Ultrasound imaging for the rheumatologist V. Ultrasonography of the ankle and foot

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Received on April 10, 2006; accepted on April 30, 2006.

Clin Exp Rheumatol 2006; 24: 493-498.

Key words: Ultrasound, ankle, foot, tendon.

ABSTRACT

Ultrasonography (US) is a useful tool for imaging, which can be used for the assessment of joints and periarticular structures in all rheumatological disorders. In patients with pain and/or swelling of the ankle and foot, US provides information about the presence of joint effusion, synovitis, tenosynovitis, tendinosis, and tendons tears, helping in the differential diagnosis between joint or tendon/enthesis involvement. Moreover, US allows clinicians to monitor and guide needle positioning to inject pharmaceutical substances more safely and effectively even in hard-to-reach sites.

US represents an accurate, safe and low-cost technique that can be used for the examination of the ankle and foot in rheumatic disorders.

Introduction

Pain and/or swelling of the ankle and foot are very frequent in patients with arthritis. As every clinician knows, the evaluation of these anatomic structures is difficult because clinical assessment often underestimates the manifestations (1) and cannot distinguish between involvement of the joint, tendon and enthesis. Furthermore, plain radiographs provide very little information about the soft tissues while MRI is expensive and not easily accessible. Ultrasound (US) is an accurate, safe and low-cost technique that can be used for the examination of joints and periarticular structures in many rheumatological disorders, particularly rheumatoid arthritis and the spondyloarthropathies (2).

Indications

Sonographic examination allows the detailed assessment of joint, tendon and entheseal involvement in patients with pain and/or swelling of ankle and foot (Table I).

Table I. Pathological conditions detectable by ankle and foot ultrasound (US).

- Joints
  - effusion
  - synovitis
  - bone erosions
  - osteophytes
- Peri-articular soft tissues
  - tenosynovitis
  - tendinitis/tendinosis
  - tendon tears
  - calcification
  - bursitis

Equipment

Ankle and foot sonography requires a linear high-frequency transducer; a 7.5 to 15 MHz probe is commonly used (Table II). Colour (CDS) and power Doppler (PDS) techniques provide useful additional information regarding the extent of soft tissue hyperemia (Table II).

Table II. Equipment requirements for US of ankle and foot.

- High-quality machine
- Range of frequency used in daily practice: 7.5-15 MHz
- Availability of instruments for colour and/or power Doppler

Scanning technique

Multiplanar, bilateral and dynamic assessments should always be performed when scanning either the foot or ankle.

ANKLE

Procedure for scanning anatomical structures

Tibiotalar joint

The patient should be placed in a supine position with the knee flexed and the foot on the examination table (Table III, *A*). The tibiotalar joint should be in plantar flexion (3). Joint effusions and synovitis are best detected by longitudinal dorsal scans.

Tendons
The ankle tendon region should be divided into four compartments and examined systematically: anterior, lateral, medial and posterior. To examine the anterior, medial and lateral compartments the patient should be placed as reported in Table III, *A*.
Anterior compartment: for each of the following tendons, transverse and longitudinal scans should be performed:
- *Anterior tibial tendon* (ATT): its position is medial to the other extensor tendons and it may be imaged along its entire length as far as its insertion on the first cuneiform bone.
- *Extensor hallucis longus tendon* (EHLT): positioned laterally to the ATT, this tendon can be examined as far as its insertion on the great toe.
- *Extensor digitorum longus tendon (EDLT)*: this tendon passes laterally to the EHLT, and beneath the inferior extensor retinaculum splits into four slips, each one of which inserts into one of the four lateral toes. It can be imaged along its entire length.

Lateral compartment: the lateral tendons should be examined from their supramalleolar musculotendinous junction, starting with transverse scans to visualize their position, and then proceeding with longitudinal scans (4).
- *Peroneus longus tendon* (PLT): this tendon should be examined to the cuboid groove and as it turns medially to run diagonally across the sole of the foot and inserts on the medial cuneiform, by plantar scans.
- *Peroneus brevis tendon* (PBT): this tendon lies immediately anterior to the PLT and may be scanned along its full length to its insertion at the base of the fifth metatarsal.

Medial compartment: The medial tendons are examined starting from their supramalleolar musculotendinous junction by transverse and longitudinal scanning. From the anterior to the posterior side, the posterior tibial tendon, the flexor digitorum longus tendon, the neurovascular bundle (tibial nerve, two veins and one artery) and finally the flexor hallucis tendon can be visualized.
- *Posterior tibial tendon* (PTT): it is preferable to examine the supramalleolar portion of the tendon first by a transverse scan to aid orientation; in proximity to its insertion into navicular bone a longitudinal scan is more informative. The PTT also sends extensions on the tarsal and metatarsal bones, so that at its insertion it may appear hypoechoic for anisotropy.
- *Flexor digitorum longus tendon* (FDLT): located immediately posterior to the PTT, this tendon runs obliquely and laterally along the sole of the foot, splitting into four tendons which insert into the lateral four toes.
- *Flexor hallucis tendon* (FHT): this tendon can usually be scanned to its insertion into the hallux, although it is rarely injured.

Posterior compartment: the patient should be placed in a prone position with the foot hanging over the examination table or resting on its toes (Table III, *B*) (3).
- *Achilles tendon* (AT): the Achilles tendon should be examined along its entire length from the musculotendinous junction to the calcaneal insertion by longitudinal and transverse scans. Dynamic examination is particularly useful when a full or partial thickness tear is suspected.
- *Plantaris tendon*: this tendon lies medially to AT, and therefore should be scanned at the same time as the Achilles tendon.
- *Superficial calcaneal bursa*: located between the skin and the AT.
- *Inner calcaneal bursa*: lies deep beneath the AT, just proximal to the calcaneus bone profile.

Table III. Patient positioning for US examinations of the ankle and foot.

A	Supine with the knee flexed and the foot resting on the examination table for visualization of the tibiotalar joint, the anterior, medial and lateral compartments of the ankle tendons, the mid-tarsal joints, MTP and IP joints, and the interdigital web space.
B	Prone with the foot hanging over the examination table or resting on the toes for visualization of the Achilles and plantaris tendons, and the superficial and inner calcaneal bursae.
C	Supine with the leg extended and the heel resting on or hanging over the examination table for visualization of the MTP and IP joints, and the interdigital web space.
D	Prone with the foot hanging beyond the examination table for visualization of the plantar fascia and tendons in the plantar region of the foot.

MTP: Metatarso-phalangeal joints; IP: inter-phalangeal joints.

US imaging of the normal ankle

Joints
On longitudinal scans, the tibiotalar joint is visualized as a triangular space located between the tibia and the talus with the apex pointing towards the lower side, and filled with a hyperechoic fat pad. The capsule image takes the form of a hyperechoic line stretching from the anterior tibia to the talus. The talar dome profile is covered by a thin anechogenous layer which represents the articular cartilage. Some fluid (≤3 mm) can normally be detected in healthy subjects in the anterior joint (3). This synovial cavity does not communicate with the adjacent structures (5).
The subtalar joint is not usually examined by US, because it is difficult to gain access to this structure with the probe.

Tendons
All tendons show a characteristic fibrillar pattern on longitudinal scanning and a finely punctate pattern on transverse scanning. Thin hypoechoic rims around the tendons of the anterior, medial and lateral compartments indicate the synovial sheaths. The AT is surrounded by loose connective tissue (peritenon) with no sheath.
The peroneal tendons lie just posterior to the lateral malleolus. They are stacked one on top of the other and enclosed in a single synovial sheath; no significant fluid is seen around them, except in the tract distal to the fibula where in healthy subjects some fluid (≤ 3 mm) may be detected as a hypoechoic halo (3). Fluid may also be ob-

Table IV. Tendon measurements: mean value (5).

Tibialis anterior (at the tibiotalar joint level)		
	transverse diameter:	8.2 mm
	sagittal diameter:	2.5 mm
Tibialis posterior (directly below the level of the medial malleolus)		
	transverse diameter:	8.4 mm
	sagittal diameter:	2.8 mm
Peroneus longus (directly below the level of the lateral malleolus)		
	transverse diameter:	6.0 mm
	sagittal diameter:	3.0 mm
Peroneus brevis (directly below the level of the lateral malleolus)		
	transverse diameter:	4.3 mm
	sagittal diameter:	2.5 mm
Achilles (2 cm proximal to the calcaneus)		
	transverse diameter:	14.3 mm
	sagittal diameter:	4.3 mm

served in the distal part of the PTT sheath (≤ 4 mm) (3), while it is usually absent in the FHT in normal volunteers. The ankle tendons may vary considerably in size with gender and the physical activity of the subject. Table IV reports tendon measurements by US.

Synovial bursae
In 24% of healthy subjects a small amount of fluid may be detected in the deep calcaneal bursa which will be visualized as a thin curved hypoechoic line (thickness < 2.5 mm) (4).

US imaging of pathological conditions in the ankle

Joints
Ankle joint effusion is detected by US as an anechoic or hypoechoic intracapsular area which displaces the fat pad and bows the capsule anteriorly (often the fluid passes over the neck of the talus). When only a small amount of fluid is present, it is useful to look for effusion in the medial or lateral compartments. In the case of synovitis, echogenic tissue proliferating within the joint cavity and representing the tickened synovium may be imaged. By PDS it is possible to assess the vascularity of synovial tissue. Loose bodies may also be detected in the synovial recesses.

Tendons
Tendinosis, tenosynovitis, and tendon tears can all be evaluated by US in the ankle.Tendinosis is characterized by swelling of the tendon with loss of the normal fibrillar pattern and areas of decreased echogenicity (6).
Acute tenosynovitis usually appears as an anechoic or hypoechoic halo around the tendon; in chronic tenosynovitis non-homogeneous or even hyperechoic materials (due to synovial tissue hyperplasia) may be seen on US in the distended sheath. PDS may show increased vascularity due to inflammation.
A longitudinal split (which indicates a partial tear) will appear as a thin, linear, hypogenic gap in the body of the tendon. In complete tears, a full-thickness discontinuity of the tendon will be seen with variable retraction of the ends, which are separated by fluid or hematoma. Dynamic examination may help in the evaluation of tendon tears.
Abnormalities are most often seen in the PTT, and chronic ruptures are frequent in patients (particularly women) with seronegative arthritis (3). PTT tears are usually located just distal to the medial malleolus; less frequently they may be seen at its insertion on the navicular bone (4). In the PBT a longitudinal split is more common than complete full-thickness tears.
A thickened and dishomogeneous AT, with or without hyperechoic spots (calcification), is the US pattern of tendinosis. Paratenonitis may accompany an acute tendonitis; in such cases the AT appears swollen, diffusely or focally hypoechoic, and surrounded by a thin hypoechoic ring due to inflammation of the paratenon. AT tears are frequently located 2 to 6 cm proximal to the calcaneal insertion (due to the relative hypovascularity of this region). In acute tears the tendon gap is filled with hematoma and appears non-homogeneous on US scanning, while in chronic lesions the presence of echogenic granulation tissue may yield a similar pattern (4). Herniation of Kagar's fat into the AT is a sign of tendon tear. On dynamic US examination, minimal dorsi and plantar flexion may help in the evaluation of an AT rupture. When AT xanthomas (considered to be pathognomonic for heterozygous familial hypercholesterolemia) are present, a thickened and non-homogenous tendon (with hyperechoic spots within) can easily be observed on sonographic assessment (7). AT US shows linear bands of calcification in a high percentage of patients affected by chondrocalcinosis (8).
The US pattern of enthesopathy is characterized by hypoechoic and/or thickened tendon at its bony attachment (may occasionally contain calcifications) that may exhibit Doppler signal and bony changes including entesophytes, erosions or irregularity. (9).
Chronic tophaceous gout may appear on US as a focal nodule within the tendon with hypoechoic, non-specific loss of the normal regular fibrillary pattern (10).

Bursae
An abnormal enlargement of the bursa – caused by an increase in synovial fluid and/or synovial proliferation or, more rarely, hemorrhagic fluid – will lead to bursitis. On US examination, bursitis is imaged as a well-defined, compressible anechoic or hypoechoic area. Bursal dimensions > 2 mm in the short axis are considered abnormal (11), although some authors consider a thickness > 1 mm and a craniocaudal diameter > 7 mm to indicate enlargement (8).

Ganglionic cysts
Ganglionic cysts appear as anechoic or hypoechoic (sometimes multi-loculated) collections, often with a narrow channel of communication to the adjacent joint or tendon sheath (10).

Bone
Bone erosions are imaged as an intraarticular discontinuity of the bone surface that is visible on at least two perpendicular planes (12).
A focal cortical irregularity with an

interrupted linear bone profile and an hypoechoic area just above it is strongly indicative of bone fracture.

FOOT

Scanning technique

Mid-tarsal joints

The patient should be placed as reported in Table III, *A*. The mid-tarsal joints should be assessed by dorsal, lateral and medial scanning, moving the transducer from the proximal to the distal side.

Metatarso-phalangeal (MTP) and inter-phalangeal (IP) joints

The patient should be positioned as in Table III, *A* for the dorsal scans. For the plantar scans the patient's leg should be extended with the heel resting on or hanging over the examination table (Table III, *C*).

All the MTP and IP joints must be examined by dorsal and plantar scanning. In addition, the 1st and 5th MTP joints should be assessed by medial and lateral scanning, respectively.

Interdigital web spaces

The patient should be positioned as in Table III, *A* and *C,* so that the web spaces can be examined by the dorsal and plantar approach, first in the transverse and then in the longitudinal plane, moving from proximally to distally to the metatarsal heads. Many operators use the plantar scan alone to detect Morton's neuroma, whose visualization may be helped by the application of finger pressure on the interdigital space.

Tendons

The patient should be positioned as in Table III, *A* for the dorsal scans. For the plantar scans, the patient should be in a prone position with the foot hanging beyond the examination table to allow active and passive movements (Table III, *D*).

The long and short extensor and flexor tendons of the hallux and the toes, and the abductor tendons of the hallux and the 5th toe are examined in longitudinal and transverse scans to identify inflammatory or degenerative lesions or tears.

Plantar fascia

The patient should be placed in a prone position as in Table III, *D.* Plantar fascia images in the longitudinal and transverse planes can be obtained by passing the probe over the calcaneal bone to the metatarsal heads; with dynamic dorsiflexion of the toe, the plantar fascia is stretched and its margins can be more clearly seen. The thickness is measured near its insertion into the calcaneal tuberosity (in a longitudinal scan).

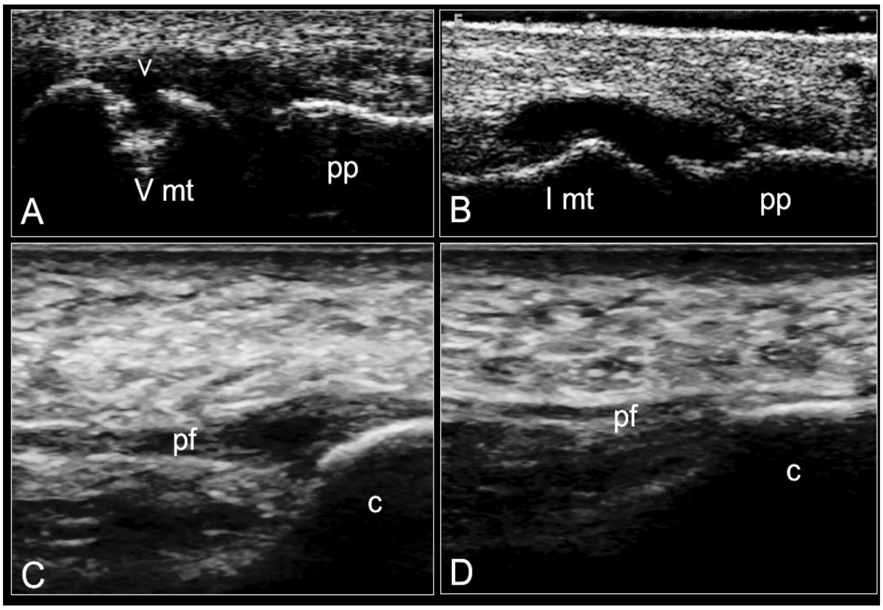

Fig. 1. A. Rheumatoid arthritis. Longitudinal lateral view of the fifth metatarsophalangeal joint showing a bone erosion of the metatarsal head (arrowhead). **B.** Acute attack of gout. Longitudinal dorsal view of the first metatarsophalangeal joint showing an exudative synovitis. **C-D.** Seronegative spondiloarthropathy. Plantar fasciitis. Right-left comparison. Longitudinal plantar view showing (**C**) a marked thickening of the insertional tract of the plantar fascia (0.53 mm). The thickness of the normal controlateral fascia (**D**) was 0.22 mm. **V mt** = V metatarsal head; **I mt** = first metatarsal head; **pp** = proximal phalanx; **pf** = plantar fascia; **c** = calcaneum.
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US imaging of the normal foot

Mid-tarsal joints

The talo-navicular, calcaneo-cuboid and inter-tarsal joints appear as thin anechoic areas delimited by the bone profile and the joint capsule.

Metatarso-phalangeal and inter-phalangeal joints

The MTP joints are imaged as a triangular echogenic space delimited by the metatarsal head, the phalangeal base and the capsule. No effusion is present when the capsule is stretched linearly over the two articular surfaces and the only anechoic area in the joint is the cartilage line (13). According to Schmidt *et al*., in healthy adults the maximum bone-capsule distance is 3.4 mm for the 1st MTP and 3.1 mm for the 2nd MTP (4).

The inter-phalangeal joints appear as thin anechoic areas delimited by the phalangeal profiles and capsule.

Interdigital web spaces

These are homogeneously hyperechoic areas due to the presence of normal fatty tissue. In the normal foot, bursae are not usually seen. However, an anechogenic area located between the distal heads of the metatarsal bones, bulging no more than 1 mm beneath the metatarsal level, may be observed in healthy subjects (14).

Tendons

The long and short extensor and flexor tendons of the hallux and the toes, and the abductor tendons of the hallux and the 5th toe show the typical linear fibrillar structure on longitudinal scanning and a finely punctate echo pattern on transverse scanning. The flexor and extensor tendons with their synovial sheaths (present only at the mid-foot level) can be evaluated along their full length.

Plantar fascia
The normal plantar fascia has a fibrillar echostructure and its thickness is < 4 mm if measured perpendicularly to the long axis of the calcaneus (3).

US imaging of pathological conditions of the foot

Joints
Joint effusion, in the form of a compressible anechoic area with displacement and bowing of the capsule, may be seen in all of the joints discussed above, as well as thickening of synovial membrane. By PDS it is possible to assess the vascularity of synovial tissue. US is much more sensitive than conventional radiography in visualizing bone erosions in the toes, even in early arthritis. Some authors have identified the 5th metatarso-phalangeal joint as the most common site of sonographic erosion in patients with rheumatoid arthritis (15).

Tendons
Tenosynovitis, tendinosis, and tendons tears can all be detected by US of the foot. Tenosynovitis can be seen as an anechoic halo around the tendon in transverse US images (sometimes, but not always, associated with synovial thickening and changes in vascularity) in the ensheathed tract of the flexor and extensor tendons. Chronic tophaceous gout may appear as a nodule on the extensor tendon, which may also show decreased echogenicity and loss of the normal fibrillar pattern (10).

Interdigital web space
Sonography is a very efficient technique for the diagnosis and localization of Morton's neuroma, a fibrotic swelling of the plantar interdigital nerve. It appears as a solid, oval or round hypoechoic mass between the metatarsal heads (most frequently between the 2nd and 3rd or the 3rd and 4th metatarsal heads). Intermetatarso-phalangeal bursitis can be seen as an anechogenic area bulging out more than 1 mm beneath the metatarsal head level (16).

Plantar fascia
Plantar fasciitis can be diagnosed when US examination shows a plantar fascia thickness > 4 mm associated with hypoechogenity and edema. Moderate to marked hyperemia can be demonstrated in acute phase plantar fasciitis. In addition, the presence or absence of fiber ruptures and calcifications can be detected by sonography.

Limitations to the technique of US

The reliablity of the US examination depends on the operator's experience and expertise. Moreover, since the structures being scanned in the ankle and foot are quite superficial, the use of a high frequency probe is mandatory. In patients with serious joint deformities (due, for example, to longstanding rheumatoid or psoriatic arthritis), the MTP and IP joints may be not easily reached by the probe and the imaging of these joints will be severely limited. These limits are summarized in Table V.

Sonography-guided procedures

Ultrasound examination can help the physician to make a more accurate diagnosis in cases of pain in the ankle or foot (for example, allowing him to differentiate between joint inflammation and inflammation of the surrounding soft tissues) and, consequently, to determine the most appropriate treatment. In 2005 D'Agostino *et al.* showed that with the information provided by US scanning, physicians modified the site for local foot injections in 82% of 68 patients studied (17).
The availability of low-cost, non-ionizing US imaging allows clinicians to monitor and guide needle positioning to aspirate fluid or inject pharmaceutical substances more safely and effectively into the talo-crural, sub-talar and mid-tarsal joints, or the ATT, PTT, PLT, PBT, and extensor toe tendon sheaths and deep retrocalcaneal bursa (18).

Table V. Limits of the ultrasound technique.

- Operator dependence
- Need for a high frequency probe
- In patients with serious articular deformities (i.e., in longstanding rheumatoid or psoriatic arthritis), the MTP and IP joints may be not reliably assessed

MTP: Metatarso-phalangeal joints; IP: interphalangeal joints.

Link

For further ultrasound images, go to: www.clinexprheumatol.org/ultrasound

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