Emergency Department Evaluation and Treatment of Pediatric Orthopedic Injuries

Matthew D. Thornton, MD\(^a\), Karen Della-Giustina, MD\(^b\), *, Paul L. Aronson, MD\(^c\)

KEYWORDS
- Pediatric orthopedics
- Salter-Harris
- Physis
- Growth plate
- Fracture

KEY POINTS
- The pediatric skeleton is unique compared with adults because of the growth plates, strong periosteum, and dynamic growth state.
- Fractures involving the physis (growth plate) must be evaluated thoroughly to avoid interfering with bone growth.
- Supracondylar fractures are high-risk injuries that may be associated with brachial artery injury and potential ischemia or compartment syndrome of the forearm.
- The child with hip pain requires a thorough evaluation to rule out septic arthritis.
- Always consider nonaccidental trauma as the source of the child’s injuries with a focus on those high-risk injuries.

INTRODUCTION: NATURE OF THE PROBLEM

Orthopedic injuries in children are unique because of the dynamic state of growth and development of children. The biochemical and physiologic differences of the child’s skeleton from that of the adult lead to distinctly different mechanisms of injury, fracture patterns, healing, and treatment needs that are crucial for the emergency medicine practitioner to understand. Moreover, infants and children of different ages are susceptible to unique fracture patterns. In this country, unintentional injuries are the leading cause of death and disability in children, and up to one-half of all Emergency Department (ED) -related visits are orthopedic in nature.\(^1\) In the ED, providers should know how to diagnose and treat children with orthopedic injuries, with particular attention to the age, growth, and development of the child.
PEDIATRIC ORTHOPEDIC BASICS

Children’s bones have structural properties that allow them to withstand greater force. In addition, fractures in children heal more rapidly than those in adults. The child’s remarkable remodeling potential allows for some longitudinal misalignment and greater degrees of angulation. New bone remodels according to local forces, especially in the plane of motion of the joint. If a child has at least 2 years of growth remaining, a fracture adjacent to a hinged joint will remodel acceptably if the angulation is less than 30° in the plane of motion. Precise anatomic reduction is required, however, for fractures with rotational deformities, excessive degrees of angulation, or those that are intra-articular and displaced. The pediatric periosteum is thicker and stronger than mature periosteum, which results in diminished fracture displacement, fewer open fractures, and more stability as well as an osteogenic potential that makes nonunion rare.

The more porous and pliable pediatric bone allows for 4 unique types of fractures seen in children: (1) plastic deformity, (2) torus (buckle) fractures, (3) greenstick fractures, and (4) fractures involving the physis. In plastic deformity, the bone is deformed beyond its ability to recoil, but not to the point at which an actual fracture occurs. The remainder of the fracture types is described later.

PHYSEAL FRACTURES

The most significant difference between the skeleton of a child and an adult is the presence of the physis or growth plate. Composed of cartilage, the physis represents the “weak link” in pediatric bone. The physis will separate or fracture before disruption or “spraining” of an adjacent strong and flexible ligament. Injuries that produce sprained ligaments or even joint dislocations in adults usually result in physeal injuries in children. Physeal injuries, which are most common during times of rapid growth, represent up to 18% of pediatric fractures.

Although physeal injuries generally heal in one-half of the time of long-bone injuries, they are the fractures in which anatomic alignment is most critical for optimal growth and minimal deformity. If the injured child is tender at the physis, the physician should suspect a fracture and not a sprain, even in the presence of normal radiographs.

In 1963, Robert B. Salter and W. Robert Harris classified epiphyseal plate (physis) injuries in terms of clinical treatment and prognosis. Salter-Harris fractures are numbered I through V, with the higher numbers corresponding to an increased risk for growth disturbances.

Salter-Harris Classification

Type I
- This injury involves a fracture through the physis only (Fig. 1).
- If the radiographs appear normal, the injury can be a nondisplaced fracture.
- Point physeal tenderness on examination is the most common finding.
- If the patient has point tenderness over the physis, even in the presence of an otherwise normal examination (including radiographs), one should treat this with cast or splint immobilization.
- The prognosis for this fracture is excellent.

Type II
- This injury is a fracture through the physis and metaphysis, with a fragment of the metaphysis remaining attached to the epiphysis.
This triangular metaphyseal fragment is commonly referred to as the Thurston-Holland sign. This injury is the most common type of physeal fracture. This injury requires treatment with cast or splint immobilization. The prognosis for this type fracture is also excellent.3

Type III
- This fracture involves a fracture line that begins intra-articularly and travels through the epiphysis into the physis.
- Because this is an intra-articular fracture, precise anatomic reduction is imperative to minimize future joint and growth abnormalities, as well as posttraumatic arthritis.
- With appropriate reduction, the prognosis for this injury is good.3

Type IV
- This fracture involves a fracture line that begins intra-articularly and travels through the epiphysis, physis, and the metaphysis.
- Precise anatomic reduction is imperative.
- This fracture commonly requires surgical fixation to maintain the reduction.
- This injury has a significant incidence of growth disturbance.3

Type V
- The physis is crushed without any other injury.
- This injury is often difficult to diagnose, because the initial radiographs are usually unremarkable.
- A careful history revealing a mechanism with significant axial load is a key factor to identifying the diagnosis.
- The prognosis is poor, owing to the premature cessation of growth.3
TREATING THE ORTHOPEDICALLY INJURED CHILD

History

Obtaining a history from an injured child can be challenging. The often-tense environment may make it difficult to obtain an accurate history from parents and children alike. In addition, the child may be preverbal or unable to localize pain because of age. Finally, pain often limits the completeness of the history taking in the setting of injury. A calm approach in addition to the proper use of analgesia can aid in obtaining the history.

Physical and Diagnostic Evaluation

By keeping in mind a child’s fear, pain, and developmental level, a gentle and systematic approach may improve evaluation and treatment. Administering appropriate analgesia will not only reduce the child’s pain and anxiety, but also aid in examining the injured area. Before palpating the injured area, one should examine the skin carefully for any breaks. Next, evaluate the neurovascular status of the limb carefully, especially before and after reduction and splinting. Finally, one should examine the injury by first palpating the areas away from the area of complaint rather than going directly to the area of injury.

The injured region should be radiographed using plain radiography in at least 2 different planes. There are some areas, such as the elbow or wrist, where oblique views may also be obtained. The radiographs should include the joint above and below the injury if there is any suspicion for secondary injury.

UPPER EXTREMITY INJURIES

Clavicle

The clavicle is the most frequently fractured bone in the pediatric population. Fractures most often occur between the middle and outer thirds of the bone. Because of its subcutaneous location, a fractured clavicle is often simple to detect. Although often fractured at birth, a clavicle fracture in a newborn may be diagnosed in the ED, when the new parents detect the palpable callus of healing after the baby’s discharge from the nursery. Older children usually sustain clavicle fractures from short falls onto an extended arm.

The child with a clavicle fracture will have pain with arm and neck movement. Local swelling and crepitus are often present, and one may see displacement of the affected shoulder downward and inward. The examining physician should perform a careful neurovascular examination to detect damage to the underlying vessels and structures. For diagnosing a clavicle fracture, an anteroposterior (AP) radiograph is usually sufficient.

Ordinarily, newborns, who have sustained a clavicle fracture during birth, require no further treatment. However, the parents should be educated about the fracture and the probability of a detectable callus developing over the following weeks. In older children and adolescents with a simple clavicle fracture, immobilization with a sling and swath for 4 to 6 weeks is generally sufficient. Older adolescents with significant displacement or shortening of the clavicle should receive orthopedic follow-up.

Shoulder Dislocations

Glenohumeral shoulder dislocations, which are rare in young children, are more commonly seen in adolescents. In most of these cases, the dislocation is anterior. These dislocations are usually reducible by the emergency physician in the ED and require orthopedic evaluation within 1 week.
Humerus

The proximal humeral epiphysis is responsible for 80% of the longitudinal growth of the humerus. In newborns and preschoolers, the typical injury is a Salter-Harris type I fracture, whereas children who are 11 to 15 years old typically sustain Salter-Harris II fractures.

The history is often that of a fall backward onto an extended arm. A midshaft humerus fracture, a severe fracture of the humeral head, or one in which the history is inconsistent with the injury should raise suspicion of abuse, especially in very young children.

The entire shoulder girdle should be radiographed after the neurovascular examination. The physician should pay particular attention to possible axillary nerve damage with resulting abnormal deltoid function and paresthesia or anesthesia over the lateral shoulder.

Most children can be treated with a sling and swath if the angulation is less than 40°, there is less than 50% displacement, and there is no malrotation. In children less than 5 years old, up to 70° of angulation and 100% displacement may be acceptable. An orthopedic surgeon should reevaluate the child within 24 to 48 hours.

Supracondylar Fractures

Supracondylar fractures are the most common elbow fracture in pediatric patients. They typically occur between ages 5 and 10 years. The typical history is a fall onto an extended arm, which forces the distal fragment upward and posteriorly. The child will hold the arm in pronation and resist elbow movement because of pain. These fractures require emergent treatment because flow through the brachial artery can be affected at the site of injury.

The physician who suspects a supracondylar fracture should do a careful neurovascular examination, checking for the 5 “Ps” of arterial injury: pain, pallor (poor perfusion), weak radial pulse (to pulselessness), paralysis, and paresthesias. Worsening pain or pain with passive extension of the fingers are also symptoms concerning for ischemia. An orthopedic surgeon must immediately evaluate and reduce a supracondylar fracture with any sign of ischemia. Compartment syndrome of the volar forearm can develop in less than 12 hours, with subsequent necrosis and fibrosis of the involved musculature. This ischemia/infarction can lead to Volkman ischemic contracture. If no orthopedic surgeon is available and there is evidence of arterial injury or ischemia, then the emergency physician must reduce the fracture. The technique for fracture reduction is placement of the forearm in supination, then applying longitudinal traction and direct pressure to the displaced fragment in a downward and anterior direction. Oblique fractures usually require open reduction.

In a child without neurovascular compromise, radiographs of the AP view in extension and a lateral view in 90° of flexion should be obtained. Because the fracture line is often difficult to visualize, one can use the anterior humeral line and pathologic “fat pads” as indirect evidence of subtle fractures. The anterior humeral line is a line that is visualized on the lateral view, being drawn down the anterior margin of the humerus. This line should intersect the capitellum in its posterior two-thirds. If this line intersects the anterior one-third of the anterior capitellum or appears anterior to the capitellum, it is strongly suggestive of a supracondylar fracture with posterior displacement of the distal fragment (Figs. 2 and 3).

In addition, one can use the fat pads as nonspecific indicators of elbow joint effusion or hemorrhage of an occult elbow fracture. Both fat pads are visualized on the lateral

Pediatric Orthopedic Injuries

427
elbow view. The posterior fat pad is recognized as a radiolucency posterior to the distal humerus adjacent to the olecranon fossa; the presence of a posterior fat pad is always pathologic and indicative of elbow effusion. The anterior fat pad, which can be seen in normal children, is an area of radiolucency located superior to the radial head and anterior to the distal humerus. The anterior fat pad is considered pathologic when it “sails” anteriorly from its normal position (Fig. 4).

Fig. 2. Anterior humeral line (on lateral). (A) Normal alignment: When drawn along the anterior cortex of the humerus, in most normal patients at least one-third of the ossifying capitellum lies anterior to this line. Be careful: in very young children the ossification within the cartilage of the capitellum might be minimal (ie, normal and age related), and so is insufficiently calcified and does not allow application of the above rule. This line helps to detect a supracondylar fracture with posterior displacement. (B) The abnormal anterior humeral line suggests a supracondylar fracture. (From Raby N, Berman L, Morley S, et al. Pediatric elbow. In: Raby N, Berman L, de Lacey G, editors. Accident and emergency radiology: a survival guide. 3rd edition. Philadelphia: Elsevier, 2015; with permission.)
A nondisplaced type I supracondylar fracture that has no signs of neurovascular compromise does not require urgent orthopedic evaluation in the ED; these can be placed in a long arm splint or cast with the elbow flexed at 90°, with the forearm splinted in either pronation or a neutral position.10 One must always evaluate the neurovascular status of the forearm, wrist, and hand following splinting. These patients should be evaluated by an orthopedist within 24 hours. Type II or III supracondylar fractures need emergent evaluation by an orthopedic surgeon, because most type II and all type III supracondylar fractures require operative repair.

Elbow Injuries

Radiographs should be obtained for children with elbow tenderness, deformity, or swelling in the setting of trauma. At least 2 views of the elbow should be obtained, with a third view, the lateral oblique, which can be helpful in diagnosing subtle lateral condyle fractures and displacements.10

ANATOMY

It is imperative to be familiar with the anatomy and radiographic features of the skeletally immature elbow. The elbow joint contains 6 ossification centers that can be easily mistaken for fractures. These ossification centers appear in a fairly predictable order that does not vary. A helpful acronym for remembering the order of appearance of the ossification centers is CRITOE, with each letter of the mnemonic representing an ossification center (Fig. 5, Table 1).

Fig. 3. This patient has an abnormal anterior humeral line that does not intersect the capitellum. (From Raby N, Berman L, Morley S, et al. Paediatric elbow. In: Raby N, Berman L, de Lacey G, editors. Accident and emergency radiology: a survival guide. 3rd edition. Philadelphia: Elsevier, 2015; with permission.)
Although they appear earlier in girls than boys, one can approximate the timing of appearance by remembering that there is a 2-year progression of the above ossification centers. Most experts remember this as 1, 3, 5, 7, 9, 11 years old, for the appearance of the capitellum to the external (lateral) epicondyle, respectively. It is worth noting that radiographs of the contralateral elbow may be helpful to assess the developmental stage of the patient, when an injury is suspicious for a fracture.

Radial Head Subluxation

Radial head subluxation, commonly known as nursemaid’s elbow, is seen frequently in the ED because of parental concern over a child’s refusal to move his or her arm. This injury occurs primarily in toddlers, but can appear in the infant or preschooler. Often, the history is difficult to obtain because the caretaker may not realize the cause of the injury. The typical mechanism is abrupt longitudinal traction on the child’s pronated wrist or hand. This action forces the annular ligament over the radial head, lodging it between the radial head and the capitellum. Usually, the child refuses to move the affected arm, holding it close to his or her body.

After carefully examining the child’s arm and shoulder girdle, the physician who is confident of the diagnosis of radial head subluxation can attempt reduction without obtaining any radiographs. If there is focal bony tenderness on examination, one should obtain plain radiographs to rule out a fracture. The 2 most popular techniques for reduction are supination/flexion and hyperpronation. Both methods are highly effective, with hyperpronation proving slightly superior in a meta-analysis of randomized control trials. In one study, hyperpronation was perceived as less painful than supination/flexion to caretakers and nurses, while physicians perceived no difference.

With both methods, the examiner supports the child’s arm at the elbow and places moderate pressure with a finger on the radial head. In hyperpronation, the examiner grips the distal forearm and hyperpronates the arm. In the supination/flexion method, the examiner holds the forearm and gives gentle traction and then fully supinates the forearm and flexes the elbow in one motion. In many cases, there is a palpable click.

Fig. 4. Physiologic versus pathologic anterior fat pads. The image on the left (arrow A) illustrates a smooth anterior fat pad, a normal physiologic variant, in an 8 year old. The image on the right (arrow B) demonstrates a “sail sign,” which is represents a pathologic fracture, in a 9 year old. (Courtesy of C. Silva, MD, Yale Department of Diagnostic Radiology, Yale New Haven Hospital, New Haven, CT; with permission.)
Fig. 5. Ossification centers of the elbow: 1, capitellum; 2, radial head; 3, inner (medial) epicondyle; 4, trochlea; 5, external (lateral) epicondyle. (From Marx JA, Hockberger RS, Walls RM, editors. Rosen’s emergency medicine-concepts and clinical practice. 8th edition. Philadelphia: Saunders/Elsevier; 2013.)

Table 1
Secondary ossification centers of the elbow and the age of appearance based on sex

<table>
<thead>
<tr>
<th>Secondary Ossification Center</th>
<th>Average Age of Appearance in Girls</th>
<th>Average Age of Appearance in Boys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capitellum</td>
<td>5 mo</td>
<td>7 mo</td>
</tr>
<tr>
<td>Radial head</td>
<td>4 y</td>
<td>5 y</td>
</tr>
<tr>
<td>Inner (medial) epicondyle</td>
<td>5 y</td>
<td>7 y</td>
</tr>
<tr>
<td>Trochlea</td>
<td>8 y</td>
<td>9 y</td>
</tr>
<tr>
<td>Olecranon</td>
<td>9 y</td>
<td>10 y</td>
</tr>
<tr>
<td>External (lateral) epicondyle</td>
<td>11 y</td>
<td>12 y</td>
</tr>
</tbody>
</table>

over the child’s radial head when the annular ligament is reduced. A younger child should start to move his arm in about 10 minutes. If the child fails to move his or her arm in that period, then another attempt at reduction can be repeated. If repeated attempts at reduction are unsuccessful, then one should obtain radiographs and place the child in a posterior elbow splint. These children should be followed up in 24 to 72 hours. Fortunately, most reduction attempts are successful. Because many parents do not realize the harm in lifting a child’s entire body from the hand or wrist, the physician should caution against lifting the child in this manner.

Elbow Fractures

Condylar fractures

Although supracondylar fractures are much more common than condylar fractures, lateral condylar fractures account for up to 15% of pediatric elbow fractures. The peak age for these fractures is 6 years, and early recognition and management are essential to avoid elbow deformity and to maintain proper function. Medial condylar fractures are much less common. A fall on outstretched hand (FOOSH) is the typical mechanism of injury for both medial and lateral condylar fractures. Patients with these types of fractures generally present with pain on the medial or lateral elbow, and limited range of motion. Serious neurovascular compromise is rare with condylar fractures.

Unlike supracondylar fractures, which can often be adequately visualized without oblique radiographs, condylar fractures may require 2 oblique views to be fully characterized. Comparison views of the contralateral elbow may be helpful to detect subtle fractures. Lateral and medial condylar fractures extend from the metaphysis through the physis and into the epiphysis, giving them characteristics similar to Salter-Harris IV physeal fractures.

Initial treatment of condylar fractures consists of pain management, splinting, and elevation of the extremity. Prompt orthopedic consultation should be obtained for any patient with an open fracture, neurovascular compromise, or a condylar fracture with greater than 2 mm of displacement. If diagnosed and managed in a timely manner, the long-term prognosis for patients with a condylar fracture is excellent.

Forearm Fractures

Forearm fractures represent approximately 40% to 50% of all pediatric fractures. Seventy-five percent of these involve the distal third of the radius and/or ulna. In general, these fractures are also the result of an FOOSH. AP and lateral radiographs of the injured forearm should be obtained. Careful examination of the wrist and elbow must be performed.

Because pediatric bones are more porous and flexible than their adult counterparts, they tolerate more bending and deformation before a fracture. Thus, comminuted fractures are rare.

Nondisplaced and incomplete fractures can generally be stabilized with splinting in the emergency department and referred for outpatient evaluation by an orthopedist. Certain distal forearm fractures require immediate orthopedic consultation (Box 1).

Physeal Fractures

With respect to forearm fractures, the type of fracture, based on Salter-Harris classification, and the degree of displacement determine the treatment. Patients with a non-displaced Salter-Harris type I fracture should receive immobilization with a sling and volar splint for 3 to 4 weeks. Those with a Salter-Harris type II fracture should receive...
Orthopedic follow-up should occur within 1 week. Patients with persistent tenderness over the radial or ulnar physis in the setting of a normal radiograph should be treated as a nondisplaced Salter-Harris type I fracture.

In the acute care setting, nondisplaced Salter-Harris type I or II fractures can be immobilized and splinted or casted as described above. These fractures must be reduced within 1 week, as the growth plate heals quickly and reduction thereafter increases risk of growth arrest. Prompt reduction leads to an excellent prognosis for healing and normal subsequent growth.

Salter-Harris type III, IV, and V fractures require prompt orthopedic consultation. Because Salter-Harris type III fractures involve the joint surface, they commonly necessitate open reduction to maintain joint stability. Salter-Harris type IV fractures are unstable, and because perfect reduction is essential for a good outcome, open reduction internal fixation (ORIF) is usually required. Salter-Harris type V fractures, which can initially be difficult to identify and are later followed by premature growth plate closure and growth arrest months later, also require ORIF.

Complete Fractures

Complete fractures extend through both cortices of the distal metaphysis of the radius and/or ulna. These fractures are caused by high-energy FOOSH and often result in displacement. These fractures do not result in disruption of the growth plate. The position of the bony fracture segments is dictated by the forces exerted on the bones by their attached muscles. As a result, overlapping fracture segments often result in shortening of the arm.

Complete metaphyseal fractures of one or both bones with minimal or no displacement have significant remodeling potential because of their proximity to the distal growth plate. Isolated metaphyseal fractures with up to 20° of angulation can be placed in a sugar tong splint or casted without reduction in patients less than 10 years of age. Isolated distal radius diaphyseal fractures with less than 2 mm of lateral shift, dorsal angulation of less than 10°, and shortening of less than 2 mm and minimal or no displacement can be safely casted without reduction. Closed reduction is required for all displaced fractures and those with greater than 20° of angulation. All complete fractures merit orthopedic follow-up within 1 week of splinting or casting.
Buckle (Torus) Fractures

The buckling of the bony cortex due to compression failure causes torus fractures. These fractures typically occur at the distal metaphysis, where young bones are most porous. Clinical examination of patients with buckle fractures reveals bony tenderness. Findings on radiograph may be very subtle. These fractures most commonly affect the dorsal surface of the radius, but both bones may be involved.

Buckle fractures are stable, and treatment is geared toward pain relief and prevention of further injury to the bone using a short arm cast or a splint. Multiple clinical trials have shown preference for immobilization with a removable splint, rather than a short arm cast. Two randomized controlled trials demonstrated that patients with buckle fractures who were splinted had a mildly increased duration of pain, but had a faster return to normal function (Fig. 6).

Greenstick Fractures

A greenstick fracture is a complete fracture of the tension side of the cortex of the radius or ulna, and a plastic deformation (buckling) of the compression side of the same bone. A greenstick fracture of one forearm bone is often accompanied by a fracture of the other bone.

Patients with greenstick fractures of the forearm generally require immobilization in a long arm cast for 3 to 4 weeks, followed by short arm cast for 2 to 3 weeks. Greenstick fractures with mild or no displacement may be splinted without reduction in the ED, with orthopedic follow-up. The degree of angulation that can be treated without reduction is age-dependent. Generally, children under 5 years of age can

tolerate 10 to 35° of angulation on lateral radiograph and up to 10° of angulation on AP view, whereas children 5 to 10 years old can have 10 to 25° of angulation on lateral and up to 10° of angulation on AP films without need for reduction. Children older than 10 years old can tolerate 5 to 20° of angulation on lateral radiograph as long as there is no angulation on the AP view. Patients with greenstick fractures that have moderate to severe displacement must undergo prompt reduction by an experienced clinician or orthopedist. Greenstick fractures that have been casted in the acute setting can be followed by an orthopedist in 7 days (Fig. 7).22

**Ulnar Styloid Fractures**

An ulnar styloid fracture is a distal avulsion fracture at the site of the triangular fibrocartilage complex (TFCC) or the ulnocarpal ligament attachment. These fractures are usually accompanied by a radial fracture, which dictates management. The exception to this is a displaced fracture that occurs at the base of the ulnar styloid, which may warrant surgical intervention if there is a disruption in the TFCC.30

**LOWER EXTREMITY INJURIES**

**Hip Pain**

Hip pain in children is disturbing for both parents and physicians. The causes of hip pain are numerous, so it is prudent for the physician to become familiar with the
significant features and epidemiology of the common and potentially serious causes of hip pain in children.

**Transient Synovitis Versus Septic Arthritis**

For the child with fever and limp, the clinician must emergently differentiate between transient, or “toxic,” synovitis and septic arthritis of the hip. Transient synovitis is a self-limited inflammatory process that occurs most commonly in children 1.5 to 7 years old, with a peak between the ages of 3 and 6 years. This entity, which occurs more frequently in boys than girls, is the most common hip disorder that causes atraumatic limp in children. The onset, which is generally acute, often follows a viral upper respiratory illness or mild trauma. Transient synovitis has a good clinical outcome in most patients.

The major concern is the differentiation of transient synovitis from septic arthritis of the hip, which can cause severe hip destruction with delay in diagnosis, especially when treatment is undertaken more than 4 days after symptom onset. Although children with septic arthritis usually have a fever and refuse to bear weight on the affected leg, children with transient synovitis may have a low-grade or no fever and may limp but bear some weight. Because of hip effusion, a child with either condition may hold the affected hip in flexion, abduction, and external rotation to widen the joint space and can have pain with passive hip movement. Classically, children with septic arthritis of the hip will have pain with micromotion on internal rotation of the hip joint. In a young child, one examination technique to assess micromotion pain is for the examiner to internally and externally rotate the child’s affected leg using the foot. In addition, a child with an irritable hip may complain of thigh or knee pain that is referred from the hip.

The first step in evaluation is often radiographs of the affected hip, although the utility is low in children with acute atraumatic limp, particularly those younger than 9 years old. Ultrasound examination of the hip is highly sensitive in detection of hip effusions and septic arthritis, but cannot reliably differentiate septic arthritis from transient synovitis. Caution should be used in children with symptoms for less than 24 hours when a small hip effusion may not be detected on ultrasound. Laboratory investigation, including C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and peripheral white blood cell (WBC) count, is often undertaken to distinguish septic arthritis from transient synovitis. Although CRP has better test characteristics than ESR and peripheral WBC count in differentiating septic arthritis from other causes of joint effusion, no single laboratory test is predictive of septic arthritis.

Because clinical features often overlap, ultrasound cannot distinguish between septic arthritis and transient synovitis, and because individual laboratory tests are not diagnostic of either condition, researchers have attempted to develop a prediction rule to differentiate septic arthritis from transient synovitis of the hip in children. Kocher and colleagues performed the first study that identified 4 independent predictors of septic arthritis that have become known as the “Kocher criteria” (Box 2).

In Kocher’s initial retrospective study of children who underwent arthrocentesis for an irritable hip, no patients with 0/4 predictors had septic arthritis. The probability of septic arthritis increased with the number of predictors present, to 99.6% with 4/4 predictors. Kocher and colleagues performed a follow-up, prospective validation study in 2004 and reported that the criteria performed similarly well in prediction of septic arthritis, although patients with 0/4 predictors had a 2% probability of septic arthritis. However, Luhmann and Luhmann reported that children with 4/4 predictors only had a 59% probability of septic arthritis, likely influenced by the high prevalence of transient synovitis in their cohort.
Caird and colleagues added CRP to the prediction rule and reported favorable test characteristics of the prediction rule, because patients with 5/5 predictors had 97.5% probability of septic arthritis and no patients with transient synovitis had a fever. Importantly, though, 12% of patients with septic arthritis had 0 or 1 predictors. Similar to the Luhmann study, Sultan and Hughes reported the 5 predictors to be substantially less accurate in differentiating septic arthritis from transient synovitis. In summary, the Kocher criteria are a useful adjunct to physical examination, but should not be used in isolation to predict septic arthritis. Patients with 0/5 predictors are low, but not zero, risk for septic arthritis. Thus, a period of close observation may be warranted.

If septic arthritis is suspected, arthrocentesis of the hip should be performed under ultrasound guidance. Synovial fluid should be sent for cell count, Gram stain, and bacterial culture. Although the literature definition of septic arthritis is a synovial fluid WBC of 50,000/μL, this synovial WBC has a sensitivity for septic arthritis of only 62%. Patients who have an irritable hip with synovial WBC greater than 50,000/μL are likely to have septic arthritis, as the specificity is 92% for septic arthritis (99% for WBC of 100,000/μL). Gram stain is positive in only 29% to 50% patients with septic arthritis. Even with synovial cell counts less than 50,000/μL and a negative Gram stain, if septic arthritis is highly suspected clinically, the clinician should consider initiation of therapy for septic arthritis.

Treatment of transient synovitis includes symptomatic relief with rest and nonsteroidal anti-inflammatory drugs (NSAIDs). The duration of symptoms is 1 week or less in 67% of patients, and less than 1 month in an additional 21% of patients. Close follow-up is important for children with a diagnosis of transient synovitis to monitor for development of symptoms or signs that are more consistent with septic arthritis.

Therapy for septic arthritis includes urgent surgical drainage and intravenous antibiotics. Empiric intravenous antibiotics should be given in the ED after successful arthrocentesis. The most common pathogen is Staphylococcus aureus, followed by Streptococcus pneumoniae. Given the frequency of community-acquired methicillin-resistant S aureus (CA-MRSA) in causing septic arthritis and its association with worse outcomes, empiric antibiotic therapy should include coverage for both methicillin-sensitive S aureus and CA-MRSA. Gram-negative antibiotic therapy

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**Box 2**

Kocher criteria for differentiation of septic arthritis from transient synovitis of the hip in children

- History of fever greater than 38.5
- Non-weight-bearing
- ESR ≥40 mm/h
- Peripheral WBC count greater than 12,000 cells/mm³
- CRP greater than 2 mg/dL


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with a third-generation cephalosporin should be added in neonates and in adolescents when disseminated gonorrhea is suspected and considered in young children because of the presence of *Kingella kingae* as a pathogen in septic arthritis. Lyme testing and empiric Ceftriaxone should be considered in Lyme-endemic areas.

**Legg-Calvé-Perthes Disease**

Legg-Calvé-Perthes Disease (LCPD) is an idiopathic avascular necrosis of the femoral head with subsequent reossification. This disorder is more common in boys and has a peak incidence between 3 and 12 years of age. Of note, children with LCPD often have delayed bone age and a history of low birth weight. The ratio of affected white to African American children is 10:1. The incidence of LCPD in patients with siblings who have LCPD is 1 in 35. The incidence of bilateral involvement is reported to be 10% to 20%.

Children with LCPD frequently present with limp and have limited internal rotation and abduction of the hip. Children often complain of either no pain or pain that is referred to thigh or knee. AP and frog leg lateral radiographs should be obtained if there is a clinical suspicion for LCPD. Radiographic stages in LCPD follow a progression.

1. Early in the illness, the radiographs may be normal.
2. Radiographs demonstrate a small femoral head with a widened medial joint space.
3. A crescent-shaped radiolucent line (“crescent sign”) appears along the proximal femoral head.
4. The ossific nucleus of the femoral head becomes more radiopaque with subsequent fragmentation and collapse of the epiphysis as avascular bone is resorbed (Fig. 8). This point is usually when the symptoms are the most prominent.
5. Reossification occurs last.
6. Residual deformities, such as an abnormal femoral head and acetabular configuration, may persist.

If the child’s radiographs appear normal but LCPD is suspected, MRI or bone scan can be the next helpful step in diagnosis.

Treatment includes orthopedic referral, restriction of activity, and NSAIDs. Age at the onset of the symptoms is the best predictor of outcome. Those patients with

![Fig. 8. This AP view of the pelvis demonstrates bilateral hip involvement with Legg-Calvé-Perthes disease. The right hip demonstrates early signs of the avascular stage with diminished femoral head size. The left hip demonstrates the fragmentation stage. (From Koop S, Quanbeck D. Three common causes of childhood hip pain. Pediatr Clin North Am 1996;43:1059; with permission.)](image-url)
the symptoms occurring before the age of 6 years have the best outcome, whereas those aged 8 years or older have the worst prognosis.53,57

**Slipped Capital Femoral Epiphysis**

Slipped capital femoral epiphysis (SCFE) is a disorder in which there is disruption through the capital femoral physis (Fig. 9). The term SCFE is actually a misnomer, because the epiphysis remains in the normal position in the acetabulum, whereas the femur distal to the physis displaces anterolaterally and superiorly. SCFE typically occurs during adolescence, and the male-to-female ratio is approximately 1.5:1.31 Obesity is also a factor in this disorder, although it has also been reported in tall, thin, rapidly growing adolescents.31,58

SCFE can be classified either in terms of duration of symptoms or in the severity of the displacement. If the symptoms have been present for less than 3 weeks, it is considered an acute slip, whereas when symptoms last longer than 3 weeks, it is considered chronic. It is possible for a child with a chronic slip to experience an acute slippage, however, sometimes known as an “acute on chronic” slip.31 Mild slips can demonstrate displacement up to one-third of the metaphyseal width. Moderate slips occupy from one-third to one-half the metaphyseal slips, whereas severe slips have a slippage of greater than one-half of the metaphyseal width.31

Children with SCFE usually have a limp and hip pain that is often referred to the thigh, knee, or deep in the groin. Physical examination usually shows loss of internal rotation of the affected hip, decreased flexion, and perhaps shortening of the affected limb.

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**Fig. 9.** SCFE, AP view. A line superimposed on the superior femoral neck normally intersects part of the head (B and D are normal). With a slipped epiphysis, the line does not intersect the femoral head (A and C). Occasionally, the frog-leg view (C and D) is needed to show the slip. (From Farber AJ, Wilckens JH, Jarvis CG. Pelvic pain in the athlete. In: Seidenberg PH, editor. The sports medicine resource manual. Philadelphia: WB Saunders; 2008; with permission and Adapted from Behrman RE, Kleigman R, Jenson HB. Nelson textbook of pediatrics. 17th edition. Philadelphia: WB Saunders; 2004.)
Radiographic studies of children suspected of having SCFE should include AP pelvis and lateral view of both hips. On the AP view, a line drawn along the superior margin of the femoral neck cortex (Klein line) is useful for demonstrating subtle slips. The line should intersect or fall within the epiphysis, usually by at least 20%. In patients with SCFE, the line passes along or outside the epiphysis. In subtle cases, the more remarkable finding will be an asymmetry from the normal hip. Because the slip in most cases of SCFE is usually posterior, the lateral view may reveal the slip better than AP view.

The physician making the diagnosis of SCFE should prescribe no weight bearing for the child and obtain immediate orthopedic consultation. Many of these patients will be admitted to the hospital for surgical pinning before discharge. Studies have shown that surgical pinning in situ provides the best results.

Bilateral SCFE can occur in 37% to 61% of children. Thus, one must examine the opposite hip closely and inform the patient and his or her parents of the potential for this problem. Interestingly, 88% of subsequent slips occur within 18 months of diagnosis of the first slip. The prognosis of SCFE is based on the chance of developing avascular necrosis or chondrolysis with the subsequent arthritis. These problems are less likely to occur when there has been a short duration of symptoms, when the slip is mild, and when the slip is surgically fixed in situ, rather than attempted reduction and then fixation.

**Toddler’s Fracture**

The toddler’s fracture is a nondisplaced oblique fracture of the distal tibia. This fracture most commonly occurs in children 1 to 4 years old and is often precipitated by only minor trauma such as tripping while walking or running, a fall from a relatively low height, or a twisting mechanism. A history of trauma may not even be elicited in some cases. The child with a toddler’s fracture presents with limp or refusal to bear weight on the affected extremity. Although tenderness may be present on physical examination, swelling and deformity are often not observed. The examiner may also elicit pain with gentle twisting of the tibia.

The characteristic radiographic finding is a subtle oblique lucency through the distal tibia that terminates medially. The fracture is most easily seen on the AP view and is often not noted on the lateral radiograph. An internal oblique film is very sensitive for toddler’s fracture and may be required to identify the fracture. In some cases, the fracture is missed on initial radiography and is not identified until follow-up examination.

A toddler’s fracture is most often nondisplaced and heals well with 3 to 4 weeks of immobilization. Importantly, a toddler’s fracture occurs in the distal half to distal third of the tibia. This location is distinct from a midshaft spiral fracture of the tibia, which is more consistent with child abuse.

**Tillaux and Triplane Fractures**

Tillaux and triplane fractures are transitional fractures, named for their occurrence during the 18-month period when the distal tibia physis transitions from open to closed. Full closure of the physis occurs around age 14 in girls and age 16 in boys, so most fractures occur between ages 12 and 16. Closure of the physis begins centrally, followed by closure of the anteromedial portion, and last, lateral physeal closure. During this transition period, the lateral distal tibia physis is weak and external rotation of a supinated foot can cause fracture and separation of the anterolateral portion of the epiphysis. Approximately 7% to 15% of adolescent ankle fractures are transitional fractures.
A Tillaux fracture is a Salter-Harris type III fracture of the distal tibia that occurs horizontally through the physis and vertically through the epiphysis of the distal tibia, with a resultant intra-articular fracture (Fig. 11). The anterior tibiofibular ligament causes avulsion of the lateral epiphysis and potential displacement of the fracture fragment. 

Fig. 10. Toddler’s fracture of distal tibia (arrow). (Courtesy of C. Silva, MD, Yale Department of Diagnostic Radiology, Yale New Haven Hospital, New Haven, CT; with permission.)

A Tillaux fracture is a Salter-Harris type III fracture of the distal tibia that occurs horizontally through the physis and vertically through the epiphysis of the distal tibia, with a resultant intra-articular fracture (Fig. 11). The anterior tibiofibular ligament causes avulsion of the lateral epiphysis and potential displacement of the fracture fragment.
A triplane fracture is a Salter-Harris type IV fracture with fracture lines in 3 planes that traverse the physis of the distal tibia. A triplane fracture involves fractures through the epiphysis in the sagittal plane, the physis in the transverse plane, and the tibial metaphysis in the coronal plane (Fig. 12).68 In both types of transitional fractures, the patient will usually not bear weight on the affected extremity and will have swelling, ecchymosis, and tenderness over the anterior ankle.66

Plain radiographs should include AP, lateral, and mortise views, as multiple radiographs are needed to identify all components of a triplane fracture.68 Although the degree of fracture fragment displacement can be determined with plain radiography alone, computed tomography can better delineate fracture configuration and its use is associated with improved outcomes.71,72 Tillaux and triplane fractures with less than 2 mm of epiphyseal fragment displacement can be immobilized with a long leg cast with good outcomes.73 Fractures with greater degrees of displacement require closed or open reduction, and functional outcomes are generally excellent if displacement less than 2 mm is achieved.74

**CHILD ABUSE**

A recent report on the incidence of child maltreatment estimates that nearly 1.25 million cases or 1 in 58 children are abused annually in the United States.75 The Department of Health and Human Services defines 4 main types of maltreatment in the Fourth National Incidence Study of Child Abuse and Neglect Report to Congress as physical abuse,
sexual abuse, neglect, and emotional abuse. Of the children who are abused, 58% have sustained some physical abuse. Fractures are the second most common injury caused by physical abuse, with bruising being the most common.

In infants and toddlers, nonaccidental trauma (NAT) is the cause of 12% to 20% of the fractures. About 80% of fractures caused by child abuse occur in children younger than 18 months of age. However, patients older than 18 months who present with long bone fractures generally have injuries that are more likely to be related to accidental trauma than child abuse. Thus, fractures from child abuse tend to occur in very young children, but can occur at any age and in any socioeconomic group. When evaluating an orthopedic injury in a child, the provider needs to carefully consider the history, the development and age of the child, the type and location of the fracture, the age of the fracture, and mechanism for the type of fracture.

Diagnosis

History

After any necessary resuscitative efforts are completed, the physician should obtain a detailed history from the child’s caretaker. Suspicion should be raised if the stated mechanism of injury is inconsistent with the child’s developmental stage. For example, a femoral or humeral fracture in a child who is not yet walking should raise suspicion for abuse. Furthermore, if the caregiver changes the history of the injury or gives no history for the injury, suspicion for abuse should be raised. In addition, if the age of the fracture is not consistent with the history or if there are multiple fractures in different stages of healing, the provider should strongly consider abuse. Likewise, if the historian is evasive, inappropriately angry, or obviously lying, suspicion should be raised. If the child is verbal, the experienced physician should ask him about the injury with open-ended questions in a nonthreatening manner, without the presence of the caregiver. A social history should be included as well. It should be noted who cares for the child, any other children in the household, Child Protective Services involvement with the family, and history of domestic or substance abuse in the child’s living situation.
Physical Examination

A thorough and gentle approach is best. The child should be examined completely, head to toe, including the genitalia. Any scarring, ecchymosis, lacerations, burns, or other lesions should be documented carefully. The skeletal examination should be complete, considering that multiple fractures may be present.

Radiography

A complete skeletal survey should be done on all physically abused children less than 2 years of age and on infants suffering from neglect. In addition, if the clinical situation necessitates, the provider should consider obtaining a skeletal survey in children ages 2 to 5 years. Highly detailed radiographs are essential and should follow the guidelines set forth by the American College of Radiology. A “babygram” or an AP view of the entire child on one film is an unacceptable alternative.

Radiographic Features of Child Abuse

The American Academy of Pediatrics has published a clinical report that categorizes fractures in children as “High Specificity for Abuse,” “Moderate Specificity for Abuse,” and “Common, but Low Specificity for Abuse.” The fractures, especially in infants, which have High Specificity for Abuse, are sternal fractures, scapula fractures, spinous process fractures, rib fractures—especially posteromedial, and classic metaphyseal lesions (CMLs). A CML is a disk-like fragment of bone and calcified cartilage that is wider on the outer edge than it is centrally.

This fracture is transmetaphyseal through the primary spongiosa and leaves the disk-like fragment attached to the epiphysis. Classic metaphyseal lesions have been termed “corner” or “bucket handle” fractures in the past and are the same entity viewed in different planes. Although these fractures appear relatively benign in terms of healing, it is their clear association with NAT that providers need to understand. The CMLs are specific for abuse due to the mechanism that causes them: traction and torsion forces, rather than falling.

Fractures that are Moderate Specificity for Abuse include multiple fractures, especially bilaterally, fractures of different ages, epiphyseal separations, vertebral body fractures

Fig. 13. Classic metaphyseal “corner” fracture in a child. Arrow pointing to the fracture fragment. (Courtesy of J.G. Smirniotopoulos, Uniformed Services University of Health Sciences, Bethesda, MD.)
and subluxations, digital fractures, and complex skull fractures.\textsuperscript{77} Facts, which have Low Specificity for Abuse, include long bone fractures, clavicle fractures, subperiosteal new bone formation, and linear skull fractures.\textsuperscript{77} It is, however, important for the providers to keep in mind that a single long bone diaphyseal fracture is the most common fracture pattern identified in abused children.\textsuperscript{78} With all of these injuries, the provider needs to take into consideration that the history of injury, the child’s age and development, the patient’s past medical history as well as an understanding of the mechanism of injury and forces that need to be applied to sustain the injury are all imperative.

\textbf{SUMMARY}

The emergency physician will inevitably encounter child abuse if their practice includes the care of children. The possibility for abuse needs to be considered by providers when caring for children with skeletal injuries, especially the very young child. Taking into consideration all of the factors of the case, including the history, age of the child, type of fracture, and understanding the specificity for abuse and mechanism of injury, are all important for determining suspicion for child abuse.

\textbf{REFERENCES}


