

Relationships of the sural nerve with the calcaneal tendon: an anatomical study with surgical and clinical implications

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Abstract The percutaneous repair of the calcaneal tendon (CT) places the sural nerve (SN) at high risk for injury up to 60%. The aim of our study, therefore, was to explore and describe the course of SN in relation to the CT and to provide an anatomical description of the area in which the SN resides in order to assist surgeons in avoiding iatrogenic injury during surgical procedures in the leg. Forty-four lower extremities of 22 adult cadavers were dissected and the course of the sural nerve investigated. The CT was divided into ten horizontal equal fractions. The widths of CT, and horizontal distances of the SN and small saphenous vein (SSV) to a vertical line connecting the midpoints of these fractions were measured. All the measurements were obtained using a computer-assisted image analysis system. In 95.5% of the specimens the sural nerve was

medial to the lateral border of the CT proximally and was intersecting with the lateral border of the CT at the 55% of the mid-tendon line. The SN divided into its terminal branches at a mean of 90% of the mid-tendon line. Based on our results, the course of the sural nerve is quite variable and seems to have the highest risk of injury at its proximal portion. The sutures placed on the CT distal to the 55% of the mid-tendon line may decrease iatrogenic nerve injury.

Keywords Achilles (calcaneal) tendon · Percutaneous Achilles (calcaneal) repair · Sural nerve injury

Introduction

The sural nerve (SN) provides sensory innervation to the posterior aspect of the leg and the lateral part of the dorsum of the foot. It descends posterior to the calcaneal (Achilles) tendon (CT), often accompanied with the small saphenous vein (SSV) [30].

Despite the fact that the surgical anatomy of the posterior part of the leg has been well described, recent reports state that SN damage following CT surgical repair is relatively common (up to 60%) [4, 6, 10, 19, 23]. The initial treatment for acute rupture of the CT is generally nonoperative cast immobilization [23, 27, 28, 31]. In cases where the non operative method is not applicable or ineffective, two surgical treatment options can be considered. These surgical treatment techniques can be classified as open or percutaneous [7, 18].

Conservative treatment has been shown to result in high re-rupture rates in up to 10.7% [31]. Open reconstruction offers better treatment outcomes and lower re-rupture rates 0–10% [2, 10, 13, 30]. However, several complications have been reported such as infections, delayed wound

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healing, necrosis, and adhesions [7, 18]. The percutaneous approach appears to reduce wound complications when compared to open invasive methods [22]. US mapping of the sural nerve can also be of help in conjunction with percutaneous Achilles tendon repairs [5]. However, despite the technique chosen, SN injury has been reported in such operations [3, 10]. SN damage can range from a slight sensory disturbance to severe pain and sensory loss in associated skin areas [21].

The aim of our study, therefore, was to explore and describe the course of the sural nerve in relation to the CT. In addition, we aimed to provide an anatomical description of the safety area in which the SN resides in order to assist surgeons in avoiding iatrogenic injury during surgical procedures of the CT.

Materials and methods

This study was carried out on 44 lower extremities of 22 adult cadavers (14 males, 8 females) (mean age 63 years, range 45–82) fixed in 4% formaldehyde, phenol and alcohol solution. None of the dissected legs had undergone any surgical procedure or had evidence of trauma and without any sign of previously conservatively treatment of CT rupture. The entire course of the SN and the SSV was dissected in order to observe their relationship with the CT.

The SN was approached through a long posterior mid-line skin incision. The skin was cut and reflected. The SN was identified within the superficial fascia by blunt dissection. Pins were used to maintain the position of the nerve and vessels during dissection. The fascia covering the SN and the SSV was cut but the fascia beneath these structures was not removed in order to maintain the position and the course of these structures. The remaining superficial fascia was cut and removed in order to visualize the lateral borders of the CT. In addition, the length of each fibula was recorded.

Following preliminary examination, images from all dissected specimens were recorded with a Nikon digital camera (model: Coolpix S5) and studied using a computer-assisted image analysis system (Lucia software 5.0 [2000 edition for Windows XP], made by Nikon [Laboratory Imaging Ltd.]). The digital camera was connected to an image processor (Nvidia GeForce 6800 GT) and linked to a computer. Digitized images of the posterior leg were stored in the Lucia program (2048 × 1536 pixels) and converted to intensity gray levels from 0 bit (darkest) to 32 bit (lightest). After applying a standard 1 mm scale to all pictures, the program was able to use this information to calculate pixel differences between two selected points, such as origin and termination of a given nerve, as previously described [14]. The purpose of the software was to allow

easy and accurate translation of pixel differences into metric measurements.

The length of the CT was recorded for each limb and this length was divided into 10 equal parts by 11 horizontal lines. The horizontal lines were enumerated proximal to distal. The parts lying between these horizontal lines were enumerated proximal to distal as well, and designated as 0–100%. The midpoint of the first and eleventh horizontal lines was determined. These points connected with a single longitudinal line which was designated as the ‘mid-tendon line’ (Fig. 1). The widths of the CT, and horizontal distances of the SN and SSV to the mid-tendon line were measured at each horizontal sections. The distances of the SN and SSV to the mid-tendon line were recorded as ‘negative’ if the nerve or the vein was located lateral to the lateral border of the CT and ‘positive’ if found medial to the lateral border of the CT. The point where the SN and SSV intersected at the lateral border of the CT was marked and the distance of this point to the lateral malleolus was measured. The distance between the point at which the SN divided into its terminal branches and the distal tip of the lateral

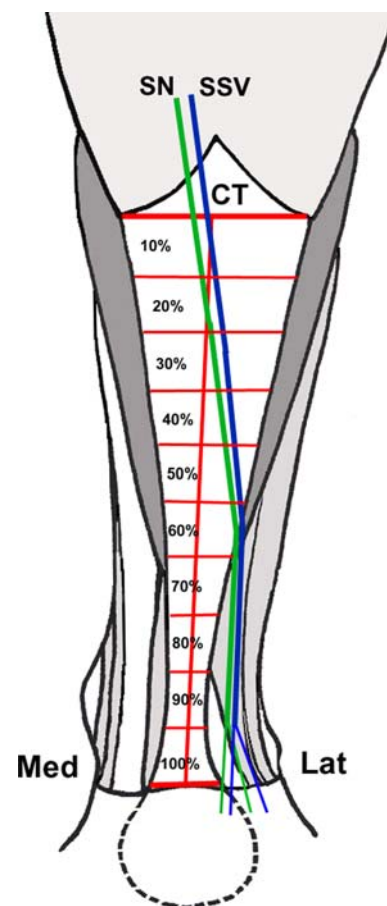


Fig. 1 The drawing of the right leg. The horizontal lines and the percentages used to measure the distances of sural nerve and the small saphenous vein are marked on the drawing

malleolus was also measured. Statistical analysis was performed using Student's *t* test.

Results

The results revealed the bilateral occurrence of the SN and SSV in all 44 specimens. In two (4.5%) of the cases the SN coursed lateral to the lateral border of the CT (Fig. 2). In the remaining 42 specimens (95.5%), the SN was medial to the lateral border of the CT proximally and intersected with the lateral border of the CT at a mean of 55% of the mid-tendon line (range 20–80%) (Fig. 3). The distance of this intersection point to the lateral malleolus had a mean of 10.4 cm (5.7–15.5). Distal to this point the SN coursed lateral to the lateral border of the CT. The SN divided into

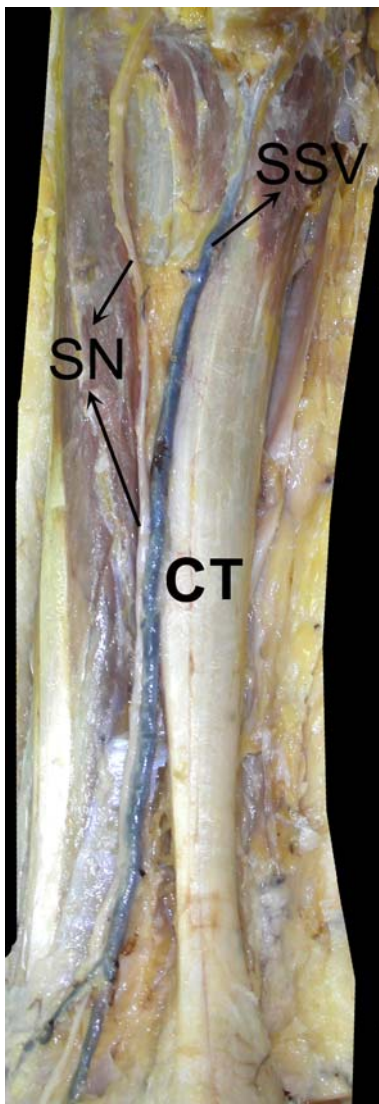


Fig. 2 The lateral position of the sural nerve compared to the Calcaneal tendon (left leg). *CT* calcaneal tendon, *SN* sural nerve, *SSV* small saphenous vein

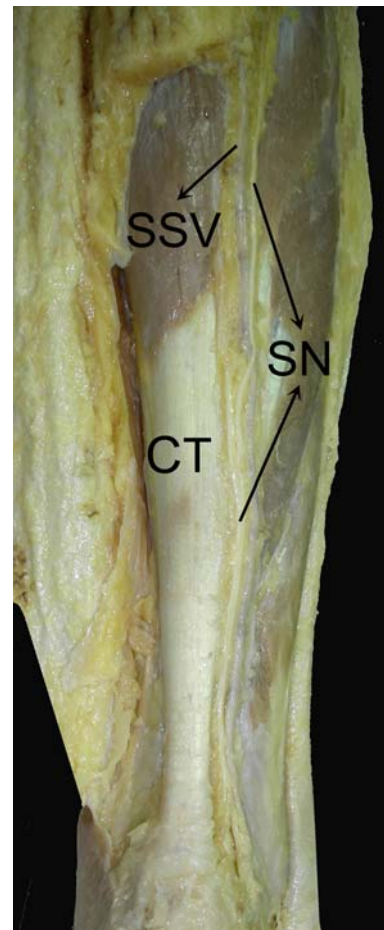


Fig. 3 The course of the sural nerve and the small saphenous vein (right leg). *CT* calcaneal tendon, *SN* sural nerve, *SSV* small saphenous vein

its terminal branches (calcaneal branch and the lateral dorsal cutaneous nerve) at a mean of 90% of the mid-tendon line (range 65–100%). The distance between the points where the SN divided into its terminal branches and the lateral malleolus was measured at a mean of 3.8 cm (0–9.6).

In all specimens the SSV was medial to the lateral border of the CT proximally. It then intersected with the lateral border of the CT at a mean of 55% of the mid-tendon line (range 20–80%). The distance between the points where the SSV intersected the lateral border of the CT and the distal tip of the lateral malleolus was measured at a mean of 11.3 cm (6.1–17.4) (Fig. 2).

The average length of the fibula was measured and found to have a mean of 37.2 cm (33.3–43.5). The average length of the CT was measured and found to have a mean of 18.2 cm (14.0–24.5). The mean width of the CT was 3.4 cm (2.0–4.8) at insertion and narrowed to 1.8 cm (1.2–2.6) at the 80% level of the mid-tendon line. From this point, the CT width gradually increased. The mean widths of the CT, and the horizontal distances of the SN and SSV to the mid-tendon line are found in Table 1.

Table 1 The mean widths of the calcaneal tendon (CT), and the horizontal distances of the sural nerve (SN) and small saphenous vein (SSV) to the mid-tendon line

Width of CT (cm)	Distance of sural nerve to CT (cm)	Distance of small saphenous vein to CT (cm)
0%		
6.8 (4.5–8.6)	–1.4 (0–3.5)	–1.1 (0–2.4)
10%		
5.8 (4.0–7.2)	–2.5 (0–3.3)	–1.2 (0–2.6)
20%		
5.0 (3.4–6.8)	–2.3 (0–3.0)	–1.2 (0–2.4)
30%		
4.4 (3.0–5.3)	–1.5 (0.9–2.6)	–1.3 (0.2–2.3)
40%		
3.8 (2.6–5.2)	–1.6 (0.5–2.8)	–1.5 (0.4–2.6)
50%		
3.2 (1.9–4.5)	–1.9 (0.8–3.0)	–1.7 (0.8–2.8)
60%		
2.6 (1.6–3.8)	+1.4 (0.9–3.1)	+1.8 (1.0–3.1)
70%		
2.1 (1.3–3.2)	+1.6 (1.0–3.2)	+1.5 (0.7–3.0)
80%		
1.8 (1.2–2.6)	+1.8 (1.1–3.4)	+1.7 (0.8–2.6)
90%		
2.0 (1.5–3.0)	+2.1 (1.2–4.0)	+2.3 (1.2–3.5)
100%		
3.4 (2.0–4.8)	+2.7 (1.5–5.0)	+3.4 (2.2–5.2)

The distances of the SN and SSV to the mid-tendon line were recorded as ‘negative’ if the nerve or the vein was located lateral to the lateral border of the CT and ‘positive’ if medial to the lateral border of CT

There was no statistically significant differences found with regard to age, sex, fibular length or side of the specimens ($p > 0.05$).

Discussion

Although most surgeons would prefer operative management in active patients, there is still controversy between repair of CT rupture and conservative treatment. Percutaneous repair of the CT was first described as an alternative method for repair in 1977 by Ma and Griffith [15]. However, sural nerve injury has increased, up to double the complication rate using percutaneous repairs compared to open repairs due to the blind passing of the suture through skin and tendon [4]. In addition to this, it has been reported by some authors to have disadvantages compared to open procedures including a higher re-rupture rate [1, 2, 8, 13, 17, 28, 31]. Some researchers reported that it provides approximately 50% of the initial strength afforded by an

open repair [6]. In a comparative study by Cretnik et al. [4], a higher percent of disturbance in sensibility was reported with a percutaneous repair group compared to an open repair group. According to Halasi et al. [7] although palpation and ultrasonography (US) can assist in adaptation control, these cannot substitute for normal visualization for the surgeon. Flavin et al. [5] suggested US mapping of the sural nerve in conjunction with percutaneous Achilles tendon repairs. The authors reported the sural nerve to be easily visualized posterior to the lateral malleolus and along the lateral border of the CT. They also reported that US had poor sensitivity for detection from approximately 4 cm proximal to the insertion of the Achilles tendon to its insertion due to the presence of a network of subcutaneous veins [5].

The original technique described by Ma and Griffith suggested using six skin incisions, three lateral and three medial to the ruptured CT [15]. In their series of 18 patients, there was no injury to the sural nerve or re-rupture. However, Rowley and Scotland [25] reported injury to the sural nerve in one of ten patients using the same technique and Klein et al. [10] reported five nerve injuries in 38 patients. In 1999, Webb and Bannister recommended a new technique for percutaneous repair using three incisions marked on the posterior aspect of the CT with no re-ruptures or injuries to the sural nerve [28]. Cretnik et al. suggested a percutaneous repair through eight holes, which were later used for needle entry and enlarged [4]. The procedure was begun and finished medially and distally with criss-cross sutures. Maes et al. [17] suggested that the high rate of sural nerve entrapment is due to its proximity to the CT. They reported that a limited open technique is more reliable and has the advantage of allowing direct visualization of the repair site and controlling adequate apposition of the tendon ends. In a series of 163 CT ruptures, minimally invasive Achilles tendon repair in combination with a functional rehabilitation program was suggested to be a safe and quick procedure with a low rate of re-rupture and a high level of patient satisfaction [11]. However 9.2% reported to suffer from dysfunction of the sural nerve. Limited open repair as reported by Jung et al. was reported to be associated with lower rates of sural nerve injury (3.3%) [9]. Pavic [24] suggested using an endoscopic camera for avoiding sural nerve injury which may not always be available for this procedure. Because numerous surgical techniques in surgical techniques for repair of ruptured AT, it is nearly impossible to demonstrate which method gives the best overall outcome.

The formation and course of the SN in the foot and ankle is well known [3, 12, 16, 20, 30]. However, there are limited data concerning the anatomical variations in the course of the SN with its relation to CT. These variations are important and should be recognized during percutaneous

Achilles repairs as well as percutaneous Achilles tendon lengthening procedures which is used to treat clinically significant equinus contractures [26]. We suggest that variability in SFN anatomy may be an important risk factor for direct injury in percutaneous techniques.

To our knowledge, there is only one study about the relation between the SN and CT [29]. In that study, Webb et al. described the course of the SN in relation to the lateral border of the CT [29]. The authors reported that the thickness of the CT and position of the SN is highly variable. Taking into consideration the individual variability of the CT, we determined the relation of SN in relation to the midline distance of the CT. The results of our study showed that the proximal course of the SN is from the midline toward the lateral border of the CT. We observed that the SN intersects with the lateral border of the CT approximately at half the length of the CT (55% fraction), which is in concordance with the study of Webb et al. [29]. These authors reported the SN to cross the lateral border of the CT 9.83 cm from the calcaneus, and in our study, 10.4 cm (range 5.7–15.5 cm) proximal to the lateral malleolus. Our results showed that the SSV was medial to the lateral border of the CT proximally in all cases. It then intersected the lateral border of the CT at 55% of its length.

In our study, all SN divided into terminal branches at the 90% level of a mid-tendon line. This point was lateral to the lateral border of the CT in all specimens; therefore, these branches will have little risk of injury in terms of a percutaneous repair.

Conclusions

In this study the course of the SN and its relation to the CT was documented using a computer-assisted image analysis and measurement system. The results of this study showed that the course of the SN is variable in different fractions of the CT. The proximal course of the SN is toward the midline and then crosses the lateral border of the CT at about the half-length of the CT. Sutures placed near the lateral border of the CT at a proximal level may put the SN at risk of injury. Whereas sutures put into the CT distal to the 55% fraction may have a lesser risk of SN injury. Knowledge of the variations of the SN with reference to the CT may be useful in percutaneous CT repair.

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