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Pediatric Orthopedic Injuries: Evidence-Based Management in the Emergency Department

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Abstract

Upper and lower extremity injuries are common in children, with an overall risk of fracture estimated at just under 1 in 5 children. Pediatric bone anatomy and physiology produce age-specific injury patterns and conditions that are unique to children, which can make accurate diagnosis difficult for emergency clinicians. This issue reviews the etiology and pathophysiology of child-specific fractures, as well as common injuries of the upper and lower extremities. Evidence-based recommendations for management of pediatric fractures, including appropriate diagnostic studies and treatment, are also discussed.

CME Objectives

Upon completion of this article, you should be able to:

1. Describe common and critical pediatric orthopedic injuries and how they typically present.
2. Determine appropriate diagnostic imaging studies to evaluate emergent pediatric orthopedic conditions.
3. Explain current treatment recommendations for pediatric orthopedic emergencies.

Prior to beginning this activity, see "Physician CME Information" on the back page.

This issue is eligible for 4 trauma CME credits.

Click on the ⧉ icon for a closer look at tables and figures.

Case Presentations

A 12-year-old obese boy presents with 1 week of progressively worsening right hip pain. He has no fever or history of trauma. He went to his primary care physician earlier in the week and was diagnosed with a hip strain, but his pain has continued to worsen. He is now unable to bear weight on the right leg. Physical examination reveals a well-appearing boy with no tenderness to palpation about the hip joint, femur, or knee, but markedly decreased internal rotation of the right hip. Neurovascular examination of the right lower extremity is normal. You wonder: What is the most likely cause of this child's pain? What laboratory or imaging studies will be most useful for diagnosis and management? Should this child be allowed to continue bearing weight? Does he need an urgent orthopedic consultation?

A 3-year-old girl presents after a fall onto her outstretched left hand. She is using the left arm much less than usual. Physical examination reveals minimal swelling at the elbow. She flinches with palpation over any part of the elbow, but has no tenderness over the distal forearm or shoulder. She can move her thumb and fingers spontaneously. Radiographs of the left elbow show no fracture. You wonder if this girl could possibly have a nursemaid's elbow. Should you be looking for something else on these radiographs? Do you need to get additional radiographs?

A 3-month-old boy is brought to the ED by his mother, who states that he seems to be moving his right arm less than usual today. Physical examination reveals a happy, interactive child with slightly decreased spontaneous movement of the right arm, but no apparent point tenderness to palpation along the extremity or shoulder. Grip strength in the right hand is normal. No bruises are noted. You try to obtain further history regarding a possible mechanism of injury, but the mother states she does not know of any traumatic incidents. What other questions should you ask? How concerned should you be about a possible fracture? You begin to think about nonaccidental injury. If you find a fracture in this child, what additional workup would be appropriate?

Introduction

Orthopedic complaints account for approximately 15% of the 5.3 million annual pediatric visits to United States emergency departments (EDs).[1] The anatomic and physiologic differences between the adult and pediatric skeletal system result in injury and disease patterns that are specific to children, and this can present diagnostic challenges. In addition to specific fracture and injury patterns in children, emergency clinicians should understand potentially nontraumatic conditions, such as slipped capital femoral epiphysis (SCFE). The possibility of nonaccidental injuries in children should always be on the differential, guided by an understanding of particular historical elements and physical examination findings that may heighten concern. This issue of *Pediatric Emergency Medicine Practice* provides an overview of various pediatric fractures and injuries, as well as practical recommendations for appropriate management.

Critical Appraisal of the Literature

A literature review was performed in PubMed for articles on pediatric orthopedic emergencies published from 1966 to 2017. Keywords included: *pediatric + fracture + ankle, clavicle, elbow, femur, foot, forearm, hand, hip, humerus, knee,* and *wrist; buckle fracture, child abuse, compartment syndrome, emergency pediatric orthopedics, Legg-Calvé-Perthes disease, Lisfranc injury, nonaccidental trauma, patellar avulsion, patellar sleeve fracture, radial head subluxation, slipped capital femoral epiphysis, supracondylar humerus fracture, tibial spine fracture, toddler fracture,* and *torus fracture.* Additional articles were identified and reviewed based on references from the initial search results. Over 800 total articles were reviewed, 157 of which were determined to be relevant to this topic. A search for relevant policy statements on pediatric orthopedic conditions by the American College of Emergency Physicians (ACEP), the American Academy of Orthopedic Surgeons (AAOS), the American Academy of Pediatrics (AAP), the American College of Radiology (ACR), and the National Guideline Clearinghouse (www.guideline.gov) yielded 4 results: 3 regarding suspected child physical abuse, and 1 on management of pediatric supracondylar humerus fractures.

The current literature on diagnosis and management of acute pediatric orthopedic conditions is based primarily on case reports and retrospective reviews. Some prospective studies have been performed that address decision rules for ankle and knee radiography, management of subluxation of the radial head, management of torus fractures, and point-of-care ultrasound for fracture diagnosis. A few smaller prospective studies have addressed knee effusions in children and the significance of the posterior fat pad in elbow trauma.

Epidemiology, Etiology, and Pathophysiology

An analysis of the fracture rate in children in the United States using the 2010 National Electronic Injury Surveillance System database and the 2010 United States Census information revealed that the annual occurrence of fracture in children aged 0 to 19 years was 9.47 per 1000, with overall risk of fracture occurring during childhood and adolescence estimated at just under 1 in 5 children. The most common sites of fracture were the forearm, finger, and wrist. Males were more prone to fractures than females across all age groups. Almost all fractures were treated on an outpatient basis.[1]

Compared to mature bones, pediatric bones have lower mineral content and are more porous and pliable. This increased compliance allows children's bones to withstand more stress before breaking, resulting in unique injury patterns, including plastic deformation, greenstick fractures, and torus fractures. Comminuted fractures rarely occur in pediatric patients. Because pediatric bones have less tensile strength than adjacent ligaments, children may be more likely to sustain fractures from mechanisms that would cause ligamentous injuries in adults. In children, the periosteum is thicker and stronger, resulting in less fracture displacement and a lower incidence of open fractures, compared to adults. Pediatric bones have greater remodeling potential than adult bones, due to the more metabolically active periosteum, allowing for some longitudinal misalignment and greater degrees of angulation, with less potential for long-term complications. Perhaps the most significant difference between adult and pediatric bones is the presence of the cartilaginous physis (growth plate) situated between the epiphysis (which is a secondary ossification center) and the metaphysis. **(See Figure 1.)** The physis is comprised of rapidly proliferating cells, and it is the area of the bone that is most susceptible to injury.

The healing process begins immediately after the fracture and proceeds through 3 distinct phases. **(See Table 1.)** Many variables influence the formation of a periosteal callus and the overall healing process, including the age of the patient, nutritional status, concurrent medical illnesses, the type of bone involved, the nature of the fracture, fracture management (immobilization, amount and timing of bearing weight), and pharmacologic agents.[2] In children, radiographic evidence of callus can typically be seen 1 to 2 weeks after fracture (compared to 2-3 weeks in adults) and as early as 4 days in an infant, which is particularly helpful when the diagnosis of fracture at initial evaluation is uncertain.[2,3]

Figure 1. Pediatric Long-Bone Anatomy

Image courtesy of Jamie Lien, MD.

Child-Specific Fractures

Plastic Deformation (Bowing Fracture)

In a plastic deformation (also known as a *bowing fracture*), the bone is unable to recoil to its normal position and undergoes microscopic fractures, resulting in a bowed appearance with an intact cortex. **(See Figure 2, page 4.)** Plastic deformations occur most commonly in the long bones of the forearm, and may be accompanied by a fracture of the other bone in the same extremity. Failure to diagnose significant plastic deformity in a long bone and subsequent lack of orthopedic follow-up can result in limited future mobility.

Greenstick Fracture

A greenstick fracture is a complete fracture of the tension side of the cortex and a plastic deformation or buckling of the compression side, most commonly occurring in the diaphysis. **(See Figure 2, page 4.)** Greenstick fractures are often accompanied by a fracture of the other bone in the same extremity. Reduction may be indicated, depending on the degree of angulation and the age of the child.

Torus Fracture

Torus fractures (also known as *buckle fractures*) represent about 20% of all pediatric fractures. They result from compressive forces on the bone, causing a buckling of the cortex at the junction between the metaphysis and the diaphysis. **(See Figure 3, page 4.)** Torus fractures occur most commonly in the distal radius, but are also seen in the distal tibia, fibula, and femur.[4] Radiographic changes can be subtle. Torus fractures are stable fractures with good prognoses.

Table 1. Phases of the Fracture Healing Process[2]

Phase	Duration of Phase	Biological Process
Inflammatory	5 to 7 days	Hematoma forms at the site of fracture. Inflammatory cells migrate to the region.
Reparative	4 to 40 days	Granulation tissue converts into cartilaginous callus that then calcifies, becoming radiographically evident.
Remodeling	> 1 year	Periosteal callus converts into mature bone. Unnecessary callus is resorbed.

Physeal Fracture

Physeal fractures comprise up to 30% of all childhood fractures, most commonly involving the distal radius, followed by the distal humerus, distal fibula, distal tibia, distal ulna, proximal humerus, distal femur, proximal tibia, and proximal fibula.[4-6] The incidence peaks in early adolescence (in boys aged 12-15 years, and in girls aged 9-12 years).[6] Most physeal fractures heal without sequelae, but about 30% of physeal fractures result in premature closure of the growth plate, asymmetric growth, and subsequent deformity.[7]

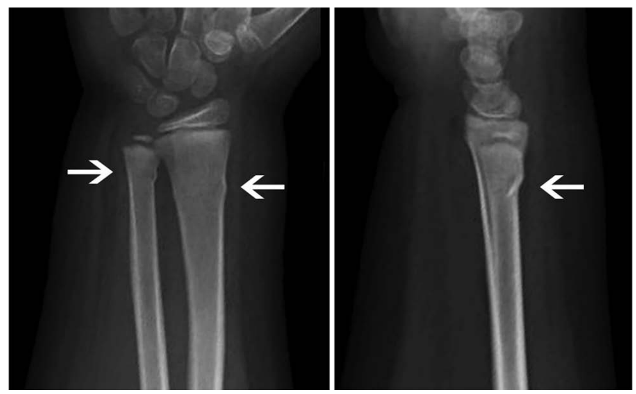
The Salter-Harris classification system, introduced in 1963, is widely used to describe physeal fractures.[8] It stratifies epiphyseal plate injuries according to the risk of growth disturbance, with the risk increasing from type I (low) to type V (high). **(See Figure 4.)**

A Salter-Harris type I injury is a fracture through the physis that can cause a widening of the physeal space, but it may not be apparent radiographically. Initial diagnosis relies largely on point tenderness over the physis with soft-tissue swelling. Type II injuries are most common, comprising about half of all physeal fractures. These extend through the physis and the metaphysis. Type I and II fractures rarely cause functional deformities. Type III and IV injuries disrupt the epiphysis, with potential for interrupting the vascular supply to the physis, thus risking premature closure. These injuries also usually involve the intra-articular surface, necessitating precise anatomic reduction to decrease the risk of future joint and growth abnormalities as well as premature osteoarthritis. Type V injuries are the least common, but have the worst prognosis, as they involve axial compression at the growth plate, resulting in pre-

Figure 2. Greenstick Fracture and Plastic Deformity

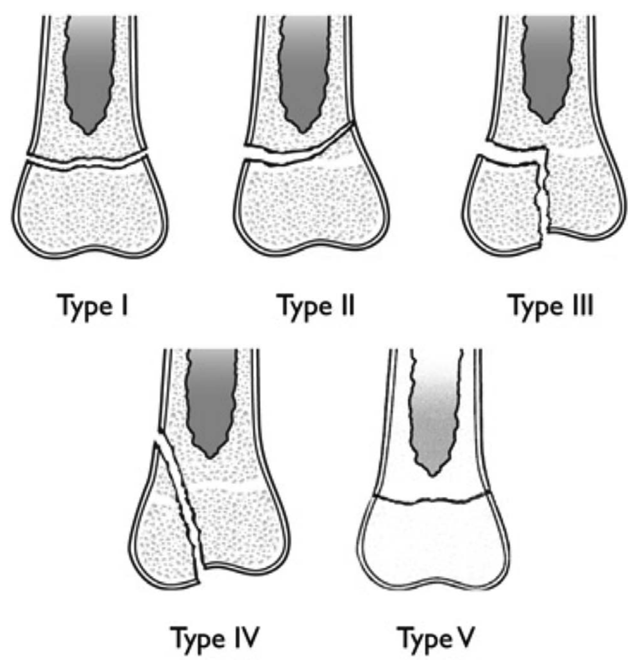
A: indicates a greenstick fracture of the ulna.
B: indicates a plastic deformity of the radius.
Image courtesy of Jamie Lien, MD.

Figure 3. Torus Fractures of the Distal Radius and Ulna



Images courtesy of Jamie Lien, MD.

Figure 4. Salter-Harris Classification of Physeal Injuries



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mature physeal closure. Like type I injuries, they are usually radiographically occult.

Apophyseal Injuries

An apophysis is a secondary center of ossification and differs from an epiphysis in that it is the site of insertion of a muscle, rather than an articular surface. Apophyseal injuries, which are mostly seen in the adolescent musculoskeletal system, involve the site of a major tendinous insertion onto a growing bony prominence. Apophysitis, in which inflammation develops at an apophysis, often from overuse, may occur at several sites. **(See Table 2.)**

Avulsion fracture may also occur at any apophysis. Avulsion fractures of the pelvis most often occur in athletes aged 14 to 17 years, and are frequently caused by sudden forceful muscular contraction. Common sites and muscles involved include the anterior superior iliac spine (sartorius), anterior inferior iliac spine (rectus femoris), ischial tuberosity (hamstrings) **(Figure 5)**, and, less frequently, the lesser trochanter (iliopsoas).

Upper Extremity Injuries

Clavicle Fractures

Clavicle fractures occur as a result of direct or indirect trauma to the shoulder region and account for approximately 10% of pediatric fractures.[5,9] Over 90% of these fractures involve the middle third of the clavicle.[10,11] Fractures of the distal third of the clavicle occur less commonly and may be associated with ligamentous injury. Fractures of the proximal third of the clavicle may occur acutely (usually associated with significant trauma) or insidiously, as a result of repetitive stress. High-energy clavicle fractures may be associated with scapula fractures, rib fractures, hemothorax, pneumothorax, and brachial plexus injury. Clavicle fractures due to birth trauma are the most common fractures in neonates, with an incidence of 0.5% to 1.6%.[12-14] Risk factors for clavicle fracture include increased instrumental delivery and shoulder dystocia, although, in most cases, the fracture occurs spontaneously during vaginal delivery.

Proximal Humerus Fractures

Proximal humerus fractures comprise approximately 2% of all pediatric fractures.[5] These fractures occur either through the physis (more commonly seen in adolescence) or the metaphysis (in younger children). The relatively late closure of the proximal humeral growth plate (between ages 16-19 years), which accounts for approximately 80% of the growth of the entire bone, results in significant remodeling potential. The mechanism of injury is usually either direct trauma to the lateral aspect of the shoulder or a fall on an outstretched hand. The humerus is a common location for bone cysts and other benign lesions, which may predispose to pathologic fracture associated with a history of minimal trauma.[15]

Humerus Shaft Fractures

Fractures of the humerus shaft represent approximately 1% of pediatric fractures.[5] A thick periosteal sleeve along the humeral shaft limits fracture displacement. The mechanism of injury is similar to that for proximal humerus fractures. In neonates, humerus shaft fractures are the second most common birth injury (after clavicle fractures), and result from rotation or hyperextension of the arm during passage through the birth canal.[16]

Elbow Fractures

Up to 10% of all pediatric fractures involve the elbow.[5] The presence of several ossification centers in the pediatric elbow makes radiographic detection of these fractures more difficult. The first ossification center to appear is the capitellum, followed

Table 2. Common Sites of Apophysitis

Type of Apophysitis	Anatomic Location
Sever disease	• Posterior calcaneus
Osgood-Schlatter disease	• Tibial tuberosity
Sinding-Larsen-Johansson syndrome	• Inferior patella
Little-League elbow	• Humeral medial epicondyle
Tennis elbow	• Lateral epicondyle
Iselin disease	• Base of fifth metatarsal
Multiple sites on pelvis	• Anterior superior iliac spine • Anterior inferior iliac spine • Iliac crest • Ischial tuberosity • Greater trochanter • Lesser trochanter

Figure 5. Avulsion Fracture of the Right Ischial Tuberosity

Image courtesy of Jamie Lien, MD.

by the radial head, medial or internal epicondyle, trochlea, olecranon, and finally the lateral or external epicondyle. The CRITOE mnemonic may be useful in recalling the order of radiographic appearance of ossification sites. **(See Table 3.)**

More than half of all elbow fractures in children are supracondylar, as this area is the weakest part of the elbow joint in children.[17] Supracondylar humerus fractures occur most commonly between 3 and 10 years of age,[18] are often caused by a fall onto an outstretched hand, and may be associated with neurovascular injury. Compartment syndrome of the volar forearm may develop within 12 hours, with potential to cause Volkmann ischemic contracture (fixed flexion of the elbow, pronation of the forearm, flexion at the wrist, and joint extension of the metacarpal-phalangeal joint) if left untreated.[17]

Lateral condylar fractures account for up to 15% of pediatric elbow fractures.[5] Medial condylar fractures are less common and are often associated with elbow dislocation.[19] Condylar fractures are rarely associated with significant neurovascular compromise, but their intra-articular nature demands accurate reduction.[5]

Radial head subluxation, also known as "nursemaid's elbow," is a common entity in children, causing elbow pain that must be distinguished from fracture. It typically occurs by abrupt longitudinal traction on a child's pronated arm, causing the annular ligament to displace over the radial head, and, thus, it may be more accurately described as displacement of the annular ligament. Radial head subluxation is the most common upper extremity injury in children aged < 6 years, with peak incidence around 2 years of age; however, it does occur rarely up to the preteen years.[20] The recurrence rate is as high as 39%.[21]

Forearm Fractures

The most common fracture site in children is the forearm, accounting for nearly a quarter of all pediatric fractures.[5] The type of fracture varies by age: torus and greenstick fractures occur most frequently in children aged < 10 years, physeal fractures tend to occur in patients aged > 10 years, and complete fractures are more likely in adolescent patients. These fractures are typically the result of a fall onto an outstretched hand, and occur most commonly in the distal third of the forearm.[22] Both the radius and ulna may be involved, due to the presence of the interosseous membrane between the radius and ulna, as well as the radioulnar articulations at the elbow and wrist. A Monteggia fracture is an injury involving a fracture or plastic deformation of the ulnar shaft and dislocation of the radial head. Monteggia fractures comprise 0.4% of forearm fractures in children.[23] A Galeazzi fracture (rarely seen in children) is a fracture of the distal radius with associated disruption of the radioulnar joint. Children may experience separation of the ulnar physis instead of true disruption of the radioulnar joint, known as a Galeazzi-equivalent injury.[24]

Table 3. Ossification Centers of the Elbow: CRITOE Mnemonic

Ossification Center	Age of Appearance
Capitellum	1 year
Radial head	3 years
Internal (medial) epicondyle	5 years
Trochlea	7 years
Olecranon	9 years
External (lateral) epicondyle	11 years

Reprinted from *The American Journal of Emergency Medicine,* Volume 20, Issue 6. Jeffery Wu, Andrew D. Perron, Mark D. Miller, et al. Orthopedic pitfalls in the ED: pediatric supracondylar humerus fractures. Pages 544-550. Copyright 2002, with permission from Elsevier.

Wrist Fractures

Carpal fractures are rarely seen in children because the carpal bones remain predominantly cartilaginous until late childhood and early adolescence. As a result, in younger children, traumatic force to the wrist (such as a fall on an outstretched hand) tends to result in forearm fractures rather than carpal fractures. Of the carpal bones, the scaphoid is the most commonly fractured. Blood supply to the proximal pole of the scaphoid originates from the palmar carpal branch of the radial artery via the distal pole, increasing the risk of nonunion with fractures of the central third or proximal third. Scaphoid fracture is rarely seen in children aged < 10 years.[25]

Hand Fractures

The hand is the second most common site of fracture in children, after the distal forearm, comprising 15% of pediatric fractures.[5,26] The phalanges are most frequently involved. Crush injuries resulting in distal tuft fractures are most common in toddlers, while metacarpal fractures are more common in older children.[27,28] Sports injury is the predominant cause of hand fracture in school-aged children.[28,29]

Lower Extremity Injuries

Hip Fractures

Fractures of the hip (proximal femur fractures) account for < 1% of all pediatric fractures,[30,31] and are usually caused by high-energy trauma. An underlying bone lesion (eg, a unicameral bone cyst, aneurysmal bone cyst, or malignancy) or metabolic bone disease (eg, fibrous dysplasia, osteogenesis imperfecta, rickets, or secondary osteopenia in a patient with myelomeningocele or cerebral palsy) may predispose children to hip fracture.[32] Neonatal hip fracture may be seen with obstetric trauma in breech or foot presentation.[30] Hip fracture in children aged < 2 years, especially in the absence of significant accidental trauma, may be associated with child abuse.[32] Complications occur frequently and include avascular necrosis (17%-47%), coxa vara (20%-30%), premature physeal closure with limb-length discrepancy (5%-69%), and nonunion (6%-10%).[31]

Slipped Capital Femoral Epiphysis

In a retrospective study of 372 children undergoing time-sensitive orthopedic surgical procedures, SCFE was the second most commonly missed pediatric orthopedic diagnosis, after fracture.[33] In SCFE, the proximal femoral epiphysis is displaced from the metaphysis of the femur due to weakening of the physis (essentially, a Salter-Harris I injury), which alters joint mechanics and ultimately leads to osteoarthritis. This condition usually presents in adolescence, with an average age of onset around 12 years.[34] SCFE is more common in males and is often associated with obesity, as well as with endocrine and metabolic conditions such as hypothyroidism and renal osteodystrophy.[35,36] Symptoms of limp and hip pain or referred knee pain may be acute or chronic, sometimes lasting for weeks prior to presentation or diagnosis. Usually, there is no history of trauma, but sometimes the patient with SCFE will present after an acute minor injury. Several retrospective studies of delayed diagnosis of SCFE found that, due to the vagueness of symptomatology, the average length of time from onset of symptoms to diagnosis of SCFE is approximately 8 weeks, with the prognosis worsening over time.[37-39] Delay in diagnosis is associated with increased severity of slip, leading to greater likelihood of avascular osteonecrosis, chondrolysis, leg-length discrepancy, osteoarthritis, and loss of range of motion.[37,39-44] In a review of 106 patients with SCFE, 15% presented with pain in the knee or distal thigh, rather than the hip or groin, which was associated with delayed diagnosis and increased severity of disease.[45] Bilateral SCFE can occur in 37% to 61% of patients, with 88% of subsequent slips occurring within 18 months of diagnosis of the first slip.[46,47]

Femur Fractures

Femoral shaft fractures account for < 2% of all pediatric fractures. These fractures have a bimodal age distribution, with peaks in early childhood, predominantly caused by falls; and in midadolescence, caused mostly by motor vehicle crashes.[48-50] Among children aged < 4 years, 9% to 15% of femur fractures are due to nonaccidental injury.[50,51]

Knee Fractures

Acute knee injuries occur frequently in children, with an incidence of 3 to 12 knee injuries per 1000 persons, based on ED visits.[52,53] The majority of these injuries are ligamentous sprains and strains, with fractures accounting for only 1.1% of knee injuries presenting to an ED.[54] In a 2-year prospective study of 23,382 patients presenting with knee injury to an ED, no knee injuries were seen in infants, and exclusively extra-articular soft-tissue injuries were found in children aged < 6 years.[54]

Physeal fractures to the distal femur and proximal tibia usually result from high-energy mechanisms, and may cause limb-length discrepancy or angular deformity, as these physes contribute 70% of the overall length of the lower extremity.[8] Distal femoral fractures comprise 2% to 5% of physeal fractures, while proximal tibial fractures make up < 1%.[6]

Patellar fractures comprise 1% of fractures in children.[55] The most common type is the patellar sleeve fracture, usually caused by a powerful quadriceps contraction against a flexed knee, creating avulsion of a bony fragment from the distal pole of the patella. These fractures are typically seen in adolescence, particularly with high-energy sports activity. Radiographs may show only patella alta, in which the position of the patella is higher than usual relative to the femoral trochlea. Significant fracture displacement and disruption of the knee extensor mechanism may require surgical reduction and reconstruction.[56] Failure to diagnose and manage patellar sleeve fractures appropriately can result in knee instability, extensor lag, quadriceps wasting and weakness, patella pain, and ossification in the stretched patellar tendon, with subsequent patella magna or duplication of the patella.[55]

The tibial tuberosity or tubercle is an apophysis at the anterior proximal aspect of the tibia, subject to traction by the patellar tendon, and is thus prone to avulsive injury. Tibial tuberosity fractures comprise < 1% of physeal fractures and usually occur in adolescent boys aged 13 to 16 years.[57,58] The usual mechanism of injury is forceful contraction of the quadriceps, often with jumping or forced flexion against a contracted quadriceps muscle (landing).[58] Tibial tuberosity fracture disrupts the quadriceps-patellar mechanism and presents similarly to a patellar sleeve fracture.

Tibial spine fractures (also called tibial eminence fractures) occur with avulsion of the anterior cruciate ligament (ACL) from its insertion on the intercondylar eminence of the tibia. They typically occur via hyperextension and internal rotation of the extended knee or a fall on a flexed and internally rotated knee, creating tension along the ACL.[59] These mechanisms would typically cause ACL injury in adults, but in children, the relative strength of the ACL compared to the adjacent bone results in tibial spine fracture. Tibial spine fractures are most common in the pediatric population between 8 and 14 years of age,[60] and accounted for 2% to 5% of knee injuries in 2 small prospective studies that evaluated children with knee effusion or hemarthrosis.[61,62] Associated complications include arthrofibrosis with loss of range of motion, residual laxity, nonunion, malunion, and physeal arrest (in association with surgical fixation).[63]

A Segond fracture is an avulsion injury of the lateral tibial plateau and midlateral capsule that frequently accompanies ACL rupture.[64] At least 75% of adults with Segond fractures have associated ACL tears. In children, Segond fracture has been noted in 6% of ACL injuries.[61] Segond fracture has been noted as an isolated finding without ACL injury in skeletally immature patients, likely due to differences in the relative strength of the ligament and the adjacent physis.[65-67]

Lower-Leg Fractures

Fractures of the tibial and fibular shaft are the most common long-bone fractures of the lower extremity, representing approximately 5% of all pediatric fractures.[4,5] The mechanism of injury varies by age; low-energy falls and twisting injuries predominate in younger children, while high-energy motor vehicle crashes and sports-related injuries account for most fractures in older children and adolescents. Approximately 30% of tibial shaft fractures are associated with fibula fractures.[68] Most tibial shaft fractures are oblique or transverse fractures of the middle or distal portion of the shaft. Torus fractures and plastic deformation also occur in the tibia and fibula.[69]

A "toddler" fracture is a nondisplaced oblique fracture of the distal tibia shaft. It typically occurs in children aged 1 to 4 years after rotation of the child's body around a fixed foot.

Ankle Fractures

Ankle fractures are the most common lower extremity fracture in children,[26] accounting for about 5% of all pediatric fractures.[5] The most common pediatric ankle injury is ankle inversion, with tenderness over the distal fibula. Classically, these injuries have been considered Salter-Harris type I fractures, diagnosed on clinical examination, with normal radiographs.[70] A recent prospective study of 135 children with lateral ankle injuries (clinically suspected to have Salter-Harris type I fractures of the distal fibula) that used magnetic resonance imaging (MRI) as the gold standard demonstrated ligamentous injury in 80% of these patients, isolated bone contusions in 22%, and Salter-Harris type I fracture in 3%.[71] Fractures of the distal fibula carry a low risk of long-term complications, but distal tibial physeal fractures have the highest rates of complications of all physeal fractures, particularly Salter-Harris type III and higher.

Closure of the distal tibial physis begins centrally, extends medially, and is completed laterally by the age of 17 years in boys and 15 years in girls. The juvenile Tillaux fracture and triplane fracture are transitional fractures, occurring during this period of closure, which lasts approximately 18 months. The Tillaux fracture is a Salter-Harris type III fracture involving the anterolateral portion of the distal tibia. The triplane fracture is a Salter-Harris type IV fracture in the sagittal, coronal, and transverse planes, creating between 2 and 4 fracture fragments. A retrospective study of 237 pediatric ankle fractures reported Tillaux fracture in 6.3% and triplane fracture in 2.5% of these cases.[72] **(See Figure 6.)**

Foot Fractures

Less than 10% of pediatric fractures involve the foot, and most affect the metatarsal or phalangeal bones, particularly the fifth and first metatarsals and the great toe.[5,73,74] Ankle inversion injury may result in avulsion of the base of the fifth metatarsal. A Jones fracture, or fracture of the proximal diaphysis of the fifth metatarsal, extends toward or into the intermetatarsal joint and is at risk for painful nonunion due to limited vascular supply.[75] Fractures of the midfoot and hindfoot are less common but are associated with higher risk of permanent disability and deformity. Injury to the tarsometatarsal joint complex, also known as a Lisfranc injury, can include isolated ligamentous disruption as well as fracture-dislocation. This injury is rare, but is misdiagnosed in up to 20% of cases, as radiographs may reveal normal or only subtle findings.[76] Without appropriate management, Lisfranc injuries can lead to progressive deformity and chronic pain.

Nonaccidental Injuries

A 2010 report on the incidence of child maltreatment estimates that, annually, 323,000 children in the United States experience physical abuse,[77] and this may be an underreported figure.[78] Child abuse can occur at any age and in any socioeconomic group. Many of these children present to EDs for medical care, and a heightened awareness of physical abuse can reduce missed opportunities for identification and intervention.[79,80] Between 20% and 30% of cases of abuse

Figure 6. Triplane Fracture of the Distal Right Tibia in a 13-Year-Old Boy

The epiphyseal component extends medially on the mortise view (thin arrow), and the metaphyseal component is noted posteriorly on the lateral view (thick arrow).

Images courtesy of Jamie Lien, MD.

were missed at the initial medical visit of children aged < 3 years who were ultimately diagnosed with abusive head trauma or abusive fractures.[80,81]

Bruising is the most common injury caused by physical abuse, followed by fractures.[82] The emergency clinician must take into consideration the history, the age and developmental stage of the child, the medical history, the location and type of injury, the mechanism of injury, and the presence of other injuries.[83] Injuries inconsistent with developmental capabilities—such as a femur fracture in a nonambulatory child—suggest a nonaccidental etiology.[84]

The 2014 AAP Clinical Report "Evaluating Children With Fractures for Child Physical Abuse" lists types of fractures according to degree of specificity for abuse.[83] Fractures with high specificity for abuse, particularly in infants, include rib fractures (especially posteromedial), classic metaphyseal lesions on long bones (as noted in **Figure 7C,** these fractures are also known as *bucket handle fractures* or *corner fractures* and can occur when an infant's limb is pulled or twisted, causing avulsion of the immature periosteum at the metaphysis[85]) and, seen less commonly, fractures of the scapula, spinous process, and sternum.[83] Radiologic findings with moderate specificity for abuse include multiple fractures (especially bilateral), fractures of different ages **(Figure 7)**, epiphyseal separations, vertebral body fractures and subluxations, digital fractures, and complex or bilateral skull fractures.[83] Fractures that are common and have low specificity for abuse include clavicular fractures, long-bone fractures, and linear skull fractures. In abused children, the most common fracture pattern identified is a single long-bone diaphyseal fracture.[83] For further information about nonaccidental injuries in pediatric patients, see the July 2017 issue of *Pediatric Emergency Medicine Practice* titled "Nonaccidental Injury in Pediatric Patients: Detection, Evaluation, and Treatment," available at www.ebmedicine.net/NAI.

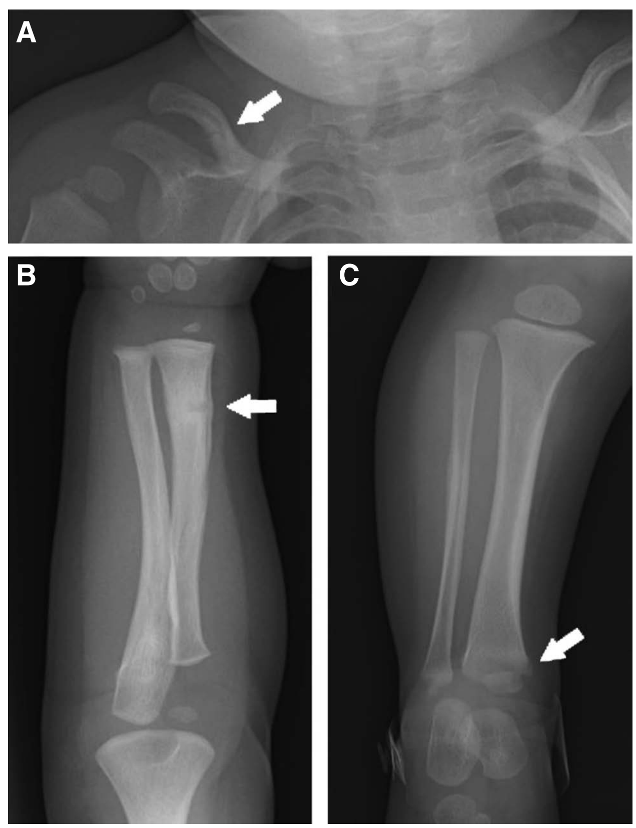
Differential Diagnosis

The differential diagnosis of pediatric musculoskeletal pain can be quite broad, including many nontraumatic causes that are not covered in this review. **(See Table 4, page 10.)** A thorough history and physical examination will refine evaluation. Prompt identification and management of more-serious conditions improves long-term outcome. Nonaccidental injuries, as discussed earlier, should always be considered in the evaluation of a young nonverbal child with an injury. For additional conditions in the differential diagnosis of fractures, see the "Tables and Figures" section of the May 2009 issue of *Pediatric Emergency Medicine Practice* titled "An Evidence-Based Approach to Pediatric Orthopedic Emergencies," available at www.ebmedicine.net/Orthoddx.

Prehospital Care

Prehospital management of pediatric orthopedic patients should focus on stabilizing the injured extremity as well as providing adequate analgesia. Extremities with suspected fractures should be immobilized using a splint, which allows for increased patient comfort and decreased risk of fracture displacement or damage to adjacent neurovascular structures. Immobilization should span the joint above and the joint below the injury, if possible. Neurovascular status should be assessed prior to splinting, immediately after splinting, and frequently throughout transport. Lack of adequate distal perfusion may respond to longitudinal traction and, ideally, should be managed in concert with an experienced pediatric specialist. Adequate analgesia may be achieved with oral agents for patients with minor fractures. Patients with more severe pain may require parenteral analgesics, but in the absence of parenteral access, oral analgesic agents should not be withheld in anticipation of possible use of procedural sedation or general anesthesia. Intranasal analgesia is another option for patients with moderate pain.

Figure 7. Multiple Fractures in Various Stages of Healing, Indicative of Physical Abuse



Radiographs of a 7-month-old boy showing (A) an acute clavicle fracture, (B) a healing distal radius fracture, and (C) a healing distal tibial classic metaphyseal lesion.

Images courtesy of Jamie Lien, MD.

Emergency Department Evaluation

History

After initial stabilization, a detailed history from the child and any caregivers should be obtained. Details such as the timing of the injury, duration of symptoms, precise mechanism of injury, location of pain, associated symptoms (such as fever), history of prior injury, analgesics given, and interventions performed can help guide the differential diagnosis. For red flags in the history that are suspicious for nonaccidental injury, see the AAP 2015 Clinical Report on "The Evaluation of Suspected Child Physical Abuse,"[78] available at: https://doi.org/10.1542/peds.2015-0356.

More than 50% of children with radial head subluxation present with the history of a pulling mechanism on their arm, but up to 20% present with a history of a fall.[20] In a child with a toddler fracture, the history may reveal no known trauma, or may include only minor trauma, such as tripping while walking or running, a fall from a relatively low height, or a twisting mechanism.[86]

Complaints of numbness, paresthesias, or muscle weakness should be elicited. Children may present with pseudoparalysis of the affected limb, or refusal to move the limb due to pain. Review of records from prior medical providers can reveal changes in examination that may raise suspicion for neurovascular injury.

Table 4. Differential Diagnosis of Limb Pain in a Child

Category	Etiology
Infectious	• Septic arthritis • Lyme arthritis • Osteomyelitis • Diskitis (can present with pain radiating to the leg/groin) • Bursitis • Cellulitis • Muscle abscess
Trauma	• Fracture • Sprain/strain • Contusion • Child abuse • Foreign object
Oncologic	• Leukemia • Lymphoma • Bone tumor • Rhabdomyosarcoma
Hematologic	• Sickle cell disease • Hemophilia
Inflammatory/ rheumatologic	• Poststreptococcal reactive arthritis • Transient synovitis • Enthesitis • Systemic lupus erythematosus • Juvenile idiopathic arthritis • Acute rheumatic fever • Henoch-Schönlein purpura • Serum sickness
Congenital	• Developmental dysplasia of the hip • Congenital limb deficiencies • Leg-length discrepancy • Cerebral palsy
Orthopedic	• Legg-Calvé-Perthes disease • Slipped capital femoral epiphysis • Overuse syndromes (apophysitis, stress fractures) • Osteochondrosis • Kohler disease • Osteochondritis dissecans • Tarsal coalition • Discoid meniscus • Osteoarthritis
Other	• Acute appendicitis • Testicular torsion

Physical Examination

After assessing the airway, breathing, and circulation, begin with a neurovascular check of the affected extremity. Palpate the regions proximal and distal to the site of injury or pain, as well as relevant bony prominences or areas of deformity. Assess range of motion in all relevant joints to the extent possible within the constraints of pain. Comparative manipulation of the uninjured contralateral extremity can provide information as to the child's baseline examination. Remove any dressings or splints to allow for thorough examination, but maintain comfort as much as possible and avoid further displacement of any fractures. Inspect the skin thoroughly for wounds that may indicate an open fracture. To decrease anxiety and improve cooperation, maneuvers that cause discomfort to the child should be performed last so that an adequate examination can be performed. Particularly in younger children, watch for nonverbal reactions such as withdrawal of the limb or facial grimacing as indicators of pain during the examination.

Upper Extremity Examination

For an upper extremity injury, examine the entire extremity, from the clavicle to the fingers, for associated fractures. Suspicion for a clavicle fracture should prompt assessment for tenting of the skin over the fracture site as well as a neurovascular and pulmonary examination. Children with subluxation of the radial head usually present with the affected arm held in a flexed, pronated position or limp at their side, and will refuse to use the arm. They will have pain with range-of-motion testing, but should have no swelling or tenderness to palpation. Supracondylar humerus fractures typically present with swelling and tenderness at the elbow/distal humerus, as well as decreased range of motion. Neurapraxia (temporary loss of nerve function) can develop from stretching of the nerve across the fracture site. A meta-analysis including 5154 displaced supracondylar fractures in children found that 11.3% were associated with traumatic neurapraxia, predominantly involving the anterior interosseous nerve (a motor branch of the median nerve) in extension-type injuries and the ulnar nerve in flexion-type injuries.[87] Full neurologic recovery may take up to 6 months.[88] Absence of the radial pulse by palpation is found in 6% to 20% of displaced fractures.[89,90] Antecubital ecchymosis signifies injury to the brachial artery,[91] and significant swelling with obvious deformity or puckering of the skin over the antecubital fossa suggests a severely displaced fracture, which raises concern for neurovascular compromise and increased risk for compartment syndrome. Increasing pain or pain with passive extension of the fingers can indicate worsening ischemia. Include supination and pronation in assessment of range of motion of the forearm. Children with distal forearm torus fractures may have point tenderness at the site of fracture, but should have full range of motion in all joints. Palpate the anatomic snuffbox when examining the wrist to assess for a scaphoid fracture. Assess for rotatory displacement with finger injuries by observing the fingers in a flexed position.

A thorough neurovascular examination of the upper extremity includes palpation of the distal pulses, assessment of skin color, temperature, capillary refill, and the motor and sensory aspects of the radial, median, and ulnar nerves. If a pulse is not detectable by palpation, attempt examination by Doppler ultrasound and obtain urgent orthopedic consultation. Collateral vascular flow at the elbow or the ulnar artery may allow for adequate hand perfusion despite loss of a detectable distal pulse. Maneuvers that establish motor function include the “thumbs up” sign (radial nerve), the “OK” sign with thumb and forefinger (anterior interosseous branch of the median nerve), and finger spread against resistance (ulnar nerve). Sensory components of the major nerves may be tested at the dorsal web space of the hand (radial nerve), index finger (median nerve), and fifth finger (ulnar nerve).

Lower Extremity Examination

Examination of the lower extremity should include palpation and analysis of range of motion from the lower spine to the toes, including attention to the ligaments of the knee and ankle. Pain in articular hip disorders often refers to the groin, and sometimes to the distal thigh or knee. In the supine position, a child with SCFE may hold the hip in lateral rotation with flexion. A displaced hip fracture will cause the affected leg to be externally rotated and shortened. The prone position allows for examination of the knee separately from the hip, which is prohibited in the supine position. On knee examination, a palpable gap at the lower pole of the patella, presence of patella alta, and deficiency of the extensor mechanism suggest a patellar sleeve fracture. A child with a toddler fracture may have no swelling or deformity to pinpoint the site of injury; eliciting localized tenderness on palpation can be difficult, particularly given the young age. Placing the hands at the knee and ankle and gently twisting in opposite directions should elicit pain, as should gently grinding the heel of the foot into the distal tibia. Palpate the base of the fifth metatarsal in any child with an ankle inversion injury to assess for an avulsion fracture. Midfoot tenderness, and particularly plantar ecchymosis,[92] should raise suspicion for a Lisfranc injury. Gait should be assessed, if possible.

Diagnostic Studies

The choice of imaging studies should be guided by the history and physical examination. For traumatic long-bone injuries, obtain radiographs in at least 2 planes—anteroposterior (AP) and lateral—that include the joint above and the joint below the area of interest. Oblique views may be added if needed for further visualization of most joints.

While radiography remains the gold standard for detection of fractures, ultrasound may also be used in some scenarios, with the advantages of being rapid, noninvasive, and cost-effective. A systematic review of bedside ultrasound use for diagnosis of long-bone extremity fractures in the ED revealed sensitivities of 85% to 100% and specificities of 73% to 100%.[93] Ultrasound has higher sensitivity for diaphyseal long-bone fractures than for compound fractures, small-bone hand and foot fractures, and fractures close to joints.[94,95]

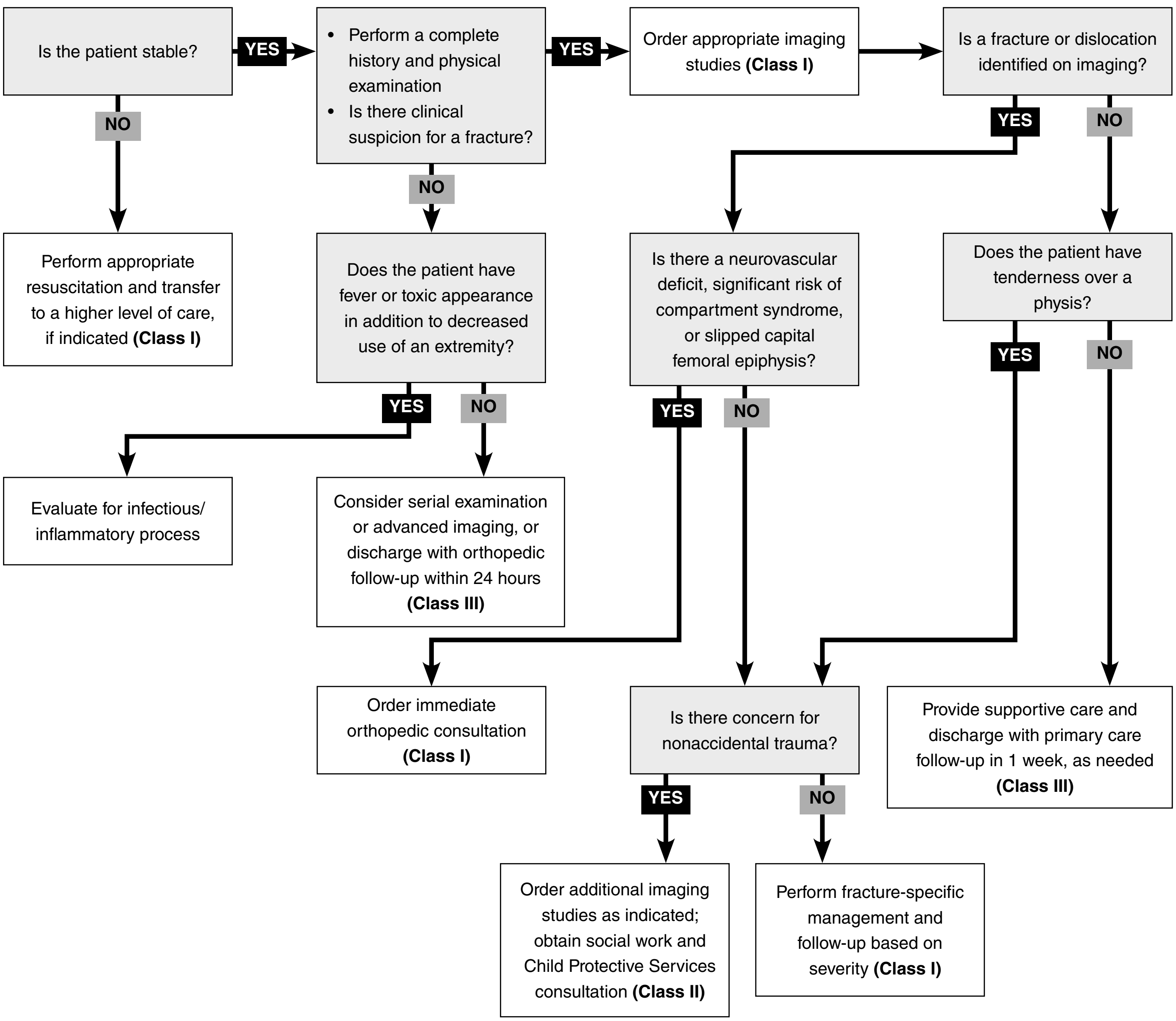
Computed tomography (CT) may be useful in diagnosis when plain radiographs appear normal but clinical suspicion for fracture remains high. CT more accurately delineates the degree of displacement, which can help guide management.

Imaging of Injuries to Upper Extremities

Any patient with traumatic injury to an upper extremity with pain or tenderness should undergo plain radiographs. Ultrasound may be helpful in diagnosing proximal humerus fractures in neonates, as the humeral head is primarily cartilaginous until 6 months of age.[16] No imaging is indicated in a child with clinically suspected subluxation of the radial head, but ultrasound may be helpful in confirming the diagnosis.[96,97]

Because forearm fractures are associated with supracondylar humerus fractures in up to 5% of cases (a condition called *floating elbow* that is associated with an increased risk of compartment syndrome and is a surgical emergency), radiographs of the forearm should include the distal humerus.[98] Evaluation for complex forearm injury patterns (such as Monteggia and Galeazzi fractures) requires imaging of the entire forearm, including the elbow and wrist.

Clinical Pathway for the Evaluation of the Pediatric Patient With Traumatic Limb Pain



Class of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

In a child with tenderness over the anatomic snuffbox, obtain a dedicated scaphoid view (AP view with ulnar deviation) of the wrist in addition to the standard wrist series.

Accurate interpretation of elbow radiographs can be challenging. In a study of fractures that were initially missed by ED physicians, elbow fractures were the most commonly missed.[99] The diagnosis of a suspected supracondylar humerus fracture or lateral/medial condylar fracture may be aided by obtaining additional oblique views as well as comparison radiographs of the contralateral elbow, to differentiate an ossification center from a fracture. However, a retrospective study of 25 injured and uninjured contralateral elbow radiographs demonstrated no improvement in diagnostic accuracy (when comparison views were available) among 2 training physicians, 2 pediatric emergency physicians, and 1 pediatric radiologist.[100]

Several radiographic signs can help discern occult or subtle supracondylar humerus fracture; these signs require that the lateral radiograph be taken at 90° of flexion. The presence of a radiolucent fat pad posterior to the distal humerus is generally considered to indicate effusion or hemorrhage, and results from displacement of fat from the olecranon fossa. In a prospective study of 45 children with elbow trauma and an elevated posterior fat pad without other radiographic evidence of fracture, 76% were confirmed to have fracture on follow-up radiography.[101] A raised anterior fat pad may also be seen. Ultrasound has been shown to have a sensitivity of 80% to 98% and a specificity of 70% to 87% for identifying an elevated posterior fat pad as indicative of an elbow fracture.[102,103]

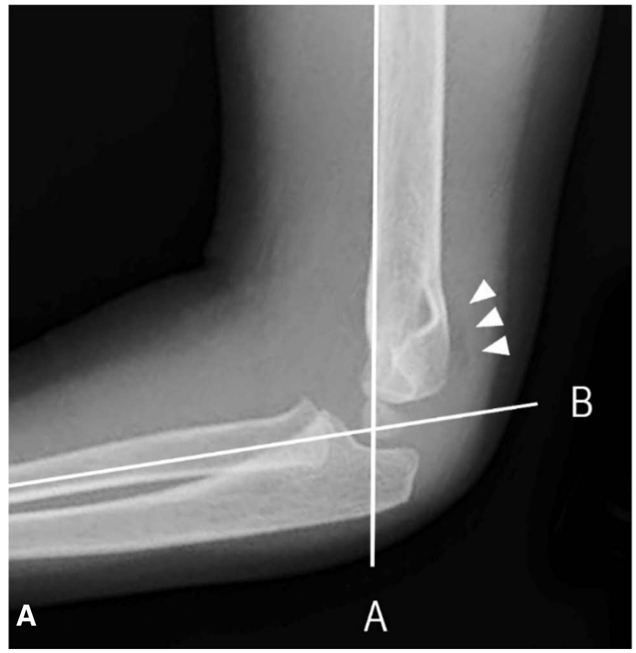
Anterior humeral lines and radiocapitellar lines may provide additional evidence of supracondylar humerus fracture. The anterior humeral line is a line drawn on x-ray through the anterior cortex of the humerus that intersects the capitellum in its middle third. The radiocapitellar line traces the axis of the radius and points to the capitellum. **(See Figure 8A.)** In a posteriorly displaced supracondylar humerus fracture, the anterior humeral line may pass through the anterior third of the capitellum or may miss it entirely **(Figure 8B)**, and the radiocapitellar line may miss the capitellum. Disruption of the radiocapitellar line can also be seen in radial head dislocation, often associated with Monteggia fracture. Of supracondylar humerus fractures, 95% are extension-type and can be described using the Gartland classification:[104]

- Type I: Nondisplaced fracture
- Type II: Displaced with intact posterior cortex
- Type III: Displaced with complete cortical disruption

Imaging of Injuries to Lower Extremities

The child with a limp and a nonfocal examination (particularly if the child is nonverbal) may benefit from radiographs from the pelvis to the foot to evaluate for fracture or foreign body if no focal deformity or tenderness can be identified on physical examination. In a retrospective study of 500 infants and toddlers with acute limp, fracture (including involvement of the pelvis, femur, tibia/fibula, and feet) was found to be the underlying etiology in 20% of the children.[105] Given the possibility of referred

Figure 8. Elbow Radiographs Depicting Anterohumeral and Radiocapitellar Lines



The anterohumeral line and radiocapitellar line are normal. The presence of the posterior fat pad (arrowheads) indicates an occult elbow fracture.
Line A: The anterohumeral line.
Line B: The radiocapitellar line.
Image courtesy of Jamie Lien, MD.

Elbow radiograph depicting a posteriorly displaced supracondylar fracture. Note that the anterohumeral line misses the capitellum and the posterior fat pad (arrowheads) is elevated.
Image courtesy of Jamie Lien, MD.

pain from hip pathology, in children complaining of knee pain, always consider obtaining pelvis radiographs in AP and frog-leg lateral views. For children with suspected SCFE, obtain AP and frog-leg lateral views of the pelvis. Bilateral imaging should be performed, given the high rate of bilateral involvement.[46] The frog-leg lateral view is considered the gold standard for revealing a slip of the epiphysis.[106] **(See Figure 9A.)** On the AP view, SCFE is indicated by failure of a line (called Klein's line) drawn along the superior aspect of the femoral neck to intersect the epiphysis **(Figure 9B)**; however, this measurement was noted to have suboptimal sensitivity when applied to 30 radiographs with known SCFE.[106] A review of 3 studies with a total of 50 patients demonstrated that ultrasound is more sensitive than radiographs for diagnosis of SCFE.[107] A retrospective study of radiographs and MRI in 15 cases of SCFE showed that MRI has greater sensitivity and may contribute to surgical planning.[108]

Examine plain radiographs of the knee closely for tibial spine fractures. CT may provide additional visualization that can help with operative management. Knee radiographs may show a high-riding patella or a distal fracture fragment in patellar sleeve fractures, but normal radiographs do not exclude the diagnosis.

Ankle radiographs should include not only AP and lateral views, but also a mortise view, with the leg internally rotated 20°. This view allows for full visualization of the dome of the talus and the position of the malleoli. A retrospective study of 26 adolescents with Tillaux fractures noted that 9 of these fractures could be diagnosed with only an oblique view,[109] and a retrospective review of 556 3-view ankle radiographs demonstrated reduced accuracy of fracture detection when only 2 views were used.[110] In patients with intra-articular fractures (including Tillaux and triplane fractures), CT imaging is not usually needed for diagnosis or initial management, but can provide useful information for operative repair.[111,112]

In children with suspected Lisfranc injury and normal initial foot radiographs, weight-bearing views can reveal subtle Lisfranc joint diastasis.[113] CT should be considered for patients with suspected talar fracture, calcaneal fracture, or Lisfranc injury whose initial radiographs are normal.

Clinical Decision Rules

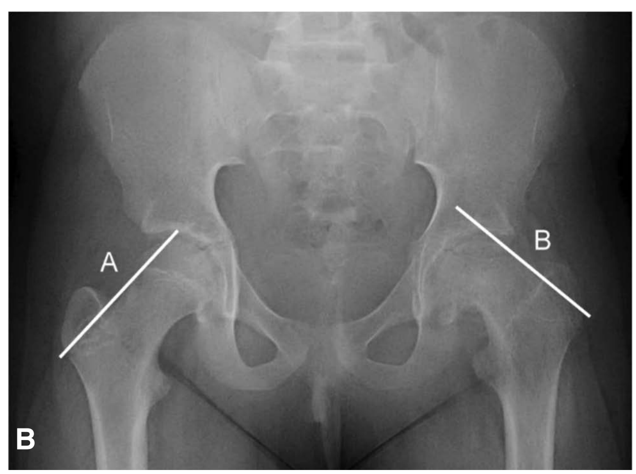
The Ottawa Ankle Rule[114] and Ottawa Knee Rule[115] are clinical decision rules developed through rigorous prospective studies to reduce unnecessary imaging by identifying patients who are at low risk for fracture. The Ottawa Ankle Rule and Ottawa Knee Rule provide a list of criteria, which, if any are met, indicate that radiographs are needed. In adults, these rules have a reported sensitivity of nearly 100%, with no missed fractures, and implementation was associated with a decrease in radiography.[114,115] In children, a systematic review of 12 pediatric studies applying the Ottawa Ankle Rule to 3130 children found a pooled sensitivity of 98.5%, with a missed fracture rate of 1.2%, and it concluded that this clinical decision rule can reliably exclude fractures in children aged ≥ 5 years.[116]

Link to online MDCalc tool for Ottawa Ankle Rule:
- www.mdcalc.com/ottawa-ankle-rule

Link to online MDCalc tool for Ottawa Knee Rule:
- www.mdcalc.com/ottawa-knee-rule

Figure 9. Radiographs of an 11-Year-Old Girl With a Left-Sided Slipped Capital Femoral Epiphysis

Frog-leg lateral radiograph.



Anteroposterior pelvis radiograph.
Klein's line, drawn along the superior aspect of the femoral neck, intersects the femoral epiphysis in the normal hip (line A), but misses it in the affected hip (line B).
Images courtesy of Jamie Lien, MD.

Other clinical decision rules have been proposed with the purpose of minimizing the number of radiographs performed on children after ankle injury, including the Low-Risk Exam[117] and the Malleolar Zone Algorithm.[118] A prospective head-to-head comparison of these 3 decision rules in 245 patients demonstrated 100% sensitivity for clinically important fractures with the Ottawa Ankle Rule, and lower sensitivities with the Low-Risk Exam and Malleolar Zone Algorithm.[119] A prospective multicenter study applying the Ottawa Knee Rule to 750 children found it to be valid in children aged > 5 years.[120]

Imaging in Suspected Nonaccidental Injury

In cases of suspected child abuse, a complete radiographic skeletal survey is recommended for detecting fractures in all children aged < 2 years, and as indicated in older children, as supported by the ACR Appropriateness Criteria®, last reviewed in 2012.[121] Per ACR guidelines, the skeletal survey should include specific views of the appendicular skeleton (AP views of the humeri, forearms, femurs, lower legs, and feet; posteroanterior [PA] view of the hands) and axial skeleton (AP, lateral, right and left oblique views of the thorax; AP view of the pelvis; lateral views of the lumbosacral and cervical spine; and frontal and lateral views of the skull).[122] A single radiograph of the entire infant is not sufficient.[122]

CT or MRI imaging of the head should be performed in children with neurologic symptoms, and should be strongly considered in children who are at high risk for intracranial injury, including those aged ≤ 6 months or those who have rib fractures, multiple fractures, or facial injury. Laboratory evaluation with hepatic transaminases should be considered for any child with suspected nonaccidental injury to screen for blunt abdominal trauma.[123,124] CT imaging of the chest, abdomen, and/or pelvis may be indicated as well.

Treatment

Splints and Casts

Most stable fractures can be splinted, with urgent pediatric orthopedic follow-up for eventual reduction (if needed) and cast placement. Splinting and casting preserve proper bone alignment and alleviate discomfort while preventing further injury and promoting healing; splinting may be preferable in the first few days after injury, as progressive soft-tissue swelling can lead to neurovascular compromise within a circumferential cast.[125] **Tables 5 and 6 (pages 16 and 17, respectively)** detail the appropriate type of splint for specific injuries. Commercial preformed splints provide convenience of application and are appropriate for sprains and low-risk fractures. Custom-molded splints provide a higher degree of immobilization and may be associated with higher patient compliance, as they are more difficult to remove. Neurovascular status should be checked again after splinting or cast immobilization is achieved.

Splinting should be performed for injuries with focal tenderness and decreased range of motion, even in the absence of definitive radiographic evidence of fracture in the initial period after injury. In particular, Salter-Harris I fractures, toddler fractures, and scaphoid fractures, among others, may become radiographically distinguishable only after callus formation. In a review of 59 patients diagnosed with toddler fracture in an ED setting, 41% of children with initial normal radiographs demonstrated radiographic evidence of new bone growth at follow-up, supporting the diagnosis of fracture.[126]

Scaphoid fractures carry a high risk of nonunion because the proximal portion of the scaphoid receives its blood supply only via retrograde flow through the distal portion. In patients with scaphoid tenderness, the wrist should be immobilized even if no fracture is visualized initially, and confirmatory radiographs should be obtained in 2 weeks to exclude occult fracture before discontinuing immobilization.[127] A systematic review of 75 studies pertaining to the diagnosis of scaphoid fracture found that 25% of patients with occult fracture had negative plain radiographs.[128] In a review of 351 scaphoid fractures, 90% healed with nonoperative treatment, with some requiring prolonged cast immobilization.[129]

Several methods of cast immobilization for scaphoid fracture can be used, including above-elbow casting, below-elbow casting, wrist flexion, wrist extension, and thumb immobilization, with no significant differences in outcome for the various techniques, as shown in a systematic review of 523 patients.[130] A study of cadaveric forearms comparing immobilization techniques demonstrated that wrist immobilization is critical to limiting fracture displacement, but thumb immobilization does not contribute to fracture stability under physiologic loading.[131]

Reduction

The need for reduction depends on the age of the patient and the involved area of bone, as well as the degree of angulation, displacement, and malrotation. Skeletal immaturity conveys higher potential for bone remodeling; in general, greater degrees of displacement and angulation can be tolerated in younger children. For example, in children aged < 5 years, proximal humerus fractures with up to 70° of angulation and 100% displacement may be managed conservatively with sling immobilization, whereas in children aged > 12 years, up to 40° of angulation and 50% displacement are acceptable.[132] In children with distal forearm fractures with < 15° of angulation, immobilization without reduction leads to complete remodeling and no clinical or functional sequelae.[133,134] A prospective study of displaced distal forearm fractures reduced and casted by experienced pediatric emergency physicians had similar outcomes when compared to similar management by orthopedic residents.[135]

For radial head subluxation, manual reduction can be achieved by various maneuvers. To view images and videos of reduction techniques for radial head subluxation, click the following links (videos are located at the bottom of the web pages): supination-flexion technique, http://emedicine.medscape.com/article/104158-technique#c2; and hyperpronation technique, http://emedicine.medscape.com/article/104158-technique#c3. Five small prospective, randomized studies generally support the hyperpronation technique compared with supination-flexion, citing more effectiveness and no measurable difference in pain.[21,136-139] Parents should be educated in avoiding a pulling mechanism on the arm in order to decrease risk of recurrence.

Pain Control

Pain is typically most severe in the first 72 hours after injury. A 2014 survey of 683 North American pediatric emergency physicians and orthopedic surgeons regarding pain management in children with musculoskeletal injury indicated overall poor management of pain, particularly in younger children, and at home after hospital discharge.[140] In a prospective study of 202 children with extremity fractures, 40% of patients reported clinically meaningful pain in the initial 48 to 72 hours after discharge from the ED.[141]

Adequate analgesia should be maintained with ibuprofen and acetaminophen as first-line medications, and opioids (oral, intranasal, or parenteral) if further pain control is required. Providers should avoid the use of codeine-containing products, as recommended by the United States Food and Drug Administration and the AAP,[142,143] given the risk of overdose or underanalgesia due to CYP2D6 polymorphism causing variable rates of metabolism to the active metabolite, morphine. Children receiving codeine may experience either inadequate analgesia or opioid overdose effects, including respiratory depression.[144]

Other Treatments/Techniques

Nondisplaced and minimally displaced fractures of the middle third of the clavicle may be immobilized using either a sling or figure-of-eight bandage, with similar outcomes.[145,146] Emergent orthopedic referral is indicated for open fracture, neurovascular compromise, and tenting of the skin. Complete fracture displacement, comminution, shortening, distal third fractures involving the acromioclavicular joint, and

Table 5. Splints Used for Upper Extremity Injuries

Region	Type of Splint	Indications
Ulnar side of hand	Ulnar gutter splint	• Fracture of fourth and fifth metacarpals and proximal/middle phalanges
Radial side of hand	Radial gutter splint	• Fracture of second and third metacarpals and proximal/middle phalanges
Thumb, first metacarpal, and carpal bones	Thumb spica splint	• Fracture of scaphoid/trapezium • First metacarpal fracture • Thumb fracture
Finger injuries	Buddy taping	• Proximal/middle phalangeal shaft fracture • Finger sprain
	Aluminum U-shaped splint	• Distal phalangeal fracture
	Dorsal extension-block splint	• Middle phalangeal volar plate avulsion • Reduced proximal interphalangeal joint dislocation
	Mallet finger splint	• Extensor tendon avulsion from base of distal phalanx
Wrist/hand	Volar/dorsal forearm splint	• Soft-tissue injury to hand/wrist • Acute carpal bone fracture (excluding scaphoid/trapezium) • Nondisplaced, minimally displaced, or torus fracture of distal radius
	Bulky hand compression dressing	• Severe hand fracture
Forearm	Simple sugar-tong splint	• Fracture of distal radius and ulna
Elbow, proximal forearm, and skeletally immature wrist injuries	Long-arm posterior splint	• Fracture of distal humeral and proximal/midshaft forearm fracture • Non–torus wrist fracture
	Double sugar-tong splint	• Elbow fracture • Forearm fracture • Nondisplaced, extra-articular Colles fracture
Shoulder and proximal/midshaft humerus	Sling and swathe splint or Velpeau bandage	• Clavicle fracture • Proximal/midshaft humerus fracture • Reduced shoulder dislocation • Acromioclavicular joint separation
	Figure-of-eight bandage	• Clavicle fracture (middle third)

Adapted from: Anne S. Boyd, Holly J. Benjamin, C. Asplund. Splints and casts: indications and methods. *American Family Physician.* 2009. 80(5):491-499, with permission from the American Academy of Family Physicians.

proximal third fractures with posterior displacement should also prompt referral.

Supracondylar humerus fractures are managed according to their Gartland classification and the AAOS 2014 Appropriate Use Criteria for the Management of Pediatric Supracondylar Humerus Fractures.[147] Type I fractures are managed with immobilization with a cast or posterior long-arm splint without reduction, whereas Type II and III fractures are typically managed operatively, with emergent orthopedic consultation, given the increased risk of compartment syndrome. The affected elbow should be maintained at 90° of flexion, as flexion beyond 90° can produce elevation of compartment pressures.[148]

A child with suspected SCFE should be made non–weight bearing immediately to prevent further slippage of the femoral head, and should be evaluated by a pediatric orthopedist for operative reduction and internal fixation as soon as possible in order to decrease the risk of avascular necrosis.[149]

Knee immobilization is appropriate for children with knee fractures. Most other knee injuries require only conservative ED management, including adequate analgesia and weight-bearing as tolerated. Range-of-motion exercises are critical to preventing loss of mobility and contracture.[150] Patients with tibial spine fractures and patellar sleeve fractures should have urgent orthopedic consultation, with possible operative repair.[60,63]

Splinting is indicated for the child with a suspected toddler fracture, even in the absence of definitive radiographic findings on initial evaluation. However, toddler fractures have been noted to heal reliably within 4 weeks, despite immobilization type and duration, and may not ultimately need any immobilization.[151,152]

Table 6. Splints Used for Lower Extremity Injuries

Region	Type of Splint	Indications
Toes	Buddy taping	• Phalangeal fracture
Foot	Short-leg splint with toe extension or hard-soled shoe	• Distal metatarsal and phalangeal fracture
	Bulky foot compression dressing	• Calcaneal fracture • Severe foot injury
Lower leg, ankle, and foot	Posterior short-leg splint	• Severe ankle sprain • Reduced ankle dislocation • Fracture of distal leg, ankle, or foot
	Stirrup splint	• Ankle sprain • Isolated, nondisplaced malleolar fracture
Knee and lower leg	Posterior knee splint or knee immobilizer	• Soft-tissue injury and bony injury of lower extremity

Adapted from: Anne S. Boyd, Holly J. Benjamin, C. Asplund. Splints and casts: indications and methods. *American Family Physician.* 2009. 80(5):491-499, with permission from the American Academy of Family Physicians.

Management of Nonaccidental Injury

Once medically stabilized, a child with concern for nonaccidental injury should be evaluated by a child protection specialist, if available. Mandatory reporting laws require that concerns for abuse be reported to Child Protective Services. Hospital admission may be warranted to facilitate further evaluation and/or protection from the home environment.[78]

Special Circumstances

Pre-existing Conditions

Pre-existing medical conditions and bone disease may increase a child's risk of fracture, and should be considered in the differential diagnosis of childhood fractures. These include osteogenesis imperfecta, osteopenia of prematurity, vitamin D deficiency rickets, disuse demineralization in severely disabled children, scurvy, copper deficiency, Menkes disease, and systemic disease affecting bone metabolism (including chronic renal disease, chronic liver disease, Fanconi syndrome, hypophosphatasia, hypophosphatemic rickets, hyperparathyroidism, and renal tubular acidosis).[83]

Legg-Calvé-Perthes Disease

Legg-Calvé-Perthes disease is an idiopathic avascular necrosis of the femoral head with subsequent reossification and development of osteoarthritis. It presents most commonly in boys between the ages of 3 and 12 years. Bilateral disease occurs in 10% to 20% of patients, with boys affected 3 to 5 times more than girls.[153] Patients with sickle cell disease have a higher risk of avascular necrosis of the hip, with an overall prevalence of approximately 10%.[154] The onset of pain can be acute or insidious, and symptoms may present intermittently.[155] As with other conditions affecting the hip, patients may present with pain in the thigh or knee, rather than the hip.

Open Fractures

Open fractures are those with direct communication of the fracture site with the outside environment due to traumatic disruption of the overlying soft tissue. The skin wound may be subtle, particularly in cases where the sharp end of a bone protrudes through the skin, then returns into the soft tissue. Initial management includes immobilization, tetanus prophylaxis as indicated, and appropriate analgesia. A 2004 Cochrane systematic review of the use of antibiotics in prevention of infection in open limb fractures examined data from 913 patients and concluded that the risk of early infection may be reduced by use of antibiotic therapy providing gram-positive coverage in the context of appropriate comprehensive open fracture management, which ultimately includes surgical washout of the wound, fracture reduction, and casting.[156]

Compartment Syndrome

Compartment syndrome occurs when increased pressure within a compartment, defined by fascial membranes, compromises the circulation and function of the tissues within that space. It develops most commonly within hours after significant trauma, particularly in long-bone fractures, but also occurs following minor trauma or from nontraumatic causes, such as ischemia-reperfusion injury, thrombosis, bleeding disorders, nephrotic syndrome, certain envenomations and bites, extravasation of intravenous fluid, and prolonged limb compression. As identified in a retrospective review of 55 patients with Volkmann contracture, risk factors for development of compartment syndrome in children include supracondylar humerus fracture, floating elbow (ipsilateral humerus and forearm fracture), operatively treated forearm fracture, and femur and tibia fractures.[157]

Compartment syndrome represents a true orthopedic emergency, as lack of prompt diagnosis and effective treatment can lead to significant morbidity, including muscle fibrosis, neuropathy, and amputation. Frequent serial neurovascular evaluation can detect the classic signs and symptoms: pain out of proportion to the injury, pallor, poikilothermia, paresthesia, and pulselessness. In children, however, these indicators are usually unreliable, and patients may experience delayed or missed diagnoses.[158] More reliable signs of worsening severe pain in children may include increasing analgesia requirement, anxiety, and agitation.[158,159] Appropriate management of compartment syndrome includes relieving external pressure on the compartment, avoidance of elevation of the extremity so as to maximize arterial pressure, judicious use of analgesics, emergency compartment pressure measurement, and emergent orthopedic consultation. Definitive treatment involves emergency fasciotomy and decompression.

Controversies and Cutting Edge

Management of distal radius torus fracture is evolving from traditional casting and orthopedic follow-up to the use of removable wrist splints and follow-up with a primary care provider.[160] A randomized controlled trial of 113 patients found that children treated with removable splinting demonstrated better physical functioning and less difficulty with activities than those treated with a cast, with no difference in pain.[161]

Lateral ankle injuries with tenderness over the physis and normal initial radiographs, traditionally treated as Salter-Harris I fractures with immobilization, have recently been shown to be comprised mostly of sprains or bone contusions.[71] As such, treatment with a removable ankle brace rather than cast immobilization may be appropriate.

Disposition

Children with stable fractures and intact neurovascular status may be discharged from the ED with a splint, with pediatric orthopedic follow-up within 1 week. Patients with nondisplaced fractures of the middle third of the clavicle and distal radius torus fractures managed with removable splints may opt to follow up with their primary care physician instead.

Emergent orthopedic consultation should be obtained for the following injuries:

- Open fractures
- Fractures with neurovascular compromise
- Compartment syndrome
- Displaced hip fractures

Urgent orthopedic consultation should be obtained for the following injuries:

- Salter-Harris III, IV, and V fractures (including Tillaux and triplane fractures)
- Displaced fractures without neurovascular compromise
- Angulated and/or complete fractures (except for some clavicle fractures)
- Plastic deformation of the radius and/or ulna
- Greenstick fractures
- SCFE
- Patellar sleeve fractures
- Tibial tuberosity avulsions and tibial spine fractures

Children with nonaccidental injury may require hospital admission for further evaluation.

Summary

Pediatric bone anatomy and physiology produce unique injury patterns and conditions that may be challenging to diagnose. Physeal fractures may be classified based on their risk of future complication and should be managed cautiously. A thorough history and physical examination can help guide diagnosis, but these may be limited in children. Radiographs are generally diagnostic, although incomplete ossification in younger children makes radiographic diagnosis of many fractures difficult, particularly in the elbow. Additional imaging modalities may be warranted. Child abuse should always be a consideration, particularly when evaluating young children with even minor injuries.

Risk Management Pitfalls in the Management of Pediatric Patients With Orthopedic Emergencies

1. **"The patient complained only of wrist pain, so I just ordered x-rays of the wrist."**
   Fractures of the forearm may be accompanied by other injuries in the same extremity, such as a supracondylar fracture. Physical examination should extend to the joint above and the joint below the area of interest, thereby guiding appropriate imaging. While radiographs of the joints above and below do not need to be ordered as reflex, a thorough examination of adjacent joints and working knowledge of fracture patterns that involve other joints are important.

2. **"The patient was complaining of worsening pain, and the pain medication doesn't seem to be helping. I told him to elevate his arm further."**
   Severe, worsening pain may be an indication of compartment syndrome, which can progress rapidly to significant morbidity. Appropriate actions in the setting of possible compartment syndrome include frequent serial re-evaluation, removal of external compression, avoidance of limb elevation, appropriate analgesia, measurement of compartment pressures, and emergent orthopedic consultation if suspicion for compartment syndrome persists.

3. **"The patient has pain over the lateral elbow, but the ossification centers look normal on x-ray."**
   Pediatric elbow radiographs can be difficult to interpret due to the numerous ossification centers that appear at different ages. Contralateral images can help differentiate fractures from normal development. Lateral condyle fractures are often operative and must not be missed.

4. **"The child was tender over the lateral malleolus, but the x-ray looked normal, so I treated it like a sprain."**
   The presence of open growth plates in children makes interpretation of radiographs more challenging. A Salter-Harris type I fracture, which traverses through the growth plate, may not be visible radiographically due to the cartilaginous nature of the physis. Point tenderness over a physis should be managed as a physeal fracture in most bones.

5. **"She has wrist pain, but no fracture was seen on wrist x-rays, so her wrist can't be broken."**
   Scaphoid fractures may not be visible on standard wrist radiographs, and can be associated with poor healing if not properly managed. Examination of a child with wrist pain should include palpation of the anatomic snuffbox, and tenderness in that area should prompt specific imaging of the wrist in ulnar deviation to better visualize the scaphoid. If the area over the scaphoid is tender, regardless of whether a fracture is noted on imaging, immobilization and orthopedic follow-up are needed, given the high rate of nonunion.

6. **"The patient was complaining that he was experiencing pain in his knee, but the knee x-ray was normal and the knee exam was benign."**
   Children with SCFE can present with only knee pain. Any patient with a complaint of knee pain should undergo thorough examination of the hip as well.

7. **"The AP view of his wrist was normal, so I didn't want to order additional x-rays."**
   Extremity radiographs should always include at least 2 views. Torus fractures of the distal radius can be quite subtle, and may be visible only on 1 view.

8. **"I didn't want to make the child uncomfortable, so I didn't remove the splint for the examination."**
   Evaluation of any patient with a suspected or known fracture should include visualization of the skin all around the extremity as well as inspection for swelling, ecchymosis, and neurovascular status.

9. **"The wound on her forearm was tiny, so I just cleaned it and put a bandage on it."**
   Open fractures may be accompanied by small wounds. Thorough visual examination of the affected extremity is necessary for diagnosis.

10. **"The parents aren't sure how this 3-month-old baby broke her arm."**
    Any fracture inconsistent with the child's developmental abilities, as well as lack of an adequate explanation for a significant injury should raise concern for nonaccidental injury.

Case Conclusions

The 12-year-old boy with 1 week of hip pain was found to have bilateral SCFE, based on AP and frog-leg lateral pelvis radiographs. He was immediately made non–weight-bearing. The orthopedic surgeon was consulted urgently and proceeded with in situ fixation that day.

The 3-year-old girl with left arm pain underwent AP and lateral radiographs of the left elbow, which showed an elevated posterior fat pad with no obvious fracture or bony displacement. Her focal elbow tenderness and radiographic finding of an elevated posterior fat pad were consistent with an occult supracondylar humerus fracture. A posterior long-arm splint was placed, and she was scheduled for orthopedic follow-up in 1 week, at which time a cast was placed.

The 3-month-old boy with decreased movement of his right arm was sent for radiographs of the clavicle, humerus, forearm, and hand. These images revealed an acute clavicle fracture as well as a healing distal radius fracture. The presence of multiple fractures in various stages of healing, lack of an appropriate explanation for these injuries, and the presence of these fractures in a minimally mobile child raised suspicion for nonaccidental injury. You ordered a skeletal survey to evaluate for other fractures as well as a head CT to evaluate for intracranial bleeding. The skeletal survey identified a classic metaphyseal lesion in the left distal tibia. The head CT was normal. You consulted social work, and Child Protective Services was notified of suspected child physical abuse.

Time- and Cost-Effective Strategies

- The Ottawa Ankle Rule and Ottawa Knee Rule may be used in children aged > 5 years, and can significantly reduce the use of radiography. Patients will be subjected to less radiation, incur lower costs for their evaluation, and spend less time in the ED. *Risk management caveat:* Discharge instructions from the ED should include follow-up with a physician for persistent symptoms, as well as review of signs and symptoms that would prompt return to the ED.
- Start with plain radiographs. Advanced imaging studies, such as CT or MRI, may not provide appropriate diagnostic information. Focal pain in a patient should dictate initial radiographic studies. *Risk management caveat*: In some conditions, such as a toddler fracture, normal radiographs do not rule out pathology.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study is included in bold type following the references, where available. The most informative references cited in this paper, as determined by the author, are noted by an asterisk (*) next to the number of the reference.

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CME Questions

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1. **A 9-year-old girl presents with right lateral ankle pain and inability to bear weight after sustaining an ankle inversion injury. Examination reveals point tenderness over the lateral malleolus. Radiographs of the ankle appear normal. Which of the following fractures is most likely?**
   a. Salter-Harris type I fracture of the distal tibia
   b. Salter-Harris type I fracture of the distal fibula
   c. Salter-Harris type V fracture of the distal tibia
   d. Salter-Harris type V fracture of the distal fibula

2. **In children, the most common site of fracture is the:**
   a. Clavicle
   b. Tibia
   c. Femur
   d. Forearm

3. **Which of the following findings on knee examination is concerning for patellar sleeve fracture?**
   a. Patella alta
   b. Patella baja
   c. Patella magna
   d. Patellar dislocation

4. **Which of the following fractures is highly specific for abuse in a toddler?**
   a. Finger fracture
   b. Rib fracture
   c. Tibia fracture
   d. Clavicle fracture

5. **Tenderness over the anatomic snuffbox can indicate a fracture of which bone?**
   a. Scaphoid
   b. Distal radius
   c. Ulnar styloid
   d. Lunate

6. **Testing of the motor component of which nerve can be accomplished by having the patient make an "OK" sign with the thumb and forefinger?**
   a. Axillary nerve
   b. Radial nerve
   c. Anterior interosseous branch of the median nerve
   d. Ulnar nerve

7. **Which of the following findings on a lateral elbow radiograph is most indicative of a fracture?**
   a. Elevated posterior fat pad
   b. Lack of an anterior fat pad
   c. Anterior humeral line intersecting the capitellum
   d. Radiocapitellar line intersecting the capitellum

8. **What is the most appropriate radiograph to order to evaluate a child with right hip pain?**
   a. Right hip radiograph
   b. Right femur radiograph
   c. Pelvis radiograph with AP and lateral frog-leg views
   d. Right knee radiograph

9. **Your patient has a supracondylar fracture and is in significant pain. Which of these analgesics would be LEAST appropriate?**
   a. Ibuprofen
   b. Acetaminophen
   c. Acetaminophen with hydrocodone
   d. Acetaminophen with codeine

10. **Which of the following signs should raise concern for compartment syndrome?**
   a. Increased warmth to the extremity
   b. Increasing need for analgesia
   c. Fever
   d. Bounding pulse

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POINTS & PEARLS

A Quick-Read Review Of Key Points & Clinical Pearls, July 2017

Nonaccidental Injury in Pediatric Patients: Detection, Evaluation, and Treatment

Points

- Though abuse may be diagnosed when a child is evaluated for a specific injury, findings such as bruising may be discovered on a routine physical examination conducted for other presenting complaints.
- In cases concerning for abuse, careful documentation is important; document words and statements in quotation marks, when possible.
- Bruising on the torso (T), ears (E), and neck (N) in any child aged < 4 years (TEN-4 clinical decision rule) or any bruising in an infant aged < 4 months is predictive of abuse.
- For patients with skin findings concerning for abuse, ask the family if they use traditional practices, such as skin scraping, cupping, or moxibustion.
- When abusive head trauma is suspected, consult an ophthalmologist within 48 hours for a dilated eye examination to detect retinal hemorrhages. Retinal hemorrhages in abusive head trauma are most commonly bilateral and involve the preretinal layer.
- Order screening liver function tests when there is concern for intra-abdominal injury associated with abuse. If the alanine aminotransferase or the aspartate aminotransferase level is > 80 IU/L, consider an abdominal CT scan.
- In children aged < 4 years, consider abuse in unwitnessed blunt thoracoabdominal injuries. In particular, duodenal trauma in children aged < 5 years is highly suggestive of an abusive etiology.
- Fractures of the posterior ribs, scapula, sternum, and spinous processes without a history of trauma are highly suspicious for abuse.
- Children aged < 2 years with suspicion of or with obvious physical abuse (including abusive burns) should have a skeletal survey to evaluate for occult fractures. Skeletal surveys should also be obtained for siblings of injured abused children aged ≤ 2 years, regardless of physical examination findings.
- Contact the patient's primary care provider prior to discharge to inform them of the situation and to aid in coordination of further outpatient management.
- Challenging periods for caregivers may trigger abuse. Acknowledging that parenting can be frustrating and providing alternative coping strategies may prevent maltreatment.
- Medical providers are mandated reporters and must report any concern for the possibility of abuse to Child Protective Services as soon as suspicion arises. Reporting to Child Protective Services facilitates the investigation and the mobilization of resources to help the child, and does not automatically trigger removal of the child from the home.

Pearls

- About one-third of children who died from abuse were previously seen by a healthcare provider for injuries that were not recognized as abuse; abuse cases are more often missed on first presentation to the emergency department due to provider biases and the misconception that abuse only happens in certain populations.
- Sentinel injuries are relatively minor injuries (eg, bruises, scleral hemorrhages, or intraoral injuries) that are inadequately explained and therefore concerning for abuse.
- Even in children with bleeding diatheses, bruises on the ears, neck, cheeks, and genitalia are rare and should raise concern of abuse.

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Table 1. Differential Diagnosis of Nonaccidental Injuries

Sign	Differential Diagnosis
Bruising	• Mongolian spots (congenital dermal melanosis) • Bleeding disorders • Hemangiomas • Phytophotodermatitis • Malignancy • Connective tissue disorders (Ehlers-Danlos syndrome) • Healing practices (eg, coining and cupping) • Osteogenesis imperfecta • Vasculitis (Henoch-Schönlein purpura) • Ink stains (eg, those caused by new clothing)
Burns	• Hypersensitivity reactions • Friction blisters • Impetigo (may be confused with cigarette burns) • Phytophotodermatitis • Dermatitis herpetiformis • Accidental laxative ingestion • Healing practices (eg, coining, cupping, and moxibustion)
Fractures	• Normal variants of bone structures • Rickets • Congenital syphilis (can cause periosteal elevation) • Birth trauma • CPR (rarely causes rib fractures and very rarely causes posterior rib fractures)[56] • Osteogenesis imperfecta • Caffey disease • Osteomyelitis
Subdural hematomas	• Bleeding disorders • Vascular malformations • Glutaric aciduria type 1[53] • Benign extra-axial fluid • Menkes disease
Retinal hemorrhages	• Vasculitis • Vascular obstruction • Vaginal delivery (generally disappear by 4 weeks of age)[54] • CPR (retinal hemorrhages are rare after chest compressions and, if present, are usually in the presence of other risk factors for hemorrhage)[55]

Abbreviation: CPR, cardiopulmonary resuscitation.

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Clinical Pathway for Evaluation of Nonaccidental Injuries in Pediatric Patients

First Responders

What change(s) do you anticipate making in your practice as a result of this activity?

" Improved documentation and lower threshold for ordering labs and imaging.

" I'll use liver enzymes and computed tomography (when appropriate) in screening for abdominal trauma.

" I will look for bruising more often and use the TEN-4 rule of bruising. I will also consider abuse in an infant with vomiting and no fever.

" Continue to be vigilant for signs of child abuse in patients who come for other reasons.

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