The Anatomical Basis of the Medial Sural Artery Perforator Flaps

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ABSTRACT

Objectives: *To study the perforators of the medial sural artery and the possible size of their flap.*
Methods: *The external iliac arteries of ten adult preserved cadavers (males and females) were injected with a mixture of red latex and lead oxide. The skin was reflected and the medial sural artery and its perforators were identified. The diameters and origins of perforators were measured from the central popliteal crease.*
Results: *The medial sural artery originated from the popliteal artery in 70% and had its external diameter at a mean of 3 ± 0.02 mm and was accompanied by two venae comitantes. The number of its perforators was at a mean of two perforators. Length of the pedicle of the medial sural artery perforator flap was at a mean of 18 ± 0.03 cm. The largest of the perforator had an average external diameter of 0.9 mm. The perforators ramified the skin with branches of the artery accompanying the posterior cutaneous nerve and the perforating branches of the peroneal and the posterior tibial arteries. The possible size of the medial sural perforators flap was at an average 8.2 cm × 13.3 cm.*
Conclusion: *The medial sural artery perforator flap has at least one or two perforators with an average size of 8.2 cm × 13.3 cm. Elevation of the flap will not affect the vascularity of the gastrocnemius muscle.*

Keywords: Flap, medial sural artery, perforators, vena comitantes

Base Anatómica de los Colgajos Perforantes de la Arteria Sural Medial

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RESUMEN

Objetivos: *Estudiar los perforantes de la arteria sural medial y el posible tamaño de su colgajo.*
Métodos: *A las arterias ilíacas externas de diez cadáveres adultos preservados (varones y hembras) se les inyectó una mezcla de látex rojo y óxido de plomo. La piel fue reflejada y la arteria sural medial y sus perforantes fueron identificados. Los diámetros y orígenes de los perforantes fueron medidos desde el pliegue poplíteo central.*
Resultados: *La arteria sural medial se originaba partiendo de la arteria poplítea en 70%. Su diámetro externo alcanzaba un valor medio de 3 ± 0.02 mm y estaba acompañada de dos venas comitantes. El número de sus perforantes fue de dos como promedio. La longitud del pedículo de la arteria sural medial tuvo un valor promedio de 18 ± 0.03 cm. El perforante mayor tuvo un diámetro externo promedio de 0.9 mm. Los perforantes ramificaron la piel con ramas de la arteria que acompaña el nervio cutáneo posterior, y las ramas perforantes de las arterias tibiales posteriores y fibulares o peroneas. El tamaño posible del colgajo perforante sural medial tuvo un valor promedio de 8.2 cm × 13.3 cm.*
Conclusión: *El colgajo perforante de la arteria sural medial posee al menos uno o dos perforantes con un tamaño promedio de 8.2 cm × 13.3 cm. La elevación del colgajo no afecta la vascularidad del músculo gastrocnemio.*

Palabras claves: colgajo, arteria sural medial, perforantes, vena comitantes

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INTRODUCTION

Perforator flaps are based on cutaneous, small diameter vessels which branch off a main pedicle and perforate fascia or muscle to reach the skin (1). The use of these flaps consequently saves the main pedicle and takes precautions of functional impairment and minimizes donor site morbidity. It was reported that a pedicle of about 2 mm in diameter and up to 8 cm in length can be obtained in perforator flaps from the lateral lower leg by retrograde dissection to the main artery (2). Using audible or colour duplex imaging in pre-operative assessment contributes to the localization of perforating vessels.

Perforator flaps have been popular recently in the field of reconstructive microsurgery (3–9). This method reduces donor morbidity and can provide very thin flaps while preserving the muscles associated. Authors found that the flap obtained by using perforator artery originating from the medial sural artery is a very thin flap containing only skin and part of subcutaneous tissue, thus not compromising function at the donor site while bringing aesthetically excellent results to the recipient area.

The perforator flap has become a vital part of the requirements for the reconstruction of various regions of the body. The perforator flap as both a free flap and a pedicled flap has been used in a variety of regions. The gluteal artery perforator flap has become vital in treatment of sacral, ischial and trochanteric pressure sores (1–7). Various lower leg defects can also be reconstructed efficiently with local perforator flaps based on the perforators derived from one of three major blood vessels of the lower leg (8, 9). Elevation of the perforator flaps needs special attention in the planning of surgery because the donor and recipient sites are located near each other. The design of the flap elevation is made on the side of maximal skin laxity, which allows for the primary closure of the donor site. However, transposition of the appropriate dimensions of tissue whilst achieving primary closure of the donor site is not always possible due to the anatomical location of the perforator and limitation of the adjacent tissue supply (9).

The limitation of the donor sites leads to elevation of two perforator flaps from opposite sides of the defect (9, 10). However, this technique not only complicates the procedure by elevation of two perforator flaps but also leads to the loss of the secondary donor sites if the wound recurs, which can occur in pressure sores. Therefore, a design for the elevation of the larger single flap whose donor site could be primarily closed would be helpful. These flaps could be used to reconstruct various wounds in the sacral, trochanteric and lower leg regions.

Free perforator flaps from the lateral lower leg offer a large skin paddle supported by a single perforator vessel up to 20 cm × 13 cm (11–12). This can facilitate the design and inset of the skin paddles and avoid the need for a second free flap. Another advantage of these flaps is the primary thin and pliable skin, which is well suited for both intra-oral lining and extra-oral skin coverage. The aim of the current study was to investigate the anatomical basis of the medial sural free perforator flap and to evaluate its perforators and size.

MATERIAL AND METHODS

The study was done at the Anatomy Department, Faculty of Medicine, Umm Al-Qura University between 2009 and 2010 according to the ethical rules of the Organizing Ethical Committee of the University. Ten adult preserved cadavers (males and females) were used in the current study. The external iliac artery was exposed through transverse incisions above the midpoint between the superior iliac spine and the pubic tubercle. The artery was cannulated and washed with normal saline solution to dissolve the blood clots and then the solution was aspirated. The arteries were injected with a mixture of red latex and lead oxide. After 24 hours, the dissection of the popliteal region and the leg started. Circular skin incision at the middle of the thigh of each cadaver was done. A vertical incision from this circular incision was made passing behind the knee joint and the back of the leg. The skin was reflected and the medial sural artery was identified and its perforating arteries to the skin were recorded. The perforators of the upper third of the skin of the postero-medial aspect of the leg were measured from the distal popliteal crease while the perforators of the lower leg were measured from the medial epicondyle. The origin and the course of each perforator were traced with localizing the subfascial vascular plexuses and the perforators sharing in supplying theses plexuses.

Parameters evaluated and recorded were as follows:

* Distance between the middle knee joint line and the origins of the perforators of the medial sural artery.
* Diameter of the medial sural artery at its origin and end.
* Number, length and diameter of the perforators of the medial sural artery.

RESULTS

The medial sural artery originated from the popliteal artery in 70% of the cases (7 cadavers) or from a common sural trunk in 30% of the cases (3 cadavers). In all the cadavers studied, it originated at the level of the knee joint (Fig. 1). The external diameter of the medial sural artery at its origin was at a mean of 3 ± 0.02 mm (ranging from 1.9 to 4.1 mm) and at its entrance into the medial head of the gastrocnemius muscle was at a mean of 2.1 ± 0.04 (ranging from 1.6 to 5.2 mm). Each artery was accompanied by two venae comitantes that passed parallel to the course of the artery in all the studied cadavers. One of them had a larger diameter than the other. The external diameter of the wider vena comitans was at a mean of 3.5 ± 0.02 mm (ranging from 2.2 to 4.8 mm) while the second was a mean of 2.8 ± 0.06 mm (ranging from 1.9 to 3.8 mm). The two venae comitantes drained into the popliteal vein either separately or by a common stem (Fig. 2).

In one cadaver, the small saphenous vein terminated into the larger venae comitantes (Fig. 1).

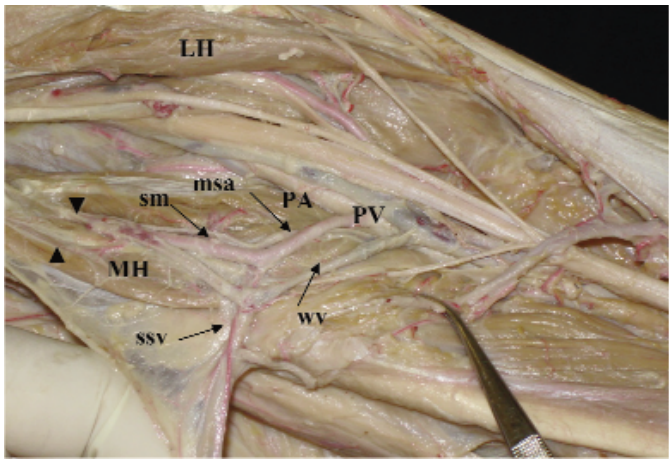

Fig. 1: The medial sural artery (msa) arises from the popliteal artery (PA). It gives longitudinal branches (arrow heads). It is accompanied by smaller (sm) and larger (wv) venae comitantes that drain into the popliteal vein (PV). The small saphenous vein (ssv) drains into the wider vena comitans. MH: medial head of the gastrocnemius; LH: lateral head of gastrocnemius.

The medial sural artery entered the deep surface of the medial head of the gastrocnemius muscle along an elongated hilum. It gave many longitudinal branches that extended to the lower border of the fleshy part or at the point of insertion of either head into the tendon-calcaneus (Figs. 1, 2).

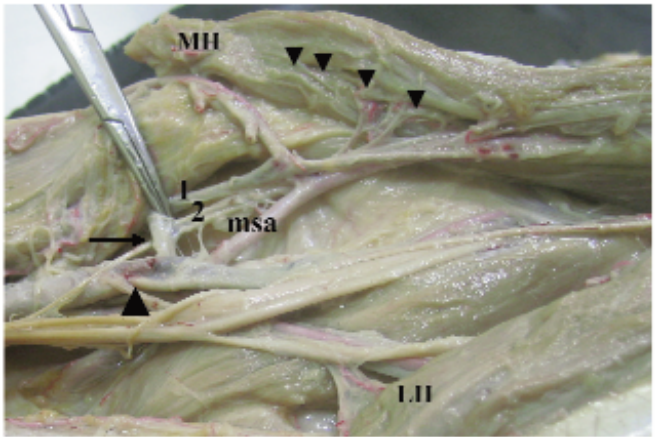

Fig. 2: The medial sural artery (msa) enters through the transverse hilum in the medial head (MH) of the gastrocnemius (arrows heads). It gives longitudinal branches before entering. The two venae comitantes (1, 2) accompanying the MSA form a single trunk (arrow) that drains into the popliteal vein (arrow head). LH: lateral head of the gastrocnemius.

The majority of musculocutaneous perforators that arose from the superficial branches of the medial sural artery passed along the posterior surface of the muscle near to the deep fascia. These perforators were more numerous in the distal half of the muscle and originated nearer the lateral border of the medial head of the gastrocnemius muscle than midline. The number of the perforators from the medial sural artery was at a mean of two perforators (ranging from 1 to 5). The perforator artery was accompanied by two venae comitantes that passed parallel to the course of the perforator artery (Fig. 3). The first perforator of the medial sural artery

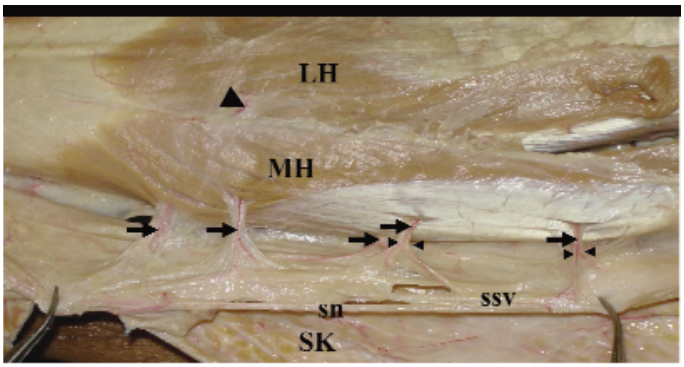

Fig. 3: Five perforators (arrows) penetrating the medial head of the gastrocnemius (MH) to the deep fascia and skin (SK). They are accompanied by two small venae comitantes (small arrows heads) that communicate with the small saphenous vein (ssv) and arteries accompanying the sural nerve (sn). Their branches ramify the deep fascia of the calf. LH: lateral head of the gastrocnemius.

was located at an average distance of 10.2 ± 0.02 cm (ranging from 9 to 12 cm) from the popliteal artery while the second perforator artery was at an average distance of 15.9 cm (ranging from 14.4 to 17 cm). The length of the pedicle of the medial sural artery perforator flap was at a mean of 18 ± 0.03 cm (ranging from 15 cm to 21 cm) [Fig. 3]. Dissection of the perforators of the medial sural artery through the medial head of the gastrocnemius was easy and the average length of the first perforator was at a mean of 9.5 cm (ranging from 7 to 11 cm). The average length of the second perforator was at a mean of 9.3 cm (ranging from 7 cm to 10.5 cm).

The diameter of the perforators of the medial sural artery varies from one another. The largest of the perforator was the proximal one and had an average external diameter of 0.9 mm (ranging from 0.8 to 1 mm). The smallest perforator had an average diameter of 0.5 (ranging from 0.4 to 0.6 mm). At least three of five perforators had an average diameter of 0.9 mm. In cases where there were only two perforators, at least one of them had an average diameter of 0.9 mm.

The perforators of the medial sural artery ramify the skin of the posteromedial aspect of the upper part of the leg with branches of the artery accompanying the posterior cutaneous nerve of the thigh that supplied the skin of the area (Fig. 4). Also the skin of the lower part of the leg was

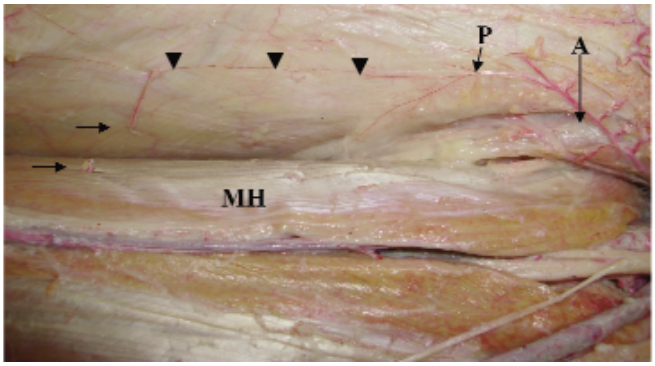

Fig. 4: The skin of the posteromedial side of the back of the right leg is supplied by anastomotic branches between a perforating branch of the medial head (cut ends are shown by arrows); it is 31.5 cm from the lateral malleolus. It anastomoses with branches from the artery accompanying the posterior cutaneous nerve of the thigh (P). MH: medial head of the gastrocnemius.

supplied by the perforating branches of the peroneal artery and the posterior tibial artery. They anastomosed with the branches of the perforators of the medial sural and the superficial middle sural arteries (Fig. 5). The perforating

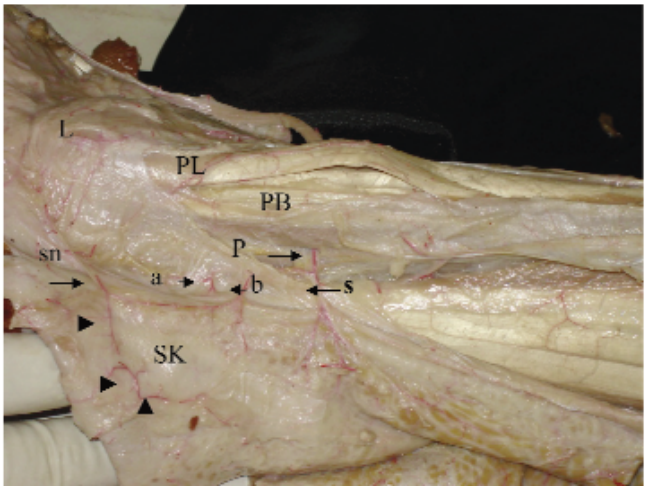

Fig. 5: The perforating cutaneous branch from the peroneal artery (P) and septal perforators from the posterior tibial artery (a, b) supply the skin and anastomose (arrow heads) with branches from the median superficial artery (arrow). PL: peroneus longus, PB: peroneus brevis, L: lateral malleolus.

branches of the peroneal artery ramified the skin and were accompanied by two venae comitantes that ended in the small saphenous vein. The perforators that arose near or at the midline were not accompanied by the venae comitantes. Also branches of the perforators communicated with those accompanying the sural nerve (Fig. 3).

The possible size of the medial sural perforator flaps that could be raised from the posteromedial aspect of the leg, just below the knee and superficial to the medial head of the gastrocnemius muscle was 8.2 cm × 13.3 cm (ranging from 6 × 7.6 cm to 9.8 × 14.4 cm). There were vascular communications (arterial and venous) between the lateral and medial heads of the gastrocnemius muscle. These vessels either connect the superficial parts of the heads or their deep parts (Figs. 3, 6).

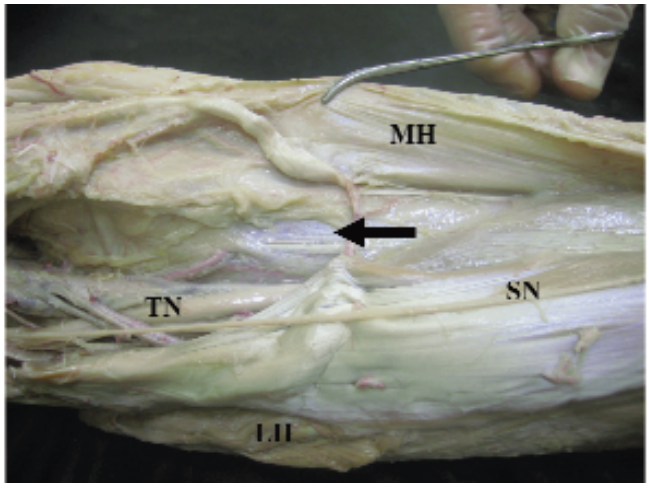

Fig. 6: A connecting blood vessel (arrow) between the lateral (LH) and medial (MH) heads of the gastrocnemius muscle.

DISCUSSION

The medial sural artery perforator flap has only been developed recently. This type of flap is used as a free flap in reconstruction of the wounds of the lower limb (13–15). Moreover, it is used in finger reconstruction (14) and in the repair of soft tissues in the hand, especially the dorsum (16, 17). The medial sural perforator flap is a thin flap and can be used as fasciocutaneous perforator flap without including the underlying head of the gastrocnemius (18–20). Therefore, the unwanted bulk of the underlying muscle is avoided to maintain the function of the muscle in the donor.

The present study showed that the average diameter of the medial sural artery was at a mean of 6 ± 0.02 mm (ranging from 4 mm to 7 mm) at its beginning and decreased to 4 ± 0.06 (ranging from 2 mm to 5 mm) at its distal end near the medial head of the gastrocnemius muscle. Therefore, it is of great importance for a surgeon who plans to perform free medial sural artery perforator flap to choose the part of the medial sural artery which will be suitable for micro-anastomosis with the recipient artery. The difference in the diameters of the arterial pedicle of the flap and the recipient artery might create difficult micro-anastomosis and consequently may affect the future viability of the free medial sural artery flap. Such difference in diameters is important,

especially the use of the flap in treatment of soft tissue defects in the dorsum or the palm of the hand.

The medial sural artery during the current study was noticed to enter the deep surface of the medial head of the gastrocnemius muscle along an elongated hilum. It gave many branches extending as far as the point of insertion of either head into the Achilles tendon. Consequent to the current study, there were vascular communications between the lateral and medial heads of the gastrocnemius. Thus, the medial head would survive after elevation of the medial sural artery perforator flap. Moreover, the surgeon can perform a medial sural artery fasciocutaneous flap and medial head of gastrocnemius flap at the same operation**.**

During the current study, it has been shown that the medial sural artery perforator flap was nourished by multiple perforators from the medial sural artery. They penetrated the medial head of the gastrocnemius to ramify the fascia overlying the muscle. The average number was 2 ± 0.3 (ranging from 1–5). The elevated flap would have at least one or two principal perforators, each with an average external diameter of 1.2 mm (ranging from 1 to 1.3 mm).

According to the present study, elevation of the medial sural fasciocutaneous perforator flap will not affect the vascularity of the medial head of the gastrocnemius as it gets its blood supply from the lateral head *via* superficial or deep connecting vessels. Moreover, the flap will be relatively thin and its colour and thickness would match the hand, particularly the dorsum of the hand. It is more superior to other pedicle flaps such as reverse pedicle flaps from the forearm, the contralateral radial artery free flap, the lateral arm free flap and the anterior lateral thigh flap (17). In such types of flaps, surgeons do not have to include the medial head of the gastrocnemius muscle for vascular supply of the flap. The flap will also be similar in constitution to other perforator skin flaps (1–5, 15).

The present study showed that the proximal perforator flap was constant in all the dissected cadavers. It has a mean diameter of 0.9 mm and originated from the medial sural artery 6 to 10 cm (at a mean of 7.6 ± 0.02) from the central popliteal crease and approximately 4.8 cm from the midline posteriorly or the raphe between the two heads of the gastrocnemius muscle. Consequently, depending on this proximal perforator, a single perforator flap can be designed. Therefore a free medial sural artery perforator flap can be elevated from the medial aspect of the upper calf. It can be useful for contouring or covering shallow defects of distal limbs (18). It has been reported that the main advantage of the medial sural artery perforator flap is that it only requires cutaneous tissue to achieve better accuracy at the reconstructive site, and it preserves the medial gastrocnemius muscle and motor nerve to minimize donor-site morbidity (19, 20). However, the current study showed that the dissection of the perforator through the medial head of the gastrocnemius was not easy and needed special care and patience. On the other hand, the possible ugly scar of the donor region was reported after elevation of the flap and primary closure of the donor sites (21, 22).

It had been shown in this study that the skin and the subcutaneous tissue covering the medial head of the gastrocnemius was supplied by the perforators of the medial sural artery. These perforators anastomosed proximally with the branches of the artery accompanying the posterior cutaneous nerve of the thigh and distally with branches of the peroneal and posterior tibial artery perforators. Consequently, the elevation of medial sural artery perforator flaps, either fasciocutaneous or myocutaneous, including the medial head of the gastrocnemius will not seriously affect the vascularity of the skin left after elevation.

Wei *et al* (23) used this flap in reconstruction of the popliteal fossa scars with satisfactory results. Flap size ranged from 7 cm × 5 cm to 12 cm × 7 cm and the flaps were found to have a good appearance. However, the current study showed that the size of the elevated flap can reach up to 9.8 × 14.4 cm with a mean of 8.2 cm × 13.3 cm (ranging from 6 × 7.6 cm to 9.8 × 14.4 cm). Therefore, it can cover and reconstruct sizeable areas in the popliteal region, hands and the distal parts of the lower limbs. Moreover, the flap could be used as a free fasciocutaneous or myofasciocutaneous with the medial head of the gastrocnemius to reconstruct distant areas in the head and neck and this supports the suggestions of other authors (24). It was reported that after elevation of the flap patients could walk with heavy load and the function of the knee joint of the affected limb was the same as that of the opposite limb. Moreover, there will be no obvious depression in donor sites (16–18, 25). The posterior cutaneous nerve of the thigh supplied the skin of the medial sural artery perforator flaps with the artery accompanying it. Thus, the flap of a reasonable size and its nerve supply will be convenient to reconstruct areas which need sensitive skin such as the head and neck reconstruction.

According to the present study, the venous drainage of the medial sural artery cutaneous flap was through the venae comitantes that accompanied the perforators of the medial sural artery into the medial sural veins that drained into the popliteal vein. In 30% (3 cases) of the studied cadavers, the small saphenous vein drained into one of the medial sural veins. Therefore, it would be more appropriate to include the small saphenous vein in the medial sural artery perforator flaps to ensure good venous drainage of the flap. Inclusion of the short saphenous vein into the flap not only improves the venous outflow, but also improves the circulation of the flap and allows proximal extension of the flap over the proximal third of the calf. It will also avoid the possible venous insufficiency that had been reported to occur in the medial sural artery flap and can affect its viability (26). It was shown in the current study that accompanying arteries of the short saphenous vein and sural nerve communicated with the branches of the perforators. They also gave venocutaneous and neurocutaneous perforators that nourish the skin from the calf down to the ankle. It should be stressed that

elevation of the medial sural artery muscle or cutaneous perforator flaps could be affected by the expected anatomical variations. Therefore, it is recommended that the blood supply of the flap be assessed preoperatively using Doppler ultrasonography (27, 28). It is important to evaluate the donor sites and localize and identify the locations of the perforators. However, preoperative ultrasonography is not a definite technique for the indication of the flaps (28).

The current study showed that the majority of musculocutaneous perforators originated from very superficial medial sural artery branches, along the posterior aspect of the muscle closest to the deep fascia. The perforators divided to anastomose with each other in the inner surface of the deep fascia. These perforators aggregated in the distal half of the muscle and originated near the raphe separating the two heads. The subfascial course of the perforators after exiting the muscle may be tortuous. These characteristics contributed to the potential for a very long vascular pedicle averaging 15 cm (range: 10–17.5 cm). The length of the pedicle of the medial sural artery perforator flap will depend on the locations of the selected perforator; it might be able to obtain vascular pedicle lengths ranging from 15 cm to 21 cm. This might be helpful to the surgeon as it provides a great rotation arc to cover wide soft tissues defects. This is in agreement with the previous results reported by several authors (5, 6, 29).

It could be concluded that the medial sural artery perforator flaps depend on, at least, one of the perforator arteries with a mean diameter of 0.9 mm. This flap can be a free flap since the mean diameter of the medial sural artery is 3 ± 0.02 mm which is suitable for micro-anastomosis. The medial head of the gastrocnemius muscle gets blood supply from other sources than the medial perforator artery so it will not be affected after elevation of the flap.

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