Original Article

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Augmenting the Reliability and Versatility of Medial Sural Artery Perforator Flap

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Objectives: Medial sural artery perforator (MSAP) flap is considered as one of the best options for reconstructing defects that require thin and pliable coverage. However, higher failure rate precludes this flap from gaining consensus as the first choice. This study focuses on increasing the reliability of the flap and expanding its versatility to cover even middle-third-leg defects.

Methods: A retrospective study was performed to analyze patients who underwent medial sural artery perforator flap surgery between 2016 and 2019. The data collected included demographics, surgical indications, operative details, and outcomes. Descriptive statistics were used to assess outcomes.

Results: Out of the total 86 patients enrolled in the study, eight (9.4%) were excluded because no sizeable perforators were found. Seventy-eight patients underwent medial sural artery flap reconstruction with 63 free and 15 pedicled flaps. Four patients with middle-third leg defects were reconstructed with a "pedicled propeller MSAP flap". There were two flap failures, and the overall success rate was 97.4%.

Conclusions: MSAP flap is reliable for the reconstruction of small- to medium-sized defects that require thin skin coverage. Careful flap selection and proper techniques are key factors in increasing its reliability. Conversion to another flap is indicated if no sizable perforators can be found. The "pedicled propeller flap" technique allows successful coverage even in middle-third leg defects.

Key words: medial sural artery perforator flap, reliability, versatility

Introduction

Perforator flaps, after initially introduced by Koshima and Soeda in 1989, have flourished in the field of reconstructive surgery because they provide various tissues for wound coverage without sacrificing the muscles or major vessels and with minimal donor site morbidity.[1-4] In particular, the medial sural artery perforator (MSAP) flap has emerged as one of the best options, as it provides thin and supple skin coverage without compromising the function of the lower extremity. Also,

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it does not develop into inconspicuous scars, and there is no need for secondary debulking procedures.[5-8]

The failure rate of the medial sural artery flap is considered relatively high compared with other standard options, such as anterolateral thigh flaps or radial artery free flaps. Most studies attribute the failures to venous compromise, but a few others also reported arterial issues as possible causes.[6,9-11] Careful selection of the perforator and proper harvesting techniques are essential to avoid flap failures. This study was designed to highlight the surgical techniques and other important factors that ensure successful MSAP flap outcomes, based on the experience and modifications made in our practice over the years. We also attempted to expand MSAP flap versatility in covering the middle-third leg defects with a modified "pedicled propeller flap" technique.

Materials and Methods

Patients and data collection

This is a retrospective study of patients who underwent MSAP flap surgery between January 2016 and December 2019 at E-Da Hospital, Kaohsiung, Taiwan. Demographic data, surgical indications, and operative details were obtained after approval from the institutional review board (EMRP-111-036). Surgical outcomes and conversions to other flaps were also recorded.

Surgical technique

Pre-operative

The patients were placed in the supine position with abducted and flexed knees, without tourniquet use. A line was drawn from the mid-point of the popliteal crease to the medial malleolus. A hand-held 8 MHz Doppler probe (Hadeco, Inc., Japan) was used to map the potential location of the perforators along this line, approximately 8 cm from the popliteal crease. Surgeons were made aware that a sizeable perforator may not be present during exploration despite the presence of a strong Doppler signal. Flap harvesting was performed using a standard technique.[12] In our practice, the surgeons preferred to place a stack of folded surgical towels under the calf to bring the medial calf forward and medially (Fig. 1). A pinch test was performed to ensure that primary closure of the donor site was feasible.

Intra-operative

An exploratory incision was made on the anterior side, and subfascial dissection was performed to evaluate the perforators. Visible pulsation was the most important indicator of a reliable perforator. After the perforators were identified, their sizes were measured with a crack scale and categorized as sizeable (> 0.5 mm) or non-sizeable (< 0.5 mm) perforators, which was where they entered the deep fascia. A high-definition camera with magnification helped to accurately determine the size of the perforator (Fig. 2). Re-evaluation of perforator size was performed again after the flap was completely raised, since the venae comitantes of the perforator could be initially engorged during exploration. When the absence of pulsation or diminution of perforator size was

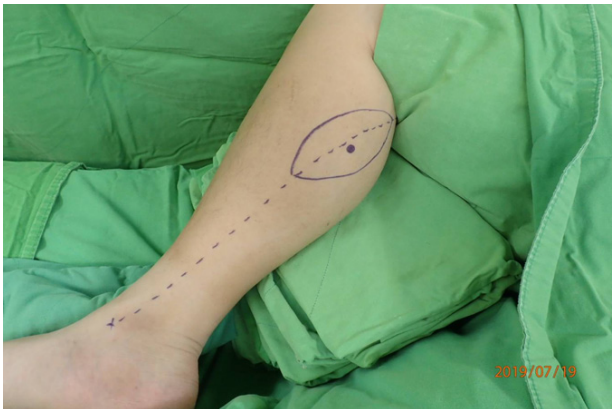

Fig. 1 Leg position for optimal flap dissection and flap marking. A stack of folded surgical towels are placed underneath the calf to bring the gastrocnemius muscle forward for easier dissection. Flap is designed on the axis of the points from the center of popliteal fossa to the tip of medial malleolus.

found despite the normal blood pressure of the patient, the flap was abandoned and converted to other options. The final flap was designed by completing the posterior incision after locating the suitable perforator. Perforator dissection was performed in a retrograde fashion until adequate vessel length and caliber were obtained. Flap inset and microanastomosis were then performed in a standard manner.

If a pedicled flap reconstruction was indicated, the conventional technique was adopted to cover upper leg defects, whereas a modified "pedicled propeller flap" technique was performed for middle leg defects. In this technique, the flap was rotated with double pivoting. The first pivot was similar to the conventional practice. The most distal perforator was selected and placed eccentrically on the distal part of the flap and then rotated towards the defect. The flap was then be rotated 180° in a propeller fashion to reach the middle third leg defect, making the second pivot (Fig. 3).

Results

A total of 86 patients were scheduled for MSAP flap reconstruction from January 2016 to December 2019. Sixty-nine males and 17 females were included, with a median age of 58 years (ranging 22 – 85 years).

The indications for the MSAP flaps were head and neck malignancies (61.5%), trauma (27.0%), infections (7.7%), and other causes (3.8%). Seventy-eight cases were included in this study, and eight cases were excluded due to the absence of sizeable perforators. Among them, 63 patients underwent free MSAP flaps, whereas the remaining 15 patients underwent pedicled MSAP flaps for lower-limb defects. Pedicled MSAP flaps were used for upper third leg defects in 11 patients (73.3%), while the "pedicled propeller flap" technique was performed for middle third defects in four patients.

The flap size ranged from 20 to 60 cm^2. There were 1 to 3 number of perforators found, with an average perforator size of 1 mm and an average artery size on the pedicle of 2 mm. Pedicle length ranged from 7 to 18 cm.

There were two total flap failures; one was due to the abnormal perforator anatomy of the obscure intramuscular course. The patient had a history of polio, possibly leading to muscle atrophy that caused the pedicle to become embedded in severe fibrosis. The remaining defect was covered with a radial artery-free flap. Another failure was iatrogenic stretch injury during perforator dissection, resulting in repetitive spasms and flap failure. One partial superficial loss was observed, but secondary healing was achieved without further surgical intervention. The overall success rate

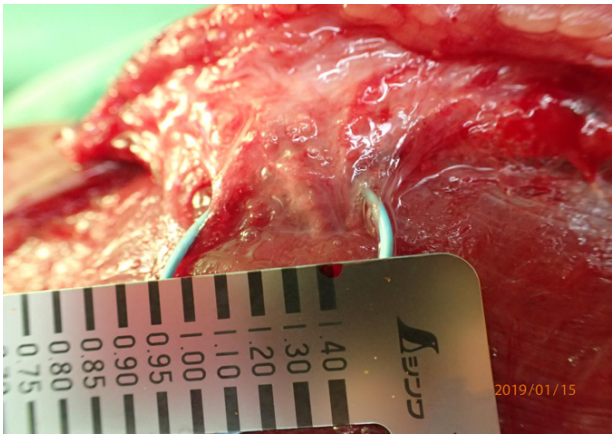

Fig. 2 Perforator size estimation using crack scale measuring more than 0.5 mm. Discrete pulsation of the perforator and size more than 0.5 mm is considered to be reliable and sizeable perforators.

Fig. 3 Demonstration of the double pivot medial sural artery perforator flap rotation.

the MSAP flap was 97.4%. Primary closure of the donor sites was achieved in most cases, except for two that required split-thickness skin grafts.

Discussion

Since the introduction of MSAP flaps over two decades ago, numerous studies have been dedicated to understanding the anatomy and improving success rates. Hallock first mentioned how the musculocutaneous perforators came from the gastrocnemius muscle with ten fresh cadaveric cases in 2001.[13] Cavadas et al. further described these perforator locations in five free and one pedicled MSAP flap cases.[14] A previous study by Kim et al. provided a detailed exact perforator location at around 8 cm from the midpoint of the popliteal crease towards the medial malleolus and within the distal half circle drawn with a radius of 2 cm.[11] Following this, MSAP flap has enabled versatility in providing thin and pliable skin, a long and reliable vascular pedicle, no need of secondary debulking and minimal donor site morbidity, with superiority to its counterpart radial artery forearm flaps.[6,10,15-19] However, the flap failure rate of 3.4% to 22.2% in MSAP flaps is still considered higher compared to the standard anterolateral thigh free flaps or radial forearm free flaps.[6,9] While most studies attribute this to venous issues,[20,21] others also suggested arterial thrombosis as a possible cause.[5,22] The ultimate solution to improve MSAP flap success rates remains a challenge in current practice.

In this study, several factors that may increase MSAP flap success were discussed. First, the modification of the standard positioning should be made with several folded surgical towels kept under the calf to push it anteriorly and medially as much as possible. This provides the benefits of making the pedicle more superficial and making the dissection easier.[12] Without the towels, the hanging calf muscle would make the dissection process more tedious. Second, the authors preferred the Doppler device for locating the site of potential perforators instead of other modalities, such as computed tomography angiogram, color Doppler, or endoscopy, which are more expensive, time-consuming, involve radiation exposure, and may not be available in all centers. However, it should be noted that the intensity of Doppler signals does not correlate with the size of the perforators. Surgeons should be prepared for conversion if the exploratory incision reveals a non-sizeable perforator despite the high intensity seen during the Doppler examination. Flap designs should also be modified to achieve an adequate pedicle length based on the location of the perforators.

Moreover, the authors recommended avoiding the use of a tourniquet for flap harvest, as it could alter the actual perforator caliber. In addition, tourniquet inflation prevents surgeons from monitoring the discrete pulsations of the perforator throughout the procedure, which could potentially overlook pedicle injuries, minor leaks, or stretch injuries during flap harvest. Many studies have shown that flap harvesting without tourniquet is easier and safer,[6,15,18] while some surgeons still prefer to use a tourniquet.[11,16,23]

The best method for perforator localization and assessment is direct visualization. Monitoring pulsation from the perforators throughout the procedure is the most critical part of flap harvests. The absence of pulsation may indicate injury to the perforator, spasm due to stretching, or hypotension, which should all be managed before harvesting. Finally, most MSAP flaps can achieve primary closure of the donor site. A pinch test is crucial for this purpose, which allows for minimal donor site morbidity, making it superior to that of radial forearm flaps (Fig. 4).

The failure rate of MSAP flaps in this study was only 2.6% in a total of 78 cases, which is comparable to other standard flap

options, as shown in Table 1. We achieved the lowest complication rate, with the largest series found in the current literature. The authors strongly recommend that surgeons convert to other flap choices if no sizeable perforators are found during exploration, as this avoids potential delayed flap loss after reconstruction. Kao et al. found three non-sizeable perforators (10.3%) in 29 MSAP flaps and had to abandon the flap harvests in the series.[6] Choi et al. also found two cases of non-sizeable perforators (10%) in 20 patients, leading to consequent flap failures.[21] The incidence of lacking sizeable perforators in these studies was consistent with the 9.4% found in our series. However, some studies claim that at least one sizeable perforator will always be present.[16,23]

The "pedicled" MSAP flap is a suitable option for reconstructing defects of knee and upper thirds of leg. However, the MSAP flap can reach the middle or even the lower third of the leg using an innovative "pedicled propeller flap" technique. This double-pivoting design incorporates the idea of transferring the skin flap to two separate pivot points, thereby increasing the movement of the flap beyond its normal reach. A distal perforator was selected and designed eccentrically on the distal part of the flap. In this way, the pedicled MSAP flap gained a pedicle length of 8 – 10 cm from the perforator to the proximal end of the flap. The flap was then rotated towards the defect. Further rotation of 180° in a propeller fashion, as the second pivot, reached the defects at the junction of the middle third or even the lower third leg. The main benefit of this technique

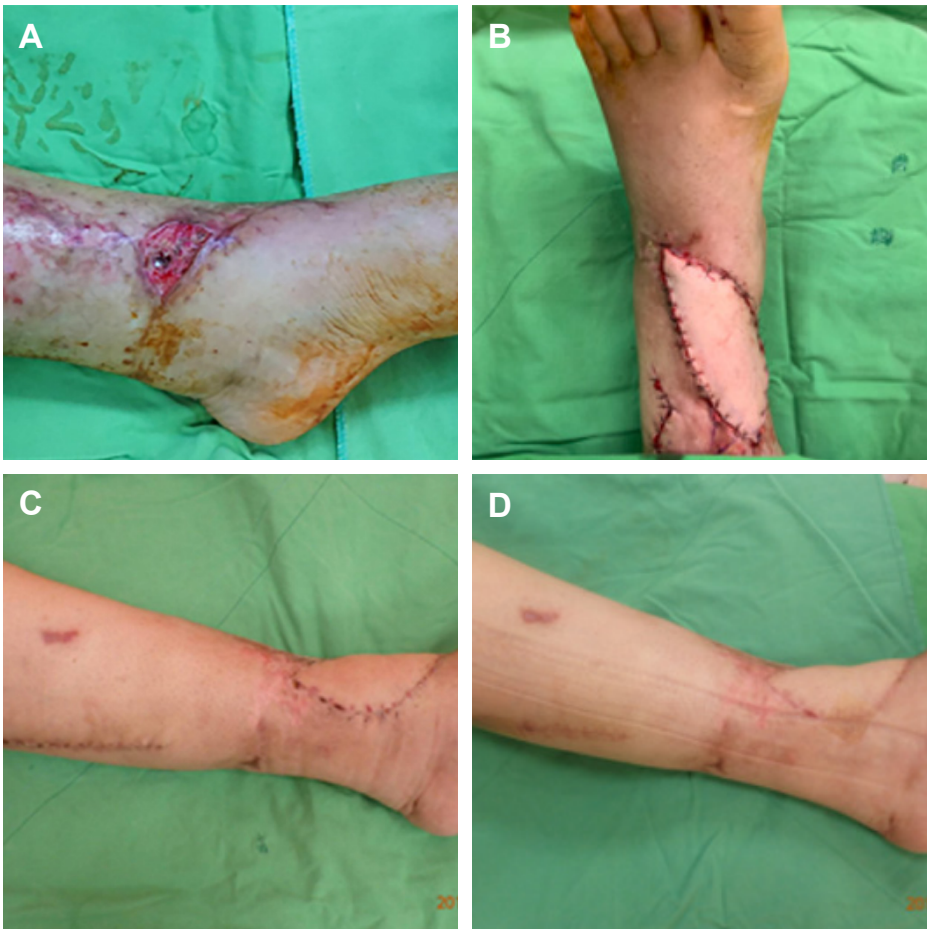

Fig. 4 Free medial sural artery perforator (MSAP) flap with primary closure of the donor site. (A) Left ankle defect with exposed hardware. (B) Thin and pliable coverage with free MSAP flap. (C, D) Early and late post-operative status showing well-healed flap and good donor site. Proper pinch test is necessary to achieve minimal donor site morbidity.

Table 1. List of the medial sural artery perforator (MSAP) flap outcomes in current literature.

	Flap types	Total cases	Total failure	Cause	Partial failure	Cause	Failure rate
Kao et al.[6] (2010)	Free MSAP flaps	26	1	Venous			3.8%
Wang et al.[10] (2013)	Free MSAP flaps	34			5	Venous	14.7%
He et al.[22] (2014)	Free MSAP flaps	9	1	Arterial			11.1%
Toyserkani et al.[9] (2015)	Free MSAP flaps	9	2	Venous			22.2%
Our series	63 free and 15 pedicled MSAP flaps	78	2	Arterial	1	Perforator non-sizeable	2.6%

is that the flap remains in the same angiosome as the medial sural artery, thus minimizing the risk of flap failure. If the flap is unable to reach the lower defects, conversion to free flap transfer can be managed easily. Furthermore, other studies suggested that the use of chimeric MSAP flap could further increase versatility in the reconstruction of complex head and neck or extremity defects.[24-26] In our series, however, no cases of chimeric MSAP flap were performed since we opted for conventional anterolateral thigh flaps in such complex defects instead.

Conclusion

The MSAP flap can serve as an effective tool for the reconstruction of small- to medium-sized defects that require thin and pliable coverage, with minimal donor-site morbidity and no need for secondary debulking procedures. Avoiding the use of tourniquets and employing a stack of towels during pedicle dissection made the procedure easier and safer. However, absence of a sizeable perforator warrants conversion to other flap options. The "pedicled propeller MSAP flap" technique allows successful coverage of even the middle-third defects.

Author Contributions

Study Design: Hsiang-Shun Shih and Chien-Chung Chen; Data Collection: Jill Chen; Statistical Analysis: Jill Chen; Data Interpretation: Hsiang-Shun Shih, Jill Chen and Chien-Chung Chen; Manuscript Preparation: Jill Chen; Literature Search: Jill Chen and Chien-Chung Chen. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of E-Da Hospital (EMRP-111-036).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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