Ultrasonography of the Sural Nerve

Normal and Pathologic Appearances

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Ultrasonography (US) of peripheral nerves has gained wide popularity because of the increased definition of modern high-frequency electronic transducers, as well as the well-known advantages of US, which include easy availability, low cost, and the possibility of realizing a dynamic examination. Traditionally, US has been deployed to assess the major nerves of the limbs. More recently, US has also been used to assess the normal appearance and pathologic changes of smaller subcutaneous nerves. The sural nerve is a small sensory nerve in the subcutaneous tissues of the calf that can be affected by a variety of disorders. This pictorial essay illustrates the normal anatomy of the sural nerve, the technique for its examination by US, as well as the US appearance of its main pathologic changes.

Key Words—musculoskeletal (diagnostic); musculoskeletal (interventional); peripheral nerves; sural nerve; trauma; ultrasonography

Ultrasonography (US) is widely considered to be an effective, accurate, dynamic, and noninvasive technique for assessment of peripheral nerves of the extremities.[1–4] The sural nerve is a small sensory nerve running in the subcutaneous tissues of the calf that can be affected by several pathologic conditions.[5,6] Because of its superficial location and rectilinear path, it can be accurately assessed by high-frequency US.[5–7] The aim of this pictorial essay is to describe the normal sural nerve anatomy, to illustrate the technique of its US examination and normal US appearance, and finally to present the US appearances of a variety of its pathologic changes.

Anatomy

The sural nerve is a small sensory nerve located in the subcutaneous tissues of the calf (Figure 1A).[3,5,7,8] It most frequently originates from the fusion of two proximal roots: the medial sural cutaneous nerve, a branch of the tibial nerve, and the lateral sural cutaneous nerve, a branch of the common fibular nerve. The roots usually fuse at the proximal part of the calf, but their union can also be observed more distally, even in the ankle region. The sural nerve can also have other anatomic variations, including asymmetry in its formation[8] and different patterns of origins from the tibial and common fibular nerves. In an anatomic study of 76 cadavers, the mean sural nerve diameter was 3.61 mm (SD, 0.07 mm).[8] In most cases, the sural nerve runs first in the midline and then moves laterally in the distal third of the calf.[9] During its course, the sural nerve passes from deep to superficial to fascial tissues.[10] The nerve has a close relationship with the Achilles tendon.[11] In its cranial portion, it is first located

Received June 26, 2017, from the Cabinet Imagerie Médicale, Geneva, Switzerland (S.B.); Orthopedic Surgeon, Geneva, Switzerland (L.D.); Orthopedic Surgeon, Geneva, Switzerland (C.L.D.); Chirurgie Orthopédique et Traumatologie de l'Appareil Moteur, Hôpitaux Unviersitaire Genève, Geneva, Switzerland (V.D.-F.); and Clinique des Grangettes, Chêne-Bougeries, Switzerland (M.D.). Manuscript accepted for publication July 20, 2017.

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Abbreviations
US, ultrasonography

doi:10.1002/jum.14444

posterior to the flat common tendon of the gastrocnemius muscles and then lateral to the Achilles tendon, running close to its external margin. The sural nerve also has a close relationship with the smaller saphenous vein.[12] The sural nerve relationship with the smaller saphenous vein at the middle-distal leg depends on high variability of the level of fusion of its two roots. In the case of distal fusion, the two roots can be seen at variable

Figure 1. Sural nerve anatomy: schematic drawings. **A**, Calf region. In the proximal calf region, the tibial (a) and common fibular (b) nerves give origin to the roots of the sural nerve (white arrow), from medial (1) and lateral (2) sural cutaneous branches. These join together at the proximal or middle third of the calf. The sural nerve runs distally close to the smaller saphenous vein (SSV) in a close relationship with the Achilles tendon (black arrowhead). In the distal region of the leg, the nerve is located between the Achilles tendon and the peroneus longus (PL) and peroneus brevis (PB) tendons. **B**, Ankle and foot region. In the supramalleolar region, the sural nerve (white arrow) runs posterior to the peroneus longus and brevis tendons and superficial to their proximal retinaculum (PRet). At the level of the calcaneus, the nerve lies superficial to the calcaneofibular ligament (CFL) and the distal peroneal retinaculum (DRet). It then reaches the region of the base of the fifth metatarsal to split into two terminal branches (3 and 4). In the perimalleolar region, the nerve gives up the calcaneal branch (5). Some anastomosis (6) with the terminal branches (C) of the superficial fibular nerve can be present. The white dashed area illustrates the area of sensory innervation.

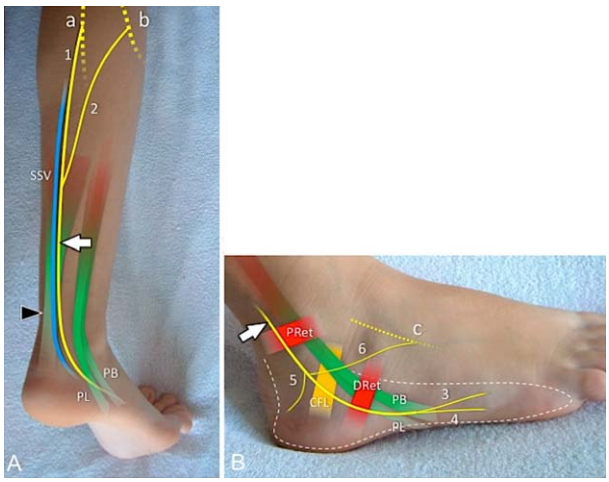
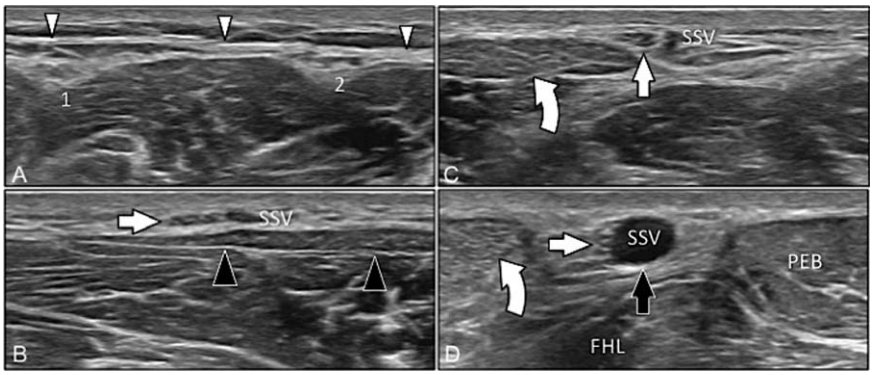


Figure 2. Sural nerve US anatomy: calf region. **A–D**, Transverse sonograms obtained from proximal (**A**) to distal (**D**). In **A**, the medial (1) and lateral (2) sural cutaneous branches are depicted running deep to the superficial fascia (white arrowheads). In a more distal position (**B**), the branches have fused to give origin to the sural nerve (white arrow) running close to the smaller saphenous vein (SSV). The structures lie superficial to the flat aponeurosis of the gastrocnemius muscles (black arrowheads). In **C**, the sural nerve and the smaller saphenous vein are located at the lateral margin of the Achilles tendon (curved arrows). More distally (**D**), note the sural nerve and the accompanying smaller saphenous vein (black arrow) surrounded by fat located between the Achilles tendon and the flexor hallucis longus (FHL) and peroneal brevis (PEB) muscles.



distances from the vein, which frequently runs between them. If the fusion is proximal, the sural nerve is usually located medial to the vein. At the distal leg and ankle, the anatomic relationship of the sural nerve is more constant, showing the nerve in close contact with the smaller saphenous vein. In the ankle region, the course of the sural nerve runs around the lateral malleolus. Distal to the lateral malleolus, the sural nerve gives origin to the lateral calcaneal branch, which innervates the lateral face of the heel region. Afterward, it follows the peroneal tendons and crosses the calcaneofibular ligament and the inferior peroneal retinaculum (Figure 1B). At the level of the fifth metatarsal, the sural nerve splits into its two terminal branches.[5,6]

The sural nerve supplies the lateral inferior third of the leg, ankle, and foot. It can have some anastomosis with the distal branches of the superficial fibular nerve.

Figure 3. Sural nerve US anatomy: ankle and foot region. **A–C**, Coronal oblique sonograms obtained from proximal (**A**) to distal (**C**). In **A**, the sural nerve (white arrow) runs close to the smaller saphenous vein (SSV). Both structures run superficial to the calcaneofibular ligament (CFL). Calc indicates calcaneus; PL, peroneus longus tendon; and PB, peroneal brevis tendon. At a more anterior level (**B**), the nerve and vein run superficial to the peroneal retinaculum (open arrowhead). PeT indicates peroneal tuberculum. Just posterior to the base of the fifth metatarsal (**C**), note the two distal branches (white arrows) of the sural nerve located superficial to the distal flat peroneus brevis tendon.

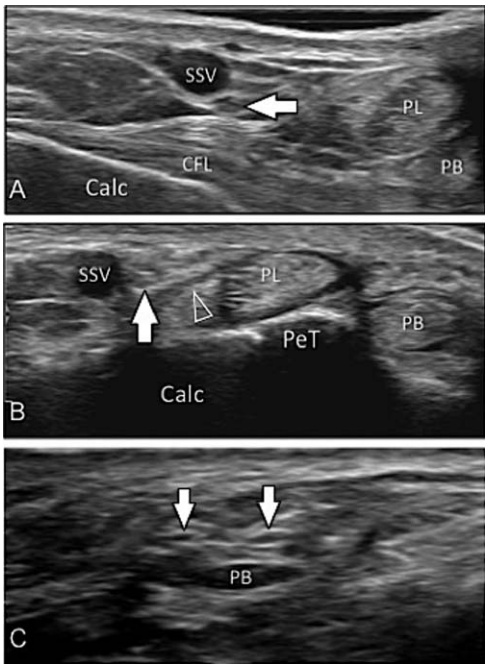


Figure 4. Direct trauma: complete tear of the sural nerve in a patient with a history of a penetrating wound at the posterior aspect of the leg. **A–C**, Longitudinal (**A**) and transverse (**B** and **C**) sonograms of the sural nerve. A posttraumatic neuroma is well shown by US in **A** and **B** as focal bulbous hypoechoic swelling of the nerve (large arrows), associated with the absence of the normal internal fascicular appearance. In **A**, note the local soft tissue posttraumatic fibrosis and calcification (curved arrow), associated with posterior shadowing (small arrows). In **A** and **C** (obtained proximal to the neuroma), note the normal internal appearance of the proximal nerve.

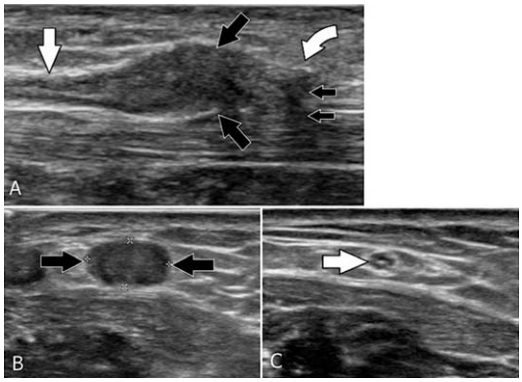
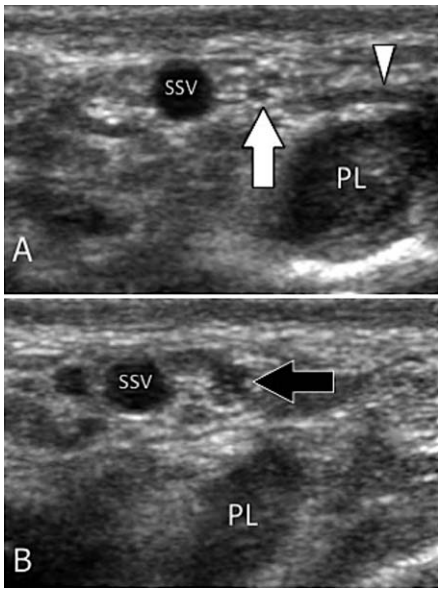


Figure 5. Direct trauma: contusion of the sural nerve in the perimalleolar area due to a motorcycle collision. **A** and **B**, Transverse sonograms obtained on the sural nerve proximal (**A**) and at the level of the trauma (**B**). The normal sural nerve (white arrow) had a fascicular appearance in **A**. In **B**, note the thickened and hypoechoic nerve that shows partial loss of the normal fascicular pattern. Ultrasound-guided local compression reproduced the distal paresthesia. Arrowhead indicates distal peroneal retinaculum; PL, peroneus longus tendon; and SSV, smaller saphenous vein.



Two points of sural nerve anatomy deserve emphasis: (1) the high anatomic variability of its origin; and (2) its close relationships with the smaller saphenous vein, Achilles tendon, and peroneal tendon.

Examination Techniques and Normal US Anatomy

For an optimal US examination of the sural nerve, the patient lies prone with the knees extended and the feet hanging over the end of the examination bed. This position allows examination of both sural nerves from their origins to their distal extremities. High-frequency transducers (15–17 MHz) are needed to assess the nerve because of its superficial position and small size. Small clubfoot transducers and a large amount of coupling gel are used to follow the nerve in the perimalleolar region. In the case of compression of the nerve by a tumor, a transducer with a lower frequency is necessary.

Figure 6. Surgical trauma: mild stretching of the sural nerve in a patient with previous surgery of the smaller saphenous vein. **A–C**, Transverse sonograms obtained from proximal (**A**) to distal (**C**). **A** and **C** show a normal appearance of the nerve (white arrows). In **B**, obtained at the level of the nerve injury, the nerve (black arrow) appears swollen but maintains a normal internal fascicular pattern. No tears of the fascicles can be seen. GM indicates gastrocnemius muscle.

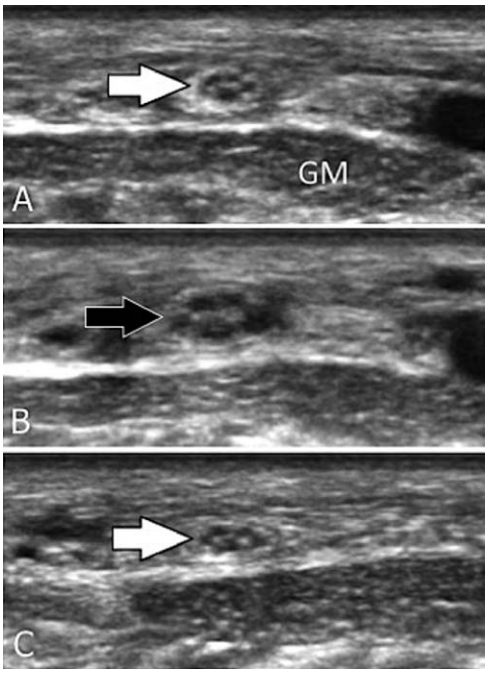


Figure 7. Surgical trauma: neuroma in contiguity with the sural nerve in a patient with previous surgery of the smaller saphenous vein. **A–C**, Longitudinal (**A**) and transverse (**B** and **C**) sonograms obtained from proximal to distal. **A** shows a normal appearance of the proximal and distal nerves (white arrows) and the neuroma in contiguity (black arrow). In **B**, obtained proximal to the neuroma, the nerve shows a normal size and internal structure. In **C**, obtained at the level of the injury, the nerve shows fusiform swelling with disappearance of the fascicular pattern, suggesting a more severe lesion. GM indicates gastrocnemius muscle.

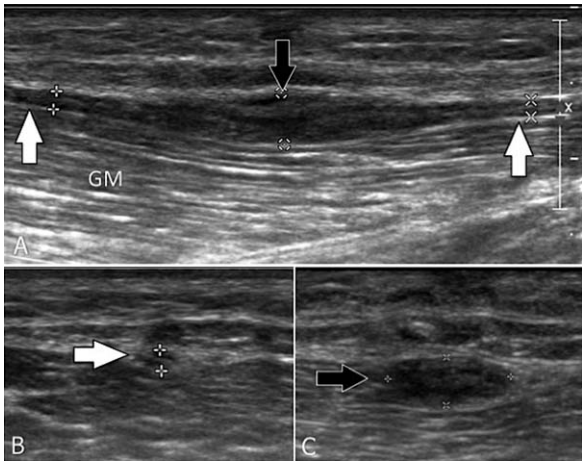
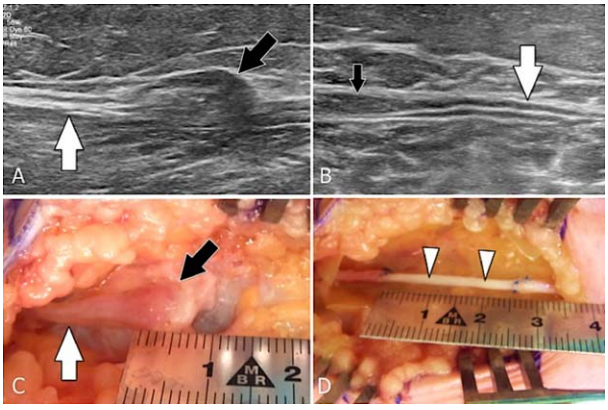


Figure 8. Surgical trauma: tear of the sural nerve with a terminal bulbous neuroma after gastrocnemius recession. **A** and **B**, Longitudinal sonograms of the sural nerve obtained at the levels of the proximal (**A**) and distal (**B**) stumps. **C** and **D**, Surgical images. Sonograms show a larger proximal neuroma (large black arrow in **A**) and a smaller distal neuroma (small black arrow in **B**). Note the normal fascicular appearance of the nerve (white arrows) proximal and distal to the neuromas. In **C**, the proximal neuroma appears at surgery as bulbous swelling of the nerve. The neuroma was exactly located at the level of the cutaneous markers realized under US guidance. **D** shows the nerve graft (arrowheads) realized after excision of the neuromas.

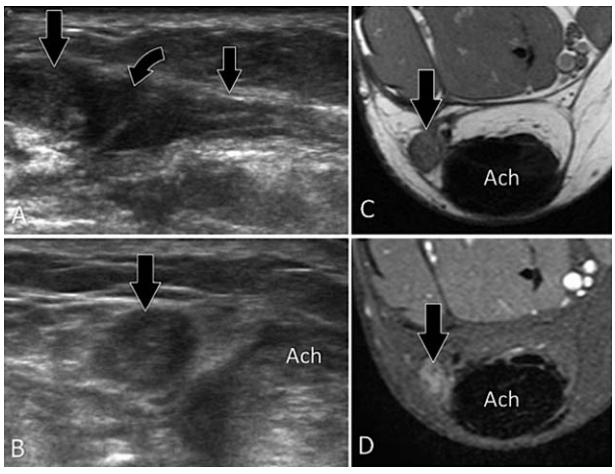


The examination starts at the midcalf with short-axis sonograms, allowing identification of the smaller saphenous vein and the adjacent sural nerve running inside the subcutaneous tissues. The nerve and vein have variable positions relative to each other. Once the sural nerve is detected, it is studied by moving the transducer upward and downward using the so-called elevator technique.[3,4] Care must be taken to always orient the transducers perpendicular to the axis of the nerve. Subtle changes in the nerve size or its internal architecture are better appreciated by contralateral comparison. If pathologic conditions are present, abnormalities may then be imaged in the long axis.[13] Color Doppler imaging is always performed to assess the presence of local hypervascular changes.

Although the sural nerve is a small nerve with a diameter of up to 1 mm on US,[5] high-frequency transducers allow recognition of its internal structure, which shows the typical fascicular pattern made by hypoechoic nerve fascicles surrounded by hyperechoic connective tissue (Figures 2 and 3). In normal conditions, the diameter of the nerve shows only a small decrease from the distal to proximal region, and color Doppler imaging does not show internal flow signals.

In assessing pathologic conditions, local pressure applied through the transducer can elicit burning pain in neuromas, making their detection easy.[1] Ultrasonography is also invaluable for accurate location of the neuroma and for marking the skin to facilitate surgical treatment.

Figure 9. Surgical trauma: tear of the sural nerve in a patient with a history of Achilles tendon surgery. **A** and **B**, Longitudinal (**A**) and transverse (**B**) sonograms of the sural nerve obtained at the level of the Achilles tendon (Ach). **C** and **D**. T1-weighted (**C**) and T1-weighted fat-suppressed postgadolinium (**D**) magnetic resonance images obtained at the level of **B**. In **A**, note a complete tear of the sural nerve (curved arrow) together with a neuroma of the proximal stump (large arrow). The distal stump (small arrow) shows moderate swelling of the fascicles. In **B**, the neuroma of the proximal stump has a hypoechoic appearance without any fascicular pattern. Magnetic resonance imaging (**C** and **D**) confirms the presence of a neuroma as an isointense mass located close to the Achilles tendon. Inhomogeneous enhancement of the nerve is seen in **D**. Note the thickened Achilles tendon. Surgery confirmed a complete section of the sural nerve.



Pathologic Findings

Trauma

Posttraumatic damage depends on the energy of the trauma and on the nature of the adjacent soft tissue. Mild contusions or stretching of the nerve results in minor swelling without local interruptions of the fascicles. More severe lesions present as interruptions of some (partial tears) or all (complete tears) nerve fascicles. Mild trauma of the sural nerve results in a temporary decrease in sensation and mild numbness in the peripheral territory. More severe trauma associated with a nerve tear results in two main clinical consequences. First, there is hypoanesthesia in the territory of the sural nerve, which is usually well tolerated by patients, since it can be partially diminished by the overlap of other adjacent nerves. Second, there may be burning neuropathic pain related to the presence of a neuroma. The sural nerve can be injured by direct trauma or by trauma related to local surgical procedures.

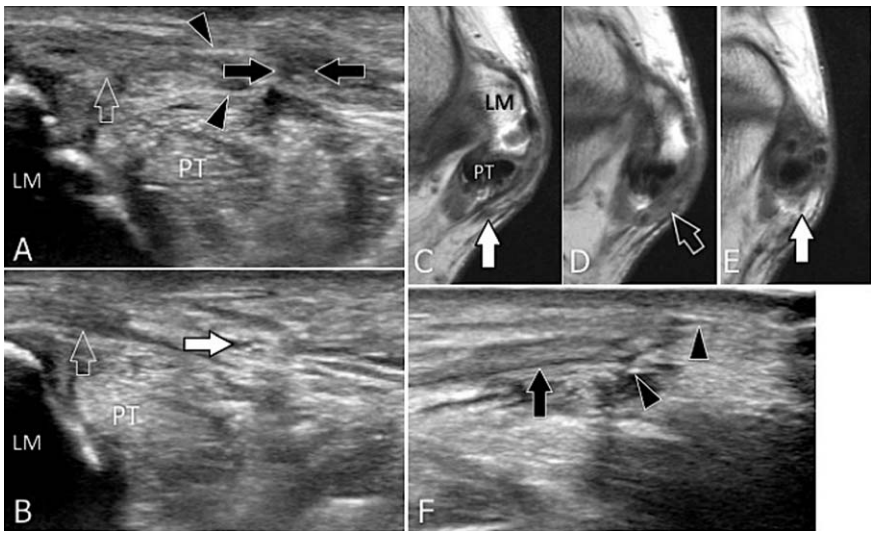
Direct Trauma

The location of the sural nerve running just under the skin makes it vulnerable to open wounds (Figure 4), and its close relationship with the bones of the lateral aspect of the ankle and foot explains how it can be injured between an external force and the bone structures in local contusions (Figure 5). Injuries of the sural nerve can also be seen in fractures of the calcaneus or adjacent bones.

Postsurgical Trauma

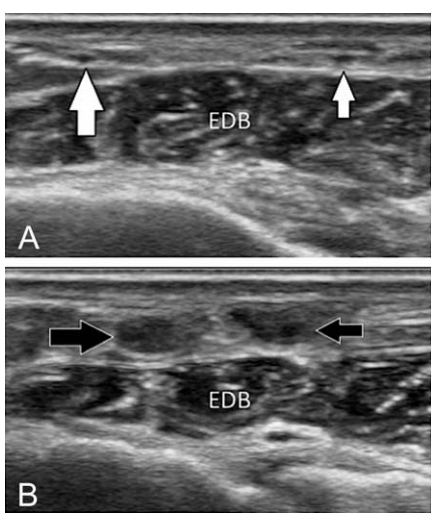
The close relationship of the sural nerve with the Achilles tendon and the smaller saphenous vein explains how it can be injured during orthopedic and vascular surgery. Although rare, stripping of the smaller saphenous vein can be complicated by injuries to the sural nerve (Figures 6 and 7).[14,15]

Figure 10. Surgical trauma: encasement of the sural nerve by surgical stitches in a patient with reconstruction of the peroneal retinaculum. **A** and **B**, Transverse sonograms obtained on the sural nerve at the level of the encasement (**A**) and more distally (**B**). **C–E**, Transverse proton density magnetic resonance images obtained proximal (**C**), at the level of encasement (**D**), and distal to it (**E**). **F**, Longitudinal sonogram obtained over the sural nerve. In **A**, the sural nerve is thick and hypoechoic (black arrows). The reconstructed retinaculum is thickened (open arrow) and contains some surgical stitches (black arrowheads). PT indicates peroneal tendons. The sural nerve (white arrow) is normal in **B**. In the magnetic resonance images, the sural nerve is not visualized at the level of encasement (**D**), whereas it is seen proximally (**C**) and distally (**E**) to it. In **F**, note the relationship between the thick nerve (black arrow) and the surgical stitches (black arrowheads). LM indicates lateral malleolus.



Trauma to the sural nerve is a well-known complication of gastrocnemius recession, a surgical procedure in which, through an open or endoscopic approach, a partial section of the proximal gastrocnemius lamina is obtained to release gastrocnemius tightness. Sural nerve trauma can be more frequent in arthroscopic release, in which the nerve is not visualized during the procedure. Trauma to the distal sural nerve can complicate orthopedic procedures on the Achilles tendon (Figures 8 and 9) and peroneal tendon (Figure 10) and the excision of local ganglia (Figure 11).

Figure 11. Surgical trauma: postsurgical trauma in a patient with previous excision of a ganglion of the dorsolateral aspect of the foot. **A**, Transverse sonogram obtained at the dorsolateral aspect of the tarsal region shows a communicating branch of the sural nerve (large white arrow) with a distal branch (small white arrow) of the superficial peroneal nerve. Note the normal appearance of both nerves running in the subcutaneous tissues over the extensor digitorum brevis muscle (EDB). **B**, Sonogram obtained immediately proximal to the surgical scar shows two neuromas (black arrows) as bulbous swellings of the two nervous branches.



Space-Occupying Lesions

A schwannoma can involve the sural nerve branch of origin (Figures 12 and 13) or its distal branches. In contrast to tumors affecting larger nerves, the relationship of a tumor with the small sural nerve can be difficult to prove. Careful scanning is necessary to show the contiguity of the mass with the nerve. Compression on the tumor under US guidance can occasionally provoke peripheral tingling.

Any tumor located in the subcutaneous tissue of the calf can compress or infiltrate the sural nerve (Figure 14). Usually the nerve cannot be detected inside the mass.

Figure 12. Space-occupying lesion: schwannoma of the lateral sural cutaneous branch. **A–D**, Sagittal and transverse sonograms (**A** and **C**) and corresponding proton density and T2-weighted magnetic resonance images (**B** and **D**). The schwannoma (asterisks) appears as a hypoechoic homogeneous well-delimited mass located inside the nerve (arrows). GLH indicates gastrocnemius lateral head.

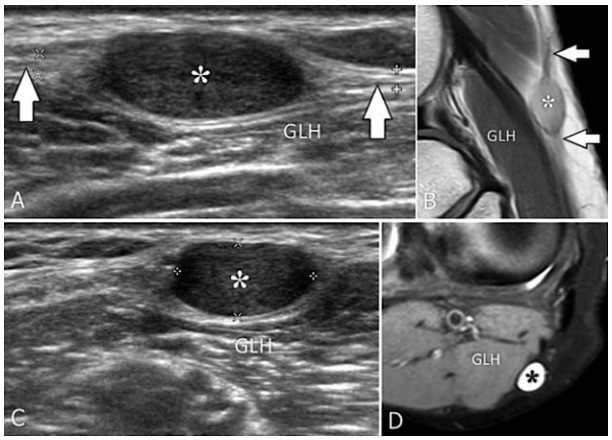
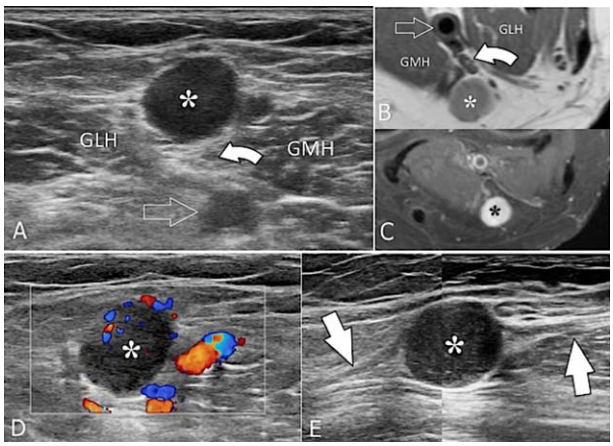


Figure 13. Space-occupying lesion: schwannoma of the medial sural cutaneous branch. **A**, Transverse sonogram. **B** and **C**, Corresponding transverse proton density and T1-weighted gadolinium-enhanced magnetic resonance images. **D**, Transverse color Doppler sonogram. **E**, Longitudinal sonogram. The schwannoma (asterisks) appears as a hypoechoic homogeneous well-delimited mass located inside the nerve (white arrows in **E**). Transverse US allows optimal assessment of the tumor and its relationships with the adjacent anatomic structures. Color Doppler imaging shows internal flow signals related to intralesional vascularization. A longitudinal sonogram (**E**) permits optimal visualization of the relationship of the mass with the sural nerve at its endings. Curved arrows indicate tibial nerve; GLH, gastrocnemius lateral head; GMH, gastrocnemius medial head; and open arrows, popliteal artery.



In the ankle region, ganglia can arise from the joint space or from the peroneal tendons. Due to the close relationship of the sural nerve with these structures, it is not surprising that ganglia can dislocate and compress the nerve (Figure 15). Ultrasonography can easily be used to image ganglia as hypoechoic or anechoic well-defined avascular cystic masses and to accurately assess their relationship with the nerve. In patients without substantial compression of the sural nerve by the ganglion, the nerve appears normal (Figure 16). When a needle puncture of the ganglion is needed, US is helpful in choosing the optimal approach and avoiding injury to the nerve.

Figure 14. Space-occupying lesion: malignant fibrous histiocytoma. **A** and **B**, Transverse grayscale (**A**) and color Doppler (**B**) sonograms obtained cranially and at the level of the tumor, respectively. In **A**, the sural nerve (calipers and arrow) is clearly seen running inside the subcutaneous tissue. In **B**, the tumor appears as an inhomogeneous hypoechoic mass (asterisk) with internal flow signals (arrowheads) infiltrating the nerve, which is no longer visualized.

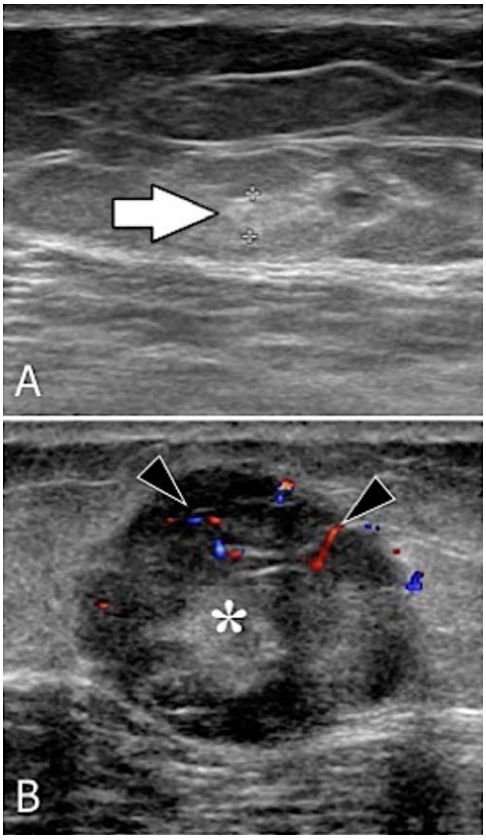


Figure 15. Space-occupying lesion: ganglion compressing the sural nerve. **A–C**, Transverse sonograms obtained on the sural nerve proximal (**A**) and at the level of the ganglion (**B** and **C**). **D** and **E**, Coronal oblique proton density (**D**) and transverse T2-weighted (**E**) magnetic resonance images. The normal sural nerve (white arrow) has a fascicular appearance in **A**. In **B** and **C**, note the extrinsic compression of the ganglion (Gang) on the nerve (black arrows), which appears hypoechoic. The compressed nerve (black arrows) is barely visible on magnetic resonance imaging. SSV indicates smaller saphenous vein.

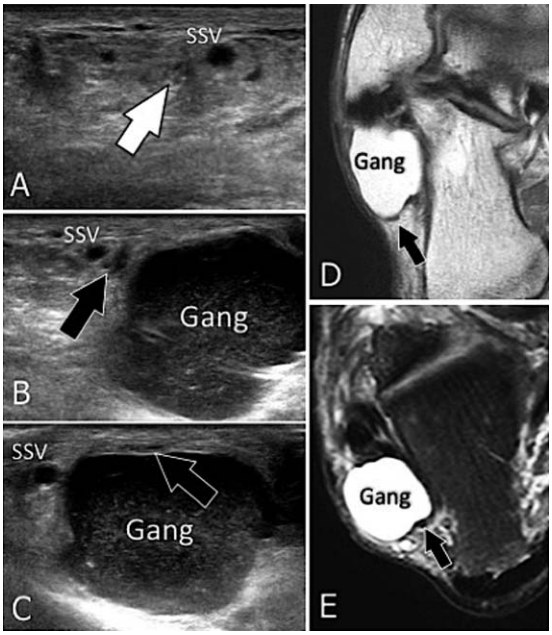
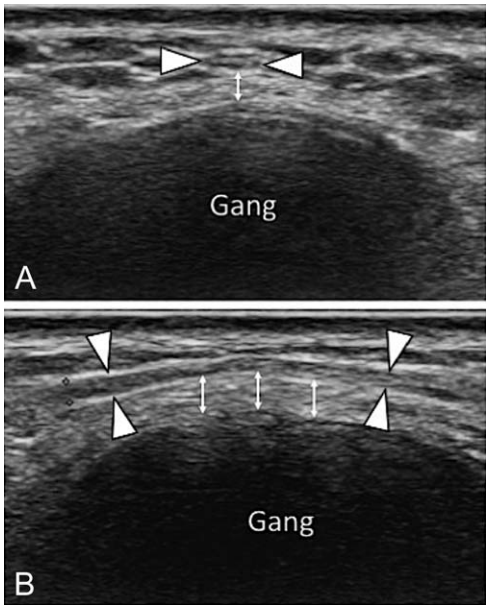


Figure 16. Space-occupying lesion: ganglion without compression on the sural nerve. **A** and **B**, Transverse (**A**) and coronal oblique (**B**) sonograms obtained on the sural nerve at the level of the ganglion. The sural nerve (arrows) had a normal fascicular appearance. Note the stripe of normal fat (arrowheads) located between the nerve and the ganglion (Gang).



Conclusions

The sural nerve is a small superficial nerve that can be damaged by a variety of pathologic conditions. It can be efficiently assessed by modern high-frequency broadband transducers. An accurate scanning technique is necessary to detect the nerve and appreciate its appearance. Knowledge of the main disorders of the sural nerve as depicted in this pictorial essay facilitates early diagnosis and prompt treatment.

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