# Maximizing the Reliability and Safety of the Distally Based Sural Artery Flap

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## ABSTRACT

Variations of the distally based sural artery flap have been used in the literature with varying success rates. This article stresses the axiality of this flap based on the sural nerve and the short saphenous vein. Forty distally based sural artery flaps were used for a variety of defects in the distal leg. In the proximal leg, the groove between the medial and lateral heads of the gastrocnemius muscle was explored to include the subfacial part of the medial sural nerve with the flap. The subfascial part of the nerve can consistently be included with the flap and gives off cutaneous supply to the tip of the flap to increase reliability of the distal part of the flap. The short saphenous vein should be harvested with an additional length to allow for supercharging or intermittent bleeding in the event of flap congestion. With this approach our success rate with this flap was 98%. To maximize the reliability of the distally based sural artery flap, the sural nerve and short saphenous vein must be included with the flap along its entire length.


**KEYWORDS:** Distally based, sural artery flap, reverse flow, axiality, anatomy, reliability, safety

In 1981, Ponten introduced the concept of a local neurovenocutaneous flap for coverage of lower limb defects.[1] As an extension of this concept, Masquelet et al[2] described skin island flaps supplied by the vascular axis of superficial sensory nerves. This eventually evolved into the distally based sural artery flap. Today, this flap is increasingly accepted as an alternative to free flaps for defects of the distal third of the leg and ankle areas.[3–10] Questions regarding its reliability remain, however, with reported flap failure rate ranging from 0 to 36%.[11] This in part can be attributed to variations in surgical technique of harvesting the flap, with some authors stating that the sural nerve could be preserved to minimize donor morbidity,[12] and others noting that the short saphenous vein should be ligated distally to minimize venous congestion of the flap.[13,14] The inclusion of the sural nerve and the short saphenous vein *along the entire length of the flap* is crucial to maximize the reliability of this flap. This article describes the arterial and venous anatomy of the distally based sural artery flap and highlights the role of the sural nerve and short saphenous vein in its axiality.[15,16] These principles were subsequently successfully employed in our clinical cases.

## METHODS AND MATERIALS

From 2000 to 2006, 40 distally based sural artery flaps were performed. Flaps were raised using the technique described in the following surgical technique section with particular attention taken to ensure inclusion of the sural nerve and the short saphenous vein along the entire length of the flap. Depending on the clinical findings,

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precipitating factor, wound requirements, and intraoperative findings, we employed a variety of techniques to improve flap survival. These included phlebotomy via the short saphenous vein ($n = 12$),[17] supercharging ($n = 2$), and delay ($n = 3$). A cuff of the gastrocnemius muscle was harvested with the tip of the flap in two patients because extra bulk was needed to fill dead space at the defect sites. Complications included one complete flap necrosis, two tip necrosis, four delayed healing, two superficial wound infections, and one loss of the skin graft over the donor site. The complete flap loss was experienced early in our clinical experience in using this flap and was attributed to pressure on the pedicle caused by the subcutaneous tunnel. We have subsequently modified our technique by opening the intervening skin between the donor site and the defect.

### Surgical Technique

Preoperatively, the lateral leg perforators are marked by handheld Doppler. These are usually located ~5 to 8 cm above the lateral malleolus.[15] The defect is debrided and their maximal dimensions measured. A racket handle flap is designed, making an allowance of 1 cm in each maximal dimensions to allow for postoperative swelling. The reach of the flap is also given an additional 2 cm for this purpose. The width of the flap at its base is designed to be ~2 cm to facilitate flap transposition. The flap is elevated under a tourniquet in a proximal to distal direction. The initial proximal incision is made through the dermis, and the sural nerve and the short saphenous vein are located in the subcutaneous plane. The short saphenous vein is traced proximally to obtain an additional length of 5 cm. As previously described, this additional length is useful to provide an additional outlet for venous drainage venous congestion develops in the flap after inset.[18] This can be achieved by supercharging (microanastomosis to veins in the vicinity of the defect) or by hourly phlebotomy to relieve venous congestion periodically as the flap establishes a more efficient venous drainage.

In cases where a long flap extending into the proximal leg is needed, the sural nerve would have pierced the deep fascia and is located deep to the fascia in the groove between the medial and lateral heads of the gastrocnemius muscle. The deep fascia is then cut, and dissection in the groove between the medial and lateral heads of the gastrocnemius muscle is performed to locate the subfascial part of the medial sural nerve. The nerve has to be "dug out" of this space. The medial sural nerve, together with the adipofascial tissue connecting the nerve to the deep fascia, is harvested en bloc with the flap. The medial sural nerve extends distally until a point at approximately the midpoint of the leg where the nerve pierces the deep fascia to lie in a suprafascial location. From this point onward, the sural nerve and the short saphenous vein are located suprafascially, and dissection can proceed expediently. As the distal leg perforators are approached, care should be taken to ensure inclusion of the short saphenous vein, which diverges from the sural nerve and runs medially toward the Achilles tendon. The surgeon can check its course by visually tracing the vein through the translucent deep fascia. The skin bridge at the base of the flap is designed to be ~2 cm wide. To include the short saphenous vein, it is sometimes necessary to bevel the dissection outward in the subcutaneous plane as the surgeon approaches the distal leg perforators. This beveling outward creates fascia extensions incorporating both the sural nerve and short saphenous vein and does not add much to the bulkiness of the pivot point. The distal leg perforators mark the distal extent of flap elevation. The skin bride between the defect and the base of the flap is opened, and the flap is transposed directly onto the defect with no tunnelling. Inset is performed loosely with fine sutures. The donor site is closed primarily or skin grafted. The patient is nursed postoperatively in a prone position with particular care to prevent compression on the lateral leg.

### Illustrative Cases

A 25-year old man sustained a skin loss and cut tendons over the distal third of his left leg in a road traffic accident. The wound was debrided and tendons repaired. Wound coverage with a long distally based sural artery extending into the proximal leg was performed as described (Fig. 1A–E). The color of the flap was good with no venous congestion after inset. Healing was uneventful, and complete survival of the flap was noted at 1-year follow-up (Fig. 1F,G).

## DISCUSSION

Understanding the arterial and venous anatomy of the distally based sural artery flap is the key to maximizing its reliability and safety.[19] Its arterial supply is from the distal leg cutaneous perforators from the major lower limb vessels. In the majority of cases, these perforators are septocutaneous perforators from the peroneal artery. These perforators give off branches to supply the vasa nervorum and vasa vasorum of the sural nerve and short saphenous vein, respectively, once it comes above the deep fascia of the leg. It is this intricate arterial network running along the sural nerve and the short saphenous vein that defines the axiality of the flap. At intervals, this vascular network along the nerve and vein gives off cutaneous branches to supply the flap.[15,16] To maximize flap reliability, it is therefore important that not only both the sural nerve and the short saphenous vein be included with the flap, but both these structures must be included along the entire extent of the flap.[20] By doing so, a long flap up to the popliteal crease can be safely harvested.

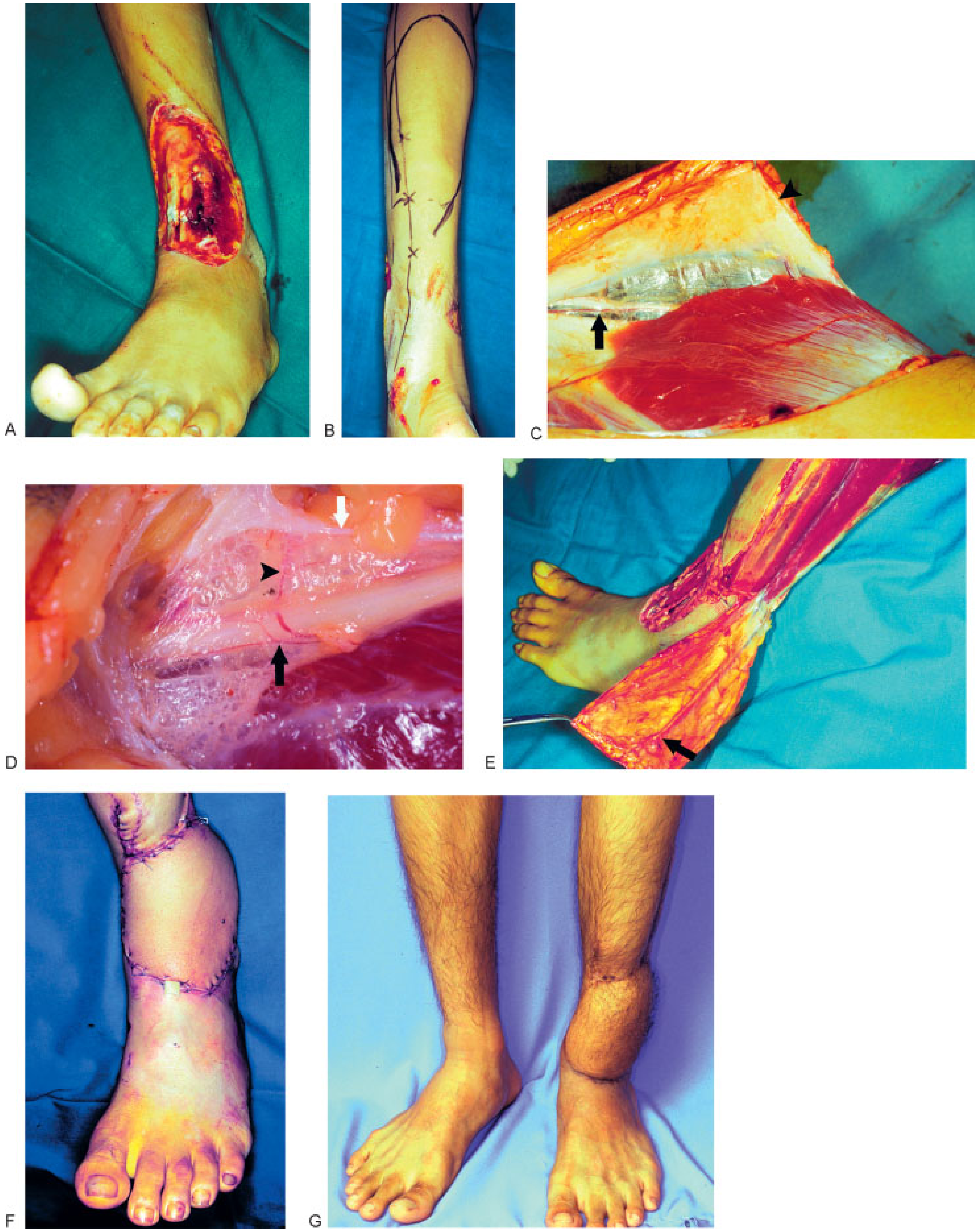


**Figure 1** (A) Left leg defect. (B) Skin markings for the planned distally based sural artery flap. X denotes the location of the distal leg perforators as detected by a handheld Doppler. (C) In the proximal leg, dissection was performed in the groove between the heads of the gastrocnemius muscle to include the subfascial part of the medial sural nerve with the flap (arrow). (D) The vasa nervorum of the sural nerve (black arrow) gives off a cutaneous perforator (black arrowhead) that pierces the deep fascia (white arrow) to supply the skin flap. (E) The distally based sural artery flap elevated. The subfascial part of the medial sural nerve is routinely included with the flap to maximize blood supply to the tip of the flap (arrow). (F) The flap on completion of the inset with no venous congestion. (G) Patient at 1-year follow-up.

The reported reliability of the distally based sural artery flap varies from 64 to 100%.[11] This wide variation in outcome is related primarily to the difference in techniques used by different authors to raise this flap. The two main variations described in raising this flap pertain to the exclusion of the nerve and vein. Some authors raised the flap without inclusion of the sural nerve with the aim to reduce donor morbidity by preserving lateral foot sensation.[12] Although success is reported with this technique, it is generally accepted today that the inclusion of the sural nerve is crucial for maximizing reliability. More importantly, although most authors included the sural nerve in their flaps, only the suprafascial part of the nerve is harvested with the flap, leaving the flap entirely dependent on the short saphenous vein and its accompanying vasa vasorum in the distal part of the flap.[4–8] Harvesting the flap in the conventional manner in the subfacial plane, one would cut the medial sural nerve once it pierces the deep fascia at approximately the midpoint of the posterior leg.

Al-Qattan has demonstrated favorable result with the inclusion of a cuff of midline gastrocnemius muscle within the tip of the flap.[20,21] This maneuver incorporates the medial sural nerve and its vasa-nervorum with the flap, giving an additional supply to the tip of the flap. Inclusion of portion of the gastrocnemius adds bulkiness to the tip of the flap and increases donor morbidity. We found routine inclusion of a cuff of gastrocnemius muscle to be unnecessary, and by dissecting in the groove between the medial and lateral heads of the gastrocnemius, one can reliably locate and include the medial sural nerve with the flap. Harvesting the nerve with the surrounding adipofascial tissue attaching the nerve to the deep fascia preserves the neurocutaneous contribution to the tip of the flap. This has the same benefit as including a cuff of muscle with less donor morbidity. Also, this reduces the bulkiness of the tip of the flap and facilitates flap inset.

The venous anatomy is equally delicate. The distally based sural artery flap has two venous drainage systems, that of the short saphenous vein and the vena comitantes accompanying the vasa nervorum and vasa vasorum.[19,22,23] The former is in a reverse flow orientation and the latter in an antegrade direction. These two systems are connected by oscillating avalvular veins. When the flap is elevated, the short saphenous vein is oriented in a reverse flow manner. Several mechanisms have been postulated to function to bypass this problem. These include "crossover" flow via bypass channels and reflux through valves.[23] Denervation after flap elevation also facilitates reverse flow.[24] In purely reverse flow flaps, such as the reverse flow radial forearm flap, these are the main mechanisms for venous outflow. In the distally based sural artery flap, however, a second venous drainage system exists;[22] this is the venules accompanying the vasa nervorum and vasa vasorum of the sural nerve and short saphenous vein, respectively. This system flows in an antegrade direction toward the distal leg perforators and eventually into the vena comitantes accompanying the peroneal artery. Blood can pass from the short saphenous to these vena comitantes via oscillating avalvular veins, effectively channeling blood from the superficial to the deep venous drainage systems. The relative contribution of each system is unknown and probably changes dynamically with time as the flap adjusts to its new physiology. To promote venous drainage and prevent congestion, both systems should be kept patent and injury to either should be avoided during flap harvest.

Venous congestion is one of the main problems with the distally based sural artery flap.[20,25] It has been postulated that ligating the short saphenous vein distally prevents venous congestion by preventing inflow of venous blood from the foot into the flap.[13,14] However, we believe that the short saphenous vein should not be ligated for the following reasons. First, ligating the vein potentially cuts off the venocutaneous contribution to the arterial supply of the flap. The contribution of the vasa vasorum of the short saphenous vein is particularly important when a long flap, extending into the proximal leg, is needed. Second, ligating the vein may paradoxically have a deleterious effect on venous drainage because it directly cuts off the reverse flow mechanism. Finally, keeping the vein patent provides an additional outlet for *antegrade* venous drainage by supercharging if suitable recipient veins are available in the vicinity of the defect or by phlebotomy if recipient veins are unavailable.[18,26]

Techniques described to improve congestion include supercharging and various techniques of bleeding the flap.[27–31] The latter can be performed by medicinal leeches or dermal bleeding by harvesting a partial-thickness skin graft from the flap to allow bleeding from the donor site, or, more recently, an externalized segment of the short saphenous vein.[17] All these techniques improve flap survival. The distally based sural artery is commonly supplied by perforators originating from the peroneal artery. One should therefore use this flap with caution in patients with peripheral vascular disease, particularly if the peroneal artery is involved. Comorbidities such as diabetes, peripheral vascular disease, and venous hypertension may complicate the use of this flap. Baumeister et al performed this flap using technique similar to ours in 70 patients and reported a partial or complete flap necrosis of 36%.[11] The authors ascribed their high failure rates compared with other published studies to patient comorbidities. They noted that diabetes, peripheral vascular disease, and venous insufficiency are major risk factors and patients with any of these comorbidities have a five- to sixfold higher risk of flap necrosis compared with a patient with no concomitant disease (60% versus 11%). Macroangiopathy and microangiopathy is the cause of arterial insufficiency and failure in these patients. In this group of patients, Kneser et al have demonstrated in a 2005 article that delay may be the key to maximizing reliability.[32]

Our success rate with this flap is 98%. We attribute this favorable rate to two factors: patient selection and surgical technique. The distally based sural artery flap is a low-flow flap with a very delicate blood supply. We prefer to use this flap in healthy patients with no comorbidities that can compromise perfusion through the distal leg perforators. We avoid this flap in patients with diabetes or peripheral vascular disease, and when it is performed in this group of patients it is always delayed to maximize reliability.

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