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EURO-MUSCULUS/USPRM Dynamic Ultrasound Protocols for Ankle/Foot

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EURO-MUSCULUS

European Musculoskeletal Ultrasound Study Group in Physical and Rehabilitation Medicine

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ABSTRACT

In this dynamic scanning protocol, ultrasound examination of the ankle is described using various maneuvers to assess different conditions. Real-time patient examination and scanning videos are used for better simulation of daily clinical practice. The protocol is prepared by several/international experts in the field of musculoskeletal ultrasound and within the umbrella of EURO-MUSCULUS/USPRM.

KEY WORDS

Ultrasonography, ankle, foot, examination, maneuver, physiatry.

Ultrasound (US) examination of the ankle has already become routine in the daily clinical practice of physiatrists. While dynamic evaluation is an absolute/added value in ankle examination, a comprehensive approach for ankle pathologies does not exist in the literature. Accordingly, as the extension of basic scanning,[1,2] an international group of experts elaborated this scanning protocol for dynamic US examination of the ankle.

ANKLE

ANTERIOR VIEW

Relevant anatomic structures in the anterior region amenable to dynamic US examination are the tibialis anterior tendon, anterior synovial recess of ankle joint, extensor tendons, anterior tibial artery and deep peroneal nerve.

Technique

Scanning starts in the neutral position, i.e., the patient lying supine on the examination bed with the knee in flexion (45°) and plantar surface of the foot lying flat on the examination bed. Different angles of ankle flexion/extension and patient positioning can easily be performed during the examination. The probe is placed anteriorly to assess several bony structures and surrounding soft tissues (e.g. tendons, recesses, ligaments, entheses). As elsewhere, short- and long-axis imaging is done while bony prominences serve as anatomical landmarks for prompt orientation.

Clinical Indications

Impingement

While ankle/foot lies flat on the examination bed, long-axis imaging over the anterior region of ankle can be performed during active/passive ankle movements. Anterior ankle impingement is a well-established clinical syndrome associated with anterior tibiotalar spurs - which are typically formed within the joint capsule, most commonly at the margin of the articular cartilage[3]. Anterior impingement causes chronic ankle pain with a feeling of locking during dorsiflexion and it may lead to premature ankle osteoarthritis **(Video 1, http://links.lww.com/PHM/C186)**. Moreover, this maneuver can be useful also to evaluate an eventual (stable or unstable) bony avulsion from tibia/talus.

Effusion/synovitis

Similar to other joint examinations, the presence of intraarticular fluid is usually the initial parameter to be assessed in the ankle. Herein, as the ankle joint is quite superficial, caution as not to apply unnecessary compression with the probe is paramount. Likewise, it is also important to recall which position of the joint facilitates accumulation of the fluid in which compartment. While plantar flexion will separate the layers of the anterior recess that will lodge the fluid, dorsal flexion will commonly push it toward the lateral recesses.[1,2,4,5]

The normal synovium is thin and hardly detected upon US imaging. Herewith, synovitis is seen as irregularly thickened, hypoechoic, non-displaceable and poorly compressible tissue in a great spectrum of inflammatory conditions. As such, in addition to joint movements, probe or manual compressions (to aid fluid accumulation) would also be contributory. Dynamic scanning with joint/probe movements also allows for better visualization - by mobilizing the fluid/edema content **(Videos 2, http://links.lww.com/PHM/C187 & 3, http://links.lww.com/PHM/C188; Figure 1)**.

Tendinopathy

Commonly due to overuse activities, e.g. running and jumping, chronic microtrauma to the tendons would be the main underlying mechanism.[6] Although static US scanning provides high resolution/quality images, the sensitivity/specificity of the examination can notably be furthered with dynamic assessment. The addition of sono-palpation or stretching is of great help for better localization of the (minor) lesion or understanding the real-life complaint of the subject. Needless to say, this maneuver can be useful to evaluate an eventual (stable or unstable) bony avulsion as well.

MEDIAL VIEW

Technique

Dynamic US imaging with eversion and valgus stress can improve the assessment of the integrity of the medial compartment anatomical structures. For this purpose, the patient is asked to maintain the supine position or seated with the plantar surface of the foot rolled externally or in a frog-leg position. After coronal images are obtained at rest, either a small stiff pillow is placed under the lateral aspect of the ankle or external manipulation is applied to produce eversion and valgus stress. Widening of the medial joint space can increase the overall visibility of structures whereby flexion/extension might better show reciprocal relations between tibia, ligaments, tendons and talus.

Clinical Indications

Ligament injury

Overuse injuries of the medial collateral ligament can commonly ensue in different sports players - causing joint instability.[7] Owing to the uncommon occurrence of ankle eversion sprains, isolated rupture of the deltoid ligament is unlikely without additional injuries. Often, it takes place in association with fractures of the lateral malleolus and lateral displacement of the talus.[8] Dynamic US assessment with passive/active eversion allows highlighting instability and/or tear of the ligament. The presence of displacement between the ligament ends can help to differentiate between them.

Tendinopathy

Tibialis posterior tendon is the most powerful inverter of the foot and helps to stabilize the medial longitudinal arch.[9] Its action during plantar flexion and eversion is to maintain congruity at the talonavicular and calcaneocuboid joints while walking.[10] The tendon can also be evaluated with the patient in prone position and foot in plantar flexion overhanging the edge of the examination table.[11] To exclude instability, it is best to scan the tendon posterior to the medial malleolus during ankle dorsiflexion and inversion. In addition, tenosynovitis or rupture would be the other clinical scenarios to evaluate the tibialis posterior tendon dynamically **(Videos 4, http://links.lww.com/PHM/C189 & 5, http://links.lww.com/PHM/C190).**

Evaluation of the flexor hallucis longus tendon is more difficult than that of the tibialis posterior. Its supramalleolar portion is well depicted on longitudinal scan - obtained with the probe placed over the Achilles tendon or slightly medial to it**.** Dynamic assessment during passive/active movements of the hallux is noteworthy. At the level of the ankle joint, careful scanning is mandatory to display the tendon running between the two posterior processes of talus. Tenosynovitis, rupture and posterior ankle impingement are common eventual clinical conditions to be encountered.[12] As regards the latter, os trigonum [13] may also be visualized with dynamic evaluation **(Video 6, http://links.lww.com/PHM/C191).**

Tarsal tunnel syndrome

This syndrome refers to the entrapment of the main trunk of the tibial nerve and/or its divisional branches (medial/lateral plantar nerve and inferior calcaneal nerve) at the medial aspect of the ankle.[14] A variety of space-occupying lesions, such as flexor tenosynovitis, ganglia, lipomas, engorgement of the posterior tibial veins, fascial septae, anomalous tendon/muscle (e.g. flexor digitorum accessorius longus) or bony irregularities may compress the nerve.[15] **(Figure 2)**

LATERAL VIEW

Technique

The lateral aspect of the ankle joint is best examined by asking the patient to roll the forefoot internally. From anterior to posterior, the structures to be evaluated are peroneal tendons and retinacula, lateral ligamentous complex, anterior tibio-fibular ligament, lateral aspect of the fibula, talus and calcaneus. Dynamic assessment can be performed while stressing the ankle joint during eversion and flexion/extension. For sure, varus stress can also be applied with manual/probe compressions and extra active/passive movements can help to better visualize the different anatomical structures simulating the daily life activities as well as provocating the relevant complaints.

Clinical Indications

Ligament injuries

Lateral ligament complex injuries are among the most frequent injuries in sports - secondary to inversion sprains with internal rotation of the foot combined with ankle plantar flexion. A frequent one is the anterior talofibular ligament injury **(Video 7, http://links.lww.com/PHM/C192)**, which might sometimes be associated with the involvement of calcaneofibular **(Video 8, http://links.lww.com/PHM/C193)** and rarely posterior talofibular ligaments.[16-20] Other structures that can be injured could be the anterior tibiofibular and interosseous talocalcaneal ligaments. A gentle dynamic inversion test or probe compression can be useful to differentiate partial from complete tears when the ligament ends are not retracted. The latter can show the surrounding soft tissues moving inside when the ligament is not intact. Like elsewhere, sono-palpation can also help to localize/differentiate the exact cause or to relate the painful complaints with the US findings **(Videos 7, http://links.lww.com/PHM/C192)**.

Peroneal tendon injuries

Peroneal tendon **(Figure 3)** pathology is frequent, especially tenosynovitis, but other injuries such as tendinopathy, tendon tears[21] **(Video 9, http://links.lww.com/PHM/C194)** or tendon instability/dislocation also occur[22, 23,24], with more significant changes **(Video 10, http://links.lww.com/PHM/C195)**. Overuse and tendon instability can lead to tendinopathy with hypoechoic thickening or tendon tear **(Video 11, http://links.lww.com/PHM/C196)**. The peroneus brevis tendon is more prone to injury as it is closely related to the lateral malleolus. In the case of tenosynovitis **(Video 12, http://links.lww.com/PHM/C197)**, effusion and hypoechoic synovial thickening might be apparent.[21] Tenosynovitis **(Video 11, http://links.lww.com/PHM/C196)** can also ensue due to mechanical reasons.[25] Sometimes, snapping between the two peroneal tendons during active inversion/eversion movements can also be present **(Video 10, http://links.lww.com/PHM/C195)**. Moreover, dynamic assessment of the peroneal tendons is fundamental for the differential diagnosis concerning the lateral ligaments. Yet, during dorsal hyperflexion of the foot, the peroneal tendons are elevated by the calcaneofibular ligament, whereas in a complete tear they remain attached to the calcaneus.[26] Additionally, shift of the peroneal tendons over the lateral malleolus could serve as an indirect sonographic sign of injury to the superior peroneal retinaculum and the fibrocartilage ridge.[27]

Needless to say, US-guided interventions **(Video 13, http://links.lww.com/PHM/C198)** targeting the peroneal tendon sheath can be performed either to aspirate the pathological fluid collection and/or to inject various therapeutic agents.[28]

POSTERIOR VIEW

The posterior aspect of the ankle joint is examined by asking the patient to settle in prone position, with the foot hanging freely over the edge of the examination bed or resting on the toes to maintain the foot perpendicular to the leg. The structures to be evaluated are Achilles/plantaris tendon and the retrocalcaneal bursa. Active/passive movements of the ankle can help to better visualize these structures. Moreover, the examiner can also study the stability of these structures with the help of counter-resistance (maneuvers).

Clinical indications

Tendinopathy and Paratenonitis

Achilles tendinopathy is commonplace in daily musculoskeletal practice.[29] Most often, the degenerative process is diffuse, leading to a painful spindle-shaped hypoechoic enlargement of the tendon. On longitudinal scans, areas of preserved and thickened fascicles can be seen. Paratenonitis - inflammation of the paratenon - can be isolated or concomitant with tendinopathy. Using dynamic examination (coupled with sono-palpation), gliding pattern of the tendon and its relationship with the nearby soft tissues **(Figure 4)** can promptly be evaluated.[30,31]

Bursitis and Haglund's disease

Chronic posterior ankle pain can be related to bursal pathology, usually associated with Achilles tendinopathy. Retrocalcaneal bursitis presents with posterior heel pain exacerbated by passive ankle dorsiflexion. Dynamically, it is possible to observe in real-time the hypertrophic bone squeezing the retrocalcaneal bursa and impinging with the overlying Achilles tendon.[32] Retro-Achilles bursitis is present due to mechanical or inflammatory disorders.[32,33] Dynamic US examination in longitudinal and axial views can demonstrate sticking of the bursae. For instance, Haglund's disease would be a mechanical/particular disorder causing heel pain, with hypertrophy of the posterior-superior portion of the calcaneal tuberosity, retrocalcaneal bursitis and focal changes in the anterior distal AP **(Video 14, http://links.lww.com/PHM/C199)**.

Achilles tendon tear

Full-thickness tears of the Achilles tendon are more common than its partial thickness tears. Of note, it is not uncommon to change the initial diagnosis/impression of a partial tear to full thickness involvement after dynamic assessment. Tears can be located at three different levels; midportion, musculotendinous junction and the distal part. Complete or partial interruption of the tendon fibres are also associated with loss of tendon volume and alteration of its borders.[34] Dynamic imaging with gentle dorsal/plantar flexion of the ankle shows separation of the tendon ends **(Videos 15, http://links.lww.com/PHM/C200 & 16, http://links.lww.com/PHM/C201)**, differentiating between complete vs. partial tears.[35,36] As elsewhere, tendon compressibility needs to be taken serious, yet a healthy tendon is never compressible.

Similarly, pertinent cases can also/readily be kept under close follow-up after surgery. In such cases, caution should always remain as the prerequisite since nothing would be normal after surgery. Further, for reasonable interpretation, sonographer should be aware of the surgical procedure as well. A markedly enlarged, hypoechoic and heterogeneous tendon with small residual cysts or calcifications would not be unlikely. Of note, sutures can be visualized as thin intra-tendinous double lines, with or without acoustic shadowing.[36] Tendon gliding, routine regenerative process or any suspicion in the presence of 'abnormal' healing **(Videos 17, http://links.lww.com/PHM/C202 & 18, http://links.lww.com/PHM/C203)** can substantially be examined.[37] In patients without a clear anechoic gap, dynamic assessment is invaluable/contributory.

FOOT AND TOES

The patient is generally kept supine on the examination bed with the examiner in different positions, depending on the structure (foot/toe) to be studied. On the dorsal side, attachments of the extensor tendons can be visualized. Flexor tendons, hind/mid/forefoot joints, intrinsic muscles of the foot and plantar fascia can be evaluated from the plantar side. Each tendon needs to be scanned in short- and long-axis views until its insertion. Dynamic maneuvers, e.g. passive, active or resisted toe flexion/extension as well as valgus/varus stress tests can necessarily be performed. In the presence of deformities, the assessment can easily be carried out inside a water basin to optimize the imaging quality.

Clinical indications

Inflammatory/degenerative diseases

Various inflammatory diseases (e.g. rheumatoid arthritis) might involve the tarsal or forefoot joints. US findings include joint effusion, thickened synovium, tenosynovitis, bursitis and erosive changes.[38] As very well known, gouty arthritis commonly affects adult men, particularly their first metatarsophalangeal joint.[39,40] Dynamic US examination can demonstrate monosodium urate crystals in the synovial fluid or the (para)articular structures e.g. small hyperechoic foci impacting the joint **(Video 19, http://links.lww.com/PHM/C204).** Moreover, dynamic imaging also allows to differentiate between effusion and synovial hypertrophy **(Video 20, http://links.lww.com/PHM/C205)**. Finally, osteophytes or intra-articular bodies causing possible impingement can be disclosed during passive/active movements **(Videos 21, http://links.lww.com/PHM/C206 & 22, http://links.lww.com/PHM/C207).** Lastly, dynamic assessment can be used to check for an eventual injury/instability of the fibrocartilaginous plantar plate.[41]

Plantar fascia pathologies

The plantar fascia is a strong fascia that runs throughout almost the full length of the plantar aspect of the foot from its origin (calcaneus) to its complex insertion (metatarsal heads) and maintains the longitudinal arch of the foot.[42] Plantar fasciitis presents with sharp pain, especially prominent in the morning, whereby US shows fusiform thickening, fiber disorganization, surrounding soft tissue edema and entheseal bone formation.[43] Plantar fibromatosis(also known as the Ledderhose's disease) is characterized by fibrous proliferation of the plantar fascia, which forms nodules of varying sizes.[44,45] Fascial rupture is characterized by marked hypoechoic swelling where the fascial ends remain lax during dorsiflexion of the forefoot. Dynamic US evaluation is mandatory to evaluate the fascial gliding and displacement of fascial ends, but also for differential diagnosis e.g. nerve entrapment (Baxter's neuropathy), stress fracture etc. Lastly, dynamic examination can also be used during the follow-up to monitor the stability of scar tissue's after the plantar fascia's injury.[46]

Foreign body

Foreign body granulomas develop in response to fragments of different materials/objects (e.g, wooden splinters and glass) that have penetrated the soft tissues of the foot.[47] They are usually found in the subcutaneous fat at the plantar aspect of the foot.[47] Dynamic exams can be used to determine their exact position and mobility, also guiding a possible onward surgery **(Video 23, http://links.lww.com/PHM/C208)**.

Ganglia and bursitis

A ganglion is an unilocular or multilocular cyst containing mucoid material surrounded by a fibrous capsule, but lacking a true synovial lining, unlike a true synovial cyst.[48] Ganglia generally communicate with a joint or tendon sheath but may also extend within the soft tissues **(Video 24, http://links.lww.com/PHM/C209)**. In identifying the 'neck', careful search for its origin (with palpation, compression, mobilization, and also tracking of the injectate flow during the eventual injection etc.) can be performed **(Video 25, http://links.lww.com/PHM/C210)**.

Morton's neuroma

Different approaches can be applied to examine a web space for the presence of neuroma; dorsal/plantar approach or Mulder sign. In the dorsal approach, the patient lies supine or seated on the examination bed with the knee extended and the ankle in neutral position. The intermetatarsal space can be examined in long-axis by applying firm pressure with the transducer on the dorsal aspect of the foot while exerting finger pressure in the web space from the plantar surface. The examiner has to visualize displacement of the metatarsal heads whereby this maneuver allows the neuroma to subluxate around the anterior edge of the intermetatarsal ligament into the dorsal web space. Using the plantar approach, the probe is placed on the plantar foot and the thumb is pressed on the dorsal side, obtaining a better quality image (being closer to the probe). The last maneuver requires simultaneous pressure application by holding the metatarsal heads from medial and lateral sides.[49-52] The neuroma is expected to move superficially, (possibly) together with a popping sound **(Video 26, http://links.lww.com/PHM/C211 & 27, http://links.lww.com/PHM/C212)**. Finally, a possible differential diagnosis in this anatomical space would be involvement of the intermetatarsal bursa that lies between the metatarsal heads, dorsal to the deep intermetatarsal ligament.[53]

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Figure and Video Legends

Figure 1. Cadaveric dissection **(A)** and long-axis ultrasound views for the tibiotalar joint. In comparison to the normal side **(B),** there is anechoic effusion *(*)* on the arthritic side of the patient **(C).** Note the interface sign *(arrow)* between the effusion and the talar cartilage. *Empty rectangle* shows the corresponding probe positioning.

Figure 2. Cadaveric dissection **(A)** and short-axis ultrasound view **(B)** over the medial malleolus (MM). *Empty rectangle* shows the corresponding probe positioning. TP: tibialis posterior tendon, FDL: flexor digitorum longus tendon, FHL: flexor hallucis longus tendon, a: posterior tibial artery, v: posterior tibial vein, N: tibial nerve.

Figure 3. Cadaveric dissection **(A)** and short-axis ultrasound views **(B, C)** over the lateral malleolus (LM). *Empty rectangles* show the corresponding probe positionings. PL: peroneus longus tendon, PB: peroneus brevis tendon.

Figure 4. Cadaveric dissection **(A)** and long-axis ultrasound view **(B)** over the Achilles tendon *(*)*. *Empty rectangle* shows the corresponding probe positioning.

Videos

Video 1. Anterior ankle impingement.

During active dorsal flexion of the ankle, the examiner can observe a contact between the calcification in the joint capsule and the bony spur on the dorsal aspect of the talar neck. (Left = distal)

Video 2. Anterior capsular recess effusion (transverse scan)

Dynamic anterior scanning (during active dorsal/plantar flexion) shows transformation of the effusion within the anterior ankle recess. It can be useful in patients with mild fluid to better visualize/stretch out the anterior recess - especially before planning an intra-articular procedure.

Video 3. Anterior capsular recess effusion (longitudinal scan)

Passive flexion/extension of the ankle can be performed to move the articular effusion into the anterior capsular recess.

Video 4. Tibialis posterior myotendinous tear.

Dynamic tracking (short-axis view) of the tibialis posterior tendon, from the calf and medial malleolus towards distally to confirm the myotendinous junctional tear**.**

Video 5. Tibial posterior tendinitis.

Proximal - distal - proximal tracking (short-axis view) around the medial malleolus to assess the tibialis posterior tendon.

Video 6. Os trigonum.

Ankle dorsiflexion and plantar flexion to visualize the accessory ossicle over the talus, impinging the posterior ankle capsule and flexor hallucis longus tendon.

Video 7. Focal injury of the anterior talofibular ligament (normal vs. pathological). Anterior talofibular ligament injury. Sonopalpation of the anterior talofibular ligament.

Sono-palpation to push the articular effusion into a focal injury of the ligament (synovial fluid used as a natural contrast agent). Partial compressibility of the ligament towards the joint suggests incomplete injury. Swollen but intact ligament is partially compressible.

Video 8. Hammock sign. Calcaneo-fibular ligament (normal vs. pathological).

Active dorsiflexion of the ankle can be used to better visualize the calcaneofibular ligament which - in that case - also pushes the peroneal tendons away from the joint. Dynamic imaging of the ligament for Hammock sign. While the sign is positive on both sides, the ligament is intact but swollen on the abnormal side.

Video 9. Peroneus brevis tendon injury.

Peri-malleolar sono-tracking (short-axis view) shows partial tear of the peroneal brevis tendon.

Video 10. Intra-sheath snapping of peroneal tendons.

During active ankle inversion/eversion, intra-sheath snapping is observed.

Video 11. Peroneal tenosynovitis.

Sono-tracking (short-axis view) depicts mild tenosynovitis.

Video 12. Os peroneum.

Dynamic imaging of the peroneal tendons (from the lateral malleolus towards the cuboid) to observe the accessory ossicle rubbing against the tendons.

Video 13. Injection of peroneal tenosynovitis.

Intrasheath injection for the peroneal tendons using the direct out-of-plane technique.

Video 14. Haglund disease.

Longitudinal view of the hindfoot shows a prominent posterosuperior tuberosity of the calcaneus associated with the thickening of the superficial Achilles tendon at its point of insertion and hypoechoic distention of the retrocalcaneal bursa known as Haglund deformity.

Video 15. Full-thickness tear of the Achilles tendon (short- and long-axis imaging).

Sono-tracking over the Achilles tendon using sono-palpation shows apparent compressibility.

Video 16. Repaired Achilles tendon tear (long- and short-axis views).

Sono-tracking for post-operative Achilles tendon shows intact suture materials.

Video 17. Repaired Achilles tendon - suture failure.

During active plantar flexion, it is evident that the deep layers move. Note the scar tissue containing fluid and suture material between the proximal and distal stumps of the Achilles tendon. (Left = distal).

Video 18. Ruptured Achilles tendon.

Under passive flexion/extension of the ankle, the distal stump of the ruptured Achilles tendon is not moving as much as the flexor hallucis longus muscle. (Left = proximal).

Video 19. Gout - metatarsophalangeal joint.

Sono-tracking over the joint in long- and short-axis views demonstrates the ‘double-contour‘ sign i.e. deposition over the cartilage.

Video 20. Synovial hypertrophy - metatarsophalangeal joint.

Great toe flexion/extension can help to distinguish between effusion and synovial hypertrophy. (Left = distal).

Video 21. Extensor hallucis longus tendon - osteophyte.

During passive movements, the tendon is seen rubbing over an osteophyte of the first metatarsal bone.

Video 22. Intra-articular body - 1st metatarsophalangeal joint.

During passive movements, an intra-articular body is seen to be "blocked" within the joint.

Video 23. Foreign body - forefoot.

Dynamic scanning of the forefoot to scrutinize for glass pieces which were invisible on plain radiography.

Video 24. Adventitial bursitis - forefoot.

Longitudinal scan shows a compressible interstitial bursa with some power Doppler activity.

Video 25. Intermetatarsal bursitis.

Sono-palpation - in addition to aggravating the patient's pain - is seen to compress the intermetatarsal bursa which contains mild fluid.

Videos 26 & 27. Sonographic Mulder sign - Morton neuroma.

Applying the Mulder test, the anechoic neuroma is observed to 'jump' (superficial - deep) between the metatarsal heads.

Figure 1

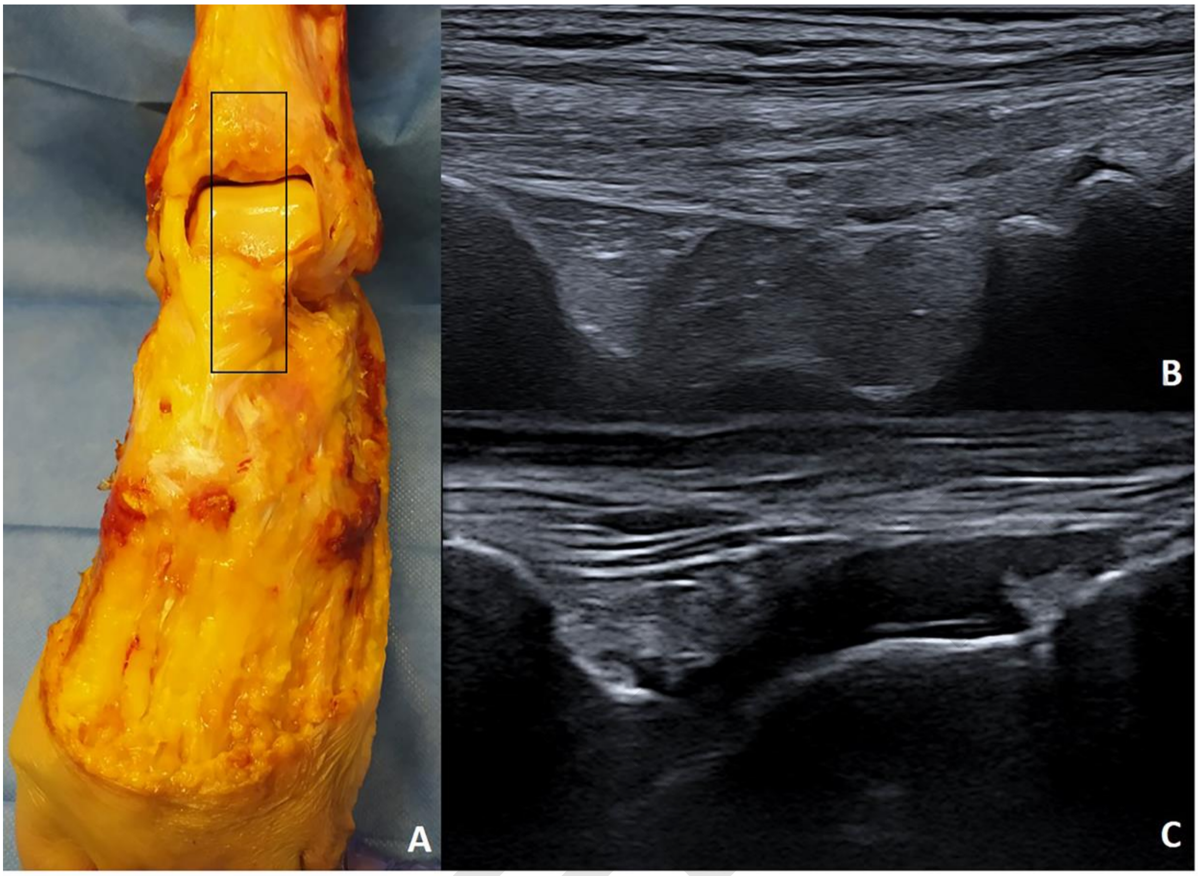

Figure 2

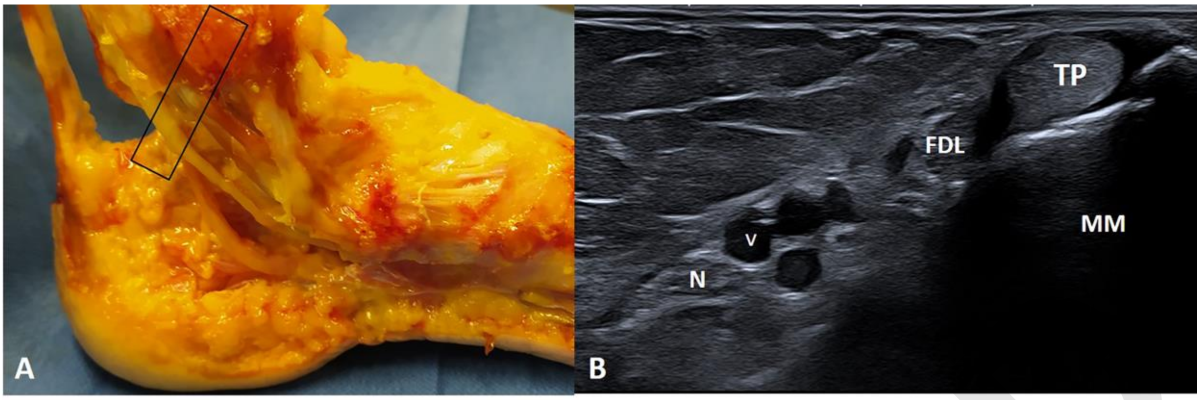

Figure 3

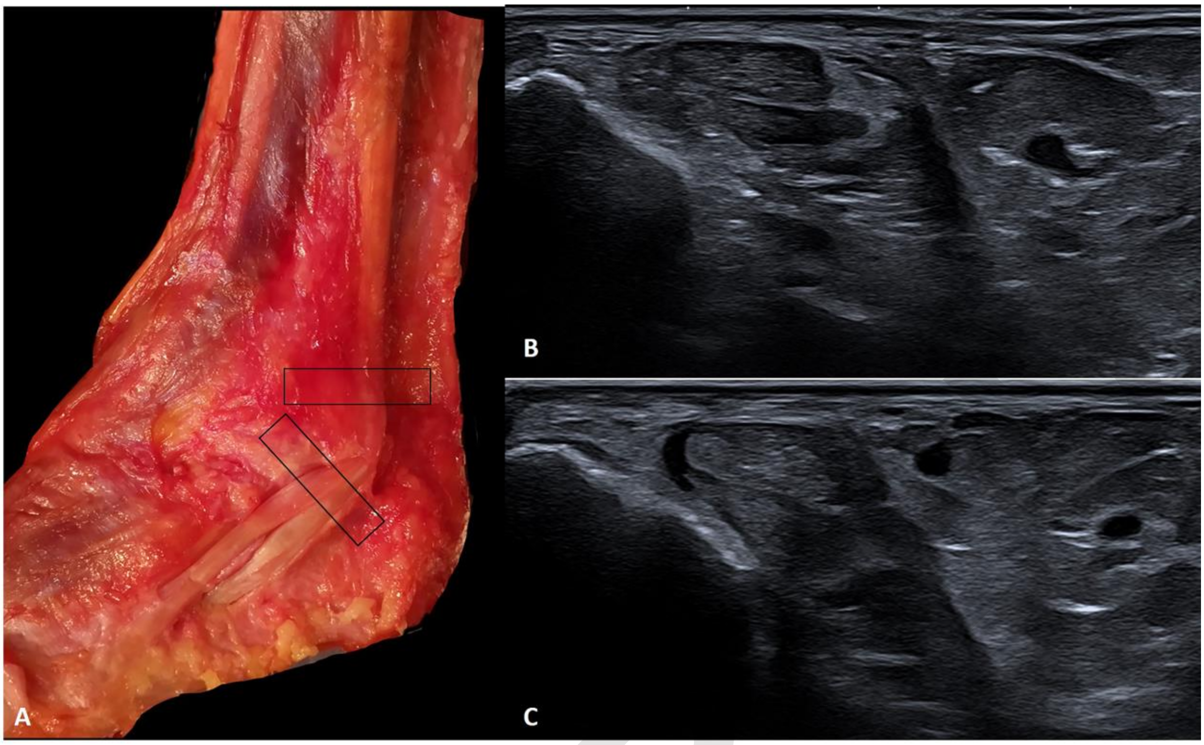

Figure 4