



## Pediatric lower extremity trauma imaging: Building blocks for the developing radiologist

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### Abstract

Pediatric lower extremity injuries are a common clinical concern and represent a substantial portion of emergency department visits and orthopedic referrals in children. These injuries differ significantly from adult trauma due to the unique anatomical and physiological characteristics of the growing skeleton, particularly the presence of open growth plates, secondary ossification centers, and ongoing skeletal maturation. Accurate and timely radiologic evaluation plays a critical role in identifying the type, extent, and implications of lower extremity injuries in pediatric patients. This is essential not only for guiding clinical management but also for preventing long-term sequelae such as growth arrest, limb length discrepancies, angular deformities, and joint dysfunction. Radiologists must possess a comprehensive understanding of pediatric skeletal development, age-specific injury patterns, and the implications of various trauma mechanisms in different pediatric age groups. Furthermore, distinguishing normal developmental variants from true pathology is a frequent challenge that requires a high level of expertise. This article provides an extensive overview of the radiologic assessment of pediatric lower extremity injuries, encompassing common fractures and soft tissue injuries from the pelvis to the foot. Detailed discussion is provided on critical entities such as slipped capital femoral epiphysis, Salter-Harris physeal fractures, toddler's fractures, triplane and Tillaux fractures, and signs of non-accidental trauma. The selection of appropriate imaging modalities ranging from conventional radiography and ultrasound to MRI and CT is discussed in the context of minimizing radiation exposure while optimizing diagnostic accuracy. In addition, the article highlights red flags for child abuse, common pitfalls in interpretation, and the importance of multidisciplinary collaboration in the care of injured children. As pediatric imaging continues to evolve with advances in technology and imaging protocols, radiologists must stay informed and vigilant to ensure accurate diagnoses and optimal patient outcomes. This review aims to serve as a practical guide and reference for radiologists encountering pediatric lower extremity trauma in clinical practice.

**Keywords:** Pediatric trauma, lower extremity injuries, radiology, growth plate, physeal injury, salter-harris fracture, MRI, non-accidental trauma, pediatric skeletal development, toddler's fracture, imaging modalities, developmental anatomy, child abuse imaging, radiographic interpretation, orthopedic radiology

### Introduction

Pediatric lower extremity injuries constitute a substantial portion of childhood trauma cases, often resulting from falls, sports-related activities, motor vehicle accidents, and non-accidental trauma. Due to their high activity levels and ongoing physical development, children are uniquely vulnerable to specific patterns of musculoskeletal injuries that differ significantly from those seen in adults. Epidemiological studies have shown that lower extremity injuries account for nearly 30–40% of all pediatric orthopedic emergencies, with fracture patterns and severity varying by age group and mechanism of injury [1, 2]. This underscores the necessity for radiologists to be well-versed in the clinical and developmental nuances that affect imaging interpretation in the pediatric population. Unlike in adults, the pediatric skeleton is in a dynamic state of growth and remodeling. The presence of physes (growth plates), cartilaginous epiphyses, and secondary ossification centers introduces complexities in image interpretation, where normal developmental anatomy may mimic pathology and vice versa [3]. The radiologist's understanding of skeletal maturity, expected radiographic appearances at different ages, and typical injury mechanisms is essential for accurate diagnosis. Growth plate injuries, in particular, carry the risk of long-term complications such as premature physeal closure, growth disturbances, angular deformities, and altered limb biomechanics if not identified and managed

promptly [4]. In pediatric trauma, radiologic imaging serves as the cornerstone of diagnosis and triage. Conventional radiographs remain the first-line modality for most suspected lower extremity injuries due to their accessibility and diagnostic value, but in cases where fractures are subtle or occult, advanced imaging such as ultrasound, CT, or MRI may be warranted [5, 6]. Modalities must be selected judiciously to balance diagnostic yield against the risks of radiation exposure and sedation in younger patients. Furthermore, radiologists are often the first to recognize imaging features suggestive of non-accidental trauma a diagnosis that carries significant medico-legal implications and requires immediate multidisciplinary intervention [7]. This article provides a comprehensive review of pediatric lower extremity injuries with a radiologic focus, covering key anatomical regions from the pelvis to the foot. It addresses age-specific injury patterns, common and rare fracture types, imaging strategies, diagnostic pitfalls, and radiographic signs that indicate underlying pathology or abuse. In doing so, it equips radiologists with the necessary knowledge to perform accurate assessments, contribute meaningfully to clinical decisions, and ultimately improve outcomes in pediatric trauma care. The radiologist's role in pediatric imaging extends beyond diagnosis; it includes radiation safety, image quality assurance, and active collaboration with pediatricians, orthopedic surgeons, and child protection services [8].

**Pediatric Skeletal Anatomy and Development  
Growth Plates (Physes) and Their Relevance in Imaging**

The growth plate, or physis, is a critical structure in the developing skeleton, composed of cartilage and located at the ends of long bones. It is the primary site of longitudinal bone growth during childhood and adolescence. In radiographic imaging, physes appear as radiolucent lines between the metaphysis and epiphysis, but their appearance varies with age, skeletal maturity, and the imaging modality used [9]. Due to their cartilaginous composition, growth plates are more susceptible to shear, compression, and avulsion forces than the adjacent bone. As a result, physeal injuries are common in children and account for up to 15% of all pediatric fractures [10]. These injuries are categorized using the Salter-Harris classification system, which is vital for assessing prognosis and determining appropriate management strategies. Salter-Harris type I and II injuries generally have favorable outcomes, while type III to V injuries pose a higher risk of growth arrest and require meticulous evaluation by radiologists [11]. Recognizing subtle physeal widening, irregular metaphyseal cupping, or early physeal fusion on follow-up imaging is crucial for predicting complications such as limb length discrepancy or angular deformities.

**Ossification Centers and Normal Variants**

Ossification in the pediatric skeleton follows a well-documented, chronological pattern, with each bone developing from one or more ossification centers. These centers appear and fuse at characteristic ages, which can be referenced using standardized atlases such as the Greulich and Pyle or Tanner-Whitehouse methods [12]. For example, the distal femoral epiphysis typically ossifies by birth, while the proximal tibial epiphysis appears shortly thereafter. Awareness of these timelines is essential for differentiating between normal anatomic development and pathology. Normal variants, such as accessory ossification centers (e.g., os trigonum, os tibiale externum), may be mistaken for avulsion fractures or bone fragments in trauma settings. Similarly, irregular epiphyseal margins or asymmetrical ossification, particularly during growth spurts, should not be misinterpreted as pathological unless supported by clinical signs or additional imaging [13]. Radiologists must remain vigilant to avoid overcalling normal developmental findings as fractures or misclassifying subtle injuries due to

underdeveloped anatomy.

**Bone Development Stages and Implications in Trauma**

Bone development in children involves a transition from a predominantly cartilaginous framework to a fully ossified skeleton. The three primary regions the diaphysis (shaft), metaphysis (flared end), and epiphysis (end cap) undergo different patterns of mineralization and remodeling during growth [14]. The metaphysis, rich in trabecular bone, is a common site for pediatric fractures due to its mechanical weakness during rapid growth phases. This area is especially prone to buckle (torus) fractures and greenstick fractures, both of which are nearly exclusive to children because of the plasticity and pliability of immature bone [15]. The presence of an open physis also alters the biomechanics of force transmission during injury, causing fractures to occur at different anatomical levels than would be expected in adults. Moreover, the healing process in pediatric bones is faster and often accompanied by robust periosteal reactions, which may obscure subtle injuries or mimic infectious or neoplastic processes in follow-up imaging [16].

**Differences from Adult Anatomy and How They Affect Injury Interpretation**

Several key anatomical differences between pediatric and adult skeletons must be considered in imaging interpretation. Children have a thicker periosteum that is more loosely attached to bone, which contributes to the stability of incomplete fractures but also complicates the radiographic appearance of cortical disruption [17]. In addition, the immature skeleton contains significant amounts of cartilage, which is not radiopaque and may render certain injuries occult on plain radiographs. This necessitates the use of adjunctive imaging modalities such as ultrasound for joint effusions or MRI for occult fractures, particularly in non-verbal or uncooperative children [18]. The incomplete ossification of epiphyses can also obscure joint alignment, complicate the evaluation of dislocations, and limit the ability to assess intra-articular fractures. Radiologists must therefore adapt their interpretation strategies and imaging protocols to account for these differences, using age-appropriate techniques and maintaining a high index of suspicion for subtle injuries that may not be radiographically apparent in early stages.

**Table 1:** Key Differences Between Pediatric and Adult Skeletal Anatomy Relevant to Imaging and Trauma

Feature	Pediatric Skeleton	Adult Skeleton
Growth Plates (Physes)	Open, cartilaginous, susceptible to injury	Closed, fused, not a site of injury
Ossification Centers	Multiple, appear and fuse at predictable ages	Fully ossified, no secondary centers
Periosteum	Thicker, more active, loosely attached, aids in fracture healing	Thinner, tightly attached, slower healing
Fracture Patterns	Torus, greenstick, Salter-Harris, plastic deformation common	Complete, comminuted, spiral more common
Bone Composition	More porous, higher collagen content, more pliable	Denser, less flexible
Healing Response	Faster healing, exuberant callus formation	Slower healing, minimal periosteal response
Joint Composition	Incomplete ossification may obscure alignment or fractures	Fully ossified, joint spaces well-defined
Trauma Response	Injury often involves growth plates or metaphysis	Injury usually affects diaphysis or articular surfaces
Imaging Limitations	Radiolucent cartilage, occult injuries common on plain radiographs	Bone more visible on radiographs, fewer occult injuries
Radiation Sensitivity	Higher sensitivity; imaging must minimize exposure	Lower sensitivity; greater tolerance to radiation

**Mechanisms and Patterns of Injury in Pediatric Patients  
Common Causes: Falls, Sports, Vehicular Trauma**

In pediatric populations, the most frequent causes of lower extremity injuries include accidental falls, sports-related trauma, and motor vehicle collisions. Falls are especially prevalent in toddlers and young children due to their relatively poor coordination, unrefined balance, and high

activity levels. The majority of these falls occur in domestic environments such as playgrounds, stairs, or furniture, often resulting in low-energy trauma like buckle or torus fractures of the tibia or fibula [19]. Sports injuries become increasingly common in older children and adolescents, particularly as they engage in organized physical activities. High-impact sports such as football, basketball, gymnastics, and

skateboarding can produce a wide spectrum of injuries ranging from soft tissue sprains and avulsion fractures to complex intra-articular injuries. Adolescent athletes are also prone to overuse syndromes and stress-related injuries like osteochondritis dissecans and apophyseal avulsions due to repetitive strain on immature skeletal structures [20]. Vehicular trauma, including pedestrian collisions, bicycle accidents, and motor vehicle crashes, accounts for a smaller proportion of injuries but often involves high-energy impact with potential for complex, multi-system injuries. These cases frequently require comprehensive radiologic assessment to identify both apparent and occult injuries to the lower extremities, pelvis, and spine. Such high-energy mechanisms increase the likelihood of physeal fractures, dislocations, and fractures involving multiple anatomical regions [21].

### Age-Specific Injury Patterns

Injury patterns vary significantly across pediatric age groups due to differences in activity, anatomy, and biomechanics. In infants and toddlers (0–3 years), non-ambulatory status makes any fracture concerning for non-accidental trauma, particularly spiral femoral fractures or metaphyseal corner fractures [22]. In this age group, subtle injuries such as toddler's fractures non-displaced spiral fractures of the tibia are common and may only be visible on oblique or follow-up radiographs. In early childhood (4–7 years), increased mobility and risk-taking behaviors lead to metaphyseal fractures of the tibia and femur, commonly following playground accidents. Ligamentous injuries are rare in this group, as the physis is weaker than the ligaments, making bony injury more likely than soft tissue damage [23]. In middle childhood and adolescence (8–16 years), more adult-like patterns begin to emerge. The closure of growth plates during puberty leads to an increased frequency of complete long bone fractures and intra-articular injuries. Avulsion injuries are common at sites of tendon or ligament attachment, such as the anterior superior iliac spine or the tibial tubercle, particularly in adolescents involved in jumping sports [24].

### Overview of Injury Classification Systems (e.g., Salter-Harris)

Among the most widely used systems for classifying pediatric fractures is the Salter-Harris classification, which specifically categorizes physeal (growth plate) injuries based on the fracture's relationship to the metaphysis, physis, and epiphysis. This classification system is crucial because it directly correlates with prognosis and the potential for growth disturbances.

- **Type I:** Fracture through the physis only, often radiographically occult. Generally, has excellent prognosis [25].
- **Type II:** Involves the physis and metaphysis, the most common type with good prognosis if promptly treated.
- **Type III:** Fracture through the physis and epiphysis, often intra-articular and requires precise alignment to prevent joint dysfunction.
- **Type IV:** Extends through the metaphysis, physis, and epiphysis, posing a high risk for physeal bar formation.

- **Type V:** Compression injury to the growth plate, often unrecognized initially and associated with a high rate of growth arrest [26].

Additional classification systems may be used depending on the anatomical site and type of injury. For example, the Ogden classification is used for apophyseal avulsion injuries, and the Peterson classification expands on Salter-Harris by including metaphyseal and diaphyseal fracture patterns [27].

### Imaging Modalities in Pediatric Lower Extremity Injuries

#### Conventional Radiography: First-line Imaging; Technique Tips

Conventional radiography remains the cornerstone of initial assessment in pediatric lower extremity trauma due to its availability, cost-effectiveness, and relatively low radiation dose. Standard views typically include anteroposterior (AP) and lateral projections, but additional oblique or stress views may be necessary depending on clinical suspicion. Pediatric radiographic interpretation must account for normal developmental variants such as accessory ossification centers, growth plates, and the appearance of cartilaginous structures, which may be misinterpreted as fractures [28]. Proper technique is critical motion artifacts, improper positioning, or inadequate field coverage can result in missed diagnoses. Immobilizing young children and using distraction techniques or caregiver assistance often ensures better image quality. Importantly, comparison views of the contralateral limb may be warranted in cases of ambiguous findings, particularly in non-displaced or subtle fractures [29].

#### Ultrasound: Role in Soft Tissue, Joint Effusions, and Toddler's Fractures

Ultrasound is an increasingly valuable adjunct in pediatric musculoskeletal imaging, offering real-time, radiation-free evaluation of soft tissue and superficial bony structures. It is particularly useful in detecting joint effusions, guiding aspirations, identifying abscesses, or evaluating tendinous and muscular injuries. In lower extremities, ultrasound can detect hip effusions in cases of suspected transient synovitis or septic arthritis and can reveal cortical disruptions in toddler's fractures, which may be radiographically occult [30]. Its sensitivity in early detection of subperiosteal fluid collections also aids in diagnosing osteomyelitis. However, operator expertise is paramount, as musculoskeletal ultrasound is highly dependent on the skill and experience of the sonographer. While it cannot penetrate deep bone or evaluate intra-articular pathology comprehensively, it remains a powerful tool in initial assessments and follow-up evaluations [31].

#### CT Scan: When to Use, Radiation Concerns, Trauma Protocols

Computed Tomography (CT) provides superior spatial resolution and multiplanar imaging, making it invaluable for complex or high-energy trauma, particularly in assessing intra-articular fractures, pelvic injuries, and when surgical planning is required. In pediatric patients, CT is reserved for cases where radiography and ultrasound are inconclusive, or when three-dimensional evaluation is critical. Despite its diagnostic strengths, CT is used judiciously due to its higher

radiation exposure, which poses a greater risk to growing tissues and increases lifetime cancer risk [32]. Low-dose pediatric protocols, shielding, and limiting scan range are crucial in minimizing exposure. Trauma centers often follow established guidelines like the ALARA (As Low as Reasonably Achievable) principle and pediatric-specific protocols to balance diagnostic yield with safety [33].

**MRI: High Soft-Tissue Contrast, Occult Fractures, Physeal Injuries**

Magnetic Resonance Imaging (MRI) offers unparalleled soft tissue contrast and multiplanar capability without ionizing radiation, making it the gold standard for detecting occult fractures, physeal injuries, and soft-tissue abnormalities. It

is particularly beneficial in cases where initial radiographs are normal but clinical suspicion remains high, such as in stress fractures, avulsion injuries, or early osteomyelitis. MRI can visualize unossified cartilaginous structures and distinguish between normal developmental variants and true pathology, a significant advantage in pediatric musculoskeletal imaging [34]. Moreover, it is highly effective in evaluating the integrity of ligaments, menisci, and muscle compartments in lower extremity trauma. However, MRI is not always readily available in emergency settings, and younger children may require sedation due to longer acquisition times. Still, its role in comprehensive, non-invasive evaluation makes it indispensable, especially when long-term skeletal growth is at stake [35].

**Table 2:** Summary of Imaging Modalities in Pediatric Lower Extremity Injuries

Imaging Modality	Strengths	Limitations	Typical Use Cases
Conventional X-ray	First-line, fast, low-cost, low radiation	Limited soft tissue detail; can miss subtle or early fractures	Initial trauma evaluation, fracture confirmation
Ultrasound	No radiation, good for soft tissue and superficial bone, real-time	Operator-dependent, limited penetration	Joint effusions, toddler’s fractures, soft tissue injuries
CT Scan	High-resolution bone detail, 3D reconstructions	High radiation, costly, less effective for soft tissue	Complex fractures, intra-articular involvement, surgical planning
MRI	Excellent soft tissue contrast, no radiation, multiplanar	Expensive, limited access, may require sedation	Occult fractures, physeal injuries, soft tissue evaluation
Nuclear Medicine	High sensitivity for bone turnover, whole-body screening	Low specificity, high radiation, poor anatomical detail	Osteomyelitis, stress fractures, multifocal bone pain

**Common Lower Extremity Injuries by Anatomic Region**  
**Hip and Pelvis**

**Slipped Capital Femoral Epiphysis (SCFE):** SCFE is one of the most serious hip conditions in adolescents, characterized by displacement of the femoral head epiphysis posteriorly and inferiorly relative to the femoral neck through the growth plate. It predominantly affects overweight males between the ages of 10 and 16 and often presents with vague groin, thigh, or knee pain and a limp.

Radiographically, the diagnosis is confirmed with anteroposterior and frog-leg lateral views of the pelvis, showing a widened and irregular physis and posterior displacement of the femoral head. The Klein’s line, which normally intersects the femoral head, fails to do so in SCFE. Early recognition is essential as delayed diagnosis can result in avascular necrosis, chondrolysis, and long-term degenerative joint changes [36] (Figure 1).



**Fig 1:** Slipped capital femoral epiphysis (SCFE). AP and frog-leg lateral radiographs of pelvis show posteromedial slippage of both femoral heads with an abnormally smooth, widened and lucent physes (greater on the right side).

**Developmental Dysplasia of the Hip (DDH):** DDH encompasses a spectrum of hip abnormalities ranging from mild acetabular dysplasia to complete dislocation. It is most commonly diagnosed in infants and is associated with risk factors such as breech presentation, female sex, and family history. Ultrasonography is the modality of choice in neonates due to the lack of ossification in the femoral head. Key sonographic findings include shallow acetabular angles and hip instability on dynamic maneuvers. Radiographs become useful after 4–6 months when ossification begins. Timely diagnosis is crucial to allow for non-surgical management options like the Pavlik harness, preventing long-term complications such as gait abnormalities and

early-onset osteoarthritis [37].

**Femur**

**Diaphyseal Fractures:** Diaphyseal femur fractures are among the most common long bone fractures in pediatric patients and often result from high-energy trauma such as motor vehicle accidents or falls. The radiologic appearance can vary widely, including transverse, spiral, or comminuted patterns. Treatment strategies differ by age, with spica casting preferred in younger children and flexible intramedullary nailing or external fixation used in older children. Radiologic follow-up is essential to monitor alignment, as remodeling capacity decreases with age [38].

**Distal Femoral Physeal Injuries:** These injuries are particularly concerning due to the distal femoral physis contributing approximately 70% of femoral growth. They are prone to complications such as growth arrest and angular deformities. Salter-Harris classification helps in guiding

treatment, with higher-grade injuries often requiring surgical intervention. MRI is valuable in assessing associated soft tissue injury and determining the extent of physeal disruption, especially when radiographs appear normal despite clinical suspicion<sup>[39]</sup> (Figure 2).



**Fig 2:** Fracture across the distal femoral metaphysis and physis (Salter Harris type II) on the frontal radiograph and better seen on coronal fluid-sensitive MRI sequence with surrounding marrow and soft tissue edema.

**Knee**

**Tibial Spine Fractures:** These are avulsion-type injuries at the tibial attachment of the anterior cruciate ligament (ACL), typically seen in children aged 8 to 14. They occur due to hyperextension or rotational forces and may mimic ACL tears seen in adults. Radiographs may demonstrate an elevated bony fragment anterior to the tibial plateau, but CT or MRI may be required for preoperative planning. Accurate diagnosis ensures appropriate surgical repair to prevent instability and restore full knee function<sup>[40]</sup>.

MRI is the imaging modality of choice to assess fragment stability and cartilage integrity, which dictates management strategy. Early diagnosis is critical for conservative management, whereas unstable lesions may require surgical fixation<sup>[41]</sup>.

**Tibia and Fibula**

**Toddler's Fracture:** This subtle, non-displaced spiral fracture of the distal tibia typically occurs in ambulatory toddlers after minor trauma. The child may refuse to bear weight but otherwise appears well. Radiographs may initially appear normal or show only faint lucency, necessitating follow-up imaging or clinical suspicion for diagnosis. Management is conservative, often with a cast, and outcomes are excellent when identified early<sup>[42]</sup> (Figure 3).

**Osteochondritis Dissecans:** This condition involves separation of a segment of articular cartilage and subchondral bone, typically affecting the lateral aspect of the medial femoral condyle. It presents with vague knee pain, swelling, and mechanical symptoms such as locking.

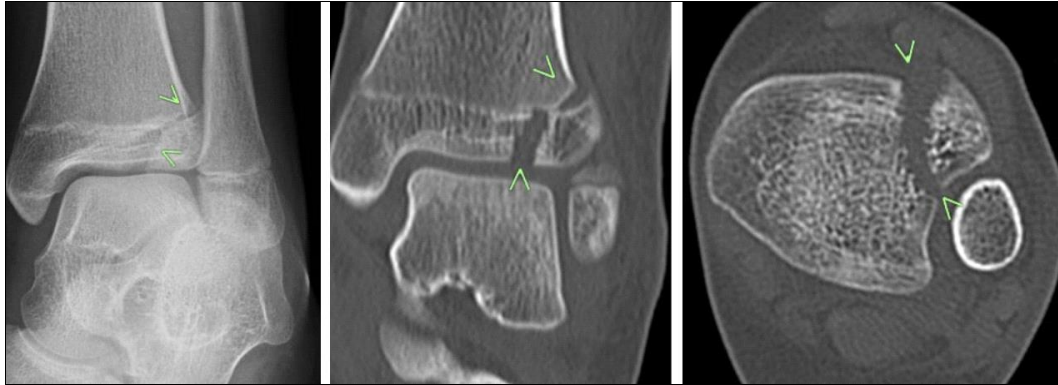


**Fig 3:** Toddler's fracture. AP and lateral radiographs of tibia and fibula show a lucency in the distal tibial diaphysis, consistent with a nondisplaced spiral fracture.

**Proximal Tibial Metaphyseal Fracture:** These injuries are usually the result of valgus stress and are commonly associated with trampoline accidents or direct blows. They pose a risk for developing late genu valgum due to asymmetric growth stimulation. Radiographs demonstrate a transverse or oblique fracture line in the proximal metaphysis, and long-term follow-up may be required to assess limb alignment [43].

**Ankle and Foot**

**Juvenile Tillaux Fracture:** This is a Salter-Harris type III fracture involving the anterolateral portion of the distal tibial epiphysis. It typically occurs in adolescents nearing physeal closure, resulting from external rotational forces. Radiographs and CT scans help in assessing displacement and guiding surgical decision-making. Prompt diagnosis and anatomical reduction are essential to prevent joint incongruity and early arthritis [44] (Figure 4).



**Fig 4:** Juvenile Tillaux Fracture. AP radiograph of ankle, coronal and axial CT show a Salter-Harris III fracture of the distal tibia. The fracture line extends horizontally through the lateral physis and vertically through the epiphysis to the articular surface.

**Triplane Fracture:** This complex fracture involves sagittal, transverse, and coronal planes of the distal tibia and is exclusive to adolescents undergoing physeal fusion. Imaging with CT is often required to understand the fracture

geometry. Open or closed reduction may be necessary based on displacement, and surgical fixation is typically warranted for fractures with >2 mm step-off [45] (Figure 5).



**Fig 5:** Triplane fracture. AP and lateral radiographs of the ankle show a triplane fracture of the distal tibia with the following fracture planes: oblique coronal of the metadiaphysis, horizontal of the anterolateral physis and sagittal of the epiphysis.

**Red Flags for Non-Accidental Trauma (Child Abuse)**

Non-accidental trauma (NAT), widely recognized as child abuse, remains a major diagnostic and social concern in pediatric radiology. The role of the radiologist is critical in identifying the signs of inflicted injury, particularly in infants and young children who are too young or developmentally unable to communicate the nature of their

trauma. Many cases of NAT come to light during radiologic assessments, especially when the provided history is absent, inconsistent, or incompatible with the child's injuries. Injuries that should raise red flags include fractures in infants who are not yet mobile, multiple fractures at varying stages of healing, or lesions that do not align with the

explanation given by caregivers. The highest risk group includes children younger than six months, where any injury without a clear medical explanation should prompt further scrutiny and investigation [46].

From an imaging perspective, several characteristic findings are strongly indicative of abuse. One of the most pathognomonic is the classic metaphyseal lesion (CML), often termed a "corner" or "bucket-handle" fracture, which typically results from repeated shearing forces, such as those

seen in shaking or violent pulling. These lesions are commonly located at the distal femur, proximal tibia, and proximal humerus. Posterior rib fractures are another significant red flag, frequently resulting from compressive squeezing of the chest. These are rarely observed in accidental trauma. Other skeletal injuries of concern include scapular fractures, fractures of the spinous processes, and complex skull fractures especially those crossing sutures or presenting with multiple fracture lines [47].

**Table 3:** Radiologic Indicators Suggestive of Non-Accidental Trauma

Radiologic Finding	Description
Classic metaphyseal lesions	Corner or bucket-handle fractures from violent pulling or shaking
Posterior rib fractures	Due to chest compression; highly suggestive of abuse
Scapular/spinous process fractures	Uncommon in accidents; result from high-impact trauma
Complex skull fractures	Multiple or sutural fractures inconsistent with minor injury
Multiple fractures in various stages	Signify repeated trauma over time
Long bone fractures in non-ambulatory children	Very suspicious in infants who cannot walk or crawl
Vertebral compression fractures	Rare in children; may reflect forceful impact or underlying pathology

**Pitfalls in Pediatric Imaging Interpretation**

Interpretation of pediatric imaging requires not only technical expertise but also a comprehensive understanding of the unique anatomical and developmental features of children. One common pitfall is mistaking normal variants for pathology. Pediatric bones undergo continuous physiological changes that can mimic disease. For instance, secondary ossification centers or growth plates may appear irregular and simulate fractures or lytic lesions. Similarly, nutrient foramina and cortical modeling can be misconstrued as pathological lucencies or defects [48].

Missed fractures constitute another major pitfall, particularly in the setting of subtle, non-displaced, or incomplete injuries. These can include buckle fractures, greenstick fractures, and toddler’s fractures, which may be occult on initial radiographs. A high index of suspicion based on clinical findings such as localized pain, swelling, or refusal to bear weight is crucial for guiding further imaging or repeat studies. Inadequate imaging technique, poor positioning, or suboptimal views may also contribute to missed diagnoses, highlighting the importance of comprehensive clinical correlation and communication between clinicians and radiologists [49].

Growth plate injuries present a distinct diagnostic challenge due to the complex and evolving appearance of the physis. Salter-Harris fractures, especially types I and V, can be radiographically occult or subtle, potentially leading to underdiagnosis or misclassification. Accurate assessment requires careful scrutiny of the metaphyseal and epiphyseal relationship and sometimes adjunct imaging such as MRI to reveal cartilaginous involvement.

**Radiologist's Role in Multidisciplinary Care  
Communication with Referring Physicians and Orthopedic Surgeons**

The radiologist plays a pivotal role in the multidisciplinary management of pediatric lower extremity injuries through precise and timely communication with referring clinicians and orthopedic teams. Pediatric injuries often involve complex presentations where clinical signs are subtle, and radiologic findings can be the primary basis for diagnosis. Therefore, radiologists must go beyond describing findings they must contextualize them. For instance, differentiating

between a benign variant and a suspicious metaphyseal lesion could change the trajectory of clinical management entirely. Direct communication, especially in cases where imaging findings raise concern for urgent intervention or possible abuse, ensures that decisions are based on shared understanding. This collaboration can occur during case discussions, in formal radiology rounds, or via electronic reporting systems with embedded recommendations. When radiologists proactively highlight subtle indicators such as periosteal reaction patterns or the orientation of fracture lines they add critical insight that might not be evident to other clinicians reviewing static images alone. Effective interdisciplinary communication not only improves diagnostic accuracy but also enhances patient safety and outcomes in acute and long-term care settings.

**Influence on Treatment Planning and Follow-Up Imaging**

Radiologists influence both immediate and longitudinal treatment strategies by providing detailed interpretations that guide clinical decisions. In the acute setting, the description of fracture alignment, growth plate involvement, or early signs of soft tissue compromise informs whether conservative management or surgical intervention is appropriate. For example, a minimally displaced tibial fracture may not require surgery, but if imaging reveals physeal widening or cortical irregularities, the plan could shift toward orthopedic consultation or urgent stabilization. Moreover, radiologists contribute to the planning of follow-up imaging schedules to monitor healing, detect complications such as delayed union or avascular necrosis, and evaluate response to treatment.

**Importance of Tailored Imaging Protocols to Reduce Radiation**

Radiologists also bear a crucial responsibility in minimizing radiation exposure while maintaining diagnostic quality. Pediatric patients are inherently more sensitive to ionizing radiation due to their smaller size, ongoing tissue development, and increased lifetime risk for radiation-induced conditions. Consequently, adherence to the ALARA (As Low as Reasonably Achievable) principle is fundamental in pediatric imaging. Radiologists must

carefully select modalities favoring ultrasound or MRI over CT when appropriate and customize radiographic protocols to reflect the child's size and the specific diagnostic need.

### Future Directions and Technological Advances

Artificial intelligence (AI) is rapidly transforming the landscape of pediatric radiology by offering decision-support tools that enhance diagnostic accuracy and streamline workflow. AI algorithms are being developed to automatically detect abnormalities such as fractures, bone age discrepancies, or early signs of infection with high sensitivity, thus acting as a second set of eyes for radiologists. Radiation safety remains a central concern in pediatric imaging, and future developments are focusing on optimizing image acquisition to achieve the lowest possible dose without compromising diagnostic quality. Emerging technologies such as photon-counting CT, iterative reconstruction algorithms, and automated exposure control systems allow for significant dose reductions compared to conventional methods. Magnetic resonance imaging (MRI) is gaining prominence in pediatric musculoskeletal radiology due to its superior soft tissue contrast and non-ionizing nature. Recent advances are pushing the boundaries of what MRI can reveal, particularly in the assessment of cartilage, ligaments, and early bone pathology<sup>[50]</sup>.

### Conclusion

Pediatric lower extremity injuries represent a uniquely challenging domain within musculoskeletal radiology due to the dynamic anatomical changes that occur during childhood, the complexity of differentiating between pathological and developmental findings, and the profound implications of missed or misinterpreted diagnoses on a child's long-term health. Radiologists must possess a comprehensive understanding of pediatric bone physiology, injury mechanisms, age-appropriate normal variants, and common pitfalls in interpretation to provide accurate assessments. The interpretation of pediatric imaging is not merely technical—it requires clinical acumen, multidisciplinary collaboration, and a deep appreciation for the context in which injuries occur, particularly in distinguishing accidental trauma from non-accidental causes such as child abuse. As outlined, injury types vary significantly with age and developmental stage, with fractures of the physis, metaphysis, and epiphysis each presenting with distinct patterns that demand careful evaluation. Furthermore, the importance of systematic approaches—ranging from appropriate modality selection to recognizing red flags for NAT and applying follow-up imaging protocols—cannot be overstated in ensuring timely intervention and prevention of long-term disability. Radiologists also play a crucial role in guiding management through communication with orthopedic surgeons and pediatricians, offering insights that inform both immediate treatment and longitudinal care. With technological innovation transforming diagnostic possibilities, tools such as artificial intelligence and advanced MRI now offer unprecedented capabilities in improving diagnostic accuracy, especially for soft tissue and cartilage assessment, while minimizing radiation exposure through low-dose CT and refined imaging protocols. These advancements are not standalone solutions but should be integrated with clinical judgment and ethical responsibility, particularly when children's welfare is at stake. In this evolving landscape,

continuous professional education, updated imaging guidelines, and institutional investments in pediatric-specific imaging infrastructure are indispensable. Ultimately, the radiologist's responsibility transcends diagnosis it involves advocacy, safeguarding, and contributing meaningfully to a child's overall health trajectory. By embracing these roles with precision, empathy, and foresight, radiologists stand as guardians of pediatric well-being in every imaging encounter involving lower extremity trauma.

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