Limb fractures: ultrasound imaging features

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Abstract

US, a non-irradiating imaging modality, is complementary to radiographs in the evaluation of limb fractures. US may in some cases demonstrate or suggest the presence of a fracture without corresponding abnormality on radiographs, or confirm or exclude a possible fracture detected on radiographs. Knowledge of the US features of fractures is necessary. In this article, the different direct and indirect US findings of fractures will be reviewed, with radiographic correlation. Direct findings include cortical discontinuity or irregularity. Indirect findings include subperiosteal or juxaphyseal hematoma suggesting cortical or physeal fractures respectively.

Key words: US. Radiology. Fractures. Limbs.


Conventional radiographs are excellent for the depiction of skeletal trauma. Fractures are typically easily detected on standard radiographic projections. However, fractures may at times be imperceptible on conventional radiographs either because it is subtle or occult, obscured by overlapping structures, or non-perpendicular to the x-ray beam; a fracture may also involve cartilage and be undetectable, especially in skeletally-immature children. Therefore complementary imaging would be desirable to eliminate or confirm the presence of a fracture in order to avoid short-term and long-term complications. Both CT and MR are highly sensitive and specific for diagnosing fractures. They provide detailed evaluation of bones, as well as evaluation of cartilaginous and tendinous pathology. However, indications are limited, especially in the acute setting after trauma, because of their high cost and longer acquisition time.

US may be valuable in this clinical context. The many advantages of US are well known: relatively inexpensive, readily available, non-invasive, high accuracy of high-end units, highly effective, though operator dependent, in the detection of fractures, with accuracy up to 87% in some series (1). However, US evaluation requires a strict protocol and comparison with the unaffected contralateral limb (2), as well as familiarity with the US features of fractures. For this pictorial essay, the most characteristic cases over the course of two years were selected with radiographic correlation. All US examinations were performed on an Acuson Antares, Siemens Medical Solutions, Mountain View, CA, USA, using a 13 MHz linear transducer.

Radiographic features

All fractures were initially detected on radiographs. Different nomenclatures or classifications were used. Fracture sites could be diaphyseal, metaphyseal and/or epiphyseal; the fracture line could be transverse, oblique or spiral; displacement could be present. In addition to the direct fracture visualization, a few indirect signs could be present (fat pad displacement, soft tissue thickening suggesting edema). Pediatric fractures were particular because they could involve the physisal cartilage (physeal fracture) or soft more pliable bones (buckle fractures, green-stick fractures, traumatic bowing).

Some of the terminology used for radiographs may also be used for US. Unlike conventional radiographs where a diagnosis of fracture is essentially based on the direct visualization of a fracture line and rarely on indirect findings, it is desirable to detect both direct and indirect signs of fracture on US.

US features of normal bones

In spite of the fact that cortical bone is a barrier to ultrasound waves, US evaluation of the bone surface provides much information (fig. 1). The cortex appears as a smooth and regular echogenic line,
clearly visible, overlying an echo-poor region called posterior shadowing. At both ends, cartilage is visualized, very hypoechoic, nearly anechoic. Tendons frequently course near cortex. On longitudinal sections, they are overall echogenic, composed of fibers parallel to bone surrounded by a matrix of intermediate signal. On transverse sections, they are oval-shaped, with small regular echogenic foci. Adjacent muscles are hypoechoic, with linear echogenic lines on longitudinal sections and dots on transverse sections. Fatty tissues are hypoechoic as well.

The soft tissues surrounding bones, especially fat, are particularly well depicted on US, especially in the setting of post-traumatic changes.

**US features of fractures**

Several US findings resulting from alterations of the normal anatomy described previously should be detected and recognized in a clinical context of fracture.

**Cortical disruption**

A fracture on US, similar to radiographs, is characterized by disruption or deformity of the normal cortical margin. Both findings correspond to direct signs of fracture. They are frequently visualized on US.

Cortical disruption may have multiple appearances on US: either cortical step-off deformity, avulsion, or impaction.

**Step-off deformity**

Fractures with step-off deformity are frequently visible on conventional radiographs. It is the result of displacement at both ends of the fracture (fig. 2).

**Cortical avulsion**

Cortical avulsion fractures are usually easy to detect on conventional radiographs since they result from avulsion of the radiopaque cortex. However, the avulsed fragment may only be visible on a tangential projection where it appears separate from the donor bone whereas it may be imperceptible on an en-face projection where it is superimposed on the donor bone. The detection of such fractures may be problematic when they arise from smaller bones, such as the carpal or tarsal bones. In these cases, the tangential projection cannot confirm the donor site, and the fracture is not visible on the en-face projection. This can easily be solved with US where the fractured bone is identified underneath the avulsed cortical fragment (fig. 3). However, it may sometimes be difficult to differentiate between avulsed cortical fragment, osteophyte and calcification on US. Nonetheless, the clinical context, absence of arthrosis (especially in children) and...
occasional presence of a hematoma will assist in making the correct diagnosis.

**Impaction**

Impaction may be difficult to detect on radiographs, especially when minimal. On US, cortical impaction is easily detected (fig. 4).

**Cortical irregularity**

Cortical irregularity is pathognomonic for pediatric fracture where the softer bone is deformed instead of broken. Deformation of cortical bone is most frequent in infants due to the increased plasticity of the bone matrix in this patient population. This may present with minor outer buckling of both cortices at the fracture line (fig. 5), a stair-step appearance (fig. 6) or traumatic bowing (fig. 7).

**Reverberation**

Reverberation echo is another direct sign of cortical fracture (4). It is most frequently associated with cortical avulsion fractures. This finding can be explained purely based on physical principles. Normally, the US wave is reflected by cortex, with underlying posterior shadowing. In patients with fracture, especially a cortical avulsion fracture, US waves are being reflected at two different levels: at the level of the avulsed cortical fragment and at the level of the donor bone. In addition, some US waves may be trapped between both cortical surfaces, bouncing back and forth before returning to the transducer, creating a reverberation artifact.

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**Fig. 3:** Cortical avulsion fracture.

a-b Wrist radiograph (a: frontal projection; b: lateral projection).

Thin cortical avulsion fracture visualized only on the lateral projection using a hot light (circle).

c US of the symptomatic region demonstrating an avulsion fracture of the capitate (arrow).

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**Fig. 4:** Cortical impaction fracture.

a Wrist radiograph (lateral projection).

No evidence of cortical fracture.

b US of the symptomatic region.

Metaphyseal cortical impaction fracture (arrow); note the presence of a small hematoma overlying the fracture site (arrowhead).

c Follow-up CT.

Demonstration of the cortical impaction fracture (arrow) on a sagittal reformatted image.
Fig. 5: Outer cortical buckling.

a Wrist radiograph (frontal projection).
   Irregularity with outer metaphyseal cortical buckling (arrow) consistent with a buckle fracture.

b US of the symptomatic region (posterior median sagittal image) showing outer cortical buckling (arrow).

Fig. 6: Stair-step deformity.

a US of the distal radius (posterior sagittal image).
   Stair-step deformity (arrow) at the fracture site.

b A buckle fracture (arrow) is confirmed on a forearm radiograph.

Fig. 7: Traumatic bowing.

a US of the proximal phalanx of the thumb.
   Cortical deformation with bowing (arrow) at the distal end of the proximal phalanx of the left thumb not present on the contralateral side. Note the presence of an overlying hypoechoic hematoma (star).

b Corresponding radiograph of the left thumb.
   Demonstration of traumatic bowing (arrow).
characterized by parallel echogenic lines at regular intervals (fig. 8).

**Posterior acoustic shadowing**

A cortical fracture may also occur following a compression injury as opposed to a traction injury. The compression mechanism of injury causes a focal increase in cortical density resulting in increased reflection of the US waves relative to the adjacent normal cortex. As a result, there is focal increase in the degree of posterior acoustic shadowing at the fracture site (fig. 9). This is a direct sign of fracture, often associated with buckle fractures.

A cortical fracture may be subtle even on US with apparent preservation of cortical continuity. The advantage of US resides in its ability to detect the presence of indirect signs such as periosteal elevation and hematoma.

**Periosteal elevation**

The presence of periosteal elevation is suggestive of fracture (1). It is characterized by the presence of an additional echogenic...
line parallel to the cortex. The main differential diagnosis is with osteomyelitis, especially in children (7), but the clinical context should allow accurate diagnosis.

Hematoma

Another indirect sign of fracture is the presence of a subperiosteal (fig. 10) or juxta-physeal (fig. 11) hematoma. The hematoma is secondary to a fracture, even if the fracture site cannot be directly demonstrated. The hematoma usually is heterogeneous on US, often hypoechoic, with echogenic components. Mass effect upon adjacent structures may be present, either tendons (fig. 12) or a fat pad normally intimately applied against cortex (fig. 13).

Conclusion

Technical advances in the field of US imaging have improved the accuracy of this imaging modality for musculoskeletal disorders and increased the number of applications, including musculoskeletal trauma (8). The addition of US to conventional radiographs is increasingly being obtained to improve the diagnostic accuracy of fractures of the limbs. In some circumstances, US may be a satisfactory alternative to radiographs. However, sonographic evaluation of musculoskeletal trauma requires time, patience, and expertise from the operator in order to develop the referral pattern.
Références


