Ultrasound Imaging of the Sural Nerve: Ultrasound Anatomy and Rationale for Investigation

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Submitted 15 July 2009; accepted 8 November 2009
Available online 17 December 2009

KEYWORDS
Sural nerve anatomy; Sural nerve ultrasound; SSV-Sural nerve relationship; Nerve lesions

Abstract  Background: Damage to the sural nerve (SuN) may arise from surgical stripping or thermal ablation of the small saphenous vein (SSV).
Objective: This study aims to demonstrate that visualisation of the SuN and its point of contact with the SSV (‘risk point’) using ultrasound imaging can be achieved in routine clinical practice.
Type of study: This is a cohort study.
Patients: Fifteen normal subjects and five patients with chronic venous insufficiency (CVI) (two with a dilated, incompetent SSV).
Method: The SuN was identified using high-resolution ultrasound imaging using 14- and 18-MHz probes. Two manoeuvres were found to improve visualisation: (1) the contrast of the nerve was increased compared with the other tissues by varying the angle of insonation; and (2) the transducer was moved up and down the limb for a short distance during transverse imaging of the calf. The muscles and other soft tissues appeared ‘out of focus’, whereas the SuN retained both shape and echogenicity. Once the nerve has been identified, proceeding proximally, the point of separation of the two components is often detectable. It is then possible to follow the two different nerves observing the medial sural cutaneous nerve (MSCN) inside the ‘triangle’ of connective tissue below the SSV joining the tibial nerve and the lateral sural cutaneous nerve (LSCN) joining the common peroneal nerve, which runs inside a tiny fascial duplication. The extent of nerves, which were identified, was recorded in each limb as well as their anatomical distribution.
Results: The SuN and the point at which it might be at risk were identified on ultrasound images in 39 of 40 limbs (97%) studied. In transverse section, it was readily identified within the saphenous compartment. It lies in close proximity to the SSV only in the distal third of the limb, where the two components of the nerve: MSCN, a branch of the tibial nerve; and LSCN, a branch of the common peroneal nerve join together. The relationship between the SuN and the SSV is very variable, with the nerve running separately or in close contact with the vein for variable distances, in many different combinations.

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doi:10.1016/j.ejvs.2009.11.024
High-resolution sonography (US) permits visualisation of peripheral nerves. Among lower limb nerves, the sciatic nerve and its divisions (tibial and peroneal) have already been extensively described for several purposes, while the sural nerve (SuN) is mentioned in a report, it has not been the subject of detailed research.

SuN runs from the popliteal crease to the lateral malleolus parallel with and in variable proximity to the small saphenous vein (SSV). Two nerve branches (tibial and peroneal) join at a variable level in the leg to form the final SuN. The tibial branch (medial sural cutaneous nerve, MSCN) emerges from the tibial nerve and runs parallel to the SSV in the connective tissue of the groove of the two heads of gastrocnemius, ventrally and outside the SSV compartment. It is usually joined by the peroneal branch in the middle third of the calf forming the final SuN. The SuN usually enters the SSV compartment at this level, but the exact anatomy is very variable. It then lies close to the SSV. Behind the lateral malleolus, it turns anteriorly along the lateral border of the foot.

The peroneal component of the SuN (lateral sural cutaneous nerve, LSCN), arises from the common peroneal nerve (the lateral division of the sciatic nerve), descends laterally in the popliteal fossa along the border of the biceps femoris muscle, towards the peroneal head. Still, in the popliteal fossa, a branch (the LSCN) separates running distally and turning medially at the middle third of the calf, where it joins the tibial branch to complete the SuN.

Variant anatomical patterns are very common. In an anatomical dissection study in 30 limbs, the union of the two components occurred in the upper two-thirds of the leg in 60% of cases, in the distal third in 10% of cases; the peroneal component was absent in 17% of cases while the tibial component was absent in 7% of cases. In 7% of cases the two nerves had separate courses. In a dissection study of 76 cadavers, 67% of the SNs were formed by the union of the MSCN and LSCN, and the site of union was variable: 6% in the popliteal fossa, 1.2% in the middle third of the leg, 67% in the lower third of the leg and 26% at or just below the ankle. One SuN was formed by the union of the MSCN and a different branch of the common fibular nerve. In the remaining 32%, the SuN was a direct continuation of the MSCN.

Due to proximity to the small saphenous vein, the SuN is at risk of injury during dissection of the sapheno-popliteal junction, stripping of the SSV, phlebectomy of the SSV and its tributaries and thermal ablation of SSV. The consequence of nerve injury is numbness, hypo-aesthesia or anaesthesia of the skin supplied by the SuN (postero-lateral surface of the leg and lateral border of the foot). When the damaged nerve evolves to become a neuroma, ‘neuritis’ — radiating pain to the forefoot may occur with constant burning and painful paraesthesia or hypersensitivity may be present. Therefore, SuN imaging prior to surgery or endoscopic procedures could help to prevent these undesirable complications. The aim of this study was to establish whether ultrasound imaging can be used to identify the SuN in healthy limbs and those with venous disease. We set out to assess how frequently the nerve could be seen with its point of contact with the SSV (‘risk point’) identified. A secondary objective of our study was to identify and follow the two components of the SuN.

**Materials and Methods**

The ultrasound anatomy of the SuN and related structures was studied in 15 normal subjects and in five varicose vein subjects (Table 1) with a total of 40 limbs investigated. Ten normal subjects were volunteers, while 10 were patients undergoing venous duplex ultrasound investigation to establish the extent of their venous disease observed during a routine exam for venous pathology. Volunteers included in this study gave informed written consent for their inclusion in this research. The study protocol conformed to guidelines set by the local Ethical Committee.

We employed a Toshiba Apio CV appliance with a 12- to 14-MHz linear probe with a tissue setting (Toshiba Medical Systems Europe — Roma, Via Canton 105) and an Esaote Mylab 25 with an 18-MHz probe (Genova — Via A. Siffredi, 58). We used high-frequency probes (14—18 MHz) since it has been shown previously that these provide detailed images of peripheral nerves, allowing identification of structures of less than 1 mm in diameter.

The legs were examined with the volunteers standing to achieve better filling of the SSV and transverse images were used for these investigations. The SuN was sought in the middle third of the calf along the course of the SSV where the nerve should be complete after the union of its two parts and lying in close proximity to the SSV within its fascial compartment. The nerve was found most frequently lying laterally to the SSV. The nerve usually appears as a round/ovoid structure of 1—2 mm diameter, moderately echogenic, containing ‘black spots’ corresponding to nerve

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient information.</th>
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<tr>
<td>20 Subjects</td>
<td>15 normal-No venous disease 5 venous disease</td>
</tr>
<tr>
<td>12 Female</td>
<td>mean age 59 years (range 31—85)</td>
</tr>
<tr>
<td>8 Male</td>
<td>31 normal 6 GSV incompetence with calf varices (3C2, 1C3, 2C4)* 3 SSV incompetence with calf varices (2C2, 1C4)*</td>
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* C of CEAP classification.
fibres and surrounded by an echogenic sheath (perineurium) (Fig. 1).

We found that the contrast of the nerve could be increased compared with the other tissues by varying the insonating angle of the transducer, as we have previously reported. As the angle of insonation increases, the total echogenicity of the tissues is reduced, but to a higher degree in muscles and tendons than in nerves. A further manoeuvre which helped in identification of the nerve was to move the transducer up and down the limb for a short distance during transverse imaging of the calf. The muscles and other soft tissues appeared ‘out of focus’ whereas the SuN retained both shape and echogenicity.

Once a nerve had been identified, we employed the rule that the observed structure had to be followed in continuity until its origin was reached (sciatic or common peroneal nerve) or at least for a substantial distance, to avoid confusion with similar structures.

In the presence of very dilated and tortuous SSVs, the SuN was not as easy to identify due to the presence of varicosities interfering with the nerve imaging. In these circumstances, the nerve was found distally in the calf and traced proximally to confirm its identity.

Once identified, the nerve was followed distally along and laterally to the Achilles tendon to the malleolus, and proximally to the point where it lost close contact with the SSV (Fig. 1) which was considered the surgical ‘risk point’. Proximal to this level, SuN injury is unlikely during surgery of the SSV. This point was marked on the skin and its distance from the popliteal crease measured. The point of union of the two components of the SuN was investigated and, when visible, both components (Fig. 2) were followed upward until their respective origins from the tibial and the common peroneal nerves were observed.

Figure 1 The nerve appears typically as a round/ovoid structure (arrow) of 1–2 mm of diameter moderately echogenic, containing “black spots” corresponding to nerve fibres, surrounded by an echogenic sheath (perineurium), laterally (here to the right) to the SSV.

Figure 2 Division of the two components of the SuN: The lateral (interrupted arrow) remains inside the compartment, the Medial (continuous arrow) passes ventrally to the SSV out of the compartment inside the gastrocnemius groove. There is still close contact with the SSV.

Figure 3 Distance (cm) of the ‘risk point’ from the popliteal skin crease and incidence (*).
Results

SuN was identified in all but one limb studied (39/40 = 97%). The only failure had chronic venous insufficiency (CVI) resulting in skin changes including subcutaneous fibrotic retraction, oedema and pigmentation. The patient was diabetic and had signs of peripheral neuropathy.

In 37 limbs the ‘risk point’ was detectable and marked on the skin. The distance of the ‘risk point’ from the popliteal skin crease ranged between 10 and 31 cm, but in the vast majority (30 out of 37) this point occurred between 20 and 25 cm below the popliteal skin crease (Fig. 3). In two cases, the SuN did not make contact with the SSV at any point.

In 15 limbs the union of the two nerve components was clearly visible. In 12 it was possible to follow both the components, in 10 only the tibial component was visible arising from the tibial nerve; in a further 10, only the peroneal component could be traced to the common peroneal nerve.

Observing the nerves in a cephalad direction, the tibial component ‘separates’ from the peroneal and pierces the muscular fascia passing from the SSV compartment to the triangular connective space created by the groove between the medial and lateral heads of the gastrocnemius (Fig. 2). In this space the sural vein is also visible (less frequently, the sural artery). In one case, the sural vein was dilated and incompetent (Fig. 4, white arrows), communicating with an incompetent SSV.

From the ‘separation point’ proximally, the peroneal component moves towards the lateral angle of the SSV compartment and then more laterally, inside a fascial duplication forming a small compartment (Fig. 5). The nerve is never free in the subcutaneous compartment but always covered by a superficial fascial layer (Fig. 4, black arrows). At the level of the popliteal crease it joins the common peroneal nerve ‘coming’ from the peroneal head.

Two unusual anatomic variants are reported in Figs. 6 and 7: in one case, a perforator of an incompetent SSV encircled the nerve before passing the deep fascia (Fig. 6). In another patient with duplication of the SSV, the SuN lay between the two venous components in close contact with both (Fig. 6). In three limbs with SSV incompetence, the nerve was easily identified, although dilatation of the veins was of limited extent in these patients.

The procedure used to visualise the SuN is summarised in Table 2.

Discussion

Apart from sporadic reports,9 to the best of our knowledge SuN US appearance has never been described and analysed before. Ultrasound findings in two cases of SuN lesions following stripping of the SSV have been reported in the
The nerve is easily visualised using a simple procedure (Table 2). The only failure to visualise the SuN was in a leg with co-existent CVI and peripheral signs of neuropathy. It is not clear whether these conditions accounted for our failure to identify the nerve or simply that the nerve anatomy was an unusual variant, with its two components remaining separated and distant from the SSV.

SuN imaging allows identification of the point where the nerve and the vein come in close contact (Figs. 1 and 2). We call this the ‘risk point’ since any surgical procedure may be at risk of SuN injury at this point and beyond. In fact, the distal portion of the SuN remains in close contact with the SSV. Some anatomic variants are likely to increase the risk of nerve injury (Figs. 5 and 6). However, no definitive data on the incidence of this complication are available. Indirect information can be gathered by medico-legal claims related to nerve damage during varicose vein surgery: in the United Kingdom, those related to SuN injury amount to 7.5% (15 over 200 claims from 1990 to 2002). Given that varicose vein surgery is very common and the risk of injury to the SuN is theoretically high, it is likely that many SuN lesions, particularly minor ones, remain unrecognised. Surgeons are aware of the risk of nerve injury in operations for SSV incompetence and may be very cautious in undertaking surgery in this region to moderate the risk of SuN injury. We consider that identifying the ‘risk point’ can make SSV surgery operation safer or may suggest that an alternative method of treatment such as foam sclerotherapy may be safer.

At present these are theoretical considerations and have yet to be evaluated in a clinical trial.

Endovascular vein ablation procedures, particularly laser ablation, incurs a 2% risk of SuN lesions. Even this low risk, which is presumably attributable to thermal injury to the nerve, might be moderated with the help of ultrasound imaging of the saphenous nerve. US-guided injection of tumescent anaesthesia could allow separation of the nerve from the SSV prior to endovenous laser ablation.

Ultrasound identification of the SuN may also be useful before surgical Achilles tendon repair procedures, following which a 13% incidence of injury to the SuN has been reported. The US observation of the two SuN components may have other applications, both diagnostic (biopsy and nerve-conduction studies) and therapeutic (nerve grafting, where SuN is sacrificed for the reconstruction of a functionally more important nerve). The LSCN is also used for creation of sensitive free flap; thus, a detailed knowledge of the anatomy of the SuN and its contributing nerves are important in carrying out these and other procedures.

Limitations of this study deserve consideration. The present study needs to be repeated in a population with severe CVI, a group of patients most likely to benefit from the identification of the SuN. The authors have already begun investigating this issue. The high success rate in visualising SuN might partly reflect the specific experience of the operators (SR and LM) and cannot be achieved in routine medical practice. We have limited experience in the finding that younger and less experienced operators obtain a comparable success rate after two or three teaching sessions. Third, the cost of a 14- or 18-MHz probe is substantial but may mitigate the risk of nerve injury avoiding costly litigation.

Despite these limitations, this study demonstrates that the SuN can be easily visualised by high-definition US probes (14 MHz or more) and the point of nerve contact with the SSV or ‘risk point’ is easily detectable. This accentuates the belief that this will diminish the risk of nerve injury following surgical or endovascular treatments for SSV incompetence and may be applicable to non-vascular procedures where SuN injury may arise.

Conflict of Interest/Funding

None

References

1 Peer S, Bodner G. High-resolution sonography of the peripheral nervous system. In: Beart AL, Knauth M, Sartor K, editors. Medical radiology — diagnostic imaging. Berlin Heidelberg: Springer Verlag; 2008 [chapter 1].

Table 2  Nerve identification procedure.

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<th>Procedure</th>
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<tr>
<td>14 MHz (or higher) ultrasound probe available</td>
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<td>Nerve identification at the distal third of leg</td>
</tr>
<tr>
<td>Nerve near the SSV, lateral, inside compartment</td>
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<tr>
<td>Search for round structure</td>
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<tr>
<td>Moderately echogenic, containing &quot;black spots&quot;</td>
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<tr>
<td>With echogenic sheath</td>
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<tr>
<td>Identify point of proximity to the SSV (Risk point)</td>
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<td>(Illustrated in Figs. 1, 2, 3, 5, 6)</td>
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<td>Identify the two components of the sural nerve</td>
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