Fractures in Children: What radiologists need to know

Poster No.: C-1681
Congress: ECR 2017
Type: Educational Exhibit
Authors: M. B. Bolina¹, F. Mazega², W. Moreira², R. L. F. C. Diniz¹, M. Ribeiro², E. G. P. C. Motta³, L. Ramos², B. Ramos², T. P. Moreira Ferreira², ¹BELO HORIZONTE, MI/BR, ²Belo Horizonte/BR, ³093, MG/BR
Keywords: Education, MR, CT, Conventional radiography, Paediatric, Musculoskeletal bone, Trauma
DOI: 10.1594/ecr2017/C-1681

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

• To provide a practice-based overview of fracture diagnosis in children.
Background

Trauma is one of the most common causes of infant mortality, and fractures make up about 25% of pediatric injuries. It is critical to determine which injuries require greater attention.

Due to anatomical and physiological differences, the effects of trauma in children can be different from adults'. Fundamental differences include:

- the physis or growth plate
- plasticity of pediatric bones, more likely to bend or to present "incomplete fractures".

High-quality orthogonal radiographic views are the initial exam performed. Computed Tomography (CT) can detail osseous anatomy and Magnetic Resonance Imaging (MRI) is superb in detecting growth plate's injury.
Findings and procedure details

PHYSEAL FRACTURES:

The physis or growth plate is the most important feature that differentiates bones of children from that of an adult. The physis is a narrow band of cartilage that lies between the epiphysis at the end of the bone and the metaphysis. Because it contains an expandable matrix, it can permit longitudinal bone growth.

Physeal fractures may provoke length discrepancies and growth disturbances. The manipulation and preservation of the physis is the most unique and challenging feature of children's fracture care. Fractures that extend through the physis or traverse the physis and its adjoining metaphysis or epiphysis are best described by the Salter-Harris classification. This radiographic classification system is based on the location of the fracture with respect to the physis. It reliably describes physeal fractures and helps to guide treatment.

Salter-Harris classification:

- Type I: is a transepiphysyal separation without evidence of a metaphyseal fragment (Fig. 1).
- Type II: the fracture line is through the physis, exiting into the metaphysis, leaving a small triangular portion attached to the physeal plate, called Thurston-Holland fragment. It represents the most common (nearly 75%) all physeal fractures (Figs. 2, 3 and 4).
- Type III: fracture traversing the physis and exiting through the epiphysis (Figs. 5 and 6).
- Type IV: describes a vertical fracture line that passes through the epiphysis, physis, and metaphysis (Fig. 7).
- Type V: fracture describes a crush injury to the physis that usually is not apparent on initial injury films.
- Type VI: fracture is a localized injury to a portion of the perichondrial ring and subsequent healing produces bone formation across the perimeter of the physis, connecting the metaphysis to the epiphysis.

A distal femoral physeal fracture indicates that the young knee was exposed to very high forces, as the distal femoral growth plate has been designed to resist very high shear and translational forces. Most distal femoral physeal injuries are Salter-Harris type I and II fractures (Figs. 1 and 4).
Ankle fractures in children constitute approximately 5% of all pediatric fractures and can be classified into two categories:

Group I. Low risk, including avulsion fractures and epiphyseal separations (Salter-Harris types I and II - Fig. 3)

Group II. High risk, including fractures through the epiphysis (Salter-Harris types III - Fig. 6 - and IV) and displaced transitional fractures.

Salter-Harris type III injuries may occur in the distal phalange secondary to extensor tendon of the finger. The deformation caused by these injuries is called "mallet finger", which in Albertoni classification may occur without fractures: tendon rupture (type I), avulsion fracture (type II), base fracture (type III) or physis fracture (type IV) (Fig. 5).

INCOMPLETE FRACTURES:

There are unique pediatric incomplete fractures as plastic deformation, greenstick fractures, and torus fractures.

- **Plastic deformation**: represents an internal microscopic mechanical failure of bone that results in both an angular and rotational distortion of long bones, seen predominantly in diaphyseal cortical bone. This occurs when the force applied is greater than the elastic limits of the bone but less than that which produces a failure of the internal structure (obvious fracture). Radiographs reveal angulation without an obvious fracture line.

- **"Torus" fracture** (Figs. 8 and 9): The metaphysis of long bones is composed mostly of cancellous bone surrounded by a thin layer of cortical bone. If a longitudinal force is applied along the axis of the extremity, this thin cortex will fail in compression producing the typical bulging of the "torus" or "buckle." This compression failure occurs most commonly at the metaphyseal-diaphyseal junction, the site of transition from the dense cortical bone of the diaphysis to the more porous metaphyseal type. Torus fractures are typically not associated with soft-tissue swelling at the fracture site. While this pattern is most commonly seen in the distal radius, it can also occur in the metaphyses of the distal femur, proximal tibia, and proximal humerus.

- **Greenstick fracture** (Figs. 10 and 11): in a typical incomplete greenstick fracture pattern there is a failure of the tension side and plastic deformation on the compressive or concave side. Thus, it is characterized by a complete fracture of one cortex and plastic deformation of the opposite cortex. Apex-
volar greenstick fracture is the most common type. Reduction is often indicated when shaft angulation is > 15 degrees.

TEENAGE FRACTURES:

- **Tibial Tubercle Fracture** *(Fig. 12)*: The tibial tubercle is the anterior and distal extension of the proximal tibial epiphysis. It develops a secondary ossification center and serves as the insertion site of the patellar tendon. Fracture of the tibial tubercle is an injury of the adolescent knee joint, usually occurring in boys between 13 and 16 years of age.

- **Avulsion fractures of the pelvis**: are not uncommon injuries seen in adolescents and young adults. The usual mechanism is a sudden and forceful concentric or eccentric muscle contraction, which occurs with rapid acceleration or deceleration. This mechanism is commonly seen in particular sporting activities. The same mechanism that would cause a muscle or tendon strain in an adult may cause an apophyseal avulsion in an adolescent. The common avulsions are from the anterior superior iliac spine (ASIS) due to violent contraction of the sartorius as seen in jumping or running; from the anterior inferior iliac spine (AIIS) due to overpull of the straight head of the rectus femoris *(Fig. 13)*, and from the ischial tuberosity due to forceful contraction of the hamstrings.

Transitional Fractures: Tillaux and triplane fractures are referred to as *transitional fractures* because they occur in adolescents during the transition from an open physis to skeletally mature distal tibia and fibula. These fractures are high risk. Closure of the distal tibial growth plate begins centrally, proceeds medially, and closes last on the lateral side. This sequence of closure is responsible for transitional fracture patterns.

- **Tillaux fracture** *(Fig. 14)*: results from an external rotational force and consists of avulsion of the anterolateral portion of the distal tibial epiphysis by the anterior tibiofibular ligament. This is a biplane Salter-Harris type III injury. Diagnosis can be difficult in patients with nondisplaced or minimally displaced fractures. CT scanning with or without three-dimensional reconstruction is useful for evaluation and management of transitional fractures.

- **Triplane fracture**: also caused by external rotation of the foot. On anterior-posterior radiographs, it appears as a Salter-Harris type III fracture, but on the lateral projection it appears to be a type II fracture. The triplane fracture may be a two-part or a three-part fracture.

UPPER LIMB FRACTURES:
Two-thirds of childhood fractures involve the upper extremity, specially forearm, elbow, and clavicle.

- **Forearm fractures** *(Figs. 15 and 16)*: Distal radius physeal fracture accounts for approximately 15% of all forearm fractures, with 70% of these injuries occurring in children older than 10 years. Eighty percent are Salter-Harris type I or II injuries. More complex injuries are uncommon but have higher rates of premature growth attest. Fractures of the distal radius and ulna are usually caused by a fall onto the hand with the wrist in a pronated, extended position. Unicortical fractures (i.e., torus or buckle fractures) are stable injuries that are quite common, however, they should be differentiated from minimally displaced or angulated bicortical fractures because the latter have a propensity for secondary angulation. Complete fractures of the forearm result from higher energy trauma than do greenstick fractures.

- **Elbow fractures**:
  - **Supracondylar fracture of the humerus** *(Figs. 17, 18 and 19)*: is the most common elbow fracture. The usual mechanism of injury is a hyperextension load on the elbow from falling on the outstretched arm. The distal fragment displaces posteriorly in more than 95% of fractures. The classification system most commonly used is that of Gartland, who described three stages of displacement: type I, nondisplaced or minimally displaced; type II, angulated with moderate disruption but with a portion of the cortex maintaining end-to-end contact; and type III, completely displaced. A type IV fracture with multidirectional instability has been described. Lateral and AP radiographs are usually sufficient, and in many instances demonstrate an obvious fracture. Often, however, no fracture line can be identified. In such cases assessing for indirect signs is essential, such as the anterior fat pad sign and the posterior fat pad sign. Displacement of the posterior fat pad *(arrow in Fig. 18b)* is a reliable indication of an intra-articular effusion. The anterior fat pad is sometimes seen under normal conditions and does not necessarily indicate joint effusion. The anterior humeral line is an easier means of assessing sagittal alignment. A line along the anterior humeral cortex should pass through the capitellum. If the capitellum is posterior to this line a displaced supracondylar, lateral condylar, or transphyseal fracture is likely. A normal elbow demonstrates the alignment of the radius with the capitellum. In supracondylar elbow fracture, the radius and the capitellum remain aligned, despite displacement of the distal humeral fragment.

  - **Fracture of the lateral condyle of the humerus**: is the second most common elbow fracture in children. The peak age range for this injury is 5 to 10 years. This is a complex fracture because it involves the physis and the articular surface. It is a Salter-Harris type IV injury in most cases *(Fig.7)*, but a significant portion of the fragment is unossified, especially in children younger than 5 years.
• **Fracture of the medial condyle of the humerus (Fig. 20):** is an unusual injury. Medial condyle fracture may be misdiagnosed as medial epicondyle avulsion in children between the ages of 5 and 7 years. The mechanism of injury is similar to that for medial epicondylar fracture, but medial condyle fracture is a much more serious injury, because it involves the articular surface. If the condyle is displaced more than 2 mm, open reduction and internal fixation is recommended.

• **Fracture separation of the distal humeral physis (Fig. 20):** is seen primarily in infants and young children. The mechanism of injury involves rotatory shear forces, resulting in a Salter-Harris type I or type II fracture pattern. Abuse should be suspected.

• **Clavicle fractures (Fig. 21):** The clavicle is frequently fractured in children, and the most common portion injured is the shaft. The mechanism of injury is usually a fall on the shoulder, an excessive lateral compression of the shoulder girdle, or a difficult birth. Birth trauma may also result in Salter-Harris type I physeal separation of the proximal humerus, which may be difficult to diagnose radiographically because the proximal humeral epiphysis does not ossify until 3 to 6 months of age. Ultrasonography or MRI may facilitate diagnosis in questionable cases.

---

**FRACTURES RELATED TO CHILD ABUSE**

The Child Abuse Prevention and Treatment Act (CAPTA) defines child abuse and neglect as "any act or failure to act resulting in imminent risk of serious harm, death, serious physical or emotional harm, sexual abuse, or exploitation of a child by a parent or caretaker who is responsible for the child's welfare". The term "nonaccidental trauma" is often used to describe injuries from abuse. However, it is a term that attempts to describe what the injury is not and is felt by some to be inaccurate. There is some debate as to which fracture patterns are most common in child abuse. Radiographic differentiation of traumatic injuries from abuse is not possible for most injuries, as many of the fracture patterns seen in abuse can also be seen after accidental trauma.

Some specific fracture patterns should be easy to recognize as being inflicted by abusive trauma:

• Metaphyseal "bucket-handle" or "corner" fractures - are considered pathognomonic for abusive trauma.
• Complex skull fractures
• Rib fractures (especially posterior) - highly suggestive of intentional injury. The finding of multiple rib fractures in children 3 years or younger had a positive predictive value of 100% when children with a defined history of accident or disease were excluded.
• Transverse fracture under 1 year old - risk factor for abuse (eg. femoral shaft fractures or fractures of the humeral shaft). Age is one of the most important factors in differentiating accidental from abusive trauma. For example, single diaphyseal spiral fractures of the tibia or femur are common accidental injuries in toddlers, but are suspicious if the child is perambulatory (Fig. 22).
• Fracture separation of the distal humeral physis (Fig. 20) - Abuse should be suspected.
• Subtle fractures and those in various stages of healing. For this reason, skeletal surveys (quality orthogonal radiographs of the skull, spine, long bones, hands, and feet) are mandatory in any case of suspected abuse.

Stages of fracture healing:

o Subperiosteal new bone formation (SPNBF) is first seen at about 5 to 7 days after the injury

o Indistinctness or resorption of the fracture line is seen at 10 to 14 days after injury

o Soft callous formation begins within 2 to 3 weeks after fracture.

o More advanced calcification and remodeling are more variable but typically occur at least 6 weeks from the injury.

o Harris-Park growth arrest lines can form after fractures and their distance from the adjacent physis can help to date older injuries.

In any instance of delay in seeking medical attention, inconsistent history of injury (Fig. 23) or evidence of concurrent injuries, there is an increased likelihood of inflicted trauma. However, there is no particular pattern of fracture that is diagnostic of child abuse.

PATHOLOGICAL BONE FRACTURE

A pathological bone fracture (Fig. 24) is a bone fracture which occurs without adequate trauma and is caused by a preexistent pathological bone lesion. Causes include resorption of bone mass (osteonerosis), reduction of bone quality (osteomalacia, osteonecrosis), insufficient bone production (osteogenesis imperfecta, fibrous dysplasia), augmented bone resorption (giant cell granulomas, aneurysmal bone cyst), pathological bone remodelling (Paget's disease), or local bone destruction due to tumorous growths.
**Fig. 1:** A 12-year-old boy with a recent history of trauma presenting a Salter-Harris type I injury. Left knee coronal Proton Density (PD) fat saturation MRI showing discrete thickening and hypersignal of the physeal plates of distal femur and proximal fibula.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 2: A 12-year-old female patient relating low energy trauma during sports practice at school. Radiographs in anteroposterior (a) and lateral view (b) presenting physeal fracture extending to the proximal tibial metaphysis (Salter-Harris type II fracture). Computed tomography images in coronal (c) and sagittal (d) reconstructions confirm and detail the lesion.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 3: A 12-year-old girl with severe pain after right ankle sprain. Radiographs (a, b, c) and CT scans (d, e, f, g) showing Salter-Harris type II fracture affecting the physeal plate and distal tibial metaphysis. This fracture was hardly evident in anteroposterior (a) and internal rotation (b) radiographs.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 4: A 14-year-old male patient presenting a Salter-Harris type II fracture involving the physeal plate and distal femoral metaphysis - radiograph (a) and MRI (b and c). Note the hypersignal of the affected portion of the physeal plate in coronal PD fat sat (b). c: Coronal T1-weighted sequence.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 5: A 13-year-old male patient with a Salter-Harris type III fracture involving the physeal plate and epiphysis of distal phalanx of left third finger - an intra-articular fracture with dorsal fragment avulsion (mallet finger - Albertoni type IV).

© HOSPITAL MATER DEI - BELO HORIZONTE/BR

Fig. 6: A 12-year-old male patient with a Salter-Harris type III fracture affecting the physeal plate and distal epiphysis of the tibia - Radiograph reveals intra-articular fracture with lateral fragment (a); CT 3D (b) and coronal (c) reconstructions confirm and detail the lesion.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 7: A 6-year-old male patient presenting an intra-articular fracture crossing the physis of the lateral condyle of the humerus and involving the capitulum (Salter-Harris type IV) - Radiographs (a and b) and CT (c) images.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR

Fig. 8: A 7-year-old male patient after low energy axial trauma in upper limb presents the typical bulging of the cortex (arrow in a) characteristic of the torus fracture involving the distal radial metaphysis.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 9: A 9-year-old male patient presenting a torus fracture (note the bulging of the cortex - arrow in a) involving the radial shaft.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 10: An 8-year-old male patient relating low energy trauma presenting angular deformity due to radius shaft greenstick fracture - note the posterior cortex complete fracture and the anterior cortex plastic deformation.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 11: A 6-year-old male patient with a Greenstick fracture involving the ulna diaphysis (posterior angle).

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
**Fig. 12:** A 15-year-old male patient with previous history of Osgood Schlatter’s disease presenting a Tibial tubercle fracture extending to the proximal tibial epiphysis and articular surface of the tibia (Salter-Harris type III). The involvement of the tibial plateau is more evident on computed tomography (b - sagittal reconstruction) when compared to radiography (a). c: CT axial image.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR

**Fig. 13:** A 15-year-old boy with pain in the right inguinal region started one week before, when he was about to kick the ball during football practice. Radiography (a) and MRI of the hip (b) showing avulsion fracture of the right anterior inferior iliac spine, where the straight head of the rectus femoris muscle originates.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 14: A 14-year-old boy presenting a Tillaux fracture - better seen in the internal rotation (b) than in the anteroposterior view (a), since the fibula does not overlap it. Tillaux fracture is an avulsion of the anterolateral portion of the distal tibial epiphysis (c - CT axial image) by the anterior tibiofibular ligament.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 15: A 6-year-old patient presenting complete distal metaphyseal radial fracture with anterior angle and posterior (dorsal) displacement of the distal fragment - Colles fracture.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 16: A 9-year-old patient presenting diaphyseal fractures of both the forearm bones, with anterior angle and posterior (dorsal) displacement of distal fragments.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 18: A 9-year-old female patient presenting a nondisplaced supracondylar fracture of the humerus (Gartland I). Radiographs (a and b) and CT (c).

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 19: Completely displaced supracondylar fracture of the humerus (Gartland III). It has been made analgesic immobilization before proceeding to imaging.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 20: 1-year-and-6-months child presenting deformity and disability in left upper limb after fall. Radiographs (a and b) and CT 3D reconstruction (c) showing a displaced medial condyle fracture. This is a Salter-Harris type II fracture which may be confused with elbow dislocation because of the lack of ossification of distal humerus in young children.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR

Fig. 21: Bilateral midshaft clavicle fractures of a newborn patient.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 22: Patient at 6 months of age presenting a diaphyseal femur fracture with misalignment (a and b) - suspicion of child abuse. Single diaphyseal spiral fractures of the tibia or femur are common accidental injuries in toddlers, but are suspicious if the child is preambulatory. Control radiograph (c) 4 months later showing fracture healing.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Fig. 23: 18-month-old patient - child abuse suspected because of inconsistent history of low-energy trauma but high energy-related fracture.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
**Fig. 24:** A 6-year-old male patient presenting pathological fracture in proximal humerus. Local bone destruction due to tumor growth with related fracture evidenced in radiograph (a), coronal (b) and 3D (c) CT reconstructions.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR

**Fig. 17:** A 17-month-old patient with a nondisplaced supracondylar fracture of the humerus. The posterior fat-pad is displaced so that it is now visible (arrow in b). This reflects joint effusion and, in the setting of trauma, is considered an indirect sign of fracture. There is also an anterior fat-pad sign, which is less specific for a fracture.

© HOSPITAL MATER DEI - BELO HORIZONTE/BR
Conclusion

- Children must not be considered "small adults", due to differences in anatomy and response to trauma.
- Radiographs are the first imaging technique recommended.
- It's indispensable not to forget the limitations of imaging techniques.
- In case of doubt it may be useful to compare both sides
- Metaphyseal corner fractures, complex skull fractures, multiple injuries, fractures in various stages of healing, posterior rib fractures, transverse fracture under 1 year old, fracture separation of the distal humeral physis and inconsistent history of injury suggest child abuse.
- Although fractures in children usually heal with little intervention, it is critical to be able to determine which injuries require greater attention.
References
