Sonographic evaluation of pediatric fractures

Poster No.: C-0346
Congress: ECR 2017
Type: Educational Exhibit
Authors: B. Garcia Martinez¹, M. Pelaz Esteban², V. Gomez-Dermite³, M. OTERO¹, P. Gallego Ferrero¹, V. Fernandez-Lobo¹, Santander/ES, Liencres, Cantabria/ES, miengo/ES
Keywords: Trauma, Inflammation, Diagnostic procedure, Ultrasound, Conventional radiography, Paediatric, Musculoskeletal bone
DOI: 10.1594/ecr2017/C-0346
Learning objectives

• To show the usefulness of the ultrasound studies in the diagnosis of fractures during the pediatric age
Background

Fractures are one the most frequent pathologies during the pediatric age. Between birth and age 16, 42% risk of fracture for boys and 27% for females.

These fractures are different from those that happen in adults, due to the special features of the immature bone.

Bone in children and is more porous than adult bone, with wider haversian canals. A child's bones are more elastic than an adult's are. Two terms are important here: plasticity and elasticity. Bones in children permit a greater degree of deformation before they break. In adult's bones resistance and elasticity to angular deformation is significantly less.

The periosteal sleeve is much thicker in children than in adults and acts as a restraint to displacement. The thick periosteal sleeve is important for pediatric skeletal remodeling. Subperiosteal resection of a child's bone shows the regeneration potential associated with the periosteum: the tubular bone eventually reforms inside the periosteal sleeve. Thus, the child's bone has an innate potential to heal itself.

The epiphysis is an important part of the growing skeleton. It is a secondary ossification center. The physis is to the growth plate, which is a disklike structure at the end of the metaphysis; the epiphysis is a cartilaginous structure that sits atop the physis. It is the most vulnerable part of children's bone.

Common types of pediatric fractures

A) Incomplete fractures:

- Torus fractures: compression failure of bone that usually occurs at the junction of the metaphysis and the diaphysis.
- Plastic deformation: a force produces microscopic failure on the convex side of bone which does not propagate to the concave side. The bone is angulated beyond its elastic limit, but the energy is insufficient to produce a fracture.
- Greenstick fractures: Bone is bent and the convex side of the bone fails. Fracture line does not propagate to the concave side of the bone, therefore showing evidence of plastic deformation.
B) **Complete fractures**: fracture completely propagates through the bone. Classified as spiral, transverse, or oblique, depending on the direction of the fracture line.

C) **Physeal fractures**: fractures to the growth plate can be caused by crushing, vascular compromise of the physis or bone growth bridging from the metaphysis to the bony portion of the epiphysis. Damage to growth plate may result in progressive angular deformity, limb-length discrepancy or joint incongruity. They are divided into five types by the Salter-Harris classification:

- **I**: Separation through the physis, usually through areas of hypertrophic and degenerating cartilage cell columns
- **II**: Fracture through a portion of the physis that extends through the metaphyse
- **III**: Fracture through a portion of the physis that extends through the epiphysis and into the joint
- **IV**: Fracture across the metaphysis, physis and epiphysis
- **V**: Crush injury to the physis

D) **Stress fractures**: spiral fractures of the long bones, typical of the first steps (12-18 months).

E) **Apophyseal avulsion fractures**: where a portion of cortical bone is ripped from the rest of the bone by the attached tendon; usually seen in adolescents in pelvis bones.
Findings and procedure details

The diagnosis of the fractures is based on the physical exam and the conventional radiology. The X-ray study should include two perpendicular views (AP and lateral) of the affected bone and the joints in which is involved. In case of doubts, oblique or contralateral views could be done. A disadvantage is the inevitable radiation exposure.

The ultrasound may replace or supplement the X-ray studies, for example, by avoiding oblique or contralateral views, which increase the radiation dose. It is also very useful in the study of the cartilage, which is not visible in X-ray, adjacent soft tissues and the presence/absence of joint leak. It allows us to identify the subtle fractures, like the torus fractures.

Advantages and disadvantages of the ultrasound studies:

A) ADVANTAGES:

- It does not use ionizing radiation
- Real time images
- It allows the interaction between the radiologist and the child, and give him the opportunity to know the exact symptoms
- Dynamic study, with maneuvers of pain provocation, to identify the pathologic area
- Detailed evaluation of the adjacent soft tissues

B) DISADVANTAGES:

- The major problem of ultrasound is that is a operator dependent study, where the experience is really important
- Requires direct contact with the affected surface, and the child may not cooperate due to the pain
- Not possible to perform in open or unstable fractures

An adequate ultrasound technique should include a quiet and relaxing environment; the child should be as much calmed and comfortable as possible. In fracture sonography, regular 4- to 12-MHz linear transducers are used with abundant amount of gel. The suspected area should be explored in two orthogonal planes (longitudinal and transverse axis) and it is mandatory to compare with the contralateral side, which is normal reference.

The normal bone (fig. 1) is seen at the ultrasound studies as an hyperechogenic regular line, composed by the peristium and the cortical. The cartilage is seen as a hipoechogenic area with fine echogenic dots.
The diagnoses of fracture could be made by following the direct or indirect signs of fracture:

1) Direct signs:
   - Hypoechogenic interruption of the cortical line (figs. 2,3)
   - Cortical irregularity (figs. 4,5)
   - Cortical angulation (figs. 6,7)
   - Bone fragments (figs. 8,9)

2) Indirect signs:
   - Leak joint / lipohemartros (the result of a fat and bone marrow blood leaking into the joint space, a reliable sign of intra-articular fracture) (fig. 10)
   - Inflammatory changes of the adjacent soft tissue (hyperechogenic fat and hyperemia) (fig. 11)
   - Hematomas (fig. 7)

In the case of the apophyseal avulsion fractures, the ultrasound study is more useful than the X-ray ones because of the cartilaginous nature of the lesion. It allows the visualization of the epiphysis displacement, the physeal enlargement and the adjacent soft tissue involvement (figs. 12-14). It is also possible to explore the unstable fractures by the dynamic maneuvers.

In addition, we report some different cases of bone fractures in children diagnosed by ultrasound studies (figs. 15-19).
Fig. 2: Example of hypoechogenic interruption of the cortical line.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
Fig. 4: Example of irregularity of the cortical, typical of the torus fractures.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
**Fig. 5:** RIGHT CUBOID FRACTURE. 10-year-old girl with pain in the outer edge of the right foot. An increase in the density in this area at the X-Ray (red circle), is related to an irregularity of the right cuboid (blue arrow) with hyperemia, at the ultrasound imaging.

© Universitary Hospital Marqués de Valdecilla - Santander/ES

**Fig. 7:** TORUS FRACTURE OF THE RIGHT PROXIMAL RADIUS. 12-year-old boy with right elbow pain after trauma. A doubtful of irregularity of the cortical of the radius is seen at the X-Ray (red arrow). With the ultrasound imaging we can diagnose a torus fracture, shown a cortical angulation of the proximal radius (blue arrow), comparing with the left side, and a small haematoma in the fat tissue.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
**Fig. 8:** Two examples of fractures with bone fragments.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
Fig. 9: EPIPHYSEAL FRACTURE TYPE II OF THE DISTAL PHALANX OF THE LEFT FIRST TOE. 6-year-old boy with pain in the left first toe after trauma. The X-ray does not show a clear image of fracture, only a doubtful metaphyseal fragment (red arrow), so we decided to complete the study with an ultrasound. It shows a epiphyseal fracture type II of the distal phalanx, demonstrating the presence of the metaphyseal bone fragment (blue arrow).

© Universitary Hospital Marqués de Valdecilla - Santander/ES
Fig. 10: LIPOHEMARTROS. 5-year-old boy with right elbow pain. The ultrasound study shows the three different layers of the lipohemartros, which is typical of intraarticular fractures (in this case, supracondylar fracture).

© Universitary Hospital Marqués de Valdecilla - Santander/ES
**Fig. 3:** SKULL FRACTURE. 2-year-old girl who underwent a head trauma. With the X-Ray we only could see a doubtful hypodense line in the lateral view (red arrow), which was demonstrated in the ultrasound study, as a hypoechogenic interruption of the cortical line (blue arrows).

© Universitary Hospital Marqués de Valdecilla - Santander/ES
Fig. 1: Normal bone appearance on ultrasound: A) the periostium and the cortical are seen as a regular hyperechogenic line. B) The articular cartilage is seen as a hipoechogenic area with fine echogenic dots.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
**Fig. 6:** Example of cortical angulation, compared with the contralateral side which is the standard of normality.

© Universitary Hospital Marqués de Valdecilla - Santander/ES

**Fig. 12:** Most frequent areas of apophyseal avulsion fractures in the pelvis.
Fig. 13: AVULSION FRACTURE OF THE LEFT ANTERIOR INFERIOR ILIAC SPINE. 11-year-old girl with left hip pain after playing football. The X-Ray of the pelvis is normal. With the ultrasound imaging we can see the avulsion of the AIIS and an small adjacent haematoma (red arrow).

© Universitary Hospital Marqués de Valdecilla - Santander/ES

Fig. 14: MR imaging of the anterior patient (fig. 13), which shows the avulsion of the AIIS, perfectly correlated with the previous ultrasound study.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
**Fig. 11:** Inflammatory changes in the soft tissue adjacent to a fracture, which appears hyperechogenic and presents local hyperemia.

© Universitary Hospital Marqués de Valdecilla - Santander/ES

**Fig. 16:** LEFT CAPITATE FRACTURE. 7-year-old boy with wrist pain after trauma. The X-Ray study shows an increase of the density of soft tissues of the back of the wrist (red arrow). With the ultrasound imaging we can diagnose a fracture of the capitate, shown a hypoechogenic interruption and irregularity of the cortical (blue arrow), comparing with the right side, and hyperemia of the adjacent soft tissues.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
**Fig. 17:** EPIPHYSEAL FRACTURE TYPE III OF THE RIGHT ULNA. 9-year-old boy with pain on the outer edge of the right ankle. On the X-Ray we only can see an increase of the density of the soft tissue (red arrow). A type III epiphyseal fracture of the ulna is seen with the ultrasound imaging, showing a small fragment of bone (blue arrow).

© Universitary Hospital Marqués de Valdecilla - Santander/ES

**Fig. 15:** TORUS FRACTURE OF DISTAL PHALANX. 6-year-old girl with pain of the left thumb after trauma. A doubtful of alteration of the cortical angulation of the distal phalanx is seen at the X-Ray (red arrow). With the ultrasound imaging we can diagnose a torus fracture, shown a cortical angulation of the distal phalanx (blue arrow), comparing with the right side.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
Fig. 19: AVULSION FRACTURE OF THE FIBULA. 9-year-old boy with pain on the outer edge of the right ankle, like in the two anterior cases. On the X-Ray we can see an increase of the density of the soft tissue (red arrow), and also a doubtful image of small bone fragment in the lateral view (yellow arrow). The ultrasound study shows a small bone fragment attached to the anterior talo-fibular ligament (blue arrow), typical of the avulsion fractures.

© Universitary Hospital Marqués de Valdecilla - Santander/ES

Fig. 18: ANKLE SPRAIN. 10-year-old girl with the same clinic than the case above. On the X-Ray we only can see an increase of the density of the soft tissue (red arrow). In this case, the ultrasound study shows an hypoechogenicity and thickening of the anterior talo-fibular ligament (blue arrow), without signs of fracture.

© Universitary Hospital Marqués de Valdecilla - Santander/ES
Conclusion

- The ultrasound studies are a bloodless technique without ionizing radiation, very useful in the diagnosis of fractures in children. Their use allows us to reduce the radiation level in children population.
- It can be used as a compliment of the conventional radiology in subtle fractures and avoiding the realization oblique and contralateral views.
- It is better than X-ray in the study of the leak joint and the soft tissue inflammation.
- In the case of the apophyseal avulsion fractures, ultrasounds allow us to identify the epiphyseal cartilaginous fragment.
References