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Ultrasound of the nerves of the knee region Technique of examination and normal US appearance

Ecografia dei nervi della regione del ginocchio Tecnica di esame e aspetto ecografico normale

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Abstract

The diagnosis of disorders of the peripheral nerves (PN) has traditionally been based on clinical and electrophysiological data since nerve tissue cannot be visualized on standard radiographs. More recently, however, nerve structures have been evaluated with magnetic resonance imaging (MRI) and ultrasound (US). The former modality is expensive and not available in all institutions. There are also some contraindications to its use, and the

assessment of long nerves can be time-consuming since different coils must be used. Thanks to recent advances in sonographic software and hardware, US can now be used for in-depth assessment of the PN of the upper and lower limbs.

Most knee disorders involve lesions to the cruciate ligaments and/or the menisci, which are difficult to evaluate with US. However, similar symptoms may be caused by compression of one or more nerves in the knee region or intrinsic disorders involving these structures.

Because of their superficial positions, the nerves around the knee can be clearly visualized with US. A thorough knowledge of the normal anatomy of this region and a careful scanning technique are essential for a successful diagnostic US examination. In this article, we will review the normal gross and microscopic anatomy of the nerves in the knee region, the US technique used for their examination, and their normal US appearance.

Key words: Ultrasound; Knee; Peripheral nerves

Sommario

La diagnosi delle malattie dei nervi periferici (NP) è tradizionalmente basata sui dati derivanti dall'esame clinico e dalla valutazione elettromiografica, in quanto i nervi non sono apprezzabili alla radiografia standard. Recentemente la risonanza magnetica nucleare e l'ecografia sono state utilizzate nell'identificazione e valutazione dei NP. La risonanza magnetica nucleare è però una metodica costosa, presenta alcune controindicazioni e non è ancora facilmente disponibile. In più, la valutazione di lunghi tratti di nervo allunga i tempi d'esame, in quanto richiede l'uso di differenti bobine. I recenti miglioramenti nell'hardware e software delle apparecchiature ecografiche hanno portato ad un miglioramento delle immagini ecografiche e ad una accurata valutazione dei NP.

Nonostante le malattie dei menischi e dei legamenti, di difficile valutazione ecografica, siano predominanti, la compressione e le malattie dei nervi del ginocchio possono essere responsabili dei sintomi riferiti dal paziente. I nervi del ginocchio decorrono superficialmente e sono quindi ben valutabili con l'ecografia. Un'ottima conoscenza dell'anatomia ed una rigorosa tecnica d'esecuzione dell'esame sono requisiti indispensabili per un corretto esame ecografico. Nella prima parte di quest'articolo ricordiamo l'anatomia microscopica dei nervi periferici, seguita da una descrizione dell'anatomia ecografica normale. Quindi, dopo aver brevemente ricordato l'anatomia macroscopica dei nervi del ginocchio, ne descriviamo la tecnica di esecuzione dell'esame e l'anatomia ecografica normale.

Introduction

The diagnosis of disorders of the peripheral nerves (PN) has traditionally been based on clinical (history and physical examination) and electrophysiological data since nerves cannot be visualized on standard radiographs. More recently, however, direct imaging of PNs has been achieved with cross-sectional imaging techniques, such as ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) [1-9].

Recent advances in the latter modality have enhanced both the resolution and visibility of nerve structures, but this technique is expensive, time-consuming, and not readily available for routine clinical use. US offers two clear advantages over MRI in the evaluation of PN. First, it is a dynamic technique that can be used to detect nerve instability during movement of joints or tendons. This is particularly useful in the assessment of friction neuritis due to chronic trauma related to the intermittent dislocation of nerves [7,10]. Second, the US examination is more rapid and it provides a more panoramic image than that offered by MRI. For example, the full length of the sciatic nerve (SN) and its branches, from the posterior

buttock to the ankle region, can be thoroughly examined with US in 5-10 minutes by an experienced sonographer. MRI evaluation of these nerves requires the use of multiple coils, which increases the duration of the examination and the patient's discomfort. The nerves of the knee region can be visualized clearly with US because of their relatively superficial location. In experienced hands, US can be a reliable, noninvasive tool for PN imaging that is also highly cost-efficient [2,6,10,11].

Normal anatomy of the PN

The PN consist in nerve fibers that are surrounded by an endoneurium and packed together to form bundles or fascicles that are surrounded by the perineurium. The size and number of fascicles depend on the individual nerve, distance from site of origin, and amount of pressure the nerve is subjected to. The nerve trunk is encompassed by a structure called the superficial epineurium. The portion lying between the fascicles is known as the interfascicular epineurium. The endoneurium and perineurium are thin, membranous structures, whereas the epineurium is a thick sheath containing loose connective tissue with elastic fibers and blood vessels.

Normal US appearance of the PN

When examined with high-resolution transducers, the PN can be easily distinguished from tendons and other adjacent anatomic structures by their peculiar echostructure [11] (Fig. 1). Their US appearance differs on longitudinal and transverse sections [9,11-13]. When examined along its long axis, the nerve seems to be composed of multiple, discontinuous bands that appear hypo-anechoic against a homogeneously hyperechoic background. When the transducer is held perpendicular to the nerve's long axis, these bands appear as oval or rounded images separated by the hyperechoic background. Side-by-side comparison of these images with histologic sections has demonstrated that the hypoechoic bands correspond to the internal fascicles while the hyperechoic background represents the interfascicular connective tissue. Sometimes the epineurium can be visualized as a thick, hyperechoic structure surrounding the nerve.

The ability to visualize a PN on US depends on several factors. Large nerves are obviously easier to visualize than small ones. The surrounding tissues also play a role in nerve detection. A given nerve can be well depicted if it is surrounded by large, hypertrophic muscles, but it will be much harder to visualize if the muscles around it are hypotrophic and infiltrated by fat, which causes them to appear hyperechoic. A large amount of perinervous fat can also hinder the detection of nerves. Technical factors are obviously important. Use of high-resolution scanners increases the probability of detecting PN because they are equipped with modern transducers and also because of their improved software capabilities. High-frequency probes that allow adjustment of the near focus provide better images of thin, superficial nerves whereas deep-seated nerves are better evaluated with 5.0-7.5-MHz transducers. Harmonic imaging is seldom helpful for nerve studies. Current high-end US systems equipped with modern linear-array transducers in the 5-to-15-MHz range have given radiologists the opportunity to assess a variety of nerve disorders.

Anatomy of the nerves of the knee region

The most important nerves of the knee region are the tibial, common peroneal, and saphenous nerves [14-17] (Fig. 2).

- The tibial nerve (TN)

The TN is the medial terminal branch of the SN. It innervates the flexor muscles of the toes and ankle. It arises from the SN at the apex of the popliteal fossa and runs distally in a median position. At the midpoint of the fossa, the TN joins the popliteal vessels, and its course continues along the lateral border of the popliteal vein. The nerve is covered by the popliteal fascia, which separates it from the medial cutaneous sural nerve and the small saphenous vein. At the end of the popliteal fossa, the TN runs posterior to the popliteal muscle and anterior to the fibrous arcade of the soleus muscle. Collaterals of the TN in the knee region include the posterior articular branch, nerves supplying the medial and lateral gastrocnemius muscles, the crural interosseus nerve, and the medial cutaneous sural nerve. This latter nerve runs between the two gastrocnemius muscles and subsequently perforates the superficial fascia together with the small saphenous vein.

- The common peroneal nerve (CPN)

The CPN, which is the lateral terminal branch of the SN, originates in the upper part of the popliteal fossa. It innervates the extensor muscles of the foot and toes, the skin of the anterolateral aspect of the leg, and the dorsal aspect of the foot. In the popliteal fossa the CPN descends obliquely through the popliteal fossa, passing along the medial border of the biceps femoris muscle and tendon. As it leaves the fossa, the nerve runs superficial to the lateral head of the gastrocnemius and then passes over the peroneal head. At the level of the peroneal head, it moves anteriorly, perforating the lateral intermuscular septum and entering the anterior compartment of the leg. Here it lies within a tunnel formed by the insertions of the long peroneal muscle and the cortex of the proximal metaphysis of the fibula. At this point, the CPN splits into two terminal branches, the superficial and deep peroneal nerves. Most of the time, this division takes place at, or distal to, the fibular neck, but in 10% of the cases, it occurs proximal to the knee joint. In fewer than 9%, it occurs distal to the knee joint. The superficial peroneal nerve runs along the lateral aspect of the fibula between the peroneal longus muscle and the anterior intermuscular septum. It innervates both peroneal muscles. At the midpoint of the leg, it perforates the crural fascia and enters the subcutaneous tissues. The deep peroneal nerve runs close to the fibular neck before perforating the anterior intermuscular septum (Fig. 4). It runs with the anterior tibial artery, initially passing between the tibialis anterior and the extensor digitorum longus muscles and more distally between the tibialis anterior and the extensor hallucis longus muscles. At this point, its course continues anteriorly to the intermuscular membrane, and it innervates the tibialis anterior, extensor longus digitorum, and extensor hallucis longus muscles.

- The saphenous nerve (SaN)

The SaN is the terminal branch of the femoral nerve. It runs in the thigh along the femoral artery and then the superficial femoral artery. At the lower part of the adductor canal (Hunter's canal), it reaches the posterior aspect of the sartorius muscle. It then perforates the fascia lata, between the tendons of the sartorius and gracilis muscles, to join the great saphenous vein [18-22]. Its infrapatellar branch innervates the skin of the anterior aspect of the knee.

Technique of examination and normal US appearance

The nerves of the knee region can be identified and distinguished from the adjacent tendons by their peculiar US appearance. Knowledge of the normal positions of the different nerves and their relations with adjacent anatomic structures obviously facilitates their detection. As with all districts of the musculoskeletal system, US examination of the knee is preceded by

collection of the patient history and clinical evaluation of the region [6,7,11,13]. The knee is palpated, starting from the anterior aspect and moving systematically to the medial, lateral, and finally posterior aspect. The presence of joint disorders, as well as diffuse or localized swelling or lumps, must be noted. Because the most important nerves of the knee region are located posteriorly, the US examination starts with examination of the popliteal fossa. The patient is placed in the prone position, and a small pillow can be placed under the anterior aspect of the ankle to keep the knee in a slightly flexed position, thus facilitating the examination of its posterior aspect.

The standard examination generally begins in the middle third of the thigh, where the distal portion of the SN is identified and assessed (Fig. 3). The most useful reference point is the biceps femoris muscle, which can be easily detected because of its lateral position. The muscle is formed by the long superficial head that arises from the tendon that inserts into the ischial tuberosity and is shared with the semitendinosus muscle. The long head proceeds inferiorly and inserts into the posterior aponeurosis of the short head, which originates from the posterior aspect of the femoral shaft. The proximal segment of the SN is located just beneath; distally, it runs deep and lateral to the short head (Fig. 3). Axial images should be obtained first since they allow easy identification of the nerve and its relations with the adjacent muscle. The biceps muscle presents as a hypoechoic structure containing hyperechoic, fibroadipose septa. The nerve appears as an oval structure with the typical internal echostructure. It is easy to identify in young patients with hypertrophied, hypoechoic muscles, which contrast sharply with the hyperechoic nerve, but problems may be encountered when the adjacent muscles are thinner and more echogenic, as they often are in elderly patients. In addition, assessment may also be difficult in obese patients, when the nerve lies farther below the surface, covered by a thick layer of subcutaneous fat. Sometimes a small, persistent sciatic artery can be seen following the sciatic nerve from the sciatic foramen to the level of the knee. It must not be confused with a nerve fascicle. The SN must be followed from the middle thigh since it can bifurcate proximally into its main branches. Images are obtained all the way down to the popliteal space, where the SN divides in the TN and CPN.

The TN runs distally, close to the popliteal artery and vein, which serve as useful landmarks for its detection. The nerve runs in a position that is posterolateral to the popliteal artery while the popliteal vein is located between the anteromedial aspect of the artery and the posterolateral aspect of the nerve (Fig. 4). Identification of the popliteal vein is easier if the leg is slightly elevated so that the vein becomes mildly distended. In a more distal location, the nerve runs close to the vessels and posterior to the popliteal muscle, which is a helpful landmark that can be easily detected on US (Fig. 5).

Shortly after its origin, the CPN runs superficially and laterally, following the distal part of the short head of the biceps femoris muscle and later its distal tendon (Fig. 6). At this level it is separated from the deeper TN by a large amount of fat filling the popliteal space. During the examination of the CPN, it is important to adjust the tilt of the transducer to obtain cross-sectional images of every segment. On proximal axial scans, the sural lateral nerve can be seen running in the fascial plane at the level of the upper leg. Identification of this small branch requires the use of high-frequency transducers and can sometimes be difficult, particularly in obese patients. The CPN is followed from the upper portion of the leg, where it lies posterior to the fibular head (Fig. 7). It then runs laterally to the fibular neck and enters the tunnel formed by the origins of the peroneal longus muscle. The point at which it divides to form its two main branches can be difficult to detect by US: a high-resolution transducer and careful scanning technique are essential. A large amount of gel or a standoff pad may be

necessary for visualization of the nerve at the level of the fibular head, where it lies very close to the surface.

After both the TN and the CPN have been assessed in the axial plane, longitudinal images are obtained to evaluate their internal echostructures. Because of the CPN's small caliber and winding course, it is sometimes difficult to obtain longitudinal images of long segments of this nerve, whereas the TN can be easily visualized with sagittal images. As a general rule, longitudinal scans are less informative than axial sonograms.

Examination of the SaN is much more difficult because of its small size and anatomic variability. The patient is examined supine, and the thigh to be examined is externally rotated. A large amount of gel must be used. As for the posterior nerves, transverse scans are initially performed. The sartorius muscle is identified first (Fig. 8). This long, flat muscle can be easily identified on the medial aspect of the knee: it is the only muscle located anterior to the gracilis and semitendinosus tendons. The muscle is then followed cranially. As the transducer is moved upward, its inclination should be adjusted to variations in the axis of the muscle belly. Attention is then focused on the deep surface of the muscle, where the saphenous nerve can be found running close to the deep fascia. In a more distal location, the nerves can be seen passing between the sartorius and gracilis tendons (Fig. 9) to reach the subcutaneous tissues, where they join the great saphenous vein. Detection of its thin prepatellar branch can be very difficult.

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Figure captions

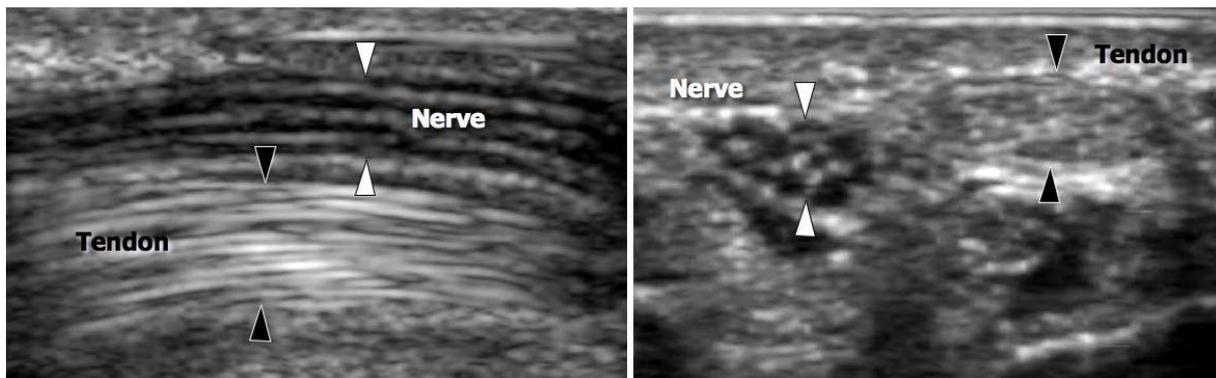


Fig. 1. In vivo appearance of peripheral nerves. Longitudinal (a) and transverse (b) images. Note the typical fascicular appearance of the nerve (white arrowheads) in the longitudinal image. Compare the US findings with the fibrillar pattern of the adjacent tendons (black arrowheads).

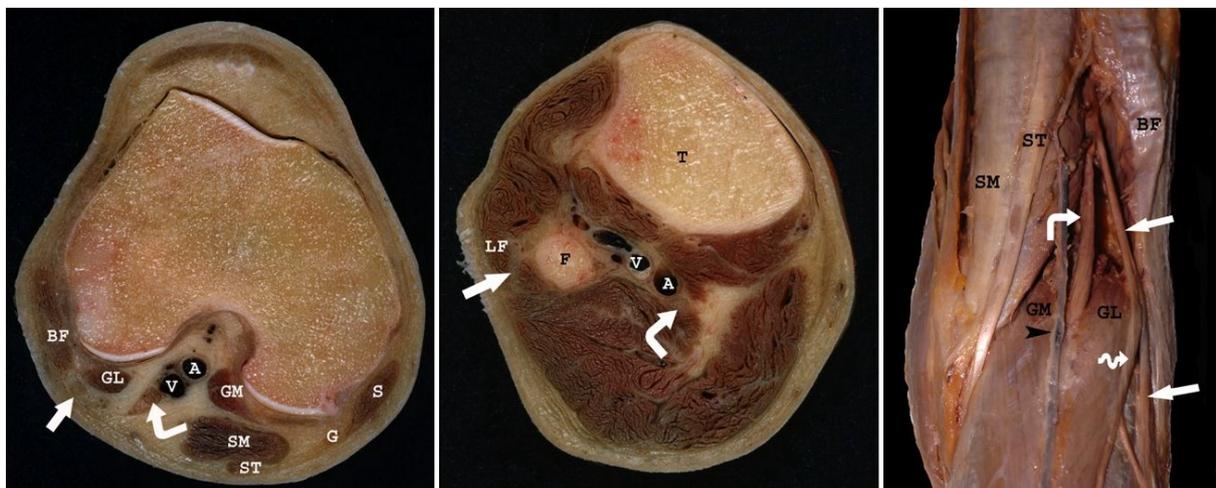


Fig. 2. Anatomy of the posterior nerves of the knee. Transverse sections obtained in the middle of the popliteal space (a) and at a lower plane (b) and posterior view of a dissection of the popliteal space. Images show the biceps muscle (BF), the lateral (GL) and medial (GM) heads of the gastrocnemius, semitendinosus (ST), and gracilis (G) tendons, and the semimembranosus (SM), sartorius (S), and peroneus longus (LF) muscles. Note the popliteal artery (A) and vein (V). Straight arrow = common peroneal nerve, curved arrow = tibial nerve, small wavy arrow = cutaneous sural lateral nerve, arrowhead = small saphenous vein.

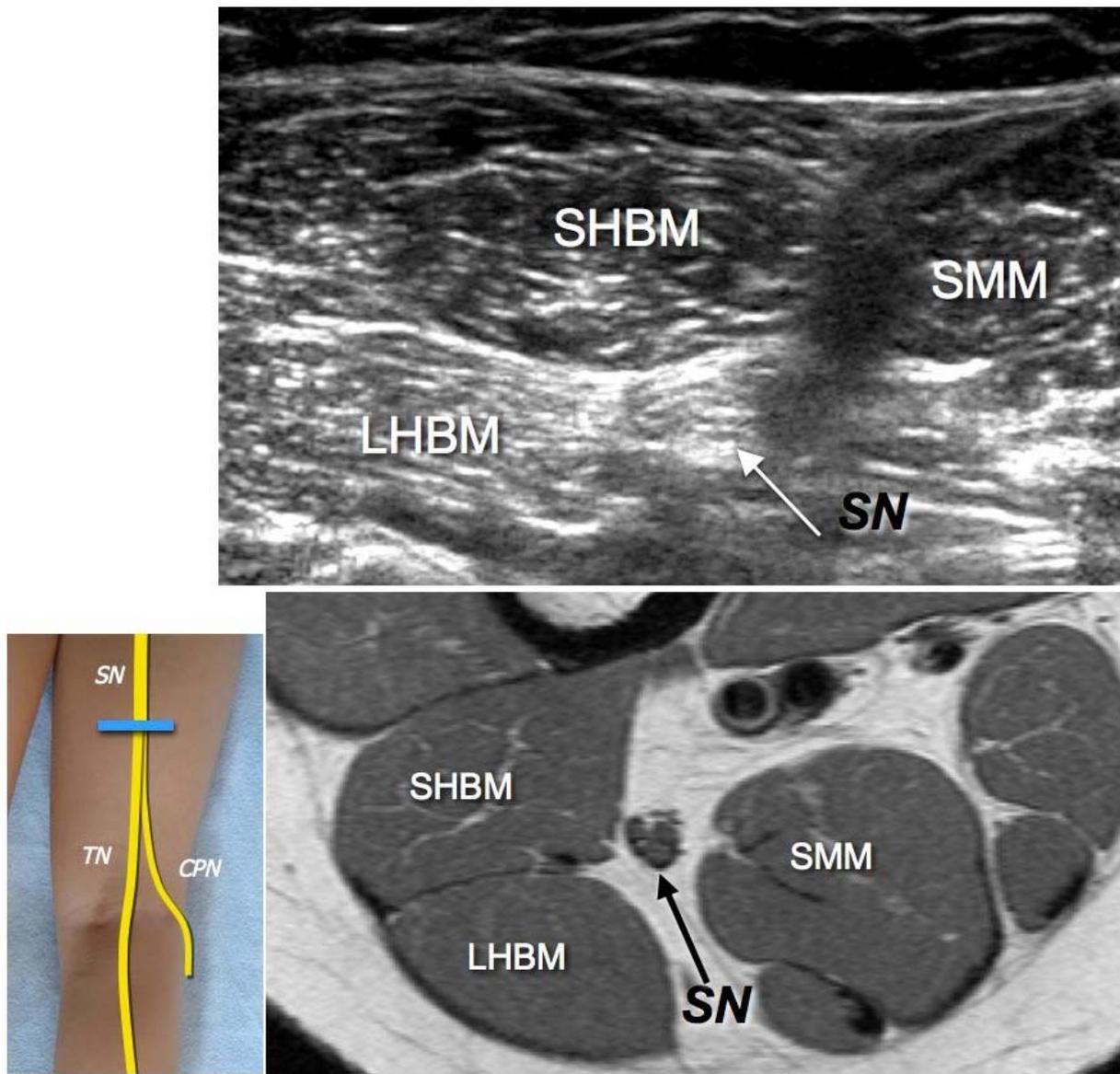
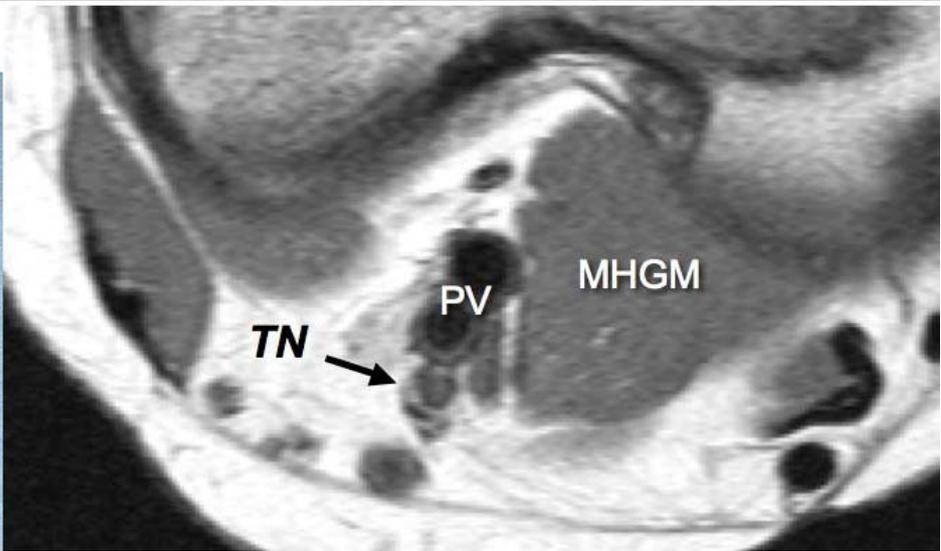
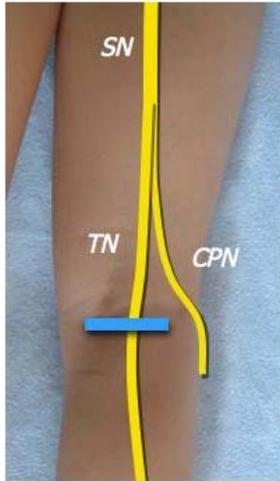
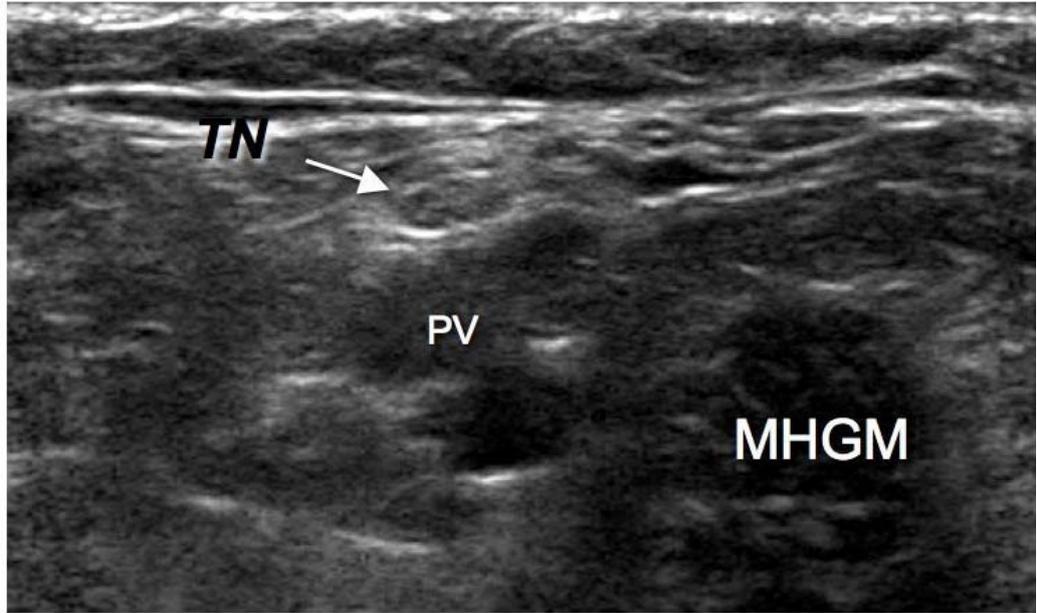


Fig. 3. Transverse US image, with MRI correlation, obtained over the distal part of the sciatic nerve.

SN = sciatic nerve, SHBM = short head of the biceps muscle, LHBM = long head of the biceps muscle, SMM = Semimembranosus muscle.



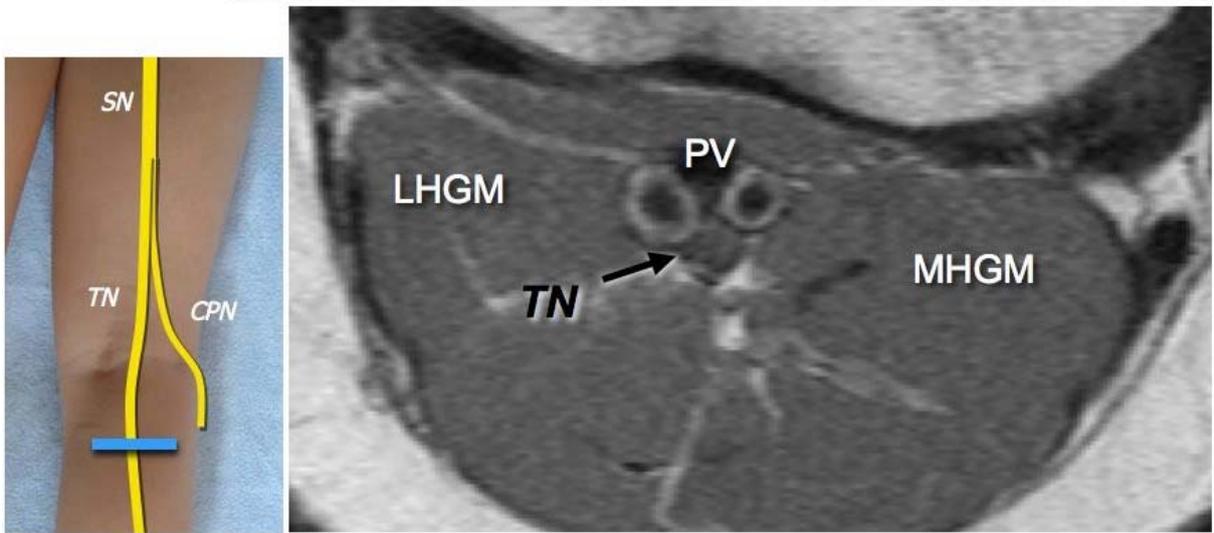
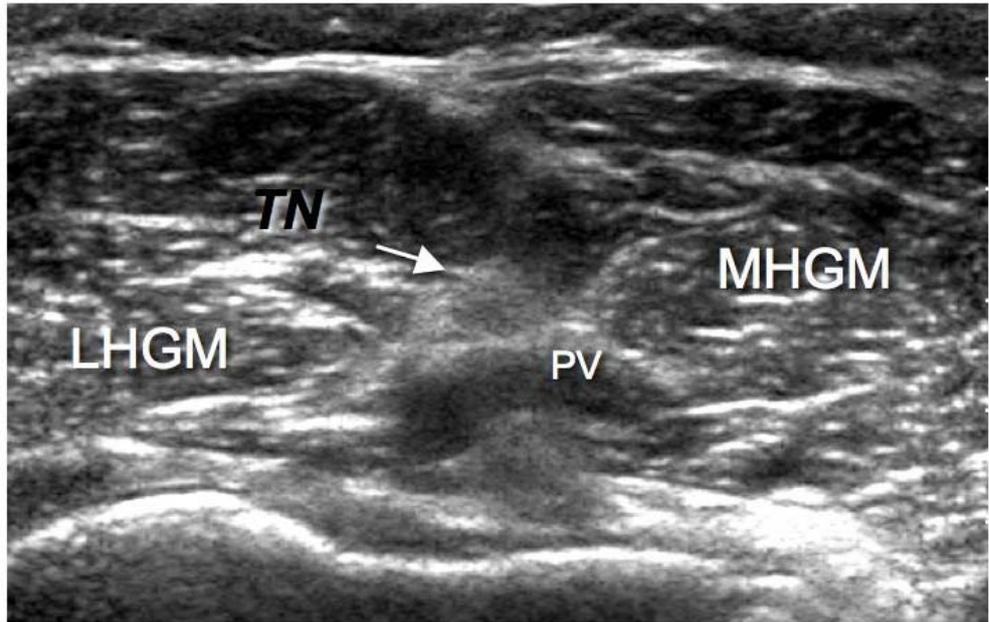
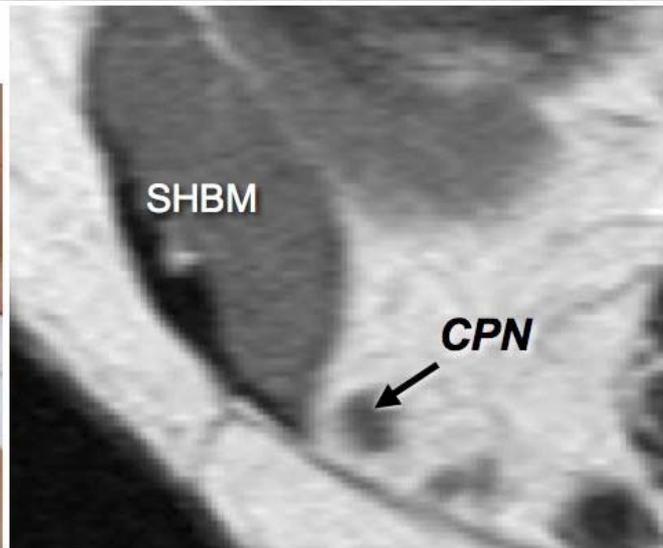
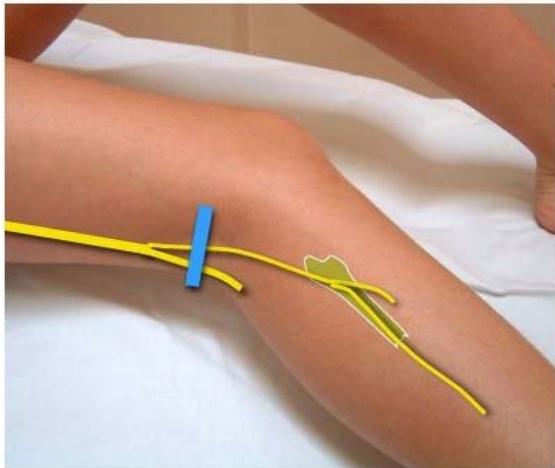
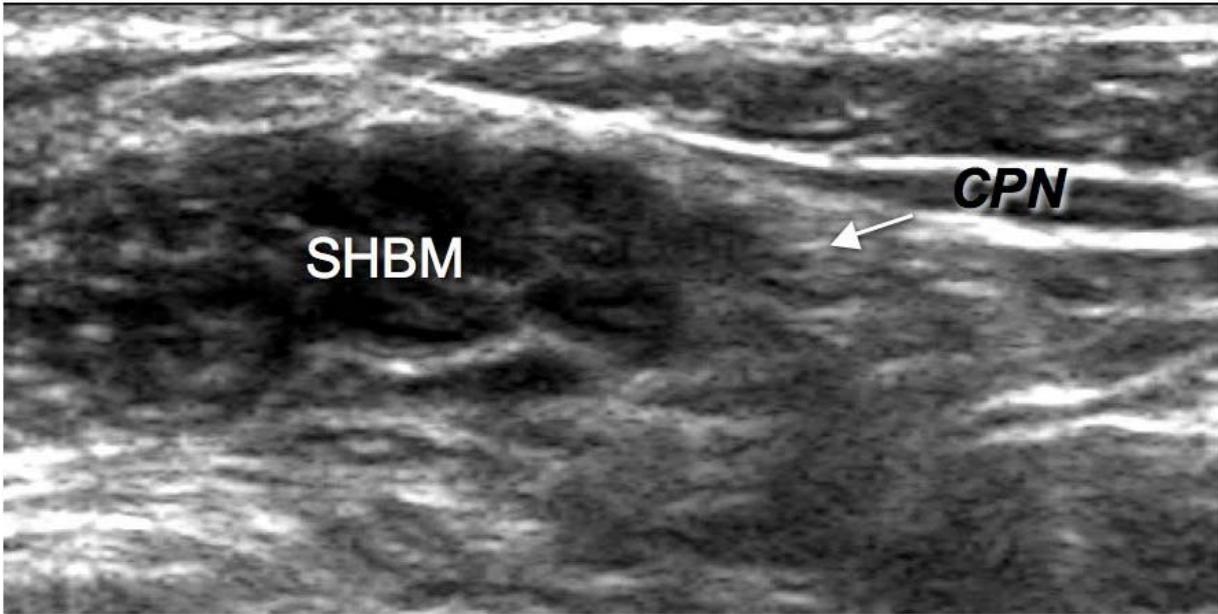


Fig. 4-5. Consecutive transverse sonograms of cranial (Fig. 4) and distal (Fig. 5) segments of the tibial nerve, with MRI correlation. TN = tibial nerve, MHGM = Medial head of the gastrocnemius muscle, PV = popliteal vessels, LHGM = Lateral head of the gastrocnemius muscle.



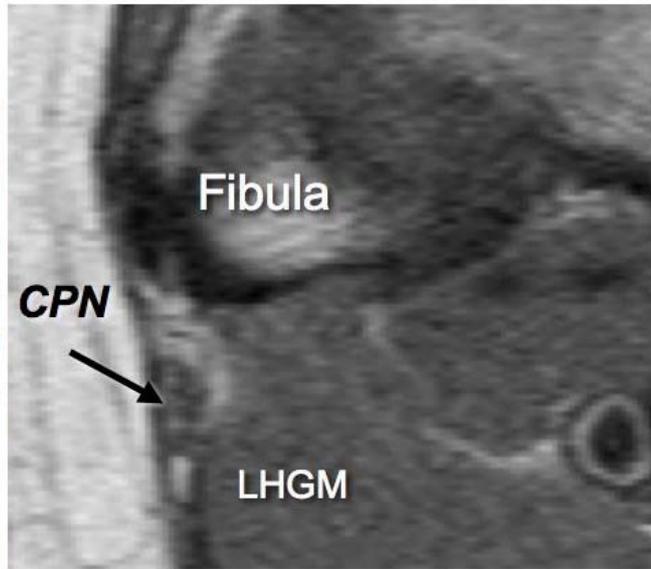
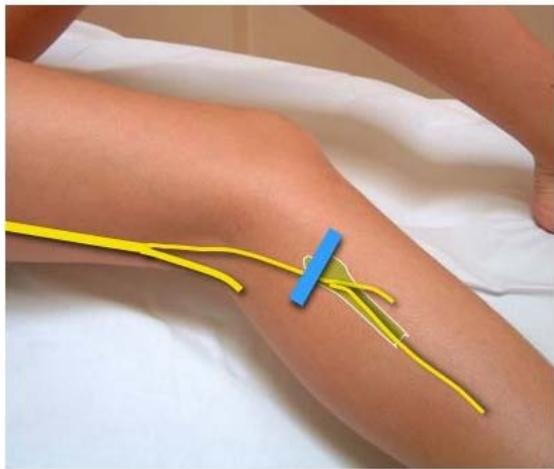
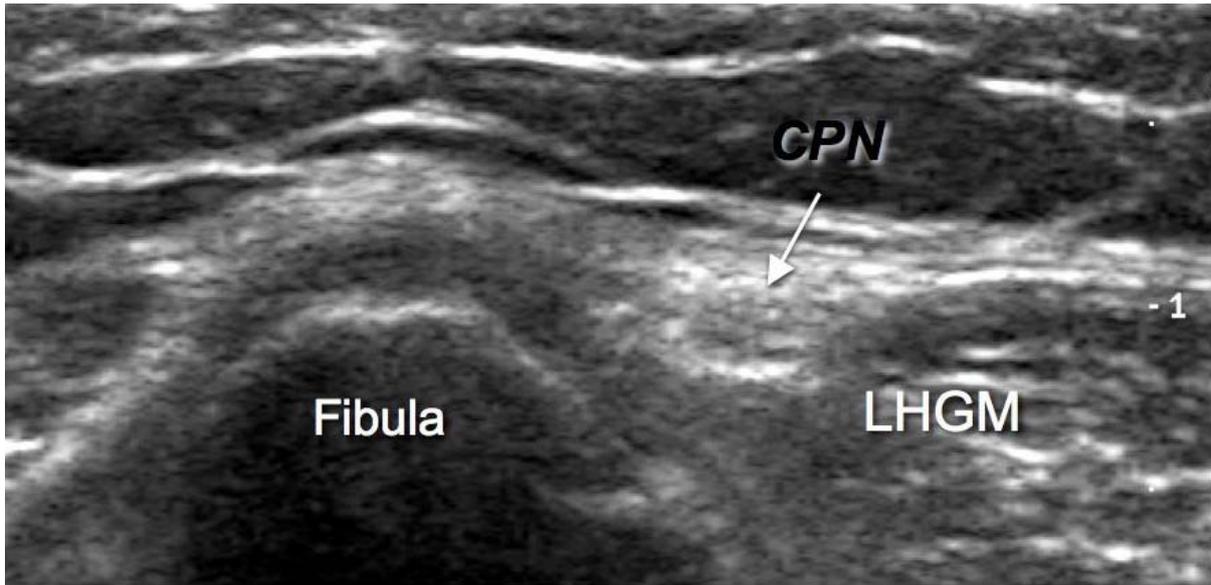
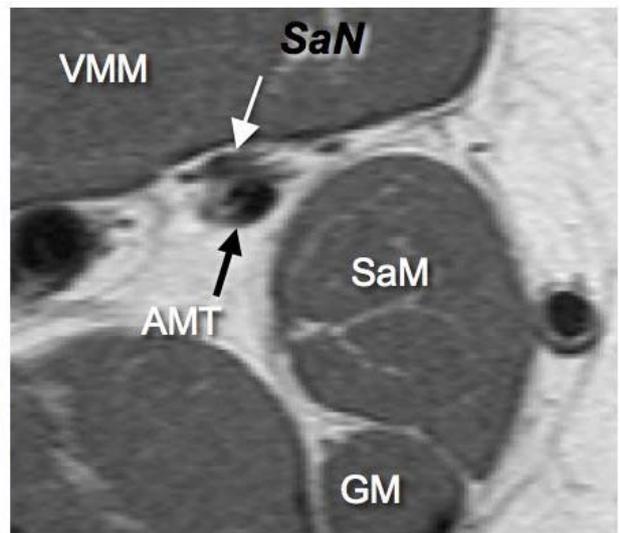
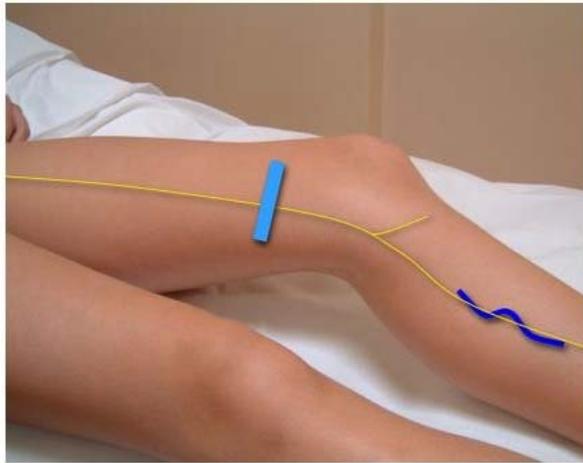
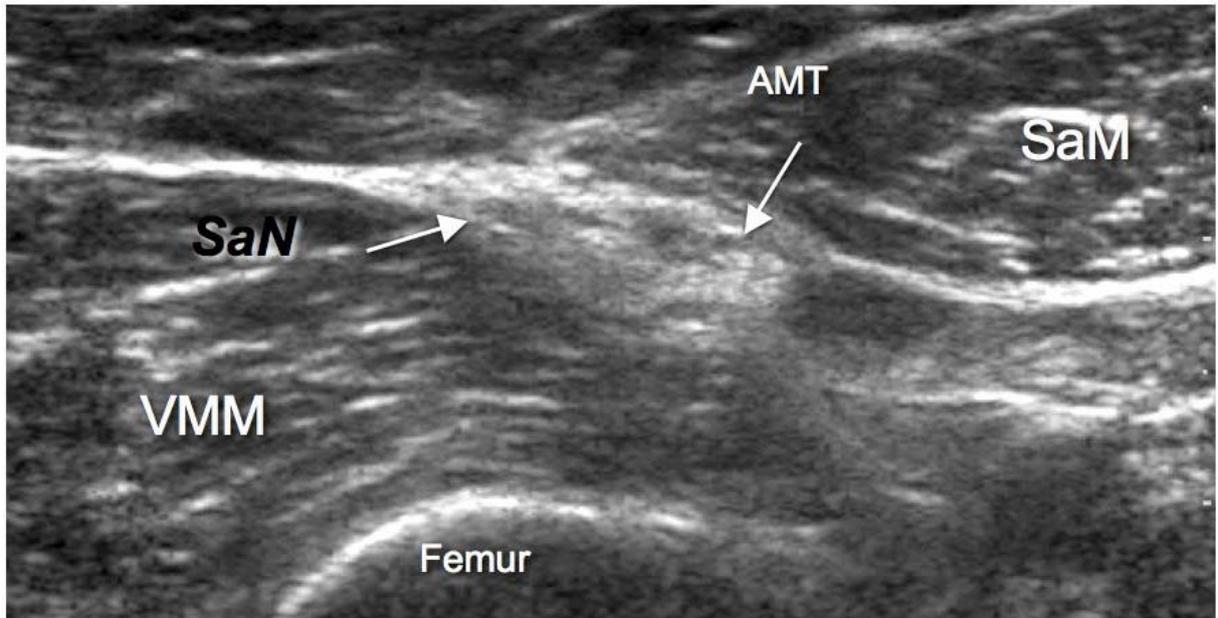


Fig. 6-7. Consecutive transverse sonograms of cranial (Fig. 6) and distal (Fig. 7) segments of the common peroneal nerve, with MRI correlation. CPN = common peroneal nerve, SHBM = short head of the biceps muscle, LHGM = Lateral head of the gastrocnemius muscle.



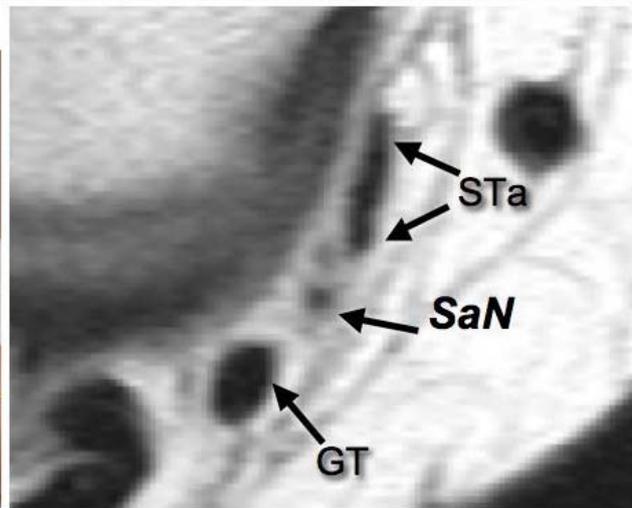
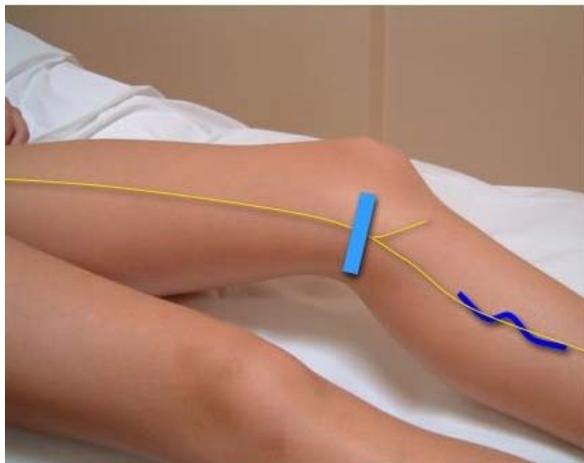


Fig. 8-9. Consecutive transverse sonograms of cranial (Fig. 8) and distal (Fig. 9) segments of the saphenous nerve, with MRI correlation. SaN = Saphenous nerve, AMT = Adductor magnus tendon, VMM = Vastus medialis muscle, SaM = Sartorius muscle, GM = Gracilis muscle, SaT = Sartorius tendon, GT = Gracilis tendon.