later become cloudy because of cellular response. The infection is self-limiting and resolves in 5 to 7 days. Care should be taken to prevent spreading by covering the area. Treatment is symptomatic and includes analgesia. Oral acyclovir may shorten the course of the infection if given early in the prodromal phase. Topical acyclovir is not effective. Repeated whitlows may be an indication of immune compromise [74].

Pyogenic tenosynovitis is infection of the tenosynovium within the flexor tendon sheaths. This space is closed and causes predictable spreading of the infection. This infection is characterized by Kanavel’s signs: fusiform swelling of the finger, tenderness over the flexor sheath, pain with passive extension of the finger, and the finger held in flexion. The infection manifests 12 to 24 hours after penetrating trauma. \textit{S aureus} is the most frequent infecting organism. Treatment is elevation, intravenous antibiotics, and repeat evaluation in 12 to 24 hours. If symptoms and signs persist, a surgical incision and drainage procedure is indicated [75].

Deep space infections include infections in the thenar and midpalmar space. The hand is usually swollen and erythematous, with a globular appearance. These infections are secondary to penetrating trauma, with \textit{S aureus} being the most common causative organism. Treatment is the same as for pyogenic tenosynovitis, and complications include skin necrosis, tendon rupture, and stiffness. Children may become systemically ill with these infections and appear toxic [68,73].

\textbf{Neonatal brachial plexus injury}

Neonatal brachial plexus palsy occurs because of birth trauma. The incidence of neonatal brachial plexus palsy has declined because of improved obstetric practices. This injury results from traction forces applied to the arm, which
stretches or tears the brachial plexus. Risk factors include shoulder dystocia, high birth weight, cephalopelvic disproportion, breech position, and prolonged labor [76,77].

Brachial plexus injury is classified by the level of nerve involvement and the nature of the injury. The nerve palsies have been categorized by the level of involvement. Type I injury, or Erb’s palsy, involves C4–6 nerve roots. Type II injury, or Erb-DuChenne-Klumpke, involves the entire brachial plexus. Type III, or Klumpke palsy, involves only C8–TI. Mild injuries are stretch injuries of C5–6. Clinically, it manifests with elbow extension, forearm pronation with active motion of the hand. These injuries generally have a good prognosis with recovery of function within 3 months. Moderate injury involves C5–7. The elbow is held in slight flexion, the forearm is adducted, and the hand is loose. Moderate injuries involve avulsion of some nerve roots and simply stretching of others [73]. The recovery of function is slow and incomplete. Maximal function is usually observed within 2 years. Severe injuries involve avulsion of nerve roots C5–T1. These patients have abducted arms, flaccid limbs with the wrist flexed, and the hand held in a claw position. Severe injuries have a poor prognosis, and these patients typically have no recovery of function [76]. Concomitant injuries or deformities that increase suspicion of brachial plexus nerve palsy include Horner syndrome, paralysis of the diaphragm, clavicle fracture, humeral fracture, traumatic shoulder dislocation, spasticity of the lower limbs or opposite upper limb, and hip dysplasia-dislocation [73].

Neonates may have other birth injuries that mimic brachial plexus palsy. Pseudoparalysis because of fracture of the clavicle, humeral physis, or humeral shaft may clinically resemble the deformities noted with these nerve injuries. Osteomyelitis or septic arthritis of the shoulder should also be included in the differential diagnosis. Any treatment is aimed at residual disabilities. Common disabilities include a loss of external rotation and abduction and shoulder dislocation.

Summary

The pediatric musculoskeletal system differs greatly from that of an adult. Although these differences diminish with age, they present unique injury patterns and challenges in the diagnosis and treatment of pediatric orthopedic problems. The differences in physical and chemical makeup of the bone, periosteum, and the presence of growth plates result in an injury pattern and complication pattern that is unique to the pediatric skeleton. Likewise, the evaluation of the child may be complicated by other injuries and the child’s lack of cooperation. The orthopedic physical examination follows the standard sequence of evaluation but requires basic knowledge of pediatric injury patterns and treatment. For this reason, the evaluation of orthopedic injuries in children requires a unique approach.
References