High-resolution Ultrasound of the Foot and Ankle

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KEYWORDS

• Foot • Ankle • Ultrasound • Musculotendinous • Ligament • Strains • Tears • Injuries

KEY POINTS

- Ultrasound (US) evaluation of foot and ankle injuries provides high spatial resolution and is a valuable tool in this assessment.
- US is an excellent option to MRI for soft tissue assessment of the foot and ankle.
- US of tendinous injuries allows visualization of the tendon itself, the synovial sheath, the paratenon and the presence of increased blood flow (inflammation) and calcifications.
- US can aid clinical examination on the diagnosis of a ligament disruption.
- US is an excellent imaging method to assess the small nerves of the foot.

INTRODUCTION

The use of ultrasound (US) in diagnosis and procedural guidance has increased significantly in recent years and involves multiple medical specialties. US is a very useful alternative for imaging the foot and the ankle. Compared to MRI, it is mainly indicated in soft tissue assessment and has a lower cost, is widely available, allows portability, has the possibility of dynamic evaluation, is easy to compare contralaterally, allows high spatial resolution assessment, and is directly correlated with the painful area. We will review the main clinical indications and pathologic conditions diagnosed by US.

TECHNICAL CONSIDERATIONS

US is an imaging method that utilizes high-frequency sound waves to produce images. The image formation depends on the tissue characteristics and, consequently, on the balance between US reflection and absorption by the tissue. The images are acquired in real time and dynamically.

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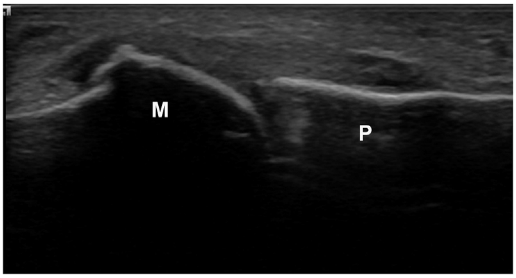

Fig. 1. *Acoustic shadowing of bone*. US longitudinal image of the metatarsal head (M) and proximal phalanx (P) shows hyperechoic cortex and posterior acoustic shadowing.

The echogenicity of a tissue is its ability to reflect or absorb US waves. It can be characterized as hyperechoic (white—US wave reflection is greater than absorption), hypoechoic (gray—US wave reflection is similar to absorption) and anechoic (black—US wave absorption is greater than reflection).[1]

US does not penetrate osseous tissue; bone appears with a bright hyperechoic rim, and posteriorly, it is black, which represents acoustic shadowing (**Fig. 1**). Fluid appears anechoic or hypoechoic (**Fig. 2**). Fat is hypoechoic, and muscles are hypoechoic with a striated structure (**Fig. 3**). Ligaments and tendons have a characteristic striated hyperechoic structure with interspersed hypoechoic lines[2,3] (**Fig. 4**).

Foot and ankle structures are usually superficial, and US evaluation requires high-frequency probes (higher than 7 MHz), usually 10 to 15 MHz, which have better resolution and less penetration.

CLINICAL INDICATIONS

US evaluation of the foot and ankle is indicated in the following acute and chronic conditions[4]:

1. Musculotendinous injuries
2. Ligament sprains
3. Peripheral nerve evaluation
4. Metatarsalgia

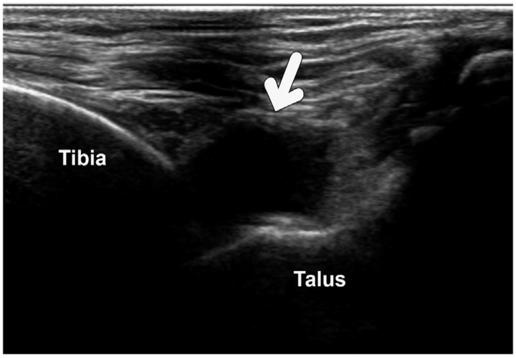

Fig. 2. *Fluid appearance.* US longitudinal image of the tibiotalar joint. Anterior tibiotalar articular recess (*arrow*) with significant amount of fluid, which appears anechoic.

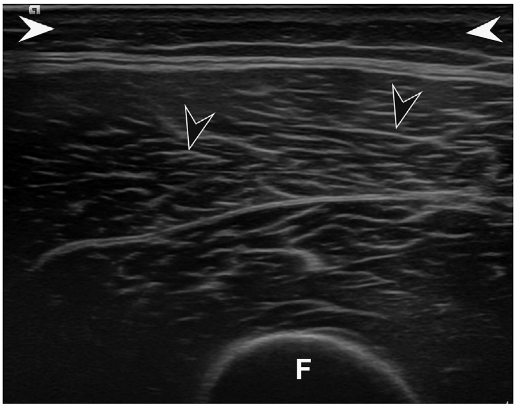

Fig. 3. *US appearance of fat and muscle*. US transverse image of the thigh shows hypoechoic aspect of subcutaneous fat (*white arrowhead*) and striated appearance of muscle structures (black *arrowhead*). Note the hyperchoic rim and posterior acoustic shadowing caused by the femur (F).

5. Evaluation of synovitis, joint fluid, and loose bodies
6. Plantar fascia injuries
7. Guiding interventional procedures (injections, aspirations)

MUSCULOTENDINOUS INJURIES

Tendinitis is defined as inflammation of the tendon, and the US appearance is tendon hypoechogenicity with possible increased vascular flow on Doppler.[5] Tendinosis is a chronic tendon condition with collagenous degeneration, and its US features are tendon hypoechogenicity with diameter increase, with or without flow on Doppler (**Fig. 5**). Calcific tendinopathy is easily diagnosed on US (**Fig. 6**). Inflammation of the tendon's synovial sheath is called tenosynovitis and it shows characteristic thickening of the synovial sheath (**Fig. 7**). The inflammation of the paratenon surrounding a tendon that does not have a synovial sheath (for example, the Achilles tendon) is called paratenonitis (**Fig. 8**). Tendon disruption (or tear) can be partial or full thickness (**Figs. 9** and **10**). A partial tear can be intrasubstance or superficial (see **Fig. 10**). A longitudinal split tear is common on peroneal tendons. Tendon avulsion occurs at the bony attachment.

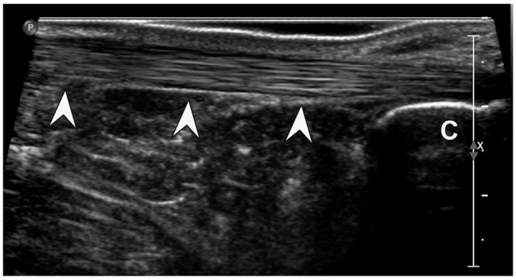

Fig. 4. *Normal tendon*. US longitudinal image of the distal Achilles tendon. Normal hyperechoic striated aspect of a tendon (*arrowheads*).

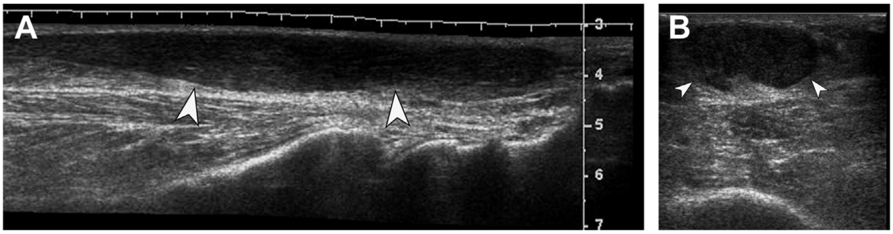

Fig. 5. *Tendinosis of the Achilles*. Longitudinal (*A*) and transverse (*B*) US images of the Achilles tendon show diffuse thickening and hypoechogenicity (*arrowheads*).

US elastography is a recently introduced method that allows for evaluation of the mechanical properties of the tissue. It is based on the principle that stress applied to a tissue causes changes within it that depend on its elastic properties.[6] The most common method applied to musculoskeletal US is strain elastography or compression elastography. In this method, compression of the tissue is manually applied by the transducer. The tissue stiffness is calculated through differences in tissue displacement after the compression is applied. Elasticity information is provided in a qualitative or semiquantitative manner. It is widely used for evaluation of the Achilles tendon, and it has been demonstrated that elastography shows increased stiffness in abnormal tendons compared with asymptomatic tendons which are softer.[7] However, elastography alterations in asymptomatic and sonographically normal tendons are not completely understood.

LIGAMENT TEARS

The diagnosis of ligament injuries is based on clinical findings. US can aid in the evaluation of a ligamentous tear, appearing as a thickened and hypoechoic structure (Fig. 11) in comparison with the normal asymptomatic contralateral side. A complete tear is represented by a complete loss of the continuity of the ligamentous substance (Fig. 12). Hyperechoic foci at the ligamentous insertion can represent a bony avulsion (Fig. 13).

PLANTAR FASCIA

US examination of the plantar fascia is performed with the patient in a prone position and the foot hanging freely over the examination table. The US aspect of the normal

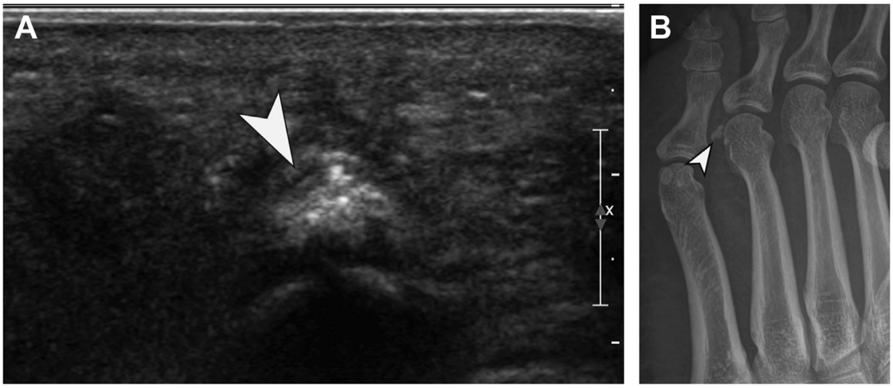

Fig. 6. *Calcific tendinopathy*. (*A*) Transverse US image at the level of metatarsal heads shows calcification (*arrowhead*) within the distal aspect of the dorsal interosseous tendon (*arrowhead*), which is confirmed by radiographic image (*B*) of the foot.

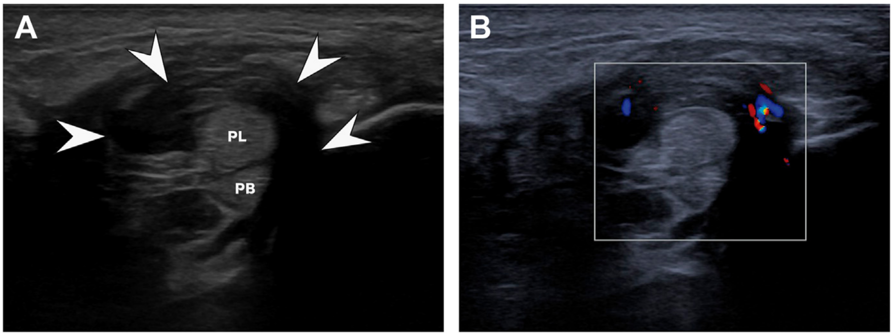

Fig. 7. *Tendinopathy on US*. (*A*) US transverse images of the lateral aspect of the ankle. Significant thickening and hypoechogenicity of the common tendon peroneal tendon sheath (*arrowheads*), surrounding the peroneus longus (PL) and Brevis (PB) tendons. (*B*) Transverse US image at the same point with Doppler shows increased blood flow at the tendon sheath, indicating acute inflammation.

plantar fascia is a fibrillar hyperechoic linear structure, usually with up to 4 mm thickness[8] (Fig. 14). Plantar fasciitis is a frequent cause of heel pain and it appears as a thickened and hypoechoic plantar fascia (Fig. 15).

PERIPHERAL NERVES IN THE FOOT AND ANKLE

Visualization of nerves at the foot and ankle may be difficult on MRI, as they have a similar appearance to adjacent vessels. On US, the usage of high-frequency probes

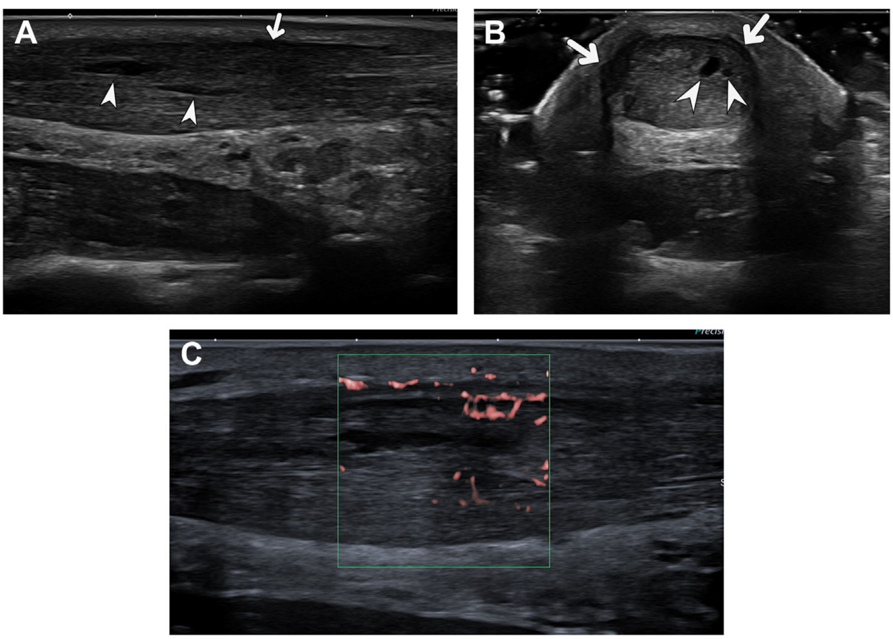

Fig. 8. *Achilles tendinopathy, partial tear and paratenonitis*. US longitudinal (*A*) and transverse (*B*) images of the Achilles tendon. Thickening and heterogenicity of the Achilles tendon with partial intrasubstance tears (*arrowheads*) and thickening of the paratenon (*arrows*), indicating paratenonitis. On power Doppler assessment (*C*), increased tendon and paratendon blood flow is depicted.

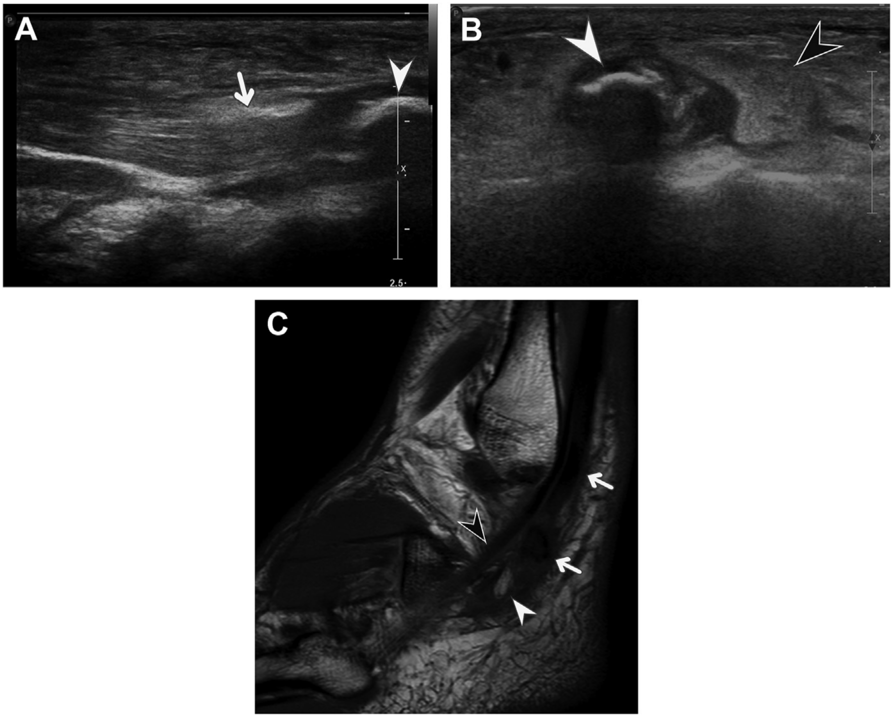

Fig. 9. *Complete peroneus longus tendon tear*. Longitudinal (*A*), transverse (*B*) US and sagittal T1-weightes MR (*C*) images of the lateral aspect of the ankle. Complete tear of the distal aspect of the peroneus longus tendon (*white arrows*) with an accessory *os peroneum* bone retracted proximally (*arrowheads*). Note the peroneus brevis tendon (*black arrowheads*) adjacent to the *os peroneum*.

allows high spatial resolution, making the nerves easier to identify and differentiate from adjacent vasculature. They appear as hypoechoic linear structures interspersed with hyperechoic linear lines (Fig. 16). The vessels are anechoic, and the blood flow can be seen on color Doppler US.[9] In compression neuropathies, the nerve can be focally or diffusely thickened and hypoechoic (Fig. 17). In traumatic nerve lesions, a neuroma might be visible (Fig. 18). External compression causes, if present, can be seen on US, such as muscle hernias, accessory muscles, cysts, soft tissue masses, bone protuberances, and scar tissue. However, in the majority of cases, no external cause is identified.[10]

Fig. 10. *Complete Achilles tendon tear*. Longitudinal panoramic US image of the posterior aspect of the ankle shows a complete rupture of the middle third of the Achilles tendon with a gap between the tendon stumps (*arrowheads*). Note the tendinopathy (thickening and hypoechogenicity) of the distal aspect of the Achilles.

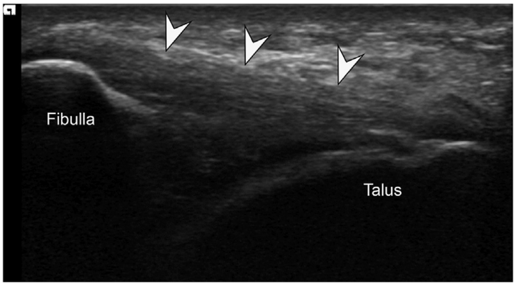

Fig. 11. *Partial tear of the anterior talofibular ligament*. Transverse US image of the anterolateral aspect of the ankle showing ATFL thickening, hypoechogenicity and loss of fibrillar pattern (*arrowheads*), corresponding to a partial tear.

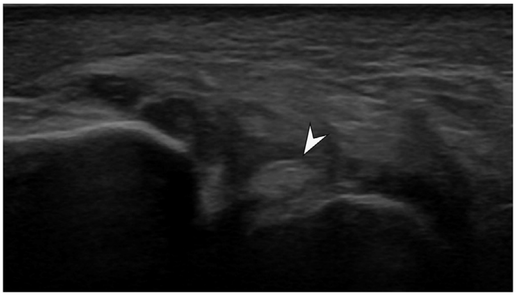

Fig. 12. *Complete tear of the anterior talofibular ligament*. Transverse US image of the anterolateral aspect of the ankle. Complete tear of the ATFL, with distal retraction of ligament fibers (*arrowhead*).

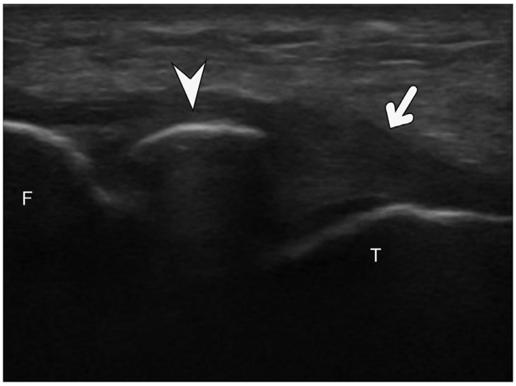

Fig. 13. *Anterior talofibular ligament avulsion*. Transverse US image of the anterolateral aspect of the ankle shows avulsed ATFL, with a bone fragment (*arrowhead*) detached to distal fibula and connected to the distal ATFL (*arrow*).

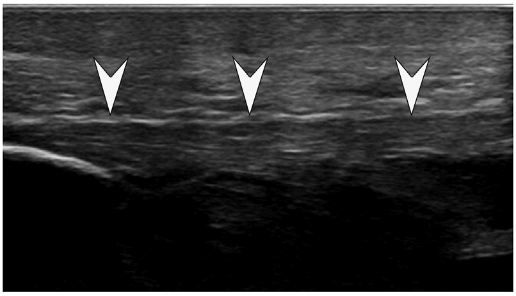

Fig. 14. *Normal plantar fascia*. Longitudinal US image of the plantar fascia (*arrowheads*) shows a fibrillar linear structure arising from the calcaneal tuberosity.

Superficial and deep peroneal, tibial, medial, and lateral plantar, medial and inferior calcaneal, sural, saphenous, and digital nerves can be seen on high-resolution US.[11]

Morton neuroma is also visualized by dorsal probe placement with web space compression[9] (Fig. 19).

METATARSALGIA

Pain in the metatarsal region is a common problem and is caused by many different structures. High-resolution US can diagnose most causes, including adventitial and intermetatarsal bursitis, Morton's neuroma, metatarsophalangeal synovitis, plantar plate injury, tendon disorders, venous thrombosis, and soft tissue masses.

The plantar plate is visualized in the longitudinal plane by a thin hyperechoic band extending from the metatarsal head to the proximal phalanx, deep to the flexor tendons.[12] US evaluation of plantar plate tears is comparable to MRI in terms of sensitivity and appears as focal or complete discontinuity, thickening and loss of normal hyperechoic homogeneous aspects[13] (Fig. 20). They typically occur at the distal insertion onto the proximal phalanx. This is frequently associated with metatarsophalangeal joint effusion and tendinosis of the dorsal interosseous tendons.[14]

Metatarsal stress fractures can also be seen on US, with periosteal thickening and hemorrhage[14] (Fig. 21).

US is also an option for diagnosis of a foreign body at the foot. Not all of them are radio-opaque and may be clearly seen on US (Fig. 22).

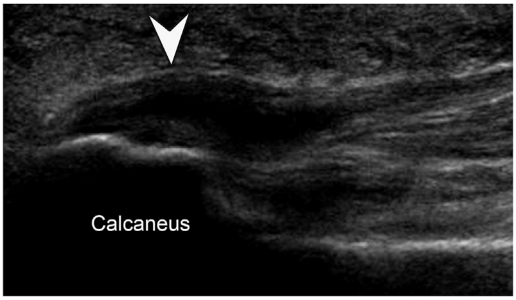

Fig. 15. *Plantar fasciitis*. Longitudinal US image of the plantar fascia (*arrowhead*) depicts thickening and hypoechogenic proximal plantar fascia, corresponding to plantar fasciitis.

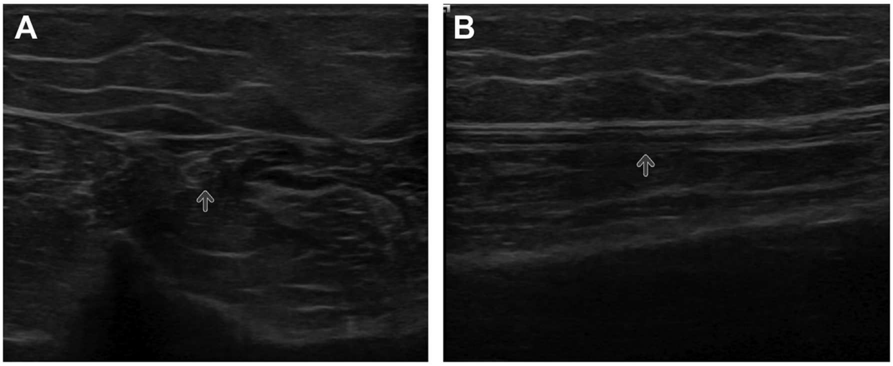

Fig. 16. *Normal peripheral nerve*. Transverse (*A*) and longitudinal (*B*) US image of the distal leg with normal morphology of the superficial peroneal nerve (*arrow*).

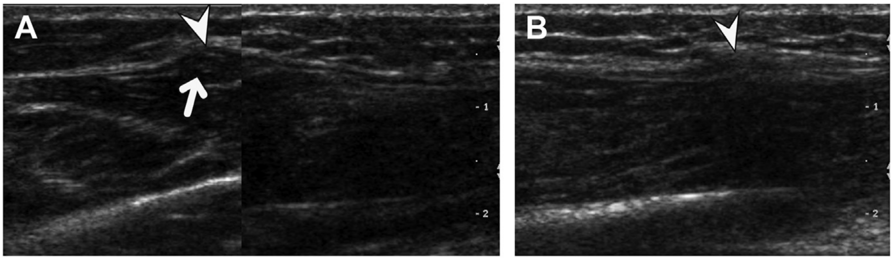

Fig. 17. *Compressive neuropathy*. Longitudinal US image (*A*) of the distal leg shows a small anterior tibial muscle herniation (*arrowhead*) and compression of the superficial peroneal neuropathy (*arrowheads*). (*B*) US image of the superficial peroneal neuropathy shows focal thickening and hypoeecgicity

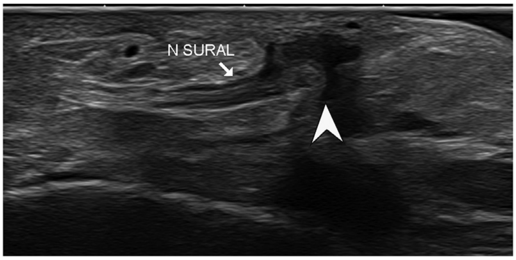

Fig. 18. *Traumatic US image*. US longitudinal image of the foot shows a complete sural nerve transection with a small stump neuroma (*arrowheads*).

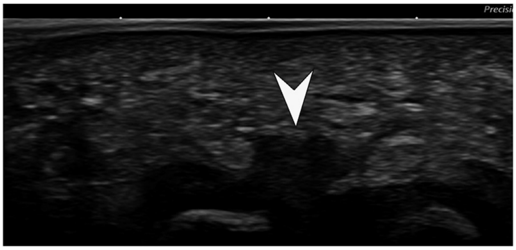

Fig. 19. *Morton neuroma.* US transverse image at the level of distal intermetatarsal spaces shows a neuroma at the plantar aspect of foot, at the space between second and third metatarsals (*arrowheads*).

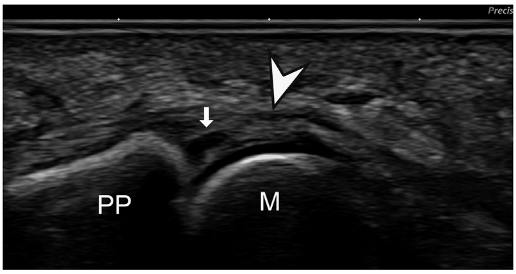

Fig. 20. *Plantar plate injury*. Longitudinal US image of the metatarsophalangeal joint with a partial intrasubstance tear at the distal insertion of the plantar plate (*arrow*). Note that the proximal plate has normal striated appearance.

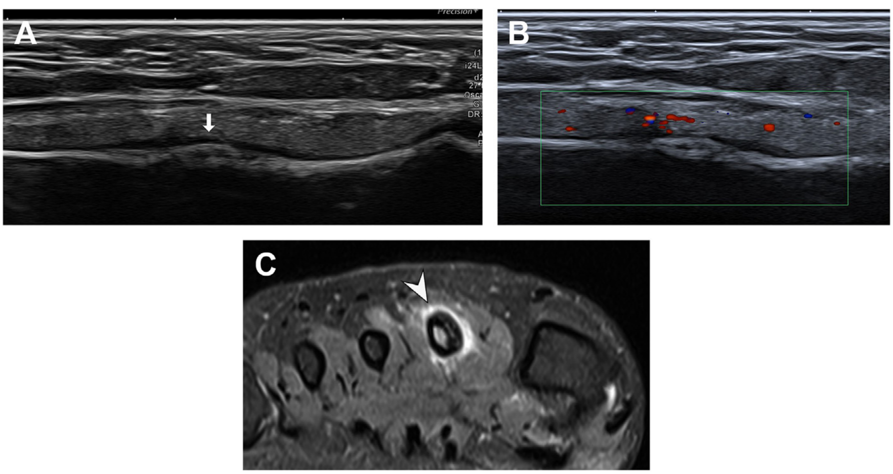

Fig. 21. *Metatarsal stress fracture*. (*A*) Longitudinal US image of the second metatarsal shows cortical irregularities and periosteal thickening (*arrow*) with increased blood flow on US Doppler (*B*) and consistent with a stress fracture. (*C*) Coronal T2-weighted MR image of the forefoot confirms diagnosis, showing increased bone marrow and periosteal edema (*arrowhead*).

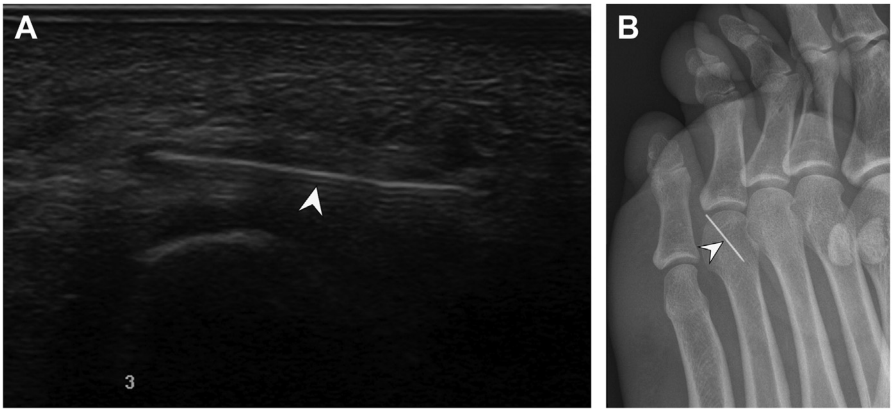

Fig. 22. *Foreign body.* (*A*) Longitudinal US image of the plantar aspect of the forefoot. There is a linear soft tissue foreign body (*arrowhead*) adjacent to the metatarsophalangeal joint. (*B*) Foot x-ray was done to confirm the presence of the foreign body (needle).

SUMMARY

High-resolution US is an excellent imaging modality for the evaluation of tendons, ligaments, and nerves in the ankle and is a useful alternative to MRI. The major advantages of US are wide availability, lower cost, and the possibility of dynamic evaluation and contralateral side comparison.

CLINICS CARE POINTS

- Is high-resoltion ultrasound indicated for peripheral neuropathy of the foot? Yes, based on our experience and in the literature, US evaluation of peripheral nerves in the foot can provide images with higher spatial resolution, compared to MRI.
- Can US detect metatarsal stress fractures: US is an useful alternative tool to x-ray and MRI for detection of metatarsal stress fractures > It might show periosteal thickening and hemorrhage at the fracture site.
- Is US indicated for evaluation of foreign bodies? Based on our experience, US is an option for detection of foreign bodies not visible on plain radiographs.
- What are the advantages and disadvantages of high-resoltion US of the foot compared to MRI? US is more available, has a lower cost and the possibility of dynamic evaluation and comparison with contralateral side. It is less useful for detection of associated injuries in the bone and cartilage and is user-dependant.

DISCLOSURE

The authors have nothing to disclose.

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