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REVIEW ARTICLE

Sonographic imaging and assessment of the sural nerve

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Abstract

The sural nerve is a sensory nerve which innervates the posterolateral distal calf and lateral foot. It can be demonstrated using high resolution ultrasound and travels near the small saphenous vein throughout most of its course. There are variations in its origin and relative position through the posterior distal calf, lateral ankle, and foot. To allow this nerve and any potential pathology or injury to be sonographically demonstrated, a good understanding of the sonographic relative anatomy, course, and common anatomical variations, as well as the sonographic normal appearances throughout need to be appreciated and these are reviewed in this paper.

KEYWORDS

lower limb peripheral nerves, musculoskeletal ultrasound, peripheral nerves, small saphenous vein, sural nerve

1 | INTRODUCTION

The sural nerve is a small sensory nerve that extends from the posterior distal calf to the posterolateral ankle and dorsolateral foot.¹ In the distal posterior calf it is superficial in location coursing near the small saphenous vein (SSV), and for this reason it can sometimes be termed the small saphenous nerve.² The sural nerve and its distal branches, can be at risk of pathology or injury including neural fascial entrapment, compression, irritation by Achilles or peroneal tendon pathology, ankle and foot fractures, or stretching during a lateral ankle sprain.³ Due to its superficial location, the sural nerve is also at risk of injury from external compression from tight footwear or casts or iatrogenic surgical or traumatic injuries.^{4,5} As it is a small structure, it can be easily overlooked both clinically and with imaging. High resolution sonographic imaging of the sural nerve can demonstrate the structural nature of the nerve and its relative position to other surrounding structures.^{3,6,7} These include the gastrocnemius muscles, crural fascia, Achilles tendon, small saphenous vein, peroneal tendons, and retinacula, calcaneofibular ligament, calcaneus, cuboid, and base of the 5th metatarsal.⁷⁻¹⁰ This paper will discuss the sonographic assessment of the sural nerve including its anatomical

course, sonographic appearance, and regions where it should be specifically imaged.

2 | CLINICAL AND PHYSICAL TESTING OF THE SURAL NERVE

The name sural nerve is derived from the Latin term Sura which means 'calf'.⁸ It provides sensory innervation to the posterolateral aspect of the distal third of the lower leg and ankle and dorsolateral aspect of the foot.¹ Injury or pathology to the sural nerve will cause sensory changes in areas of its distribution. This can result in hypoesthesia, radiating pain, including burning or 'dragging' pain, or hypersensitivity to the skin in the lateral lower leg and foot, extending to the lateral dorsal aspect of the fifth toe¹⁰ (Figure 1).

Clinical examination has been historically considered the principle method of diagnosis of sural nerve neuropathies.¹¹ Differential diagnoses such as sciatic radiculopathy, common peroneal or tibial nerve pathology, compartment syndrome of the lower limb, popliteal artery entrapment and Achilles tendinopathy may, however, present with similar symptoms.¹² The sural nerve neurodynamic test can be performed to replicate clinical symptoms experienced

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FIGURE 1 Sensory innervation of the sural nerve (blue shaded regions) including the posterolateral aspect of the distal third of the lower leg and dorsolateral aspect of the foot.



by the patient.^{13,14} A positive Tinel sign or point tenderness over the nerve can also be used as clinical indications for pathology.¹⁵ If pain is present, it may be exacerbated by plantar flexion and/or inversion of the foot.^{15,16}

The sural nerve in the calf has a relatively straight path and therefore can be used as a donor nerve for peripheral nerve grafting such as facial nerve reconstruction, postoperative erectile dysfunction after radical prostatectomy, and reconstruction of major nerves after trauma.^{2,17,18} Due to its superficial location and sensory features, the sural nerve has commonly been used as a site for nerve biopsy to establish the cause of peripheral neuropathies when the diagnosis could not be gained by other means.^{19,20} As it is a sensory nerve, biopsy will not result in loss of any motor function but can result in numbness in the distribution of the nerve.²⁰

3 | SONOGRAPHIC IMAGING OF THE SURAL NERVE

High frequency ultrasound imaging can demonstrate nerve and fascicle anatomy to characterise and localise structural change in the sural nerve, to guide patient management.²¹ Ultrasound guided regional sural nerve blocks can be used to anaesthetise the posterolateral calf and latero-dorsal foot for pain relief or to provide regional anaesthesia for foot and ankle surgery.²² To sonographically image the sural nerve, a high frequency linear or hockey stick transducer is required. The patient is positioned prone on the bed, with the feet hanging over the end of the examination bed. The nerve should be imaged in both short and long axis planes. In short axis imaging, the normal sural nerve will demonstrate the classic fascicular and 'honeycomb' sonographic appearance.²³ Hypoechoic nerve fascicles appear round, similar sized and are surrounded by echogenic interfascicular perineurium, internal epineurium and an outer layer of echogenic epineurium²⁴ (Figure 2).

Care must be taken to ensure the angulation of the transducer is altered whilst following the nerve in short axis, to ensure the nerve is imaged with perpendicular sound incidence, as the echogenicity of the nerve can alter due to anisotropic effects, and the nerve can become difficult to visualise at times.²³ The cross sectional size of the sural nerve will decrease when examined from proximal to distal²⁵ as the number and size of the fascicles will decrease with increasing distance from the site of origin as branches are given off.²³ Nerves are sonographically imaged in short axis using the elevator technique where they are followed throughout their course, usually from proximal to distal.^{3,26} The sural nerve is initially identified in the distal calf, where it is close to the SSV, as it is easy to identify here.²⁵ It can then be traced proximally in short axis to its origin in the mid-calf, and then followed distally to the ankle and foot. Further studies are still required to investigate the cross sectional area of the normal sural nerve throughout its course.²¹

In long axis, the sural nerve will demonstrate a fascicular echotexture, with hypoechoic parallel lines (fascicles) separated by echogenic bands.²⁴ Long axis imaging allows changes in the nerve and fascicle diameter to be appreciated which can include focal abnormal areas of compression or swelling of the nerve, or individual fascicles. Trauma to the nerve such as stretching or mild contusion may demonstrate focal swelling.²⁵ Sonographically, partial tears in long axis may appear as interruptions to some fascicles and complete transections of the nerve, in cases of nerve laceration, will demonstrate a discontinuous nerve with a gap between nerve ends.³ Post surgical trauma may demonstrate a swollen nerve encapsulated by scar tissue.³ Nerve lesions can appear as a hypoechoic swelling of the whole nerve or a single fascicle.²³ Comparison of sonographic appearances with the contralateral limb including the nerve size and internal architecture can allow subtle structural changes to be appreciated.³ When abnormalities of the sural nerve are identified, transducer pressure can be applied, which may elicit pain or other clinical symptoms. This allows for confirmation of the sonographic Tinel sign, which can guide

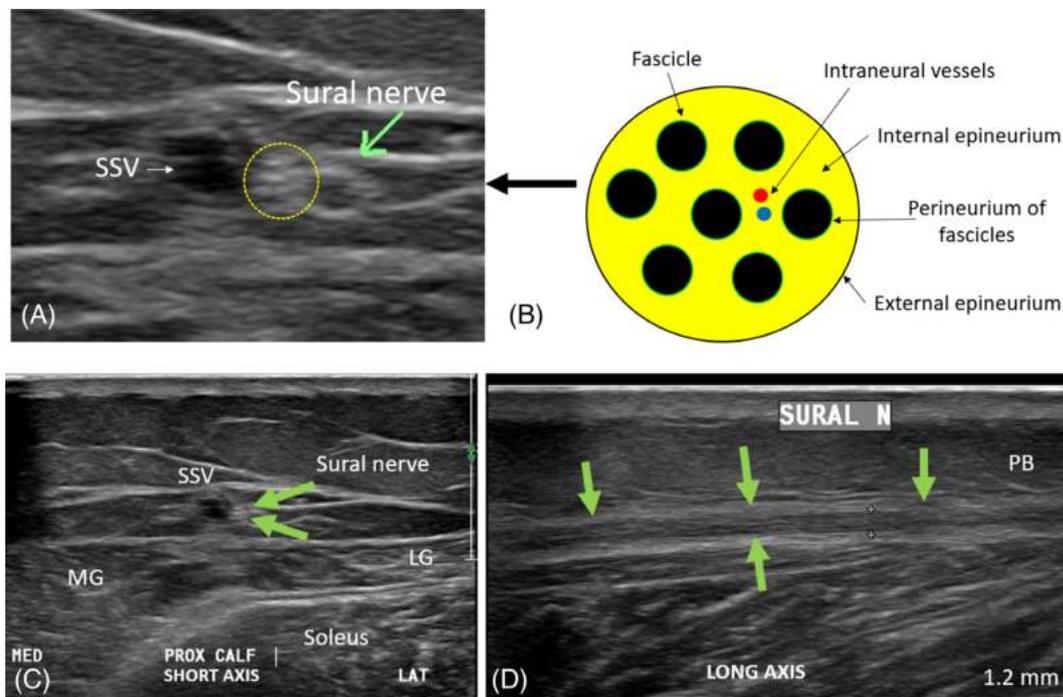


FIGURE 2 Sonographic appearance of the sural nerve. (A) Short axis appearance of the sural nerve (yellow dotted line) near the small saphenous vein (SSV). (B) Components of the nerve in short axis. (C, D) Short axis (C) and long axis (D) imaging of the sural nerve in the calf. The nerve is small (1.2 mm diameter) and outlined by green arrows or dotted lines.

reporting of the location of nerve pathology to inform patient management and surgical treatment if necessary.^{3,27}

4 | RELATIVE STRUCTURAL AND SONOGRAPHIC ANATOMY OF THE SURAL NERVE

The path and size of the sural nerve and its distal branches has been defined predominantly by cadaveric studies.^{1,8,28–35} Sonographically, the sural nerve should be assessed at several distinct areas throughout its path which include: (1) Its proximal origin, (2) Where it pierces the crural fascia to move from deep to superficial, (3) Through the posterior distal calf, (4) As it passes around the ankle, and (5) Along the lateral foot. Imaging of the sural nerve at these points are outlined below.

4.1 | Origin of the sural nerve proximal calf

The origin of the sural nerve is variably described, both in terms of the proximal nerves that join to form the sural nerve and the level of its formation in the posterior calf.^{1,2,36} The most prevalent pattern of origin of the sural nerve is from two proximal nerves which are branches from the tibial and common peroneal nerves.^{1,2,22,28,32,37–39} These two branches commonly include the medial and lateral sural cutaneous nerves (Figure 3).

The tibial nerve gives rise to the medial sural cutaneous nerve (MSCN) which either travels between the two heads of the gastrocnemius muscle in a relatively straight path, deep to the crural fascia^{38,39}

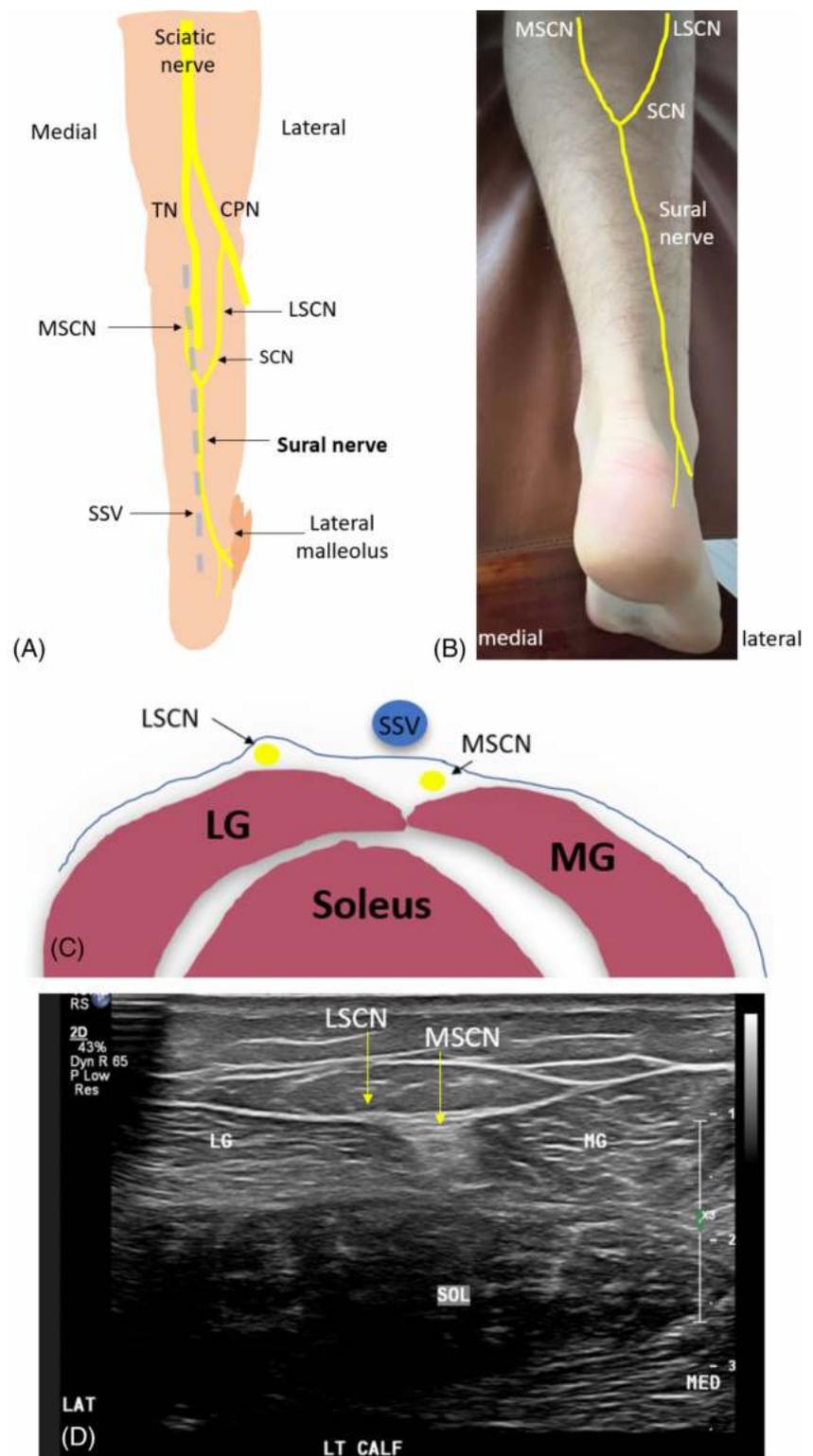
or via an intramuscular course where it travels within the medial or lateral gastrocnemius muscles.^{4,40} It potentially can be compressed in its intramuscular course during muscle contractions or gastrocnemius muscle injury.⁴⁰ The common peroneal nerve gives rise to a branch called the lateral sural cutaneous nerve (LSCN).⁴¹ It can variably give rise to the sural communicating nerve (SCN).^{32,37} The LSCN and/or SCN join the MSCN to form the sural nerve.¹ Anatomical variations of the sural nerve origin include it arising directly from the sciatic nerve, the common peroneal nerve or the MSCN or LSCN.^{2,22,38,39} Due to this variation of its origin, the proximal sural nerve can be termed the proximal sural nerve complex.²² The origin is commonly observed at the level of the mid to distal end of the gastrocnemius muscles in the mid-calf.¹²

4.2 | Sural nerve piercing crural fascia

Once formed, the sural nerve travels distally in the posterior calf, initially deep to the crural fascia,²² superficial to and between the two distal heads of the gastrocnemius muscle.⁵ Around the level of the myotendinous junction of the Achilles and gastrocnemius, the sural nerve pierces the crural fascia to become superficially located^{1,22,38} (Figure 4).

At the point of fascial piercing, the sural nerve is vulnerable to entrapment which can cause subsequent sensory changes.⁴² When pinched where it pierces the fascia, the sural nerve may appear thinned and subsequently swollen distal and/or proximal to the entrapment point.²⁵ This can be seen in runners.³ The sural nerve size in the normal state has been reported to be between 2.7 to 3.4 mm from cadaveric studies.³⁸ However sonographically, the normal sural nerve is anecdotally reported to measure less, between 1 and

FIGURE 3 (A) Origin of the sural nerve formed by the medial sural cutaneous nerve (MSCN) and the lateral sural cutaneous nerve (LSCN) +/- the sural communicating nerve (SCN). (B) Sural nerve along the posterior aspect of the calf. (C) Axial diagram of the LSCN and MSCN. (D) Associated short axis sonographic image of the MSCN and LSCN, superficial to, and between the heads of the gastrocnemius muscles, deep to the crural fascia (outlined in blue). LG, lateral gastrocnemius; MG, medial gastrocnemius; SOL, soleus; SSV, small saphenous vein.



2 mm.^{3,21} Studies investigating the sonographic size of the sural nerve throughout its path are lacking. Hence, evidence-based studies regarding quantitative measures of the sonographic size (cross sectional area and diameter) of the sural nerve, including the symmetry between contralateral limbs, and the effect of limb dominance, age, weight, height, and sex on sural nerve size are required. The use of quantitative measures of sural nerve may aid the sonographic identification of changes in sural nerve thickness around areas of entrapment.

4.3 | Sural nerve in distal third of superficial calf

Once superficial in location in the distal calf, the sural nerve travels to sit near the SSV.² Its distance to the SSV is variable, and it can sit medial or lateral to the SSV, more commonly lateral.¹⁰ Where it sits close to the SSV, it is at risk of iatrogenic injury from stripping, thermal ablation or injections of the SSV.¹⁰ Sonographically, when the nerve is injured, it may appear thickened and hypoechoic.³

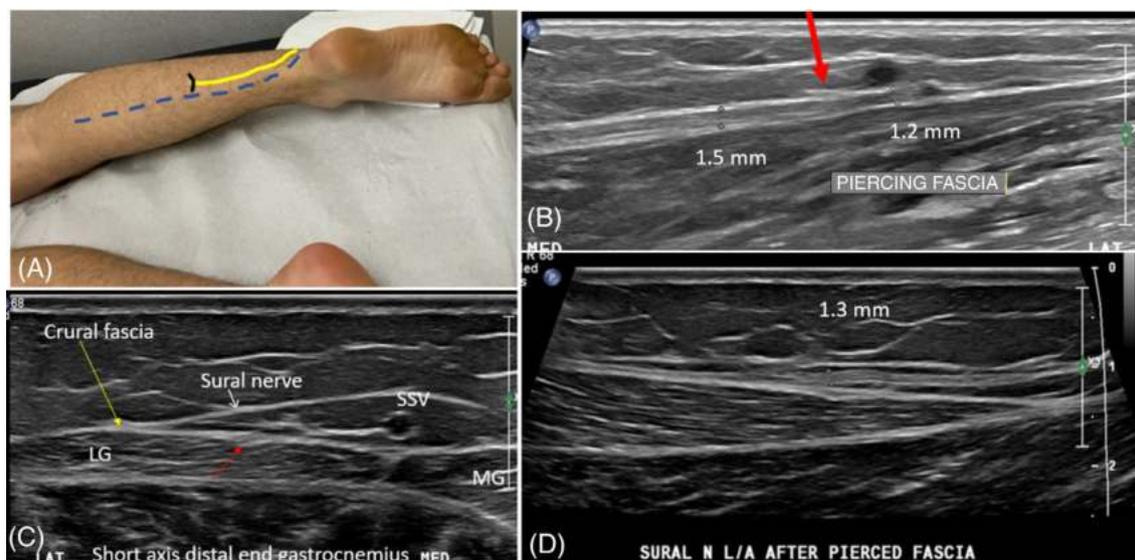


FIGURE 4 (A) The sural nerve (yellow) pierces the fascia around the level of the gastrocnemius-Achilles myotendinous junction (black curve), small saphenous vein (SSV) = blue dotted line. (B) Long axis image of the sural nerve piercing the fascia. The nerve measures 1.5 mm in diameter deep to fascia and 1.2 mm passing through fascia. (C) Short axis image of the sural nerve piercing the fascia (red arrow). (D) Long axis view of the sural nerve 1.3 mm in diameter once superficial. LG, lateral gastrocnemius; MG, medial gastrocnemius.

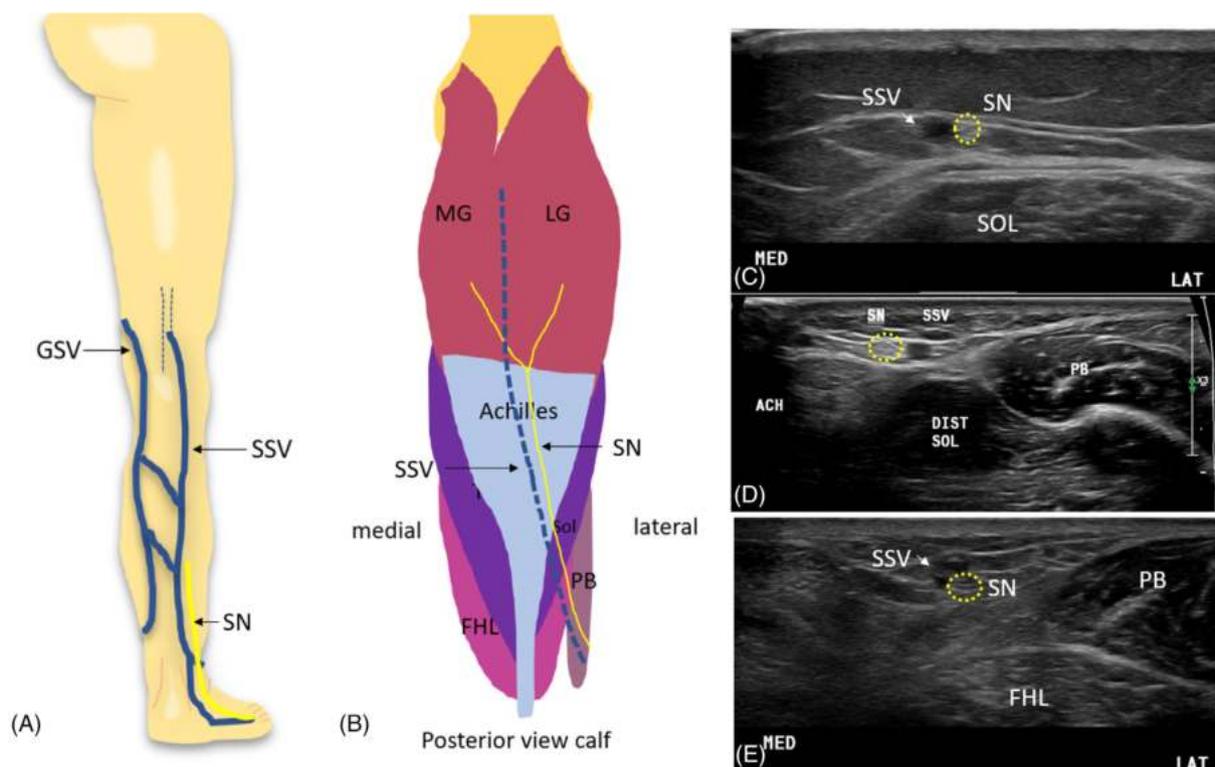
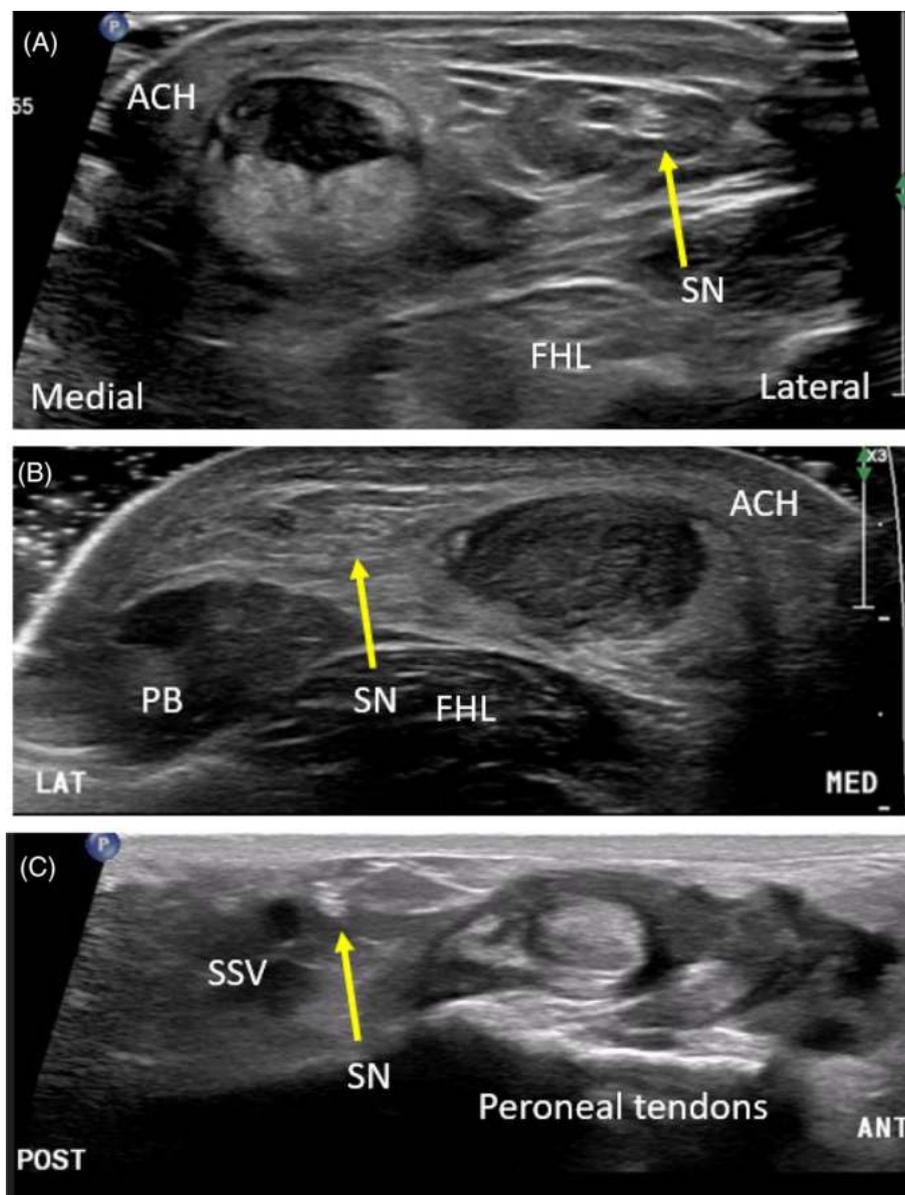


FIGURE 5 Sural nerve (SN) in the distal calf. (A) SN follows the path of the small saphenous vein (SSV) which drains the lateral foot and lower leg. (B) The SN commonly sits lateral to the SSV C-E. Short axis imaging of the SN from proximal to distal, near the SSV (C), superficial to the soleus (SOL) muscle (D) between the Achilles tendon (ACH) and the peroneus brevis (PB) muscle. (E) Distally, the SN overlies the flexor hallucis longus (FHL) muscle. GSV, Great saphenous vein; LG, lateral gastrocnemius; MED, medial; MG, medial gastrocnemius; LAT, lateral.

Distally, the sural nerve travels lateral to the Achilles tendon, and posterior to the peroneal muscles and fibula.⁵ It also sits superficial to the soleus muscle and more distally, the flexor hallucis longus muscle²² (Figure 5).

As the sural nerve runs close to the Achilles tendon, it can be affected by Achilles tendon pathology, injury, or surgical repair. When the Achilles tendon is acutely ruptured, the sural nerve is vulnerable to compression by an adjacent haematoma.⁵ Lateral approaches for

FIGURE 6 The sural nerve (SN) near Achilles tendon ruptures (A and B) and peroneal tendon pathology (C). ACH, Achilles tendon; FHL, flexor hallucis longus muscle; PB, peroneus brevis muscle; SSV, small saphenous vein.



Achilles tendon surgical repairs are often avoided to reduce the potential injury to the sural nerve or its branches.²⁸ Mapping of the sural nerve and its branches prior to open or percutaneous surgery have been proposed to minimise sural nerve damage⁴³ (Figure 6).

4.4 | Sural nerve at ankle level

At the lateral ankle, the sural nerve courses posterior to the lateral malleolus of the fibula and the peroneal tendons.¹⁰ At a variable level (0–5 cm superior to lateral malleolar tip), the sural nerve gives rise to small anterior and posterior nerve branches.³¹ The lateral calcaneal branch (LCB) is a posterior branch of the sural nerve³⁴ which travels to and innervates the lateral calcaneal region.²⁸ It often follows a posterior tributary of the SSV.²⁹ The anterior dorsal branch of the sural nerve (ADBSN) is a communicating branch that travels to the dorsum of the foot.^{1,2} It anastomoses with a branch of the superficial peroneal

nerve (SPN), the intermediate dorsal cutaneous nerve (IDCN), at the distal edge of the extensor retinaculum¹ (Figure 7).

4.5 | Sural nerve in the foot

Distal to the lateral malleolus of the fibula, the sural nerve follows the path of the peroneal tendons and SSV into the foot. It courses superficial to the inferior aspect of the superior peroneal retinaculum, the calcaneofibular ligament (CFL) and inferior peroneal retinaculum.³ Along the lateral aspect of the foot, the sural nerve courses superficial to the peroneus longus tendon up to the level of the cuboid.³ The sural nerve should be carefully assessed in cases of peroneal tendon injury or pathology, CFL injury post lateral ankle sprains, calcaneal fractures and their subsequent surgical repair.³⁷ The sural nerve can also be traumatised by a foreign body or external compressions or lacerations to the leg or foot⁵ (Video 1).

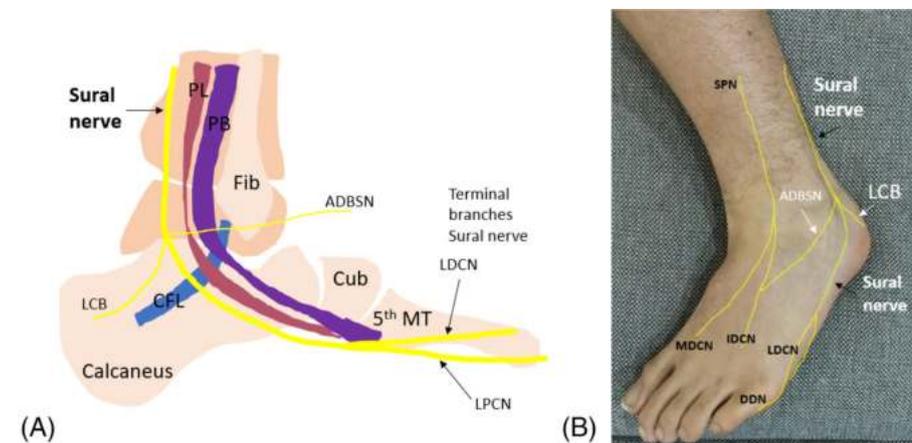
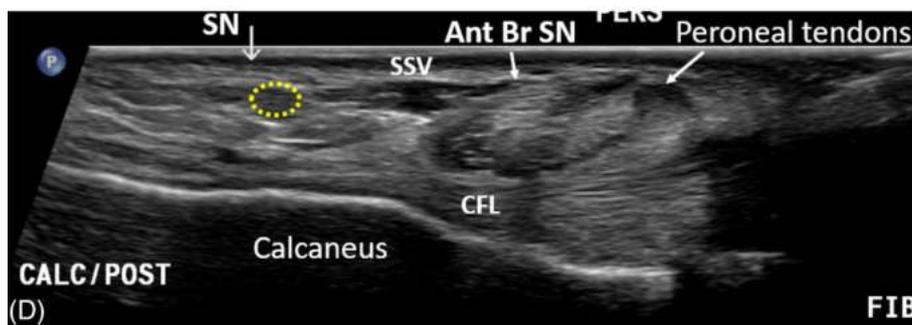


FIGURE 7 (A) The sural nerve in the lateral ankle and foot follows the path of the peroneus longus (PL) and peroneus brevis (PB) tendons and gives rise to the lateral calcaneal branch (LCB) and the anterior dorsal branch of the sural nerve (ADBSN). (B) Surface anatomy of the sural nerve. (C, D) Short axis images of the (C) small saphenous vein (SSV) and the sural nerve (SN) and the LCB (Post Branch SN) and (D) SN and anterior branch of the SN (Ant Br SN) superficial to the peroneal tendons; LDCN, lateral plantar cutaneous nerve; MDCN, medial dorsal cutaneous nerve (branch of superficial peroneal nerve).



VIDEO 1 Sural nerve video. Video content can be viewed at <https://onlinelibrary.wiley.com/doi/10.1002/sono.12372>

At a variable distance between the calcaneocuboid joint and base of the 5th metatarsal the sural nerve gives rise to two distal branches.⁴⁴ The main terminating branch, the lateral dorsal cutaneous nerve (LDCN) travels along the dorsal lateral aspect of the 5th metatarsal and terminates as the dorsal digital nerve (DDN).⁴⁴ It provides the sensory supply of the lateral aspect of the fifth toe²² and is vulnerable to injury from base of 5th metatarsal fractures and subsequent surgical repair.⁴⁴ The other distal branch, the lateral plantar cutaneous nerve (LPCN) travels plantarly relative to the LDCN.⁴⁴ The distal divisions of the sural nerve can be identified sonographically following distal SSV tributaries along the lateral aspect of the foot. Understanding the distribution pattern of these distal branches, can assist sonographic identification of potential pathology or injury (Figure 7A,B).

5 | CONCLUSION

Injury or pathology to the sural nerve can cause sensory changes to the lateral aspect of the distal lower leg, ankle, and foot. Sonography can be used to directly image the sural nerve, however familiarity with the anatomy, sonographic technique and normal and abnormal sonographic appearances of the sural nerve, and areas of risk of injury and entrapment are essential. Studies investigating and reporting the sonographic size of the sural nerve throughout its path are lacking and are required. A timely diagnosis of sural nerve injury or pathology can be used to optimise patient management.

CONFLICT OF INTEREST STATEMENT

The author declares no conflicts of interest.

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QUESTIONNAIRE

A20(25) Part 1 of 2

Sonographic imaging and assessment of the sural nerve

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Introduction

Question 1: Due to the superficial location of the sural nerve as well as its small structure, it can be?

- A:** At risk of injury from external compression from tight footwear or casts
- B:** Easily overlooked, both clinically and with imaging
- C:** Easily recognised clinically but less so with imaging
- D:** At risk from casts but not tight footwear

Clinical and physical testing of the sural nerve

Question 2: The sural nerve provides sensory innervation to which area?

- A:** Anterior aspect of the lower leg
- B:** Medial aspect of the foot
- C:** Posterolateral aspect of the distal third of the lower leg and dorsolateral foot
- D:** Entire plantar surface of the foot

Question 3: Is it **TRUE** that clinical examination has historically been and still is considered the principal method of diagnosis of sural nerve neuropathies because no other differential diagnoses present with similar symptoms?

- A:** YES
- B:** NO

Question 4: Which clinical test can be performed to replicate clinical symptoms of sural nerve pathology and can also be used as clinical indications for pathology? Choose all three correct options

- A:** Straight leg raise test
- B:** A negative Tinel sign
- C:** Sural nerve neurodynamic test
- D:** A positive Tinel sign
- E:** Point tenderness over the nerve

Question 5: Due to the relatively straight path of the sural nerve in the calf and due to its superficial location and sensory features, it?

- A:** Can be used as a donor nerve for peripheral nerve grafting
- B:** Can be used as a donor nerve for central nerve grafting
- C:** Can be used as a site for nerve biopsy to establish the cause of peripheral neuropathies
- D:** Cannot be used as a site for nerve biopsy

Sonographic imaging of the sural nerve

Question 6: What type of transducer is required for imaging the sural nerve?

- A:** Low-frequency curvilinear transducer
- B:** High-frequency linear or hockey stick transducer
- C:** Low-frequency linear transducer
- D:** High-frequency curvilinear transducer

Question 7: What is the correct patient positioning for sural nerve examination?

- A:** Supine with knee flexed
- B:** Right lateral recumbent position
- C:** Fowler's position
- D:** Prone with feet hanging over examination bed

Question 8: In which imaging plane will the sural nerve demonstrate a fascicular echotexture with hypoechoic parallel lines separated by echogenic bands?

- A:** Long axis imaging
- B:** Short axis imaging

Question 9: What happens to the cross-sectional size of the sural nerve from proximal to distal?

- A:** Increases in size
- B:** Remains the same in size
- C:** Decreases in size
- D:** Fluctuates randomly

Question 10: When abnormalities of the sural nerve is identified, transducer pressure

- A:** Can be applied to elicit pain or other clinical symptoms
- B:** Can be applied to allow for confirmation of the sonographic Tinel sign
- C:** Can be applied to guide reporting of the location of nerve pathology to inform patient management
- D:** Cannot be applied

THE END

QUESTIONNAIRE
A20(25) Part 2 of 2
Sonographic imaging and assessment of the sural nerve

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Relative structural and sonographic anatomy of the sural nerve

Question 1: The most prevalent pattern of origin of the sural nerve is from two proximal nerves which are branches from the and nerves?

- A: Sciatic and tibial nerves
- B: Sciatic and common peroneal nerves
- C: Common peroneal and saphenous nerves
- D: Tibial and saphenous nerves
- E: Tibial and common peroneal nerves

Question 2: Where does the sural nerve pierce the crural fascia to become superficially located?

- A: Around the level of the myotendinous junction of Achilles and gastrocnemius
- B: At mid-calf
- C: In the proximal calf

Question 3: Studies investigating the sonographic size of the sural nerve throughout its path are conclusive and have established that the size is between 1 and 2 mm. Is this statement **TRUE** or **FALSE**?

- A: TRUE
- B: FALSE

Question 4: In relation to the small saphenous vein (SSV), where does the sural nerve most commonly sit?

- A: Medial
- B: Posterior
- C: Anterior
- D: Lateral

Question 5: At which level does the sural nerve give rise to small anterior and posterior nerve branches?

- A: At a variable level of 5 - 10 cm superior to lateral malleolar tip
- B: At an exact level of 10 cm inferior to lateral malleolar tip
- C: At a variable level of 0 - 5 cm superior to lateral malleolar tip
- D: At an exact level of 5cm superior to lateral malleolar tip

Question 6: Which structure does the lateral calcaneal branch follow?

- A: Anterior tibial artery
- B: Posterior tributary of the small saphenous vein
- C: Peroneal artery
- D: Great saphenous vein

Question 7: Which nerve does the anterior dorsal branch of the sural nerve anastomose with?

- A: Intermediate dorsal cutaneous nerve
- B: Deep peroneal nerve
- C: Tibial nerve
- D: Medial plantar nerve

Question 8: Where does the lateral dorsal cutaneous nerve travel?

- A: Along the medial aspect of the foot
- B: Along the dorsal lateral aspect of the 5th metatarsal
- C: Along the plantar aspect of the foot
- D: Along the dorsal aspect of the 1st metatarsal

Question 9: What is the main vulnerability of the lateral dorsal cutaneous nerve?

- A: Ankle sprains
- B: Achilles tendon rupture
- C: Injury from base of 5th metatarsal fractures
- D: Calcaneal fractures

Question 10 Is it **TRUE** that injury to the sural nerve can cause sensory changes to the lateral aspect of the distal lower leg, ankle and foot and a timely diagnosis of sural nerve injury or pathology can be used to optimise patient management?:

- A: YES
- B: NO

THE END



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ANSWER SHEET

A20(25)

Sonographic imaging and assessment of the sural nerve

	*Time spent on activity						hour					min				
	A	B	C	D	E		A	B	C	D	E	A	B	C	D	E
1						1										
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3						3										
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How relevant was the content of this activity to your scope of practice?			
			
Not at all	Somewhat	Mostly	Extremely
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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