ABSTRACT • PURPOSE: To assess the value of ultrasound as an adjunct to radiography in minor musculoskeletal pediatric trauma.

METHODS: Fifty children with 53 suspected fractures were referred for upper and/or lower limbs X-rays, followed by ultrasound. On radiography, we noted presence of fracture, of soft tissue thickening, or absence of any lesion. On ultrasound, we noted presence of fracture, of soft tissue lesion, or absence of lesions.

RESULTS: A fracture was seen on both examinations in 25 patients with 28 fractures. In 4 patients where only soft tissue thickening was seen on radiography, ultrasound showed fracture in 1 patient, hematoma in 1 patient and was normal in 2 patients. In another patient with a doubtful diagnosis of fracture on radiography, ultrasound was normal. In 20 patients with normal X-rays, ultrasound showed fracture in 6 patients, hematoma in 7 patients and was normal in 7 patients.

CONCLUSION: Ultrasound was helpful as an adjunct to radiography, it yielded additional bone (7/50 patients) and soft tissue (8/50 patients) diagnostic information in 30% of patients. However, ultrasound remains operator-dependent and can be used only in particular circumstances, especially in children with normal X-rays and a high index of clinical suspicion for an occult or subradiological fracture.

INTRODUCTION

There were major changes in ultrasound equipment this past decade with a steady and major improvement of image quality, and notably of spatial resolution. This technical progress, along with a better knowledge of musculoskeletal ultrasound allowed extending its use to musculoskeletal trauma [1-5]. In these settings, ultrasound can play an important role in pediatrics [6-9]. Several studies have already shown that ultrasound imaging can be better than radiography in some circumstances such as scaphoid fractures in adults and ankle or rib fractures in children [1-3, 9-10]. This study compares radiography and ultrasound in 50 consecutive pediatric patients referred for minor limb trauma.

MATERIALS AND METHODS

A prospective study was undertaken from November 2006 to February 2007 concerning 50 consecutive children, aged between 6 months and 14 years, who had an
X-ray and an ultrasound for a minor limb trauma. A minor limb trauma was defined as a limb trauma having all the following characteristics:

- Involving one or two sites.
- Not associated to an open wound.
- No fracture detectable on X-ray or fracture detectable on X-ray but not displaced and involving only one cortical line.

According to our study protocol, a senior pediatric resident or a qualified specialist first examined all patients in the Emergency Department. Then if a fracture was suspected, an X-ray was performed in the Radiology Department. If the trauma met the criteria of minor as defined above it was followed systematically by an ultrasound performed by a senior radiology resident trained in musculoskeletal imaging. He studied the X-rays and performed the ultrasound. The combined results of ultrasound and radiography were presented to the physician in charge of the patient to apply treatment. A specialized musculoskeletal radiologist reviewed all the X-rays and ultrasound examinations within 14 hours.

Ultrasound was performed using Acuson Antares (Siemens Medical Solutions, Mountain View, CA) machine with a linear high resolution probe (13 MHz). The study technique consisted of exploring the painful area and/or the site of the confirmed or suspected fracture, as well as the cortical line, growth plate cartilage, ligaments, tendinous structures and the fat planes. A comparison with the normal contralateral side was always done.

On X-ray, a fracture was defined as the presence of a cortical disruption (classical fracture) or deformity (torus fracture). A soft tissue lesion on X-ray was defined as the presence of soft tissue thickening.

A fracture on ultrasound was defined as the presence of a cortical disruption or cortical deformity. A hematoma on ultrasound was defined as the presence of an anechoic or hypoechoic non vascularized collection on color Doppler; the hematoma, when present, was classified as subperiosteal, juxta-physeal, periarticular or muscular. A ligament lesion on ultrasound was defined as the presence of one or more of the following findings: 1) thickening of a ligament, 2) intra-ligament hematoma, and/or 3) disruption of the ligament.

Comparative results between X-rays and ultrasound were based on clinical information obtained the day of injury, on clinical follow-up, and on follow-up by X-rays:

- A fracture was considered present when:
  - seen on X-rays and ultrasound;
  - in case of discordance between X-ray and ultrasound for detection of a fracture, the follow-up X-ray was checked for the presence or absence of bone healing. Fracture was considered present if bone healing was detected and absent if no bone healing was detected.
- A “significant musculoskeletal lesion” was considered present if a fracture was present and/or if a hematoma or a ligament lesion was seen on ultrasound. In case of soft tissue thickening on radiography, we considered it true positive if a fracture, a hematoma or a ligament lesion was found on ultrasound and false positive if ultrasound was strictly normal.

**RESULTS**

On radiography, 20 patients had a normal radiograph, 25 patients had 28 fractures (associated to soft tissue thickening in 4 cases), one patient had a doubtful diagnosis for a fracture and 4 patients had soft tissue thickening only. All 28 fractures seen on X-rays were also seen on ultrasound (Fig. 1). In these 28 fractures, ultrasound showed also a subperiosteal hematoma in 27. In one patient a fracture
**Figure 2.** Periarticular hematoma of the ankle.

**Figure 3.** Avulsion fracture at the metaphysis of the proximal humerus.
was suspected radiographically but it was eliminated by ultrasound. In 4 patients where soft tissue thickening was seen on radiography, ultrasound showed a fracture associated to a hematoma located near the growth plate cartilage in one patient, an isolated periarticular hematoma in another patient (Fig. 2), and was normal in the remaining 2 patients. In the 20 patients with normal radiography, ultrasound showed a fracture with an associated subperiosteal hematoma in 6 patients (Fig. 3), an isolated hematoma in 7 patients (2 subperiosteal, 1 near the growth plate cartilage and 4 periarticular), and was normal in 7 patients. Overall, ultrasound showed 35 fractures associated to subperiosteal hematoma in 33 patients and a juxta-physeal hematoma in one patient, as well as 8 isolated hematomas, and 10 normal exams. No ligament lesion, muscular hematoma or periosteal elevation was found in this series.

Discordance between the radiologist specialized in musculoskeletal imaging and the radiology senior resident was present in only one case, a fracture that the radiology resident missed on radiography but detected on ultrasound. This case was classified in our results as a positive X-ray finding of fracture.

In 7 of 8 cases of discordance between X-ray and ultrasound concerning the presence of a fracture, follow-up X-ray showed callus formation confirming the diagnosis of fracture made by ultrasound. In the last case where ultrasound was normal and a doubtful diagnosis considered on X-ray, the patient was classified as having no fracture and no follow-up X-ray was requested by the physician because the clinical follow-up was satisfactory.

The results are summarized in table I. Overall, ultrasound yielded additional bone and soft tissue diagnostic information in 30% of traumatized patients.

**DISCUSSION**

The first applications of ultrasound (US) in musculoskeletal diseases in children were limited to non ossified structures such as developmental dysplasia of the hip joints and articular effusions [11]. Afterwards, there were studies comparing US to X-ray in bone fractures using X-rays as gold standard; these studies showed comparable results with some benefit of X-rays in few situations such as comminuted fracture [6-8, 12]. Other studies followed comparing ultrasound and X-rays but using a different gold standard such as MRI, CT scan, radiographic follow-up, or combination of several of these examinations e.g. combination of follow-up X-ray, CT scan, MRI and scintigraphy. These studies involved mainly the scaphoid bone and to a lesser extent other areas such as the ankle and demonstrated the superiority of ultrasound in all cases with sensitivity and specificity values that reached 100% in some series [1-3, 9].

X-ray, as it is shown above, can no more be considered the gold standard for diagnosis of occult bone fracture. It is still considered as a useful tool, easy to access, easy to perform and easy to read. It can give a rapid overview of the situation in severe trauma with complex fractures but is less effective than ultrasound performed by an experienced sonographer for diagnosis of occult fractures as in this series i.e. fractures without displacement and only one cortical line interrupted or deformed. Performing CT scan or MRI for all patients or patients with discordance between results of ultrasound and X-ray as a routine procedure in our practice is not justified considering cost, irradiation, difficulty to immobilize the child, and previous data that have shown the reliability of ultrasound in the hands of experienced sonographers. A follow-up X-ray looking for bone healing was the reference in our study but the treatment was based on findings available on the day of the trauma. Treatment decisions were based on two principles:

- A fracture was present if seen on either X-ray or ultrasound. In our series, all fractures seen on X-ray were also seen by ultrasound. Six fractures with normal X-rays where seen only on ultrasound and follow-up X-rays performed in all these patients confirmed the presence of bone healing. One patient with a doubtful diagnosis of fracture on X-ray had a strictly nor-

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**TABLE I**

DETAILED COMPARATIVE RESULTS OF RADIOGRAPHY AND ULTRASOUND IN 50 PATIENTS WITH 53 SUSPECTED FRACTURES
Ultrasound changed clinical management in several patients. In case of negative X-ray and positive ultrasound findings for fracture, the patients were treated as having a fracture and managed by fixation. In the absence of fracture, weight-bearing is allowed in trauma of the lower limb, and the upper limb is not put at rest.

The superiority of ultrasound to X-rays in detecting occult limb fractures can be explained by the accessibility of the cortical bone surface to high frequency transducers in the pediatric patient. These good results can be achieved even in the hands of an in-training radiologist outside working hours, provided that trainees have the appropriate training in osteo-articular ultrasound and the dedicated equipment. If these two conditions are not available ultrasound can be postponed, to be performed by experienced radiographers during working hours. However, ultrasound is not useful in open fracture, comminuted fracture, polytrauma and skeletal survey.

CONCLUSION

Ultrasound can be superior to radiography in diagnosis of occult fractures or hematomas not detected by radiography. It is also capable of ruling out a fracture in patients with a doubtful radiographic diagnosis, or a hematoma in patients with soft tissue thickening. It needs however an experienced operator and a dedicated equipment, two conditions not always available in emergency. This limits its actual use to an adjuvant examination in patients with a high index of clinical suspicion for a fracture and a normal or equivocal radiographic diagnosis.

REFERENCES