Role of magnetic resonance Imaging in pediatric suspected metaphyseal fractures

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Purpose

The immature bones of children present structural and functional changes; these are mainly due to the presence of many components (epiphysis, apophysis, physis, metaphysis, diaphysis and periosteum), which are able to change the response to a particular traumatic agent in relation to the time.

The epiphysis and the growth plate are the main contributors to bone growth, so injury to these structures can have lasting and devastating effects on the potential growth and can lead to limb shortening and deformity [1].

Although radiography allows a reasonable evaluation of metaphyseal fractures and is the initial method for evaluation, MR imaging has emerged as an important adjunct, and in most cases a primary tool, in occult traumatic injuries of growth plate for the evaluation of type of fracture, localization and degree of physeal involvement, besides detecting the presence of bone bridge [2,3].

The most widely accepted system for classifying these fractures has been proposed by Salter-Harris, describing five classical types of fractures [4], and S-H II type is the most frequent of them (Figure 1). The Salter-Harris classification has been subsequently extended by Ozonoff, Rang and Odgen, with the assistance of more careful study of lesions using MRI, and four additional types were added (Figure 2) [5].

The purpose of our study is demonstrating the role of MR in order to recognize metaphyseal injuries which are difficult to identify through other imaging methods.

Images for this section:
**Fig. 1:** Schematic representation of Salter-Harris classification.

**Fig. 2:** Schematic representation of Salter-Harris additional fractures types (type VI, VII, VIII and IX), according to Ozonoff, Rang and Ogden.
Methods and Materials

A total of 6904 pediatric Patients were seen for acute osteoarticular trauma in the Emergency Department of Regina Margherita Children's Hospital between July 2010 and July 2011.

In 907 (13,13%) Patients, aged 10 weeks -18 yrs, metaphyseal injury was suspected [6].

602 were male (66,37%) and 305 were female (33,67%); 9 were birth fractures and were studied only with US imaging.

After orthopaedic investigation in 898 patient, CR was performed, but only 54 (6%) were studied with MR. They were between 8-17 yrs, 29 were male and 24 were female.

We excluded young patients who requested narcosis for a long time, patients with absolute contraindications like orthodontic appliance, magnetic heart valve prothesis and those whose CR had shown evident physeal widening and associated fracture lines within epiphysis, metaphysis [8] and patients whose parents didn't agree to perform RM.

The skeletal sites we had studied with MR are:

- distal radial bone 10 (18,86%) (7);
- proximal ulnar bone 2 (3,77%);
- proximal humeral bone 5 (9,4%);
- proximal tibial bone 13 (24,5%) (6);
- distal tibial bone 8 (15%);
- distal fibular bone 1 (1,8 %);
- proximal femoral bone 4 (7,5%);
- distal femoral bone 10 (18,86%) (6).

The MR study included axial and coronal FSE T1w, FSE T2w fat sat, T2w STIR and motion-sensitived driven equilibrium prepared rapid GRE (MERGE) scans.

Results
MR was performed in 16 patients (5 distal radius, 7 proximal tibia, 4 distal femur) where asymmetrical physeal widening was seen on CR (in suspected Salter-Harris 1) but no physeal signal alteration was shown because this finding in proximal tybia and distal femur corresponded to metaphyseal bowing.

In 5 distal radius (2 gymnasts and 1 tennis player) the irregular physeal widening was expression of overuse.

In 38 patients, MR imaging detected physeal signal alteration but in 3 cases with suspected CR 1 was a Trevor's disease at distal fibula, 1 femoral notch at the proximal femur and 1 an osteochondritis desicans at the distal femur.

At the end 35 MR were characteristic for trauma:
- distal radial bone 5 (14.3%) 3 Salter-Harris (SH) fractures VIII (Figures 3, 4) and 2 SH V;
- proximal tibial bone 6 (17.1%) 3 SH VII, 1 SH I (Figures 5, 6) and 1 SH III;
- distal tibial bone 8 (22.8%) 5 SH III, 1 SH II (Figures 7, 8), 1 SH IV and 1 SH V;
- proximal femoral bone 3 (8.57%) SH I;
- distal femoral bone 6 (17.1%) 3 SH VIII, 2 SH 1 and 1 SH III;
- proximal ulna bone 2 (5.7%) SH 7;
- proximal homeral bone 5 (14.3%) 2 SH 3 and 2 SH1;

MR diagnostic accuracy was 100% because recognized all the metaphyseal traumatic lesions, all the false positive (FP) plain radiography.

In our experience MR represents an essential imaging tool in the diagnostic evaluation of Salter Harris I, V, VII and VIII fractures.

Finally, MR has shown high sensitivity in the early detection of the development of metaphyseal bone bridges especially during the follow-up of Salter Harris fractures type I, IV and V.

MR proved to be particularly useful in S-H fractures type I (Figures 9, 10 and 11, 12), V, VII and VIII with negative or poorly significant CR.

Type I fractures follows an impact lesion of the physeal plate and is characterized by a tear of the growth cartilage along the orizontal plane, corresponding to the layer of hypertrophic or degenerated cells, while the rest of the cartilage remains supportive to the epiphysis, with a cross-slip of the epiphyseal nucleus. Salter-Harris type 1 lesion may also be minimal and take place without a recognizable epiphyseal displacement, thus
resulting in a negative radiographic inspection: in doubtful cases, the diagnosis has been confirmed by performing a MRI examination.

Type V lesions are the results of compression forces that affect the growth of cartilage surface, more or less orthogonally, causing its destruction by crushing and/or serious damage to the loco-regional vasculature, but without involvement of the epiphyseal nucleus.

Type VI damages the perichondral structures.

Type VII only affects the epiphysis, without involving the physis.

Type VIII gives isolated injury to the metaphysis, with a potential injury related to endochondral ossification.

Type IX damages the periosteum that may interfere with membranous growth.

Images for this section:
Fig. 3: S-H fracture type VIII, distal radio, female of 14 yrs old. CR: negative result.
**Fig. 4:** Same case as the previous image. MR (coronal FSE T2w fat sat): the spongiosa metaphyseal appears hyperintense.

![Image](image-url)

**Fig. 5:** Dislocation of the left knee: Male of 13 yrs old. C.R.: - absence of bone lesions - soft tissues swelling of the tibial apophysis
Fig. 6: Same case as the previous image. MR (coronal FSE T1w (a) and STIR (b)): - Oedema of the subcutaneous tissue; - Traumatic sofference of the tibial epyphiseal cartilage; - Intrarticular effusion; -Irregularity of the fibres of the patellar tendon in proximity of the tendon insertion; - Hoffa's fat pad edema.
**Fig. 7:** S-H fracture type II, distal tibia. CR : doubtful result.
**Fig. 8:** Same case as the previous image. MR (coronal T2w standard STIR image): - Oedema of the spongy epyphysis; - hypointense line of fracture; - oedema of the peri-articular soft tissue.
**Fig. 9:** S-H fracture type I, distal femur, Male of 10 yrs old. CR: asymmetrical expansion of the left distal femoral physis.

**Fig. 10:** Same case as the previous figure, MR (coronal STIR image): the lateral femoral growth plate appears hyperintense.
**Fig. 11:** Suspected S-H fracture type I of the right distal tibia, female of 12 yrs old. CR: suspected asimmetrical extension of the right tibial physis.
Fig. 12: Same case as the previous image. MR (coronal STIR image): normal appearance of the tibial growth plate.
Conclusion

Musculoskeletal injuries remain an important cause of morbidity in the pediatric population.

Although plain radiography is still the primary imaging tool, MR imaging has evolved into an essential additional diagnostic tool for the prompt identification of occult musculoskeletal injuries.

Growth plate injuries and their complications can be diagnosed early and confidently with MR imaging when other imaging modalities are equivocal [2]. Infact, recent data have confirmed that Salter Harris fractures are often underreported because a significant number of normal radiographs turned out to have physeal fractures after undergoing MR imaging and such identification led to a significant change in the clinical management of these patients [7,10].

MR provides useful information and has valuable advantages for demonstrating some radiographically hidden fractures, and in assessing impact bone lesions, balancing the extent of dislocation of ossification nuclei (in order to address a conservative or surgical approach) and in subsequent determination of a possible growth arrest caused by premature closure of the physis (partial or full) [9].

In monitoring physis trauma, MR shows the extent and direction (transverse or longitudinal) of the lesion and is also capable of recognizing the possible presence of a post-traumatic transphyseal vascularity that predisposes to the formation of osteofibrous bridge (Figure 13), prodromal growth disorders (growth arrest, angular deformities shortenings) if not promptly treated (resection for bone bridges involving less than 50% of the physis or epiphysiolysis for more extensive bone bridges) [9].

MR imaging, therefore, offers an unreplaceable aid in clinical decisions because the patients without trauma weren't treated; in those with fractures, the therapy strategy hasn't changed but MR permits to detect patients who risked further complications like the formation of osteofibrous bridge (especially in SH V and III) and to do a clinical and radiological long-term follow-up.

Images for this section:
**Fig. 13:** S-H fracture type V distal radio, Male of 11 yrs old. C.R.(left): physis irregularity and slight disacement of the epyphysis. MR follow-up (right): coronal STIR image with metaphiseal bridge.
References


Personal Information