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Consideration in Using the LSCN in Sural Flap Sensory Reconstruction: An Anatomic Evaluation

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The distally based or the reverse pedicle sural flap (abbreviated as the sural flap) is widely used for the coverage of soft-tissue defects in the lower leg, ankle, and foot. Clinical studies have tended to confirm that almost all the cases receiving the sural nerve (SN) anastomosed to the recipient nerve had sensory reconstruction for the weight-bearing heel in past decades. However, these results were incompletely consistent with the published anatomic literature about the variations of the SN branches in the lower legs. We conducted a clinical anatomic study to clarify some ambiguous view points in the sensory reconstruction of sural flap. Thirty-two lower legs of Chinese cadavers were dissected, and the data about distribution and variations of the SN branches were collected. The medial sural cutaneous nerve (MSCN) and the peroneal communicating branch (PCB) had no sensory subbranches to the upper and middle posterolateral surface of the lower leg except that the PCB had sensory subbranches in one leg. The lateral sural cutaneous nerve (LSCN) ramified 1 to 8 sensory subbranches to above the area in 24 of 32 (75%) legs. The LSCN is the nerve of choice for sensory reconstruction of the sural flap, anatomically; at most, about two-thirds to three-fourths (65%–75%) of the sural flap could

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have the sensate reconstruction via anastomosis. In contrast, the PCB nerve offers a very low possibility of reinnervation. The MSCN cannot neurotize the sural flap, although protective sensation recovery may be obtained.

Key words: Possibility – Sensory reconstruction – Sural flap – Lateral sural cutaneous nerve – Anastomosis

The coverage of the soft-tissue defects in distal lower leg, ankle, and foot has been a challenge to trauma, orthopedics, foot and ankle, and plastic surgery departments due to the limited availability of the soft tissue in this region.[1–5] The sural flap, first introduced by Donski *et al* in 1983 and reintroduced by Masquelet in detail in 1992, with its modified types,[3–11] provided versatile choices in the repairing of soft-tissue loss. Moreover, the free transplantation of the peroneal perforator–based sural flap was recently used in a large soft-tissue defect coverage of the forearm, wrist, and hand.[11–13]

The sural flap was widely adopted for the following advantages: one-stage, flexibility and versatility of procedure, large size, harvested relatively simply and quickly, reliable, minimal loss of blood, no sacrifice of a major artery, and sensory reconstruction by reinnervation.[2,4,5,10] Nowadays, some specialists recommend it as the first choice in trauma, orthopedics, and plastic surgery.[3,14]

The sensory reconstruction of the flap is important to the reconstructed weight-bearing heel and sole for improve stability of the flap, avoiding the recurrent ulceration for durability, and early return to ambulation and activity.[2,10,15] Many researchers believe that the sural flap is a sensate flap and have tended to confirm that all patients could get sensory reconstruction with the sural flap by the sural nerve (SN) anastomosed to the nerve in recipient sites.[1,2,10–12,16–18]

This conclusion has almost become a consensus in related Chinese publications and communications. By March 10, 2016, a total of 2680 publications involved in the use of sural flaps had been identified in Chinese and made available from China's most famous medical website (med.wanfangdata.com.cn), and 415 publications reported the successful result of sensory reconstruction by nerve anastomosis. In contrast, only 654 reports involved in the use of the sural flap in PUBMED had been noted during the same period of time. A few such Chinese sources are cited here for reference.[9–13,17,18]

We have not found published literature that argued against the above conclusion and consensus in the last 3 decades. This study aims to clarify the possibility of sensory reconstruction by observing the SN branch distribution and variations in selected cadavers.

Material and Methods

Data were collected by dissecting 32 formalin-fixed lower legs of the Chinese cadavers. None of the specimens showed evidence of deformity or previous wounds in lower legs. The skin incision border was incised from the popliteal crease to the lateral malleolus level, and the dissection coursed along the SN in the subfascial and suprafascial planes. The anatomic findings of the distribution and variations of the SN branch and its sensory subbranches in the posterolateral surface of the lower leg were recorded.

Results

The lateral sural cutaneous nerve (LSCN) was present in 24 of 32 (75%) cases. The LSCN and the peroneal communicating branch (PCB) branched off the common peroneal nerve (CPN) by the common trunk (CT) or multiple trunk in 14 legs (Fig. 1), and by separate trunk in 10 legs (Fig. 2). They bifurcated above the level of the popliteal crease. The LSCN coursed down and penetrated deep fascia behind the fibular head to suprafascial plane. Its cutaneous branch ramified 1 to 8 sensory subbranches (SSs) and terminated in the upper and middle posterolateral surface of the lower limbs (Figs. 1 and 2).

The PCB was present in 23 of 32 (72%) legs. The PCB and the LSCN came from the common trunk above the level of the popliteal crease in 14 of 23 (61%) legs (Fig. 1) and arose independently from the common peroneal nerve in 9 of 23 (39%) legs (Fig. 3). The PCB coursed down subfascially and ran across the crural fascia at the second and third quarters of the leg and then jointed with the medial sural cutaneous nerve (MSCN). No SSs to the upper and middle posterolateral surfaces of the lower leg were found from the PCB except 1 leg (Figs. 1 and 3).

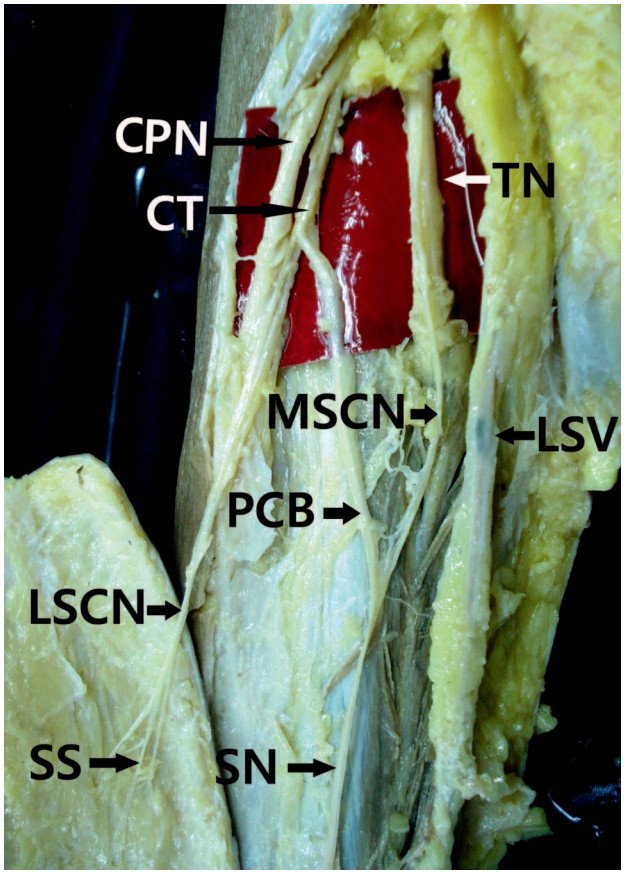

Fig. 1 Common pattern of the SN. The CT branched off the common peroneal nerve (CPN), and then bifurcated to the LSCN and the PCB, present in 14 of 32 (44%) legs. The LSCN ramified 3 SSs to the upper and middle posterior surface of lower leg. No SS split from the MSCN and the PCB.

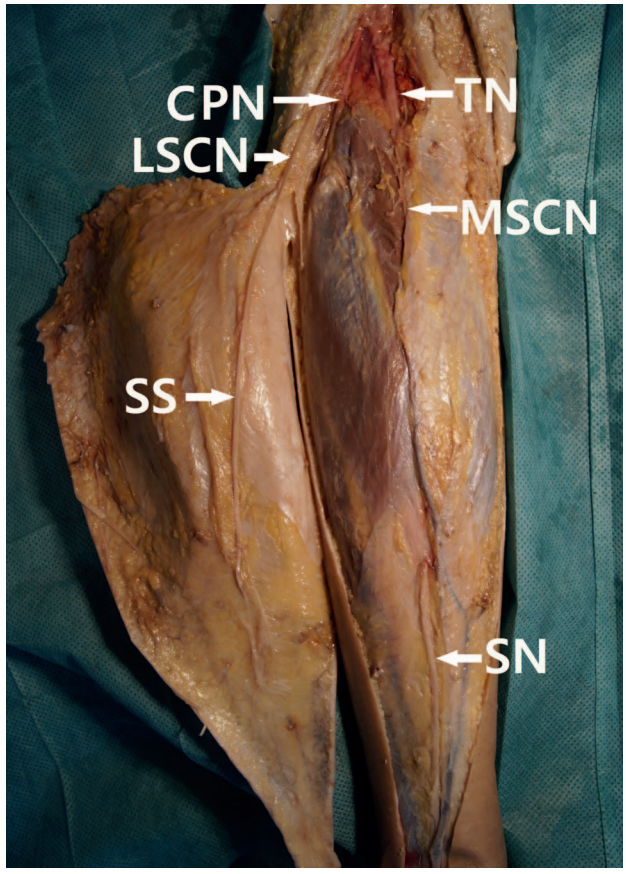

Fig. 2 The LSCN separately branched off the common peroneal nerve (CPN) and gave off 1 to 2 SSs to the upper, middle, and low posterior surface of the lower leg, present in 10 of 32 (31%) legs. The PCB was absent. The MSCN continued exclusively to become the SN, and no SSs split from the MSCN.

The MSCN was present in 27 of 32 (84%) specimens. It originated above the popliteal crease from the tibial nerve and descended between the surface of 2 gastrocnemius heads or under the gastrocnemius aponeurosis. It pierced out off the deep fascia between the upper edge to the lower edge of the middle one-third of the posterior surface of the lower leg. The MSCN union with the PCB formed the SN (Figs. 1 and 3) and ran to the lateral malleolus, heel, and foot. Above the MSCN-PCB union point, we found no SSs split from the MSCN to the posterolateral aspect of the lower limb (Figs. 1–3).

Discussion

The sensory reconstruction in the sural flap plays an important role to the reconstructed weight-bearing surface. It means an early and better return to sensibility and a good 2-point discrimination in the heel and sole.[2,15] There have been many research findings indicating researchers' success in reconstructing the sensation of the sural flap by the SN anastomosed or coapted to the superficial nerve in the plantar wound bed, a seemingly undoubted conclusion.[1,2,9,10,12,13,16–20]

This study's idea comes from our series of operations of the SN harvested as grafts at the donor site. We experienced some difficult cases in dissecting and seperating the SN grafts from the upper and middle part of the lower calf even with a long incision. It seems that the sural nerve is highly variable in its branches. These variations might influence the possibility of sensory reconstruction in the sural flap. The goal of this anatomic observation is to focus on the SS innervation of the SN in the area where the sural flap is elevated.

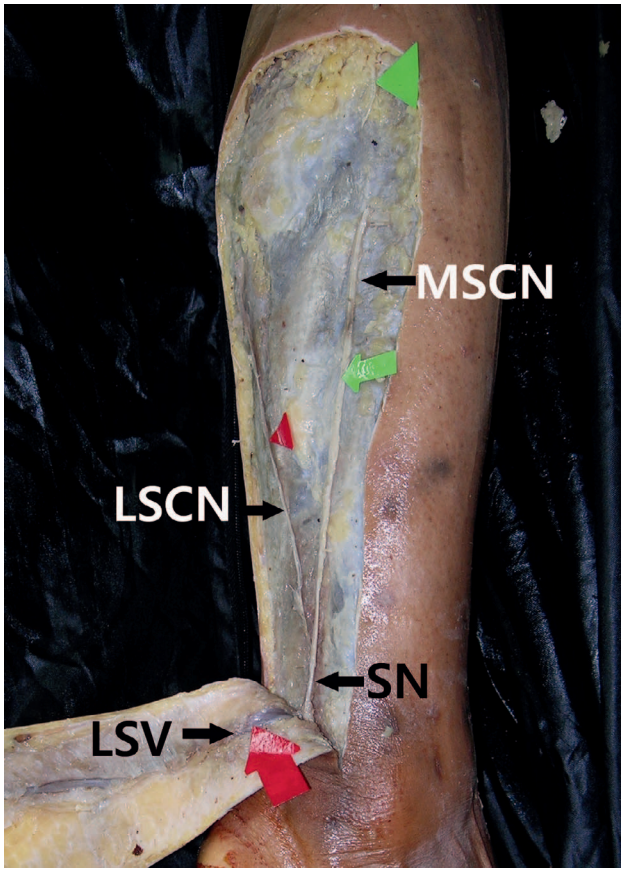

Fig. 3 Pattern of the LSCN and the SSs was absent in the legs. The PCB and the MSCN merged to the SN in the distal one-quarter of the lower leg. No SS split from the PCB and the MSCN. In the previous literature, the MSCN/PCB and lesser saphenous vein were commonly ligated and cut to be included in the sural flap for ensuring stable blood supply to the flap, and then the MSCN/PCB was anastomosed to the recipient nerve. This caused failed sensory reconstruction of the sural flap in Figs. 1 to 3.

Indeed, the MSCN and the PCB normally form the SN in the lower one-third part of the lower leg, the MSCN is relatively reliable, and the PCB and the LSCN are more variable and cause many anatomic variations in the SN makeup and the collateral branches.[21–23] Our research confirms that the MSCN and the PCB had no SSs (with 1 exception for the PCB in 1 leg only) to the upper and middle posterior surface of the lower leg, in agreement with data reported by Riedl and Frey,[21] where the sural flaps were usually elevated. Under the MSCN-PCB union point, the SN gave off several SSs to the posterolateral integuments of the distal lower leg, lateral malleolus, heel, and lateral dorsum of the foot, which provided more anatomic evidence.[21,23,24] Nuri *et al* reported the cutaneous branches of the MSCN were not found even in the whole lower leg.[22] These findings imply that the MSCN and the PCB anastomosed to the nerve near the wound bed may not offer sensory reconstruction to the sural flap.

Many authors, specially some Chinese authors, have asserted their satisfaction in sensory reconstruction to the sural flap by anastomosing the MSCN/PCB to the recipient nerve (including the described method: "dissecting sural nerve together with lesser saphenous vein alone the flap's middle axis or between the gastrocnemius muscles").[1,2,12,13,17,18] Thus far, these results lack anatomic evidence and may be confused with the outcome of similar protective sensation recovery acquired in the non-innervated sural flap, although the SN coapting is not performed.[3,5,8,19,25] The mechanism was attributed to the nerve ends in the noninnervated sural flap reinnervated from the neighboring sensory nerve in the recipient wound margin and the ingrowth of peripheral neural sprouting.[3,5,10,15] Santanelli *et al* found constant improvement to the protective sensation in the nonsensate flap after 6 months but no enhancement in the 2-point discrimination in a quantitative sensory study of reinnervation.[15] This sensory recovery quality was inferior to that of the nerve-anastomosed cases in that it is diminished sensation in the nonsensate sural flap.[5] The reason why there have been no arguments about the results of the sensory reconstruction by anastomosing the MSCN/PCB in the last 3 decades may be due to the fact that researchers have applied different sensory assessment criteria or techniques and also used different follow-up windows. Moreover, we found that the PCB had the SSs to the upper and middle posterolateral surface of lower leg only in 1 case. There is a reason to assume that the possibility of the sensory reconstruction is very low if the PCB is anastomosed. In fact, if the MSCN and the PCB were anastomosed, the sensibility would return to the posterolateral distal surface of the lower leg, lateral malleolus, heel, and lateral foot, which is the original territory of the SN supply and which the non-reconstruction cases could not acquire. We haven't found a similar analysis and opinions in the published literature.

This anatomic research indicated that the LSCN had the SSs providing sensory innervation to the upper and middle surface of the lower leg where the skin paddle of the sural flap was mostly elevated, consistent with the following anatomic studies that were not for the sural flap: the study of Riedl and Frey aimed for SN harvesting[21]; the report of

Mestdagh *et al* observed the makeup of the SN[23]; Dolan *et al* found that the LSCN terminated in the midleg for the osteoseptocutaneous fibula free flap[26]; and the study of Mahakkanukrauh and Chomsung aimed for sensate composite free flap.[27] Our findings are similar to the result of Nuri *et al*, where they enlarged the innervating territory to the whole area of the sural flap and omitted the possibility of sensory reconstruction caused by the percentage of the LSCN occurrence[22]; moreover, the studies of Mahakkanukrauh and Chomsung and Nuri *et al* did not distinguished the PCB from the LSCN.[22,28] In reviewing the previous clinical literature, we identified that fewer studies mentioned the use of the LSCN in the sural flap.[16,19] Jeng *et al* applied the LSCN for neurorrhaphy in 4 cases in the sural flap based on the "references" and presented that 3 cutaneous nerves could be used for sensory reconstruction: the posterior cutaneous nerve of the thigh, the MSCN, and the LSCN.[21] Some reports indicated the LSCN within the sural flap but without using the neurorrhaphy procedure.[4,24]

The key sensitive nerve to innervate the skin paddle of the sural flap is the LSCN; it does not get enough attention.[1,2,12,13,17,18] Therefore, anastomosing the LSCN to the recipient nerve presents the best opportunity of restoring sensibility or being sensate, because the dissection of small branches of the SN in the operation is unnecessary.[26]

Our observation also found that the sensory subbranches of the LSCN presented in 75% of legs; the percentages of other studies are as follows: Riedl and Frey, 68%[21]; Mestdagh *et al*, 70%[23]; Mahakkanukrauh and Chomsung, 67%[27]; Nuri *et al* (thick branches from the lateral branch and not limited to the LSCN), 65%.[22] Additionally, some authors had not distinguished the PCB from the LSCN in the posterolateral lower leg because of the tight relationship between the above two constituents[8,22–24,27,28]; meanwhile, the PCB and the MSCN had similar diameters, both greater than that of the LSCN,[21] so regarding the PCB as the LSCN during anastomosing were inevitable. From an anatomic perspective, we may assume that, at most, about two-thirds to three-fourths (65%–75%) of the patients are capable of obtaining sensory reconstruction if the LSCN-anastomosed procedures are performed at the recipient site, regardless of other influences, such as the quality of the neurorrhaphy. This is the study's core point and differs from that of many previous reports. Most clinical authors have reported a high satisfaction rate with sensory reconstruction of the sural flap but with no indication of how the anatomic mechanism, specifically the LSCN, may work toward the goal since the sural flap's first introduction by Donski *et al*.[6]

To summarize, there is a universal consensus on sensation achieved after sensate sural flap reconstruction via SN anastomosis without considering the branch distribution and variations of the SN, in the last 3 decades. The current study emphasizes that the LSCN should be the first option for sensate reconstruction. Furthermore, we should be aware that the possibility of sensory reconstruction of the sural flap may be much lower than that indicated through previous reports on an anatomic basis.

The number of cadaveric specimens chosen is limited in this study, and further cadaver studies with larger numbers and multiple races, incorporating clinical case reports, are worth pursuing in the authors' humble opinion. However, our findings seem to be supported by other anatomists. The authors' suggestion will help trauma, orthopedics, foot and ankle, and plastic surgeons in decision making regarding the sensory reconstruction of the sural flap. It is anticipated that more authors will present objective reports that correspond with the anatomic character of the SN in the future.

Conclusion

The LSCN is the nerve of choice for sensory reconstruction in the sural flap, anatomically. At most, about two-thirds to three-fourths (65%–75%) of the sural flaps may develop sensate reconstruction via anastomosis. In contrast, the nerve of PCB offers a very low possibility for sensory reconstruction. The MSCN does not neurotize the sural flap, despite that protective sensation recovery may be obtained.

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