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ULTRASOUND

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Ultrasound assessment of the spring ligament complex

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Abstract This study was conducted to document the normal ultrasound anatomy of the spring ligament in asymptomatic subjects and to prospectively determine the frequency of ultrasound abnormality of the spring ligament in patients with suspected posterior tibial tendinopathy. The superomedial calcaneonavicular ligament (CNL) of 10 healthy volunteers was examined by ultrasound. Nineteen patients with a clinical diagnosis of suspected posterior tibial tendinopathy and/or chronic pain along the course of the tendon were examined by ultrasound. The superomedial CNL thickness was measured. Normal anatomy of the superomedial CNL could be demonstrated in all the volunteers. The mean of the combined proximal measurements was 4 mm and of the distal measurements 3.6 mm. Sixteen patients with posterior tibial tendinopathy had increased thickness of the spring ligament, which was more evident on its distal portion over the talar head. One patient had superomedial CNL insufficiency with normal posterior tibial tendon. The mean proximal measurement in the study group was 5.1 mm and the distal measurement 6.1 mm. The differences between the measurements in the study group and controls were highly significant (proximal site $P<0.01$, distal site $P<0.001$). Spring-ligament laxity or tear is characterised by thickening. There is a strong association between posterior tibial tendinopathy and abnormality of the spring ligament.

Keywords Ultrasound · Spring ligament · Posterior tibial tendinopathy

Introduction

The spring ligament is an essential stabiliser of the longitudinal arch of the foot together with the posterior tibial tendon (PTT), the plantar fascia, and the plantar ligaments, providing support for the head of the talus, which articulates with the superomedial component of the spring ligament [superomedial calcaneonavicular ligament (CNL)]. Laxity or rupture causes insufficiency of the spring ligament, which permits plantar flexion of the talus resulting in valgus alignment of the calcaneus and a flatfoot deformity (pes planovalgus) [1–4]. Spring-ligament insufficiency, in the form of laxity or rupture of the ligament, can develop in cases of chronic dysfunction of the PTT. The area affected is usually confined to the superomedial part of the spring ligament where the ligament becomes thickened [5]. In PTT dysfunction, surgical management may include plication of the spring ligament in addition to repair or reconstruction of the tendon to stabilise the medial column of the foot. Thus, the status of the spring ligament can be a significant consideration in preoperative planning [1, 2].

The spring ligament complex is comprised of the ligaments between the calcaneus and navicular bones at the superomedial to inferoplantar aspect of the foot. It is composed of superomedial, inferoplantar and medioplantar CNLs (Fig. 1). The distal part of the superomedial CNL articulates directly with the talar head. Here the articular

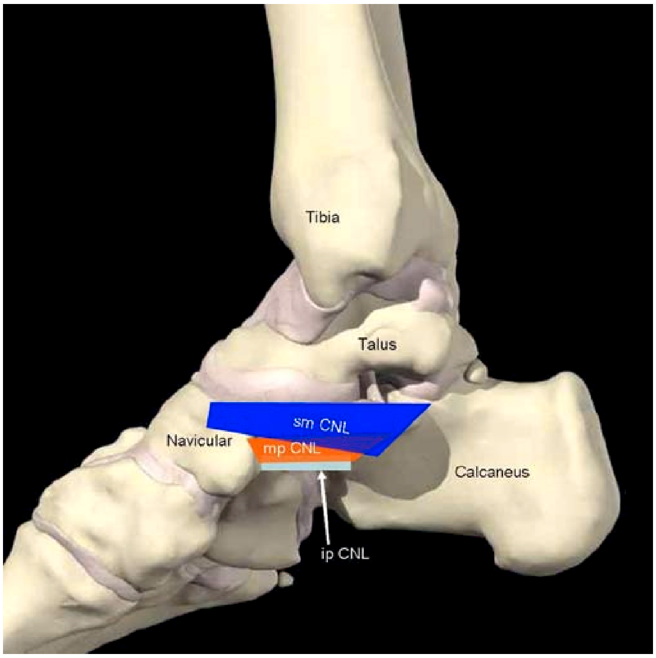

Fig. 1 Diagram of the medial aspect of the ankle and foot showing the three components of the spring ligament. *sm CNL* Superomedial calcaneonavicular ligament, *mp CNL* medioplantar calcaneonavicular ligament, *ip CNL* inferoplantar calcaneonavicular ligament (*arrow*)

surface of the spring ligament is covered with fibrocartilage, creating an articular surface with the head of talus, termed the spring ligament–fibrocartilage complex [2]. Between the superomedial CNL and the PTT, there is loose connective tissue [6] that provides a gliding layer. The superomedial CNL–fibrocartilage complex and the PTT provide support for the medial aspect of the talar head [2]. The tibiospring ligament arises from the anterior aspect of the medial malleolus and blends with the superomedial CNL. The medioplantar CNL originates from the coronoid fossa at the anterior aspect of the calcaneus [7, 8]. It attaches just below the tuberosity of the navicular bone. The short and thick inferoplantar CNL originates from the coronoid fossa anterior to the medioplantar CNL and inserts at the inferior beak of the navicular bone [7, 9]. The ligament was thought to act as a spring for the longitudinal arch of the foot [10], but histological and biomechanical analysis of the CNL has shown this to be a purely collagenous structure with no elastic properties [10, 11].

In our institution, we use ultrasound for the evaluation of the PTT in cases of suspected tendinosis. In these cases we routinely assess the condition of the superomedial part of the spring ligament (superomedial CNL). Although it is recognised that a pathological spring ligament frequently accompanies posterior tibial tendinosis, the strength of this association is not well documented.

Aim

The aim of the study was to document the normal ultrasound anatomy of the spring ligament in asymptomatic subjects and to prospectively determine the frequency of ultrasound abnormality of the spring ligament in patients with suspected posterior tibial tendinosis.

Material and methods

Full approval from our institutional research ethics committee was obtained prior to the start of this study.

Asymptomatic volunteers

Ten healthy volunteers (seven females, three males, age range 28–51 years) agreed to participate in the study. Informed consent was obtained in all cases. Inclusion criteria for volunteers were (1) the absence of a history of foot or ankle symptoms requiring consultation with a physician or podiatrist, (2) no current ankle or foot pain, (3) no previous operations on the ankle or foot and (4) no trauma to the ankle or foot in the past 5 years. All examinations were performed by one of three radiologists experienced in musculoskeletal ultrasound. A standard sagittal oblique view along the long axis of the superomedial CNL was recorded. All three radiologists agreed on the method of obtaining this standard view. The ultrasound images were obtained using a Sonoline Anatres (Siemens) ultrasound system with a high linear array transducer (5–12 MHz).

Ultrasound technique

The patients were positioned supine with extended knee and slight plantar flexion of the ankle. The standard sagittal oblique images were obtained by placing the probe parallel to the long axis of the superomedial CNL to avoid artifactual hypoechogenicity. The probe was placed inferior to the medial malleolus, with one end placed over the sustentaculum tali and the other end slightly tilted superiorly over the talar head towards the superomedial aspect of the navicular bone. The ultrasound images were obtained in which the sustenaculum tali, the PTT, the medial border of the talar head and the attachment of the superomedial CNL to the sustenaculum tali were visualised (Fig. 2). The ligament was identified by its hyperechoic fibrillar echo pattern. We used the same technique as was described in a recent study of cadavers and asymptomatic patients [12].

Quantitative analysis Two experienced musculoskeletal radiologists (with 6 and 15 years of musculoskeletal ultrasound experience) independently measured, electronically with a PACS workstation, the thickness of the

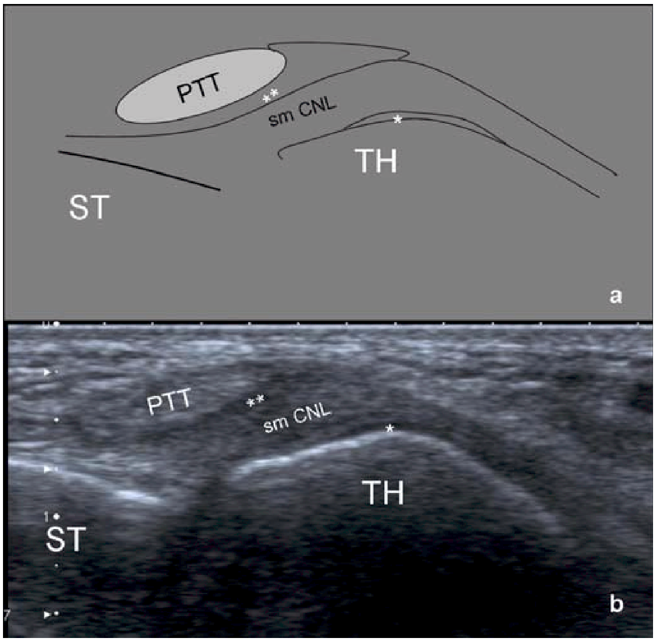

Fig. 2 Superomedial CNL. **a** Schematic diagram and **b** corresponding ultrasound image of the superomedial calcaneonavicular ligament (*sm CNL*) (*arrowheads*). It originates from sustentaculum tali (*ST*) passing over the talar head (*TH*). The inner portion of the superomedial CNL articulates directly with the talar surface. The articular surface of the spring ligament is covered with fibrocartilage (*), creating an articular surface with the head of the talus, termed the spring ligament–fibrocartilage complex. Between the superomedial CNL and the posterior tibial tendon (*PTT*), there is a loose connective tissue that provides a gliding layer (**)

ligament proximally at the level of the PTT and more distally 0.5 cm distal to the PTT as the ligament articulates with the head of the talus. To obtain standard measurements, the proximal measurement was made from the undersurface of the PTT to the surface of bone. The "gliding layer", which is the loose connective tissue between the superomedial CNL and the PTT that articulates with the PTT, was therefore included in the measurement. The distal measurement was from the superficial surface of the ligament to the surface of the bone and therefore the articular cartilage of the talar head was included in the distal measurement. At both sites the measurement was taken perpendicular to the long axis of the ligament (Fig. 3). Correlation was estimated using a plot of the differences against the mean combined measurements [13]. In order to compare the proximal and distal ligament measurements in the control and symptomatic groups, the mean measurement from the two observers was used. Analyses were carried out using Stata, version 9.2 (STATA Statistical Software).

Symptomatic study group

Nineteen patients (13 females and 6 males, age range 37–71 years) referred to the radiology department with a clinical diagnosis of suspected posterior tibial tendinosis and/or chronic pain along the course of the tendon were examined by ultrasound. All patients were referred from a single foot-and-ankle surgeon after thorough clinical examinations. The superomedial CNL thickness was measured using the same method used for the volunteer group and by the same radiologists. Also, the echogenicity of the ligament was described as normal or reduced.

The ultrasound criteria for diagnosing posterior tibial tendinosis were increased thickness, loss of fibrillar echo pattern, intratendinous areas of low echogenicity and increased vascularity on Doppler examinations [14]. Doppler was used to examine vascularity for PTT but was not included in the formal assessment of the spring ligament.

Results

Asymptomatic volunteer study group

Normal anatomy (Fig. 2) of the superomedial CNL could be demonstrated in all volunteers. There was good interobserver concordance for measurements at both the proximal and distal portions of the ligament. The limits of agreement were 0.6 and -0.9 mm at the proximal site and 0.9 and -1.2 mm for the distal site. In the normal volunteers, the mean of the combined proximal measurements was 4 mm (range 3.4–5.3, SD 0.6) and of the distal measurements 3.6 mm (range 2.4–5.2, SD 2.0) (Tables 1 and 2).

Symptomatic study group

Eighteen out of 19 patients had typical ultrasound features of PT tendinosis. In 16 out of 19 patients, increased

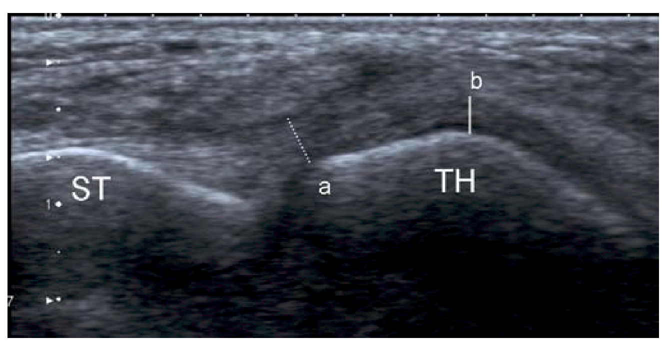

Fig. 3 Longitudinal US image of the superomedial CNL (right foot) showing how the proximal (*a*, *dotted line*) and distal (*b*, *solid line*) measurements were obtained. Note that the articular fibrocartilage and the synovial "gliding zone" were included in the distal and proximal measurements respectively. *ST* Sustentaculum tali, *TH* talus

Table 1 Comparison of ligament measurements in the control group vs. symptomatic group at the proximal site (mm)

Group	Number	Mean	SD	95% Confidence interval	P value[a]
Control	10	4.0	0.6		
Symptomatic	18	5.1	1.2		
Difference		1.1		0.3 to 2.0	0.01

[a]Two-sample *t*-test

thickness of the superomedial CNL and loss of the normal fibrillar echo pattern, which was more evident on the distal portion over the talar head, were visualised (Fig. 4). Only one patient had normal PTT and superomedial CNL insufficiency; this patient had a history of acute onset of sharp pain in the medial side of the ankle while running and since the time of injury had suffered worsening pain over the medial aspect of the foot and flatfoot deformity. Later, this patient had surgery for plication of the spring ligament and tibialis posterior augmentation with flexor digitorum longus where the ligament tear was confirmed.

The mean of the proximal measurements in the study group was 5.1 mm (range 3.3–7.3, SD 1.2) and of the distal measurements 6.1 mm (range 3–10, SD 2.0). The differences between the measurements made in the study group and controls were highly significant (proximal site $P<0.01$, distal site $P<0.001$) (Tables 1 and 2).

It can be seen from the tables that, on average, the mean ligament measurement at the proximal site was 1.1 mm greater in the symptomatic group than the control group. The 95% confidence interval indicates that the true difference could lie between 0.3 and 2.0 mm. The difference is statistically significant ($P=0.01$).

At the distal site, the ligament measurement was an average of 2.5 mm greater in the symptomatic group compared to the control group. The true difference could be as large as 3.9 mm. The difference is statistically significant ($P<0.001$).

Table 2 Comparison of ligament measurements in the control group vs. symptomatic group at the distal site (mm)

Group	Number	Mean	SD	95% Confidence interval	P value[a]
Control	10	3.6	1.0		
Symptomatic	18	6.1	2.0		
Difference		2.5		1.1 to 3.9	<0.001

[a]Two-sample *t*-test

Doppler examination was not included in the formal criteria for assessing the spring ligament. However, as Doppler examination was used for the diagnosis of PTT, it was observed that five of the patients also had increased power Doppler blood flow of the ligament (Fig. 4).

Discussion

The spring-ligament complex includes the superomedial CNL, medioplantar oblique CNL and inferoplantar longitudinal CNL. The superomedial CNL appeared as thick hyperechoic fibrillar structure originating from the medial side of the sustentaculum tali passing over the medial side of the talar head to be inserted at the superomedial aspect of the navicular bone. The ligament is at its widest in its proximal portion (Fig. 2).

Spring-ligament insufficiency is commonly seen in association with a PTT dysfunction. A dysfunctional PTT fails to invert the hindfoot and lock the transverse tarsal joint during the middle to late stance phase of gait. As a result, the power of the contracting gastrocnemius-soleus complex may act across the talonavicular joint rather than the metatarsal heads. In this situation, the talar head repeatedly loads the spring ligament, contributing to accelerated attrition of this static restraint. A lax or ruptured spring ligament permits the talus to plantar flex, and a valgus alignment of the calcaneus, or pes planovalgus, results [5, 15–18]. The condition is typically seen in middle-aged women and may result in an acquired flatfoot [5]. There is usually no history of trauma, although acute injury of the spring ligament has been reported [19, 20]. The pathology is usually confined to the superomedial CNL. Because of the important function of the spring-ligament complex in the stability of the longitudinal arch of the foot, reconstruction of this ligament complex is recommended [21, 22].

On ultrasound, the normal superomedial CNL appeared as fibrillar structure originating from the medial side of the sustentaculum tali passing over the medial side of the talar head to be inserted at the superomedial aspect of the navicular bone (Fig. 2).

In our study, 16 out of 18 patients with posterior tibial tendinosis had signs of insufficiency of the superomedial CNL. Although in our study there was significant thickening of the ligament at both sites (i.e. proximal and distal), it was more pronounced at the distal measurement. This concurs with the finding at surgery where this portion of the ligament is predominantly seen to be pathological [21, 22]. In one case, the PTT was considered normal. Although spring-ligament dysfunction is classically associated with posterior tibial tendinosis, it is recognised that the spring ligament may be torn in isolation [19, 20].

The spring ligament can also be clearly depicted on MRI. Heterogeneous increase in signal and thickening of ligament may be seen in patients with associated posterior

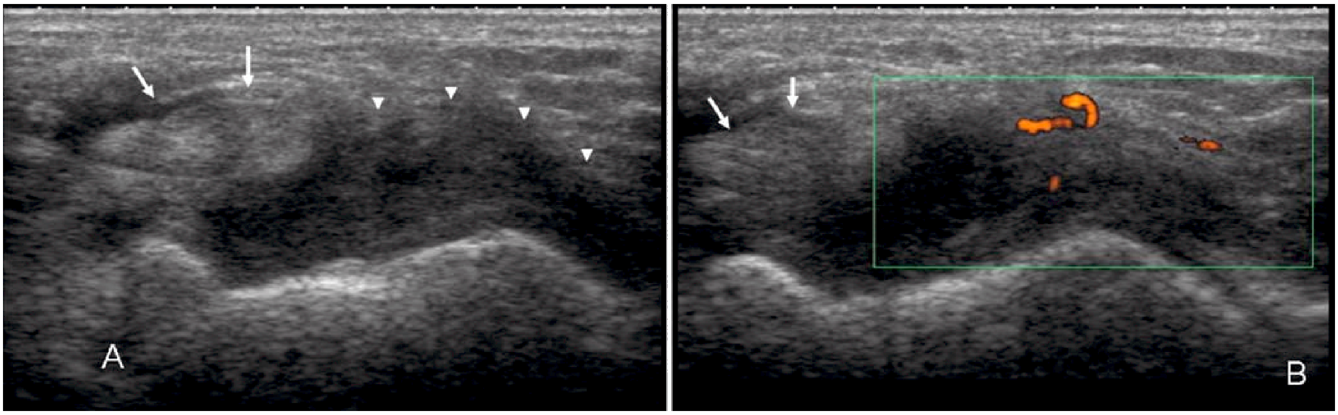

Fig. 4 Longitudinal US images of the superomedial CNL insufficiency (*arrowheads*) in the right foot showing loss of fibrillar echo pattern, thickening and increased vascularity. Posterior tibial tendon (*white arrows*) is normal

tibial tendinosis [5, 6]. In two different anatomical [2] and ultrasound studies [12], the mean width of the normal ligament at the talar head was 2.5 and 3 mm respectively as compared to 3.6 mm (distal measurement) in our study. The difference may be due to a slightly different orientation of the standard image or because we included the articular cartilage of the talar head in our measurement. In two different MRI studies [11, 18], the mean thickness of the superomedial ligament in normal volunteers was 4 and 4.7 mm because, in the first study [11], only the proximal portion was measured,and in the other study [18], the medioplantar and inferoplantar CNL were not differentiated from the superomedial CNL. In our study, the mean thickness for the proximal measurement was 4 mm.

To our knowledge, there are no previous ultrasound studies for abnormal spring ligament. In our study, the mean thickness of the proximal and distal measurements of the superomedial CNL in patients with insufficiency were 5.1 and 6.1 mm. This is quite a different result from an MRI study [5] in which the mean thickness of the abnormal superomedial ligament was 6.5 mm. However, in that study, the maximum ligament thickness was measured, and therefore some measurements were obtained at the proximal portion and some at the distal portion of the superomedial CNL. Doppler was used to examine vascularity for PTT but was not included in the formal assessment of the spring ligament. However vascularity of the spring ligament was recorded in five cases, indicting that hypervascularity is a feature associated with abnormal morphology.

In our institution, we favour the use of ultrasound for the initial assessment of most soft-tissue conditions, particularly in the extremities. Ultrasound is particularly effective in imaging of peripheral tendon and ligament abnormalities on account of the high near-field spatial resolution and high sensitivity of Doppler imaging and is therefore our preferred technique for investigating suspected PTT or spring ligament problems. Although abnormalities of the spring ligament can be visualised on ultrasound and MRI, the usefulness of imaging in clinical management has yet to be established. The benefit may be marginal in the typical case of chronic ligament dysfunction, but potentially useful in early cases where therapy may be appropriate to prevent progression of the condition.

This study has some drawbacks. The measurements were performed on static ultrasound images, and defining the edges of the ligament was occasionally difficult. This would account for some of the variation between the readers. However inter-observer agreement was good, particularly at the proximal site. Obtaining the standard image is also subject to variability. To minimise this effect, images were obtained by radiologists who have experience in imaging the spring ligament and producing this standard view.

Conclusion

Ultrasound can consistently depict the normal superomedial component of the CNL spring ligament. Thickening of the ligament, loss of normal echogenic internal structure and intrasubstance vascularity are features seen in ligament insufficiency. There is a strong association between posterior tibial tendinopathy and abnormality of the spring ligament. We recommend that ultrasound examination of PTT include assessment of the superomedial CNL.

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