Sonographic visibility of the sinus tarsi with a 12 MHz transducer

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Abstract

Objectives To assess the value of ultrasonography in studies of the ligaments within the sinus tarsi (ST) in healthy subjects.

Materials and methods We examined 20 healthy volunteers using a 12-MHz transducer with THI and compound imaging. With the foot in inversion, the following structures were examined with coronal and transverse scans: (1) the root of the inferior extensor retinaculum (RIER); (2) the interosseous talocalcaneal ligament (ITCL); (3) the cervical ligament (CL); (4) the bifurcate ligament (BL); (5) the synovial recesses, which were examined for possible distention (distended synovial recesses, DSR). The

sonographic features, orientation, and thickness of each ligament were assessed.

Results The easiest structure to identify (visualized in 20/20 subjects) was the RIER, which formed a semiarch. The two deeper layers were hypoechoic, the superficial layer hyperechoic. The ITCL was situated posteriorly and deep with an oblique course. It appeared hypoechoic with a mean thickness of $4.06 \text{ mm} \pm 0.7$. It was visualized in 18/20 (90 %) subjects. The CL (isoechoic/hyperechoic) was located more anteriorly at an intermediate depth. The orientation was almost vertical. It was visualized in 17/20 (85 %) subjects, with a mean thickness of $2.28 \text{ mm} \pm 0.34$. The BL appeared hypoechoic. It was visualized in 19/20 (95 %) subjects with transverse (anterior end of the ST) and longitudinal scans. The calcaneonavicular and calcaneocuboid components displayed mean (SD) thicknesses of $2.09 \text{ mm} \pm 0.37$ and $2.7 \text{ mm} \pm 0.32$, respectively. The ITCL and RIER were visualized in the same scan as a semiarch. DSR was observed in 4/20 (20 %) subjects.

Conclusions The present study shows that, in patients with suspected ST pathology, the anatomic structures that make up this recess can be adequately examined with ultrasonography performed with ordinary 12-MHz transducers.

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Sommario

Obiettivi indagare la capacità degli ultrasuoni (US) di identificare le strutture legamentose del seno del tarso (ST) in un gruppo di soggetti sani.

Materiali e Metodi abbiamo studiato 20 volontari sani, utilizzando sonde da 12 MHz, Compound e THI attivati. Sono stati indagati con piede in inversione: (1) radice del

retinacolo inferiore degli estensori (RIER) (2) legamento interosseo (ITCL) (3) legamento cervicale (CL) (4) legamento biforcuto (BL) (5) eventuali distensioni di recessi sinoviali (DSR), con scansioni coronali e trasversali, valutando ecostruttura, orientamento e spessore dei legamenti.

Risultati (1) la RIER, repere ecografico, è stata la struttura di più agevole identificazione: con decorso a semiarco, ipoecogena nei 2 strati profondi, iperecogena in quello superficiale, visualizzata in 20/20 soggetti (2) il ITCL in situazione posteriore e profonda, con andamento obliquo ha presentato spessore medio di $4.06 \text{ mm} \pm 0.7$, ipoecogena, visualizzato in 18/20 (90 %); (3) il CL, più anteriore e orientamento quasi verticale, in situazione di profondità intermedia, iso/iperecogena, visualizzato in 17/20 (85 %), con spessore medio di $2.28 \text{ mm} \pm 0.34$; (4) il BL, ipoecogena, indagabile in scansione trasversale (estremità anteriore del ST) e longitudinale, visualizzato in 19/20 (95 %), con spessore medio $2.09 \text{ mm} \pm 0.37$ (componente calcaneo-navicolare) e spessore medio $2.7 \text{ mm} \pm 0.32$ (componente calcaneo-cuboidea). Il ITCL e il RIER hanno presentato (80 %) nella medesima scansione un aspetto a semicerchio. (5) sono stati riscontrati infine 4/20 (20 %) DSR.

Conclusioni lo studio evidenzia la potenzialità degli US con comuni sonde da 12 MHz nell'individuare le strutture anatomiche che formano il ST nella prospettiva di approfondimenti anche per la patologia del recesso anatomico.

Introduction

The sinus tarsi (ST) is a small anatomic space in the foot situated between the neck of the talus and the anterosuperior surface of the calcaneus at an angle of approximately 45° relative to that of the body of the calcaneus [1, 2]. The sinus is more or less cylindrical or cone-shaped with a lateral opening, and it is filled with adipose tissue containing small arteries and veins, nerve endings, synovial recesses, which may be distended, and important ligaments [3], which stabilize the subtalar articular complex during ambulation [4]. The latter include: (1) the three roots of the inferior extensor retinaculum (RIER), which insert into the floor of the recess at different levels. The lateral band—the most superficial—inserts into the outermost border of the floor of the ST, lateral to the insertion of the extensor brevis digitorum muscle. The insertion of the intermediate root lies in the same plane as that of the cervical ligament, medial to that of the extensor brevis digitorum muscle. A common variant consists in the division into two distinct bands at the point of insertion. The medial root is the deepest. Its initial course parallels those of the other two

bands, but thereafter it plunges downward, almost at a right angle, and continues on to its insertion in a deeper plane [2], near that of the interosseous talocalcaneal ligament (ITCL); (2) the cervical ligament (CL), a fibrous bridge running vertically or slightly obliquely between the neck of the talus and the calcaneus. It inserts into the central portion of the floor of the ST, just anterior to the interosseous talocalcaneal ligament; (3) the interosseous talocalcaneal ligament (ITCL), the deepest of the ligaments, stabilizes the joint during walking. It is located in the medialmost portion of the recess near the tarsal canal, and its fibers form an obliquely oriented semiarch between the talus and calcaneus; (4) the bifurcate ligament (BL) is situated anterior to the other three ligaments in the periphery of the recess. It is a Y- or V-shaped structure that connects the calcaneus to the cuboid laterally (lateral band of the bifurcate or calcaneocuboid ligament, CCL) and to the navicular medially (medial band of the bifurcate or calcaneonavicular ligament, CNL). It represents an important connection between the hindfoot and midfoot [2, 5–8].

The interosseous talocalcaneal and cervical ligaments (the latter known also as the anterior talocalcaneal ligament) [6] are intrinsic ligaments. They form a strong stabilizing connection between the articular surfaces of the calcaneus and talus [2]. The complex formed by these two ligaments was considered by some anatomists [7, 8] as a single powerful structure (interosseous talocalcaneal ligament) that is the true stabilizer of the talocalcaneal joint. It was described as being composed of flattened bands separated by adipose tissue. The deeper of the two—the interosseous—running obliquely from the calcaneal to the talar sulcus, and slightly anterior to this, a vertical band joining the talus and the calcaneus (the anterior talocalcaneal ligament or, as it is known today, the cervical ligament). Depending on the severity, injuries involving these important intrinsic ligaments can cause abnormal movement of the subtalar joint leading to instability [9, 10].

In the present study, we investigated the value of ultrasonography in identifying and characterizing these complex ligament structures. For completeness' sake, it is important to recall that the talocrural joint complex is also stabilized by extrinsic ligaments—the calcaneofibular ligament, the posterior talofibular ligament, and the deltoid ligament—which are easy to study with other imaging methods [3, 4, 11–14] and are not included in the present study. US examination of the ST is complicated by the amount of adipose tissue within the sinus and by the depth and orientation of some of the intrinsic ligaments. For this reason, tissue harmonic imaging (THI) and real-time spatial compounding (in resolution mode) should be used to increase contrast resolution [15–17] and eliminate background noise and artifacts [18]. Compared with standard imaging, THI markedly reduces artifacts (e.g., lateral lobes,

backscatter, reverberation, speckle and clutter) and clearly increases contrast resolution. Compounding involves the acquisition of multiple images at different insonation angles (angles of incidence of the ultrasound beam of $\pm 20^\circ$), which are then combined to produce a single digital image. It greatly reduces the artifacts produced by anatomic angles and near-field reverberation artifacts, diminishing anisotropy and increasing image definition [18–21], all of which are of crucial importance in the examination of ligaments with complex spatial orientations.

Reports in the literature indicate that only part of the retinaculum of the ST and part of the adipose tissue in the cavity can be well-visualized with US [22]. For this reason, magnetic resonance imaging is currently considered the method of choice for examining the structures within the ST [3, 4, 11], even though its ability to visualize the three components of the root of the inferior retinaculum of the extensors is limited [2].

Methods

The ligamentous structures of the sinus tarsi were studied bilaterally (total: 20 feet) in 20 healthy, asymptomatic volunteers with no history of significant trauma (11 women, 9 men, mean age 44 ± 15 , range 22–69, mean body mass index 24.48 ± 3.63). All examinations were carried out by a single skilled operator using multifrequency transducers (12 MHz) and a Philips HD 15 or a GE Logic E ultrasound device with compounding (resolution

mode) and THI. Each examination included the following anatomic structures: (1) the lateral, intermediate, and medial roots of the inferior extensor retinaculum (RIER) (Figs. 1, 2); (2) the interosseous talocalcaneal ligament (ITCL); (3) the cervical ligament (CL); (4) the bifurcate ligament (BL) and its components, the calcaneonavicular (CNL) and calcaneocuboid (CCL) ligaments; (5) the synovial recesses, which were examined for possible distensions (distended synovial recesses, DSR). Coronal scans (perpendicular to the long axis of the sinus tarsi)—the main approach used to identify the anatomic structures of interest—which were done with the foot in inversion and included the entire axis of the recess. Transverse scans (parallel to the long axis of the sinus) were done mainly to detect DSR. The BL, which lies at the anterior extremity of the sinus tarsi, was initially examined with a coronal scan, when the articular margins of the calcaneal apophysis and the head of the talus (anterior articular facet for the calcaneus) are aligned with the borders of the navicular and cuboid bones. This allows visualization of the two components of the BL (the CCL and CNL) (Fig. 3). The anatomic landmarks used for these coronal scans were the borders of the navicular (medially) and cuboid (laterally) bones, at the level where the two bands of the BL diverge. Each component of the BL was then examined with a longitudinal scan, parallel or slightly oblique to the main axis of the ST, and its thickness was measured at the approximate midpoint. Every ligament was evaluated in terms of its echostructure, form, and orientation relative to the scan plane. We measured the thickness (and calculated

Fig. 1 Schematic showing the ligaments of the sinus tarsi as they appear on a coronal scan (which offers the best visualization of these structures). The transducer is held perpendicular to the long axis of the sinus

Fig. 2 Schematic showing a dorsal view of the calcaneus with the calcaneal insertions of the various ligaments on the floor of the sinus tarsi

the mean and SD) of the ITCL, CL, and BL. For the latter ligament, we recorded the thicknesses of the two component ligaments, the CCL and the CNL. The thickness of the CL was measured at its midpoint.

Results

The RIER and its component bands were the easiest structures to identify on US and thus served as a true landmark for study of the sinus tarsi. Owing to its semiarch course and the phenomenon of anisotropy, the innermost roots (the intermediate and medial bands) appeared hypoechoic, whereas the outermost portion was iso- or hyperechoic. All three layers (lateral, intermediate, medial) could be well-visualized on all 20 of the subjects examined (Figs. 4, 5, 6).

The ITCL occupied the deep posteromedial portion of the sinus. The depth never exceeded 30 mm in any of the subjects examined. Owing to its vertical/oblique course relative to the transducer, it was subject to anisotropy artifacts. The mean thickness was $4.06 \text{ mm} \pm 0.7$ (range 3–5.4 mm). It was consistently hypoechoic. The ITCL could be visualized in 18 of the 20 subjects (90 %) with appropriate adjustment of the focus and gain; in 13 of the 18 cases, the transducer frequency also had to be reduced from 12 to 10 mHz (Fig. 7).

The CL was visualized in 17 (85 %) of the 20 subjects, running slightly anterior to the ITCL at an intermediate

Fig. 3 Dorsal view of the foot showing the anatomic position of the bifurcate ligament. The anatomic landmarks are the margin of the navicular bone (medially) and the margin of the cuboid bone (laterally). The dotted blue line indicates the position of the transducer, which is moved anteriorly/posteriorly and tilted over the landmarks to visualize the bifurcation

Fig. 4 Root of the inferior extensor retinaculum (RIER)—lateral (superficial) band. Asterisk talus; double asterisk calcaneus

depth. Its course was almost vertical in 10/17 (59 %) subjects and slightly more oblique in the other 7 (41 %). The mean thickness was $2.28 \text{ mm} \pm 0.34$ (range

Fig. 5 Root of the inferior extensor retinaculum (RIER)—intermediate band. At the calcaneal insertion (*double arrow*), the band often divides, producing two insertions. *Asterisk* talus; *double asterisk* calcaneus. *Arrowhead* lateral root of the RIER

Fig. 7 Interosseous talocalcaneal ligament (ITCL). *Asterisk* talus; *double asterisk* calcaneus

Fig. 6 Root of the inferior extensor retinaculum (RIER)—medial band (deep). The medial root initially runs parallel to the other two roots and then plunges downward, at almost a right angle to the transducer. *Asterisk* talus; *double asterisk* calcaneus. *Arrowhead* dual insertions of the intermediate root of the RIER

1.8–3 mm). In some cases (12/17) it was thicker at the two insertions and thinner in the middle, giving it a biconcave shape. It was iso- or hyperechoic relative to the surrounding adipose tissue and essentially free of all anisotropy artifacts since it had to be examined at a 90° angle. Without THI and compounding (resolution mode), precise localization of this ligament may be difficult, particularly when it is perfectly vertical relative to the transducer. If THI and compounding are not used, precise localization of the CL may be difficult when it lies perfectly vertical relative to the transducer, and its full length is being insonated at a 90° angle. The absence of anisotropy in this case renders the ligament isoechoic relative to the surrounding fat tissue. When the course was less vertical and more oblique (from

Fig. 8 Cervical ligament (CL). *Asterisk* talus; *double asterisk* calcaneus

outer to inner), the ligament was more hypoechoic (secondary to moderate anisotropy) and thus easier to identify (Fig. 8).

The BL is visualized on coronal images to examine the bifurcation (Figs. 3, 9) and longitudinal images, parallel or slightly oblique relative to the main axis of the ST, for biometric analysis of the two components. In 19/20 (95 %) cases, it was visualized correctly as a hypoechoic structure on transverse scans at the level of the bifurcation. The calcaneonavicular and calcaneocuboid components displayed mean thicknesses of 2.09 mm ± 0.37 (range 1.5–2.9 mm) and 2.7 mm ± 0.32 (range 2.1–3.2 mm), respectively. In 80 % of the subjects examined, the ITCL and RIER were visualized in the same image as a C-shaped (left ST) or inverted C-shaped (i.e., ∩) (right ST) semiarch. In the remaining cases, it was L-shaped. In 4/20 (20 %) subjects, DSR was observed in the ST, consisting of

Fig. 9 Bifurcate ligament at the level where it divides into a medial band and a thicker lateral band. The *longer arrows* indicate the bifurcation. Asterisk navicular; double asterisk cuboid

subcentimeter anechoic cyst-like formations, round or oval and in some cases loculated, near the CL or ITCL. No effusions were seen in the talocrural recesses (anterior tibiotalar, posterior recess, tibiofibular syndesmosis).

Conclusions

The sinus tarsi is a roughly cylindrical space located between the neck of the talus and the anterosuperior surface of the calcaneus. Because it contains adipose tissue and the important ligaments that stabilize the subtalar articular complex during ambulation, it has thus far been imaged exclusively with scanographic techniques, particularly magnetic resonance imaging, which is clearly the best method for visualizing the ITCL, the CL, and the other ligaments that constitute the anatomic recess [3, 4, 11]. Recent reports in the sonographic literature indicate that only part of the retinaculum of the ST [22] can be visualized with US, along with any distention of the synovial recesses that may be present.

The results of the present study demonstrate that US has great potential for investigation of the structures in the ST. Even with ordinary 12-MHz transducers and moderately-priced scanners, we were able to define the sonographic and biometric aspects of these structures in the vast majority of the subjects we examined. Because of the amount of adipose tissue present in the sinus and the depth and orientation of the ligaments therein, tissue harmonic imaging and real-time spatial compounding (resolution mode) [15–21] were used to improve contrast resolution and reduce artifacts produced by anatomic angles and anisotropy, appreciably improving image definition. Use of these aids and proper positioning of the foot during the examination (i.e., in inversion) are fundamental given the

complex spatial orientation of the ST ligaments and their tendency to be masked by the fairly abundant adipose tissue surrounding them. It is important to stress that DSR in normal subjects almost always involves the subtalar joint. As we have seen, effusions at this level are visualized as cyst-like collections of anechoic synovial fluid. In the literature on ultrasonography [23, 24] the sinus tarsi is generally included (along with the recesses of the anterior tibiotalar joint and the tibiofibular syndesmosis) among the recesses in which synovial fluid from the talocrural joint may be found. However, communication between the talocrural and talocalcaneal joints, via a synovial extension, has been reported as an occasional finding in certain anatomic descriptions [25], which lends support to the observations of the authors of those studies, even though this communication has not been demonstrated in arthroscopic studies [26].

Conflict of interest Salvatore Massimo Stella, Barbara Ciampi, Eugenio Orsitto, Daniela Melchiorre, Piero Vincenzo Lippolis declare that they have no conflict of interest.

Informed consent The study was conducted in accordance with the ethical standards dictated by applicable law. Informed consent was obtained from each owner to enrolment in the study and to the inclusion in this article of information that could potentially lead to their identification.

Human and animal studies The study described in this article does not contain studies with human or animal subjects performed by any of the authors.

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