

## Ultrasound of the ankle and foot in rheumatology

Mihaela C. Micu<sup>1</sup>, Rodina Nestorova<sup>2</sup>, Tzvetanka Petranova<sup>3</sup>, Francesco Porta<sup>4</sup>,  
Goran Radunovic<sup>5</sup>, Violeta Vlad<sup>6</sup>, Annamaria Iagnocco<sup>7</sup>

<sup>1</sup> Rheumatology Division, Department of Rehabilitation II, Rehabilitation Clinical Hospital Cluj- Napoca, Romania

<sup>2</sup> Centre of Rheumatology "St. Irina", Sofia, Bulgaria

<sup>3</sup> Clinic of Rheumatology, Medical University, Sofia, Bulgaria

<sup>4</sup> University of Florence, Department of Internal Medicine, Section of Rheumatology

<sup>5</sup> Institute of Rheumatology, Medical School, University of Belgrade, Belgrade, Serbia

<sup>6</sup> "Sf. Maria" Clinical Hospital, Bucharest, Romania

<sup>7</sup> Rheumatology Unit, Dipartimento Medicina Interna e Specialità Mediche, Sapienza Università di Roma, Rome, Italy

### Abstract

In the last years musculoskeletal ultrasound (US) has become a very useful imaging tool for the evaluation of rheumatic patients and a natural extension of the clinical examination of the ankle and foot.

Musculoskeletal US allows the evaluation of the symptomatic and asymptomatic ankle and foot with a detailed analysis of a wide range of elementary lesions at the level of different anatomical structures and their distribution in early or long standing disease. In inflammatory pathology, it helps in the assessment of the disease activity and severity at the joint, tendon or enthesal level and in the detection of subclinical pathological features in early disease or residual activity after therapy. Moreover, US guided procedures allow accurate diagnostic and therapeutic interventions. It is a valuable imaging method that can be also used in the follow up of the treated patients (systemic and/ or local therapies or surgical procedures), being a patient friendly, non-invasive, and quick to perform method.

The aim of this paper is to review the US technique of scanning and the indications of US in the analysis of the ankle and foot in rheumatic diseases.

**Keywords:** ankle, foot, ultrasound, anatomy, pathology

### Introduction

The ankle and the foot are not only the most frequently areas injured by trauma of the lower limbs, but they are also frequently involved in patients with arthritis. Usually, clinical examination may underestimate the type and distribution of the pathology because the anatomical structures (joints, tendons, ligaments, neuro-vascular

bundles) are very close to each other [1-4]. Moreover, the physical examination is often difficult and frequently does not allow the identification of the lesions, especially when only minimal involvement is present [1,2].

Conventional radiography (X-ray) of the ankle and foot usually offers limited information regarding the bony structures, while very little and indirect data may be provided about the surrounding soft tissues [5,6]. Magnetic resonance imaging (MRI) is a high resolution imaging method that may disclose either bone or soft tissue abnormalities, but it is expensive and not always available for the clinical rheumatologist. Moreover, information cannot be collected in real time, the number of scanning planes is limited and a dynamic evaluation is not possible.

Ultrasound (US) is an easy, accurate, safe, relatively cheap and time sparing imaging technique that can be used at the bedside. US allows frequent patient evalua-

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Corresponding author: Annamaria Iagnocco,

Dipartimento Medicina Interna e Specialità

Mediche: Reumatologia,

Sapienza Università di Roma,

V.le del Policlinico 155, Rome – 00161, Italy.

Tel: +39 06 49974634

FAX: +39 06 49974642

Email: annamaria.iagnocco@uniroma1.it

tion and is more sensitive in detecting soft tissue modifications than physical examination and X- ray [3,5,6]. It offers multiplanar evaluation and allows parallel dynamic assessment of multiple target structures as joints, tendons, ligaments and bony cortex. For this reason, US is considered a user-friendly technique which may be very useful for the rheumatologist in clinical practice.

The aim of this paper is to review the scanning technique and role of US in the analysis of ankle and foot abnormalities in the rheumatic patient.

**US scanning technique**

The US assessment can be performed at bedside both in the in-patient and out-patient clinic with the use of a high quality machine, equipped with linear probes hav-

ing a range of frequency varying between 7.5 and 15 MHz; in addition, colour Doppler (CD) and power Doppler (PD) modalities consent the detection of inflammatory abnormalities. In order to optimize the scanning of the superficial and deep structures, several settings- focus, dynamic range, gray scale (GS)/ PD frequency, wall filters, pulse repetition frequency and colour box should be continuously adjusted during the US examination [7].

A systematic US assessment is recommended, in order to evaluate all important anatomical structures of the anterior, medial, lateral, and posterior compartments at ankle and foot level, using standard scanning protocols and a multiplanar as well as dynamic approach. The delineation between ankle and foot is made purely by didactic reasons and some structures can be examined in both areas.

Table I. Ankle and foot US examination – patients positions, US access, anatomical structures

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1. supine, with flexed knee, foot on the examination bed
– TTj anterior aspect
– tendon compartments
– anterior:
– TAT
– EHLT,
– EDLT
– lateral
– PBT
– PLT
– medial (frog position)
– TPT
– FDLT
– FHLT
– midtarsal joints
– TNj
– CCj
– NCj
– MTPj
– IP j
– interdigital space
– the distal part of TAT, EHLT, EDLT, short extensors of the hallux and digits and plantar
– the long and short flexors of the hallux and digits, abductor of hallux and 5 th toe
2. prone, with the foot hanging over the examination bed
– posterior compartment
– AT
– FPT
– superficial and retroachillian bursae
– TTj posterior aspect, TCj
– plantar fascia
– tendons of the plantar region: – the long and short flexors of the hallux and digits, abductor of hallux and 5 th toe
3. supine, with extended leg, with heel resting on the examination bed
– examination of MTPj, IP j and interdigital space.

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*Legend:* TTj - tibio- talar joint, TAT - tibialis anterior tendon, EHLT - extensor halluc longus tendon, EDLT - extensor digitorum longus tendon, PBT - peroneus brevis tendon, PLT - peroneus longus tendon, TPT - tibialis posterior tendon, FDLT - flexor digitorum longus tendon, FHLT - flexor halluc longus tendon, TNj - talo-navicular joint, CCj - calcaneo-cuboidal joint, NCj - naviculo- cuneiform joint, MTPj - matatarso-phalangeal joint, IPj - interphalangeal joint, AT - achilles tendon, FPT - flexor plantaris tendon

Table II. US imaging characteristics of the normal anatomical structures

joints	– triangular space between bony cortex and capsule (hyperechoic line) filled up by synovial content (hypoechoic)
tendons	– longitudinal scan (fibrillar pattern) – transverse scan (punctate pattern) – ± synovial sheath – hypoechoic rim
ligaments	– longitudinal scan (fibrillar pattern) – transversal scan (punctate pattern)
bursae	– hyperechoic wall with possible fluid visualisation within them
plantar fascia	– thick hyperechoic fibrillar band – anisotropy at level of insertion
interdigital web space	– hyperechoic homogenous area
neurovascular bundles	– arteries – hypoechoic, Doppler signal positive, pulsating – veins – hypoechoic, Doppler signal positive, compressible – nerves – fascicular structure, compressible and with change in shape
bony cortex	– hyperechoic, regular shape, stops the US beam penetration

The following anatomical structures are usually assessed: joints, tendons, ligaments, bursae, plantar fascia, interdigital web space, neurovascular bundles and bony cortex. Data about the positioning of the patient and anatomical structures to be scanned are presented in table I. US imaging characteristics of the normal anatomical structures at ankle and foot level are presented in table II.

US assessment of the joints shows the bony cortex, capsule and joint content (synovial fluid, synovial tissue, and fat pads). In longitudinal scanning, joints usually present as a triangular shaped space between the bony cortex and the capsule which is identified as a hyperechoic line with proximal and distal bony insertions. In the ankle region, tibio-talar joint (TTj) is filled with an echoic fat pad, the talar dome is covered by the hyaline cartilage and a small amount of fluid can be detected also in healthy individuals [7].

The tendons have a fibrillar pattern on longitudinal scan and a punctate pattern with hypoechoic rims around, representing the synovial sheath, and a small content of fluid (thickness of the surrounding halo <2mm), in transversal scan. The synovial sheath is present at the level of the anterior, medial and lateral tendon compartments (as a separate tendon sheath only at midfoot level). Posteriorly, Achilles tendon (AT) has a peritenon, a structure of loose connective tissue. Distally, tibialis anterior tendon (TAT) has no synovial sheath and is separated from the navicular and cuneiform cortex by a bursa. The ankle tendons sizes depend on the individual structure (body mass index), gender and physical activity [8].

US assessment is based on an extensive evaluation of tendons from the miotendinous junction, to all tendon body length up to the enthesis. A dynamic evaluation is

highly recommended in order to identify the correct anatomical structure and to facilitate the depiction of structural damage lesions on stretched fibres. Therefore, the following manoeuvres are recommended: for TAT evaluation: dorsiflexion and inversion of the ankle and foot; for extensor hallucis longus tendon (EHLT) and extensor digitorum longus tendon (EDLT) assessment: dorsiflexion of the foot and extension of the hallux/ digits 2-5; for peroneus brevis tendon (PBT) and peroneus longus tendon (PLT) study: plantar flexion and eversion of the foot; for tibialis posterior tendon (TPT), flexor digitorum longus tendon (FDLT) and flexor hallucis longus tendon (FHLT) evaluation: inversion of the foot, plantar flexion / flexion of the hallux.

The plantar fascia (PF), attached to the calcaneal bone and to the metatarsal bones, is depicted in longitudinal scanning as a distinct thick (< 4 mm) hyperechoic fibrillar band, running parallel to the skin, with anisotropy artefact present at the level of bone insertions. The dynamic evaluation (dorsal flexion of the foot) induces the stretching of the structure and the margins become more clearly visible. Deeper to PF, other structures may be identified: flexor digitiis brevis (FDBT), quadratus plantae muscle (QPM) and FHLT. In transverse scanning, PF appears as a sharply defined flattened band with a thickness of 1-2 mm.

Interdigital web spaces are hyperechoic homogenous areas due to normal fat presence. The ankle bursae detection is generally difficult because they are virtual spaces, with the exception of the deep retroachilleal one, in which a small quantity of fluid can be present in 25% of healthy subjects. At foot level, bursae are rarely visible as small hypo/anechoic areas below the metatarsal heads (< 1mm) [8].

The nerves are located close to vessels, have a fascicular structure, and are compressible, with the shape depending on the volume of the anatomical spaces within which they proceed [9]. The anterior compartment hosts, lateral to the dorsalis pedis artery, the deep peroneal nerve (medial branch) and the medial compartment, the tibialis posterior nerve close to the homonym artery. In the plantar area, interdigital nerves are not visible by US in normal conditions.

The bony cortex is hyperechoic and has a regular sharp shape. It blocks the penetration of the US beam through.

At Doppler evaluation, no blood flow can be detected in normal conditions in synovial, enthesal and tendinous structures, except for the presence of nutritive vessels.

**US imaging of pathological conditions in ankle and foot**

Table III presents the distinct anatomical structures that can be evaluated by using US and the corresponding ultrasonographic pathological findings. Outcome Measures in Rheumatology Clinical Trials (OMERACT) US definitions for the most common pathological findings occurring in inflammatory arthritis are presented in Table IV together with other published definitions [10-12].

**Joint assessment**

On US, TTj *synovitis* is depicted as an anechoic or hypoechoic intracapsular material represented by two components: effusion and synovial hypertrophy. Anterior and posterior recess scanning can identify from mild to severe effusions, when the fluid can lead to the displace-

ment of the fat pad covering the talus neck and creating capsule distension [13]. In very mild effusions, the medial and lateral compartments have to be checked adding the dynamic examination with plantar flexion of the foot in order to increase the sensitivity of the technique. PD examination allows the assessment of the activity by measuring the pathological vascularity of the synovial tissue. *Bone cortical abnormalities* are mainly represented by *osteophytes* (fig 1A) and *erosions* that can be present respectively in osteoarthritis (OA) and rheumatoid arthritis (RA). Osteophytes may appear as anterior tibio- talar intracapsular *spurs* that can generate the anterior impingement syndrome. The subtalar joints, TNj - anterior and talo- calcaneal joint (TCj) posterior, metatarso- phalangeal joints (MTPj), interphalangeal joints (IPj) may be more difficult to be assessed on US. They may show the same pathological modification as TTj [14].

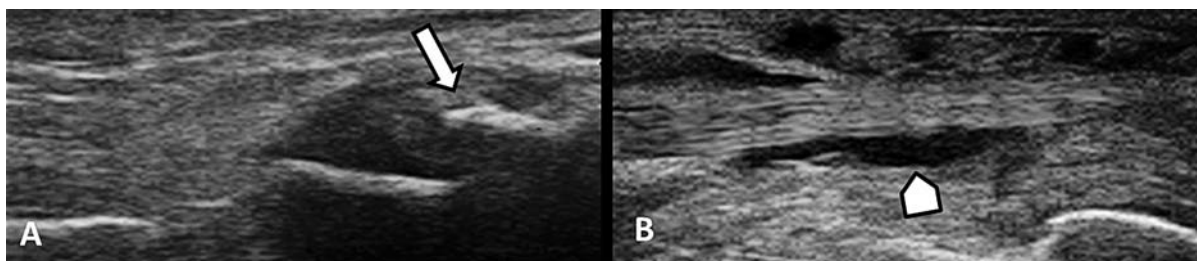
US has a higher sensitivity than clinical examination and X- ray in detecting synovitis and erosions and appears to be similar or even superior to other imaging techniques such as MRI [15]. Moreover, subclinical joint involvement in early disease or in patients with clinical remission according to the disease activity score (DAS) were detected by US assessment [3-6,16-18]. In gout, US was found more effective in detecting bone erosions in comparison to X-ray in symptomatic as well as asymptomatic joints, and an increased perfusion was demonstrated even after clinical remission [19, 20].

**Tendon assessment**

The range of ultrasonographic pathological findings at tendon level is represented by: *tenosynovitis*, *enthesopathy*, *tendinosis*, *tendon erosions*, *partial/ total*

Table III. Anatomical structures and corresponding pathological findings detected on US

joint	<ul style="list-style-type: none"> <li>- effusion</li> <li>- synovial hypertrophy</li> <li>- capsule - distension, thickness</li> <li>- bone cortex irregularities: erosions, osteophytes</li> <li>- cartilage: thickness, crystal depositions, erosions</li> </ul>
tendons, ligaments (body and enthesal involvement)	<ul style="list-style-type: none"> <li>- tenosynovitis</li> <li>- tendinosis</li> <li>- tendon erosions</li> <li>- partial and total tears – tendons and ligaments</li> <li>- calcifications</li> <li>- enthesopathy</li> </ul>
bursae	<ul style="list-style-type: none"> <li>- bursitis</li> </ul>



**Fig 1A.** Longitudinal scan over the dorsal aspect of the talo-navicular joint shows the presence of an osteophyte (arrow); **Fig 1B.** Longitudinal scan over the medial aspect of the ankle, showing tenosynovitis of the tibialis posterior tendon

tears. The dynamic examination allows the identification of the correct structure and tendon tears.

The most frequent US pathology in ankle tendons is seen in AT and TPT. AT enthesopathy is a common finding in spondylarthropathies (SpA), and can be present both in symptomatic and asymptomatic patients [1,3,20,22-25]. Paratenonitis may accompany inflammatory or structural damage (tendinosis, tendon erosions and tears) lesions and, in this case, AT appears surrounded by a thin hypoechoic halo. AT tears are frequently localized at 2-6 cm proximal to the insertion. In acute tears, the gap is usually filled with a haematoma, characterised by a non-homogenous structure. The Kager fat pad herniation may accompany this modification. Old tears show on US the absence of the tendon at its normal anatomic site [26,27]. Other US-detectable pathological findings are calcifications in chondrocalcinosis, described as hyper-echoic intra-cartilaginous linear bands or foci [28]; xantomas, characterised by thickened and non homogenous tendon with hyperechoic spots inside the structure [29]; gout tophus, described as focal echoic nodules inside the tendon with a local hypoechoic area due to loss of the fibrillar pattern [13] and large internal calcifications.

Tenosynovitis of TPT is often present in RA (fig 1B) and ruptures, distal to the medial malleolus or at navicular insertion level, were shown to occur more frequently in patients with RA and SpA [11,12,28]. At foot level, FHLT tenosynovitis was also more frequently reported in patients with early RA [31,32] and chronic tophus were found more frequently on extensor tendons [13].

### Bursae

Bursitis is an abnormal enlargement of a bursa induced by synovitis, overuse / mechanical disorders or haemorrhagic pathology.

On US, retro-achillean bursitis is a well defined anechoic/ hypoechoic compressible area (thickness > 1mm; cranio-caudal diameter > 7mm) [13,25].

Bursitis may be detected even at the level of the interdigital space with evidence of hypo-anechoic formations that should be differentiated by Morton's neuromas, fibrotic swellings of the plantar interdigital nerve, described on US as oval, solid masses characteristically located at the second, third and fourth metatarsal web-spaces. Mulder sign is positive at dynamic assessment [30,31].

### Fasciitis

The inflammation of the PF (fasciitis) has the same US characteristics of the enthesopathy (table IV). The thickness of the structure is > 4 mm. Inflammatory pathology may be followed by structural damage such as fibre rupture, calcaneal entesophytes, or fibromatosis.

### Ankle masses

Several types of masses can be identified by US. They are usually not related to rheumatologic pathology and are represented by ganglionic cysts- hypoechoic/ anechoic uni or multilobulate masses with acoustic enhancement, close to tendon sheaths [13], aneurisms or pseudoaneurisms of local vessels [32], tenosynovial giant cell tumors- with non-specific solid hypoechoic appearance adjacent to a normal tendon [33], neurogenic tumors on the deep peroneal nerve in the anterior compartment and at distal fibula for the superficial peroneal nerve, abscess – hypoechoic or mixed content, acoustic enhancement, diffuse margins [34]. These structures represent the cause of pathological modifications by affecting directly an anatomical structure or they can have a mass effect on the surrounding anatomical structures generating compression/ entrapment pathology.

### Clinical application of US

US gives a wide range of information that can be used as complementary data to the clinical assessment. It usu-

Table IV. OMERACT definitions [10-12] and other published descriptions of US pathological findings

<b>Synovial hypertrophy</b>	– abnormal hypoechoic (relative to subdermal fat, but sometimes may be isoechoic or hyperechoic) intraarticular tissue that is nondisplaceable and poorly compressible and which may exhibit Doppler signal.
<b>Effusion</b>	– abnormal hypoechoic or anechoic (relative to subdermal fat, but sometimes may be isoechoic or hyperechoic) intraarticular material that is displaceable and compressible, but does not exhibit Doppler signal.
<b>Erosion</b>	– an intraarticular discontinuity of the bone surface that is visible in 2 perpendicular planes.
<b>Tenosynovitis</b>	– hypoechoic or anechoic thickened tissue with or without fluid within the tendon sheath, which is seen in 2 perpendicular planes and which may exhibit Doppler signal.
<b>Enthesopathy</b>	– abnormally hypoechoic (loss of normal fibrillar architecture) and / or thickened tendon or ligament at its bony attachment (may occasionally contain hyperechoic foci consistent with calcification), seen in 2 perpendicular planes that may exhibit Doppler signal and / or bony changes including enthesophytes, erosions, or irregularity.
<b>Tendinosis</b>	– as loss of normal fibrillar echotexture
<b>Tendon erosion</b>	– focal tendon defect
<b>Tendon partial tear</b>	– partial-thickness interruption of the tendon fibers
<b>Tendon complete tear</b>	– full-thickness interruption of the tendon fibers
<b>Osteophytes</b>	– step-up prominence of the bony cortex due to new bone formation

Table V. US Pitfalls in ankle and foot region

Anisotropy –	artefact characteristic for tendons which may appear falsely hypoechoic when the US beam is not perpendicular to tendon fibers; it should not be confounded with tendon pathology like tenosynovitis or tendon tear [9]
Excessive skin pressure –	of the probe can lead to false negative PD evaluation due to vessel compression.
Other pitfalls –	TPT diameter is 2-3 times larger in comparison to the FDLT and should not be confounded with it in a case of partial or total rupture [ 36]
–	total rupture of AT should not be missed and AT confounded with plantaris tendon
–	Kager fat pad should not be confounded with synovitis

ally helps the rheumatologist in the routine clinical practice to evaluate inflammatory and degenerative disorders as well as to adapt an appropriate treatment and monitor the therapeutic response. US consents detailed identification of different *elementary lesions* in many musculoskeletal anatomical structures, evaluates their *distribution* inside the ankle and foot area, and/ or identification of the indirect involvement of these due to compressing masses of different origin [15,16,19]. US allows comparison of different structures without radiation exposure and assessment of lesions both in early and late disease [15,35], and it can help, sometimes, in differential diagnosis among various rheumatic disorders [21,28,29]. Moreover it can assess the *disease activity and severity* at joint, tendon, enthesal level [35,37] and the *subclinical pathological* features in early disease or in the evaluation of the *residual activity* after therapy [38,39]. In healthy subjects, assessment of normal structures can be made

without any radiation risk, allowing comparisons with control groups [8].

Rapid diagnostic and therapeutic US guided injections for aspiration/ biopsy and precise local drug deposition is another advantage of the method as well as the follow up of the treated patients with systemic and/ or local therapies and after surgical procedures [40-45].

There are some limits in the US evaluation of some structures because the US beam does not penetrate the bone cortex and metallic prosthesis or because some bony deformities or large calcifications stop the penetration of the US beam and limit the achievement of information [16]. Moreover US is still considered an operator and machine dependent technique and standardisation is still lacking for some issues. A huge effort has been made over the last years to prove the validity and reliability of US in the assessment of joint and tendon pathology [46-48].

Pitfalls in US assessment at ankle and foot level are presented in Table V.

In **conclusion**, MSUS is a sensitive, useful method for ankle and foot area evaluation in rheumatic patients and may be considered as an integral part of the clinical assessment procedure in daily practice.

**Conflict of interest:** none

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