



Study of formation of the Sural nerve complex in human cadavers

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ABSTRACT

Sural nerve is formed by communication of medial sural cutaneous nerve, that arise from tibial nerve in popliteal fossa and peroneal communicating nerve, a branch directly from common peroneal nerve or from lateral sural cutaneous nerve. The objective of this study was to determine the formation of sural nerve, describe an unusual and few reported anatomical variation and review the clinical and surgical significance. A total of 16 cadavers of both sexes (15 men and 1 women) with different age group were used for the study in the Morphology Laboratory at the University of Pamplona. The typical sural nerve was formed in 93,75% of the cases (type A). The peroneal communicating nerve originated from common peroneal nerve and too originated from lateral sural cutaneous nerve. In 6,25% (2 lower limbs) of the cases peroneal communicating nerve was considered as absent. In the left lower limb, both medial sural cutaneous nerve, and lateral sural cutaneous nerve were absent. The sural nerve arose directly from the tibial nerve. It's observed a communicating branch between tibial nerve and common peroneal nerve. In the right lower limb, lateral sural cutaneous nerve was absent. The sural nerve arose directly from the common peroneal nerve. Peroneal communicating nerve was considered as absent. The knowledge of the sural nerve complex (normal anatomy and variations in origin and course) is important in evaluating of the patients, as well explaining the different clinical findings necessary for accuracy treatment.

Keywords: Anatomical variation, common peroneal nerve, lateral sural cutaneous nerve, medial sural cutaneous nerve, peroneal communicating nerve, sciatic nerve, sural nerve, tibial nerve.

INTRODUCTION

The sural nerve (SN) is clinically important, as it is commonly used for nerve conduction studies, nerve biopsies, and as a convenient source for nerve grafting. The SN is a sensory nerve supplying the skin of the lateral and posterior part of the inferior third of the leg and lateral side of the foot. The SN, next to the small saphenous vein, extends downwards following the lateral margin of the tendon calcaneus. Later, it extends forward to the lateral part of the foot and the fifth toe passing behind the lateral malleolus. The SN gives off lateral calcaneal branches out on the outer part of the calcaneus[1].

The sural nerve innervates the cutaneous part of the posterolateral aspect of the lower third of the leg, the lateral malleolus, and the lateral side of the dorsal part of the foot to the fifth toe. This nerve can be easily found about 10 cm above the calcaneus. Here, slightly lateral to the Achilles tendon, this nerve adheres to the lesser saphenous vein. Distally from this point the sural nerve runs between the lateral malleolus and the calcaneus and continues to the fifth toe. The sural nerve is widely used for many therapeutic interventions to determine nerve conduction velocity,

for nerve biopsy and during nerve grafting procedures. This nerve is the most commonly used donor nerve for peripheral nerve reconstruction. The histological structure of the graft should be compatible with the nerve that will receive that graft [2].

The sural nerve is a branch from tibial nerve (TN) in the popliteal fossa, descends between the two heads of the gastrocnemius muscle, and pierces the deep fascia in the middle third of the posterior surface of the leg. It is usually joined by the peroneal communicating nerve (sural communicating nerve) which is a branch of common peroneal nerve (CPN). The sural nerve is formed by the union of medial sural cutaneous nerve with the peroneal communicating nerve. Some other authors describe that sural nerve is formed by the union of medial sural cutaneous nerve with the lateral sural cutaneous nerve. Because of these controversies the term sural nerve complex was coined by Ortiguera, which includes medial sural cutaneous nerve, lateral sural cutaneous nerve, peroneal communicating nerve, and sural nerve [3]. Medial sural cutaneous nerve originates from the tibial nerve in the popliteal fossa. It descends between the two heads of gastrocnemius muscle, deep to deep fascia covering the muscle. It becomes superficial by piercing the deep fascia at the junction of middle and distal thirds of the leg. The nerve lies usually medially sometimes laterally to the short saphenous vein. The nerve joins the peroneal communicating saphenous vein. The nerve joins the peroneal communicating nerve to form sural nerve. When there is no communication between medial sural cutaneous nerve and peroneal communicating nerve, the medial sural cutaneous nerve supplies the lateral surface of the leg and gives off lateral branch to the heel and continues as lateral dorsal cutaneous nerve. Lateral sural cutaneous nerve originates from common peroneal nerve in popliteal fossa; it descends between deep fascia and lateral head of gastrocnemius muscle; at the middle of the calf it pierces is deep fascia to become subcutaneous. Peroneal communicating nerve originates in the popliteal fossa either from lateral sural cutaneous nerve or directly from the common peroneal nerve. The nerve communicates with the medial sural cutaneous nerve to form sural nerve. The sural nerve is a sensory nerve of the lower limb that supplies the lower posterolateral part of the leg and lateral part of the dorsum of the foot. It is generally described as a sensory nerve but may contain motor fibres. The sural nerve is universally recognized by surgeons as a site for harvesting an autologous nerve graft. The nerve is widely used for electrophysiological studies. The formation and distribution vary in different individuals. The sural nerve is the most frequent donor nerve used for peripheral nerve grafting. Despite the widespread use of the sural nerve, there is scant attention reported in the literature about associated donor site problem. The peroneal communicating nerve is readily accessible to surgical harvest as it lies superficially. When there is a situation requiring limited length of nerve graft material, the peroneal communicating nerve alone can be harvested and medial sural cutaneous nerve can be preserved and associated symptomatic neuroma of the sural nerve will be diminished [4].

The sural nerve is characterized by great anatomical and topographical variability and is rarely involved in entrapment neuropathies. Sural nerve is vulnerable to injury as it is firmly fixed to the surrounding tissue in all its length and may be compressed and entrapped proximally and distally, leading to pain and sensory abnormalities in its distribution area. Some of the first reported cases in the literature were documented by Pringle et al. in 1974 [5]. The superficial anatomic location of the nerve predisposes for injury and entrapment neuropathies, although these conditions are uncommonly reported but may be undiagnosed. However, the main etiology of the sural nerve mechanical lesion and entrapment is fascial thickening and consequent nerve compression or fixation [6].

The purpose of this study was to determine the formation of sural nerve, describe an unusual and few reported anatomical variation and review the clinical and surgical significance.

EXPERIMENTAL SECTION

A total of 16 cadavers of both sexes (15 men and 1 women) with different age group were used for the study in the Morphology Laboratory at the University of Pamplona. A vertical incision was made from an approximately medial point of the infraglutal groove to a line, drawn horizontally, between the medial and lateral malleoli of the ankle region. Each anatomical plane of the thigh and calf posterior regions was dissected from the skin to the fascias, from where they were recognized and the nerves of the calf region could be identified. Nerves from the sural nerve complex were dissected using dissecting instruments. The origin of the SN was classified into Type A, B, C, or D. Type A was the anastomotic type, in which both the MSCN and the PCN contributed to the formation of the SN. Then Type A was classified into two subgroups. The first of these PCNs originates in the CPN, and the second PCN originates in the LSCN then joining the MSCN. When the SN was formed only by the MSCN, it was designated as Type B. Type C was divided into four subgroups: first, the PCN and fibres of the posterior femoral cutaneous nerve

(PFCN) joined the MSCN; second, the MSCN, PCN, and sciatic nerve did not unite and coursed separately; third, the SN arose directly from the sciatic nerve alone and the MSCN made little contribution; and fourth, the PCN, fibres of the sciatic nerve and the MSCN formed the SN. When the SN was formed only by the PCN it was defined as Type D (from reference 1). The described anatomic variations were dissected in a male cadaver of 75 and 65 years of age, respectively. The topographic details were examined and the variations were recorded and photographed. The history of the individual and the cause of death are not known.

RESULTS AND DISCUSSION

The typical sural nerve was formed by the union of peroneal communicating nerve (PCN) with medial sural cutaneous nerve (MSCN) in 93,75% of the cases (type A). The peroneal communicating nerve (PCN) originated from CPN (in 10 of the 30 lower limbs) and peroneal communicating nerve (PCN) originated from LSCN (in 20 of the 30 lower limbs), corresponding a subgroups first and second respectively. Of the total number of typical sural nerves observed (30 cases- lower limbs), the union of PCN with MSCN was found in the distal 1/3 of the leg in 65% of the cases, middle 1/3 of the leg in 30%, and the popliteal fossa in 5%. Length of the medial sural cutaneous nerve ranged from minimum 7 cms to maximum 42 cms, peroneal communicating nerve from minimum 3.5 cms to maximum 38 cms, lateral sural cutaneous nerve from minimum 7.5 cms to maximum 41 cms, and sural nerve from 4.5 cms minimum to 40.5 cms maximum.

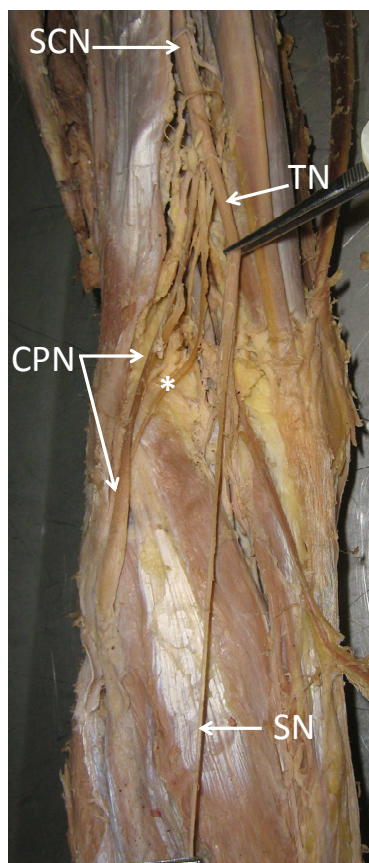


Figure 1. Showing variation in the formation of the sural nerve in left lower limb. SCN: Sciatic nerve; CPN: common peroneal nerve; TN: tibial nerve; SN: sural nerve arose directly from the tibial nerve; asterisk: communicating branch between tibial nerve and common peroneal nerve

In all cases, at a point 6.5 cm proximal to the tip of the lateral malleolus, the sural nerve was found to be a mean of 25.5 mm, posterior to the edge of the fibula. In the hind foot, the sural nerve curved distal to the malleolus in all specimens. The trunk was located at a mean distance of 13,5 mm, posterior and 13,5 mm inferior to the tip of the malleolus along the "malleolar line" (a vertical line parallel to the fibular shaft and through the tip of the malleolus).

Along this line, the sural nerve was commonly situated superficial and slightly inferior to the peroneal tendons. However, in 6 of 16 (37,5%) specimens, the sural nerve was found to be crossing the peroneus longus tendon sheath or had crossed more proximally and was found coursing superior to the tendon. In the inframalleolar region, the oblique and plantar ward course of the peroneus longus tendon, combined with the relatively horizontal course of the nerve, resulted in the nerve (or its branches) crossing over the tendon in each specimen.

In 6,25%(2 lower limbs)of the cases PCN was considered as absent. In the left lower limb of the male cadaver of 75 years of age (3,125%), both MSCN and LSCN were absent. The SN arose directly from the tibial nerve. It's observed a communicating branch between tibial nerve and common peroneal nerve, this branch obliquely crossing the popliteal fossa (medial toward lateral) has a length of 13,5 cms and diameter of 2.18 mm (measurement performed with digital caliper which has the accuracy of 0,01 mm/0,0005"). Figure 1.

In the right lower limb of the male cadaver of 65 years of age (3,125%), lateral sural cutaneous nerve was absent. The SN arose directly from the common peroneal nerve. PCN was considered as absent Figure 2.

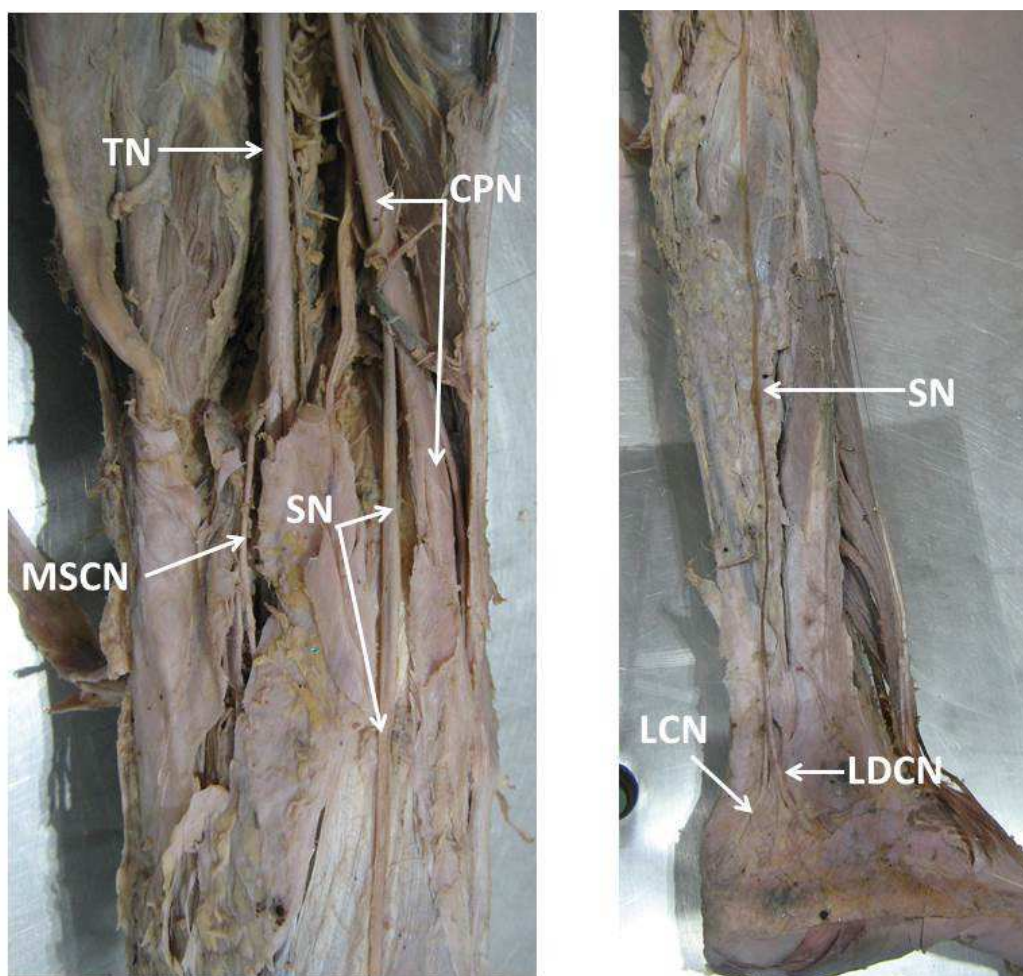


Figure 2. Showing variation in the formation of the sural nerve in right lower limb. CPN: common peroneal nerve; TN: tibial nerve; SN: sural nerve arose directly from the common peroneal nerve; MSCN: medial sural cutaneous nerve; LDCN: lateral dorsal cutaneous nerve; LCN: lateral calcaneal nerve

Nerve conduction studies are important diagnostic tools to evaluate the integrity and function of the peripheral nervous system. The sural nerve is one of the most commonly examined nerves by nerve conduction studies, mainly for the diagnosis of polyneuropathy, but it is also useful in the evaluation of focal nerve injury of the lumbosacral plexus and the sciatic and tibial nerves. The sural nerve is traditionally described by three different formation types,

designated A, B, and C [7]. Type A, the most common type, is formed by the union between the medial sural cutaneous nerve (MSCN), which is a branch of the tibial nerve, and the peroneal communicating branch (PCB) of the common peroneal nerve, while type B is the direct continuation of the MSCN with the PCB absent, and type C is formed by the PCB only (figure 3). The union in type A may take place anywhere between the popliteal fossa and the lateral malleolus [8]. When the SN was formed only by the PCN it was defined as Type D [1]. Numerous cadaver studies have been conducted worldwide documenting the anatomical variations of the sural nerve [8-11]. In one of these, sural nerve conduction studies from healthy adults were done in addition to the cadaver studies showing highly variable sural nerve formation. Recently, an ultrasound study of anatomic variants of the sural nerve has shown similar variations as the cadaver studies [14]. These studies have mainly focused on surgical implications such as reconstruction of peripheral nerves, since the sural nerve is commonly used for nerve biopsies as well as a convenient source for nerve grafting.

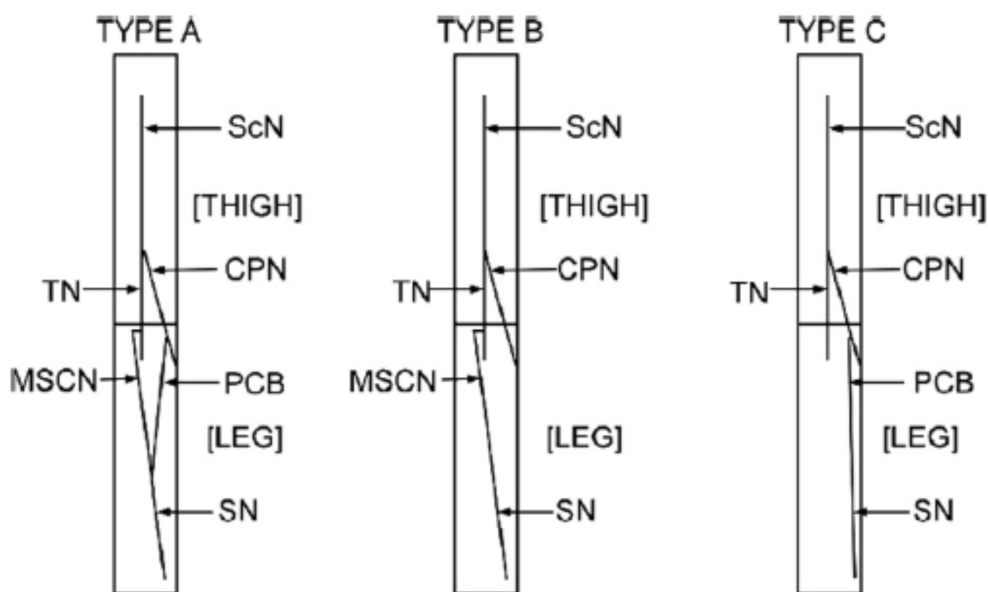


Figure 3. Schematic diagram showing the different types of formation of the sural nerve as described by Huelke (1957). ScN: Sciatic nerve, TN: Tibial nerve, CPN: Common peroneal nerve, MSCN: Medial sural cutaneous nerve, PCB: Peroneal communicating branch or PCN: peroneal communicating nerve (from reference 8)

Many authors have explained about the incidence of MSCN in the formation of sural nerve and considered it to be the main component of sural nerve. Mahakkanukrauh and Chomsung [11] studied in 76 Thai cadavers and they found that one SN (0.7%) was formed by the union of the MSCN and a different branch of the common fibular nerve, running parallel and medial to but not connecting with the PCN. In study done by Coert HJ et al. MSCN was present in all the lower limbs [15]. Shankar N et al has reported the origin of MSCN from the sciatic nerve in 1 out of 38 cases (2.6%) [16]. Ugrenovic S et al have reported that MSCN present in 99% of cases and reported that MSCN originated from the posterior surface of the tibial nerve within popliteal fossa and was present in all the cases [17], while Uluotku H et al [18] detected in 95% and Ortiguela et al in 100% of cases study [19]. Williams DD in his study has reported conditions in which MSCN of a left leg was quite short ending in the skin on the medial side of superior one third of the leg [20,21]. Huelke [7] found the MSCN to be completely absent in one case of 352 extremities. Aktanlkiz et al. [22] found that the MSCN was absent in two (6.7%) specimens in 30 lower limbs. In the present study we reported the MSCN to be completely absent in one case of 32 extremities (3.125%).

Lateral sural cutaneous nerve (lateral cutaneous nerve of calf) arises as one of the cutaneous branch of Common peroneal nerve often from a common trunk along with PCN [23]. Kavyashree et al found what LSCN was present in 82% of specimens [21]. Ortiguela et al found LSCN present in 95% of cases [19]. Few authors reported the absence of LSCN. Coert H J et al [15] has reported that LSCN was absent in 4% of cases and Aktanlkiz et al has observed in 16.7% of cases [21,22]. In the present study we reported the LSCN to be completely absent in two cases of 32 extremities (6.25%).

Williams DD have mentioned about the authors describing the PCN as arising in all or the majority of the cases from LSCN and few describing the PCN arising alone in majority of cases or in common with the LSCN from the CPN. Williams DD observed that PCN arose from the CPN in 93% of cases, from LSCN in 1.17% of cases and in 1.55% PCN and LSCN both arose from a common trunk from the CPN.[20,21]. PCN originated from LSCN in 93.7% cases in study by Ortigueta et al.[19]. Huelke DF observed that, out of the 159 sides PCN arose directly from the CPN in 54.7%, usually as a branch separate from the lateral sural cutaneous nerve (41.5%). The PCN was a terminal branch of LSCN in one third of specimens, and arose from a trunk common to it and the LSCN in 12%. Huelke DF had observed that the PCN was absent in 19.7% of the 198 cases, and due to its absence typical sural nerve is not formed in these cases. In 22% of cases PCN was the only branch of the CPN to the posterior aspect of leg, the LSCN being entirely absent.[7,21]. Kavyashree et al found PCN arose directly from CPN in 10 cases (20%). PCN and LSCN arose from a common trunk in 52% of specimens and it was absent in 28% of specimens, hence in these there was no formation of typical sural nerve [21]. In the present study the typical sural nerve was formed by the union of peroneal communicating nerve (PCN) with medial sural cutaneous nerve (MSCN) in 93,75% of the cases (type A). The peroneal communicating nerve (PCN) originated from CPN (in 10 of the 30 lower limbs) and peroneal communicating nerve (PCN) originated from LSCN (in 20 of the 30 lower limbs), corresponding a subgroups first and second respectively. In two lower limbs PCN was considered as absent.

In the present study at level of popliteal fossa was observed a communicating branch between tibial nerve and peroneal common nerve, this branch obliquely crossing the popliteal fossa (medial toward lateral) has a length of 13,5 cms and diameter of 2.18 mm (measurement performed with digital caliper which has the accuracy of 0,01 mm/0,0005”), there are few reports in the literature on this type of anastomosis between tibial nerve and common peroneal nerve at the popliteal fossa.

Sural nerve is widely used for both diagnostic (biopsy and nerve conduction velocity studies) and therapeutic purposes (nerve grafting) [24-27] the consistent location of the sural nerve, 1-1.5 cm behind the posterior border of lateral malleolus provides a precise surgical approach and efficient electrode placement for sensory conduction studies [11]. Sural nerve conduction studies are done in focal neuropathies to know the conduction velocity, action potential and amplitude. It is also considered in diagnosis of focal neuropathies, compressive lesions, traumatic nerve lesions and diffuse polyneuropathic conditions. It can be used as an aid in diagnosing neuromuscular junction disorders, and also to know their prognosis by using repetitive nerve stimulation [7, 22]. Sural nerve biopsy is a valuable method for establishing the cause of peripheral neuropathies and also employed in peripheral nerve disorders. It is useful in establishing the diagnosis of certain neuropathies like leprosy, vasculitic neuropathy, amyloid neuropathy, sarcoid neuropathy and chronic inflammatory demyelinating polyradiculoneuropathy [27].

Studies showed that the SN may course either intramuscularly or subfascially. During the regular dissection, a precise assessment of the frequency of this muscular course is important because of the possibility of this nerve being confused with included fascia instead of the muscular course. As shown by the foregoing literature reports, there are many cases in which the SN or its branches are surrounded by fascia or scar tissue the sural nerve followed a transmuscular course, which corresponded to a frequency of 6.7% of all legs and 10% of the cadavers [15, 28-30]. The SN pierced the gastrocnemius muscle along with the small saphenous vein instead of passing superficial to it. In concordance with Kosif et al [30] in the present study this variation was found in the right leg of a male cadaver of 75 years of age and was unilateral.

Entrapment of the SN could occur due to compression and fixation of the nerve caused by fascial thickening. Intrinsic causes, such as ganglions and lipomas, as well as prolonged external compression by heel straps [31,34], positioning [35,36], repetitive ankle sprains [33], fractures of the area [37] and gastrocnemius muscle injury [31,35,36] may eventually lead to SN lesion. However, entrapment of the SN is mainly caused by compression and fixation of the nerve due to fascial thickening [31,34]. At the emergence point of the nerve, a fibrous arch is formed at the fascial opening through which SN passes, presenting a potential entrapment site. The “superficial sural aponeurosis” may be thickened and doubled, forming a fibrous tunnel that may compress the nerve[31,33].

The diagnosis of entrapment neuropathy of the SN is based on clinical examination. The symptomatology includes sensory alterations over the distribution area of the nerve, thus the posterolateral side of the distal third of the leg, as well as the lateral aspect of the foot and fifth toe. It should be mentioned that SN presents variable patterns of innervation over the dorsum of the foot, while it often communicates with the superficial peroneal nerve [31], leading to inconstant clinical findings after SN entrapment. Burning pain, hypaesthesia, dysaesthesia or paraesthesia,

possibly with radiation over the foot or upper calf, may appear and worsen during night or exacerbate after exercise; thereby dynamic examination may appear helpful [31-33]. In addition, tenderness may be observed over the nerve course, while pressure over the point of maximum tenderness can reproduce the symptoms [31,38,39].

A positive Hoffman-Tinel's sign may affirm the diagnosis, although neurological examination could be normal. It is uncertain whether imaging techniques or electrodiagnostic studies can assist in establishing the diagnosis [31-33]. Doppler studies, ultrasonography, computed tomography or magnetic resonance imaging scanning may assist in visualization of the entrapment site, whereas increase in distal latency and decrease in amplitude of the sensory action potential of SN could indicate long-termed SN entrapment neuropathy [31,33,35]. Moreover, injections with local anesthetic in the area of tenderness can lead to temporary resolution of the symptoms, representing an additional diagnostic tool [31,33]. Should furthermore highlight that SN entrapment neuropathy should be differentiated from other conditions, such as sacral 1 (S1) sciatica, exertional compartment syndrome, piriformis syndrome, popliteal artery entrapment that could present similar symptoms [31,33,39].

Treatment of SN entrapment can be conservative or surgical. Non-operative approach may be initially preferred in cases of extrinsic etiology. In these cases, avoiding or removing the offending agent may provide relief. However unrarely, conservative treatment has been proved unsuccessful and surgical intervention is suggested. Surgical removal of space-occupying masses is necessary, while in fascia-related cases of compression, neurolysis is the most effective technique [31-34]. Knowledge of the etiology, symptomatology and treatment approach of such a condition is essential for surgeons and physicians, in order to establish a correct diagnosis and assist in improving patient's quality of life [31].

The concept that sural nerve is purely sensory is changing. Many worked on this and showed that the nerve does contain motor fibers. It is recommended to screen the nerve electrophysiologically for motor fibers before nerve biopsy for interpretation of pathologic findings [4].

Inadvertent injury to the sural nerve is increased by its anatomic variation and the minute size of the nerve's terminal branches. Significant morbidity may result from iatrogenic injury to the nerve and its branches. Sural neuromas are of great concern, since they tend to recur even when properly excised. The subcutaneous location of the nerve, as well as repetitive irritation secondary to shoe wear, may contribute to this vexing problem. The sural nerve is placed at considerable risk by incisions commonly utilized in lateral ankle reconstructions, Achilles and peroneal tendon repair or tenolysis, subtalar arthrodesis, or fracture fixation of the distal fibula, calcaneus, cuboid, or bases of the lateral metatarsals. Therefore, we recommend identification and isolation of the sural nerve and its branches during these procedures [40].

CONCLUSION

The anatomical variations and complexity of the sural nerve it makes significantly difficult to establish an anatomical standard. The variation of the sural nerve is an important surgical consideration and the knowledge of kind of entrapment as well as the variability of the peripheral nerve distribution is very important in general medicine, neurosurgeons, neurologists, general surgery, plastic surgery, sport medicine, physical therapy, clinical and surgical procedures, orthopaedists, physiatrists, physiotherapists, in electrophysiological studies for planning safety operative approach and minimize the risk of nerve injury and allows better insight into diagnoses, treatment and procedures it is involving the nerve and surrounding anatomical structures.

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