

Perforator Propeller Flaps for the Coverage of Middle and Distal Leg Soft-tissue Defects

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Background: Local propeller flaps preserve the main vascular arteries of the lower extremity and muscle function, avoiding the need for a microsurgical anastomosis and the benefit of providing a “like with like” coverage. Our goal in this study was to demonstrate the versatility, safety, and complications of the local propeller flaps for lower extremity reconstruction.

Methods: We present a series of 28 patients in whom we used local propeller flaps to restore small-to-medium soft-tissue defects of the lower limb in different hospitals of Managua, Nicaragua.

Results: Flap average dimensions were of 48 cm². Flap rotation was performed in 180 degrees in 85% of the cases. The propeller flaps were based on a single perforator, from the posterior tibial artery in 50%, anterior tibial artery in 39.3%, and peroneal artery in 10.7% of the cases. Complications occurred in 14% of the propeller flaps performed, with 3 partial necrosis of less than 15% of the flap transposed. Complications of the patients occurred in both sex groups; however, for the female group, there was a 75% of complications with a tendency toward statistical significance of $P = 0.038$. Donor site of the flap was closed primarily in 85.7% (24) of the cases.

Conclusions: In our opinion, the availability and safety of local propeller flaps, justifies its use in cases where microsurgical techniques are not an option for the reconstruction of the middle and distal extremity, in small-to-medium defects of soft-tissue coverage of the lower limb. (*Plast Reconstr Surg Glob Open* 2018;6:e1759; doi: 10.1097/GOX.0000000000001759; Published online 2 May 2018.)

INTRODUCTION

Soft-tissue coverage of the middle and distal third of the leg represents a problem due to the inherent characteristics of the lower limb, paucity of soft tissues, bone prominences, diameter, and biomechanics. A simple defect can turn into a major challenge, for which several therapeutic options have been described.¹⁻⁴

The approach for soft-tissue coverage is based on the wound size and its location, contamination, types of tissues involved, and functional requirements. Additional factors include the area and extension of the zone of injury, the length and diameter of the pedicle if a free flap is performed, donor-site morbidity, bone fixation type, and aesthetic outcome.^{5,6}

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Local options for reconstruction and coverage of defects in the distal third of the leg are limited. The cross-legged flap popularized by Stark⁷ was used in his time with much popularity; however, today it is performed very little because of its high morbidity of the donor site and the necessary immobilization of both lower extremities.

Although free microsurgical flaps have been the first choice for reconstructive procedures in the leg, there are some local flaps that may be of choice in some cases, providing adequate coverage of cutaneous defects.

As the use of free flaps has been broadly practiced, the innovation and technical refinement has allowed the evolution of flaps applied to the lower extremity, including perforator-based flaps or freestyle flaps.⁸

The availability and better understanding of the vascular axes anatomy of the leg, its interrelation with muscle groups, and lower morbidity have motivated the use of pedicle perforator flaps. The techniques described in the dissection of perforator flaps from anatomical studies have provided a variety in the design of pedicle flaps.^{9,10}

The perforator flaps are very attractive as a resource, because it has diversity with more than 500 perforating

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vessels. In the upper limb, there are an average of 48 perforators from 15 vascular territories, and in the lower limb, we can find 93 from 21 territories.¹¹ The perforator propeller flaps are versatile in our therapeutic armament, initially described by Hyakusoku et al.,¹² to define a method in which a flap with a length exceeding its width is rotated 90 degrees on its central axis based on a central subcutaneous pedicle. It was technically refined by Teo¹³ with a higher degree of rotation by completely releasing the perforating vessel as a single pedicle, which led to its subsequent definition and classification.¹⁴

The application of the pedicle perforator flaps and its propeller variant for leg reconstruction has many advantages. The main artery and underlying muscle are preserved, and the need to perform a microsurgical anastomosis is avoided. Dissection of the flap is relatively fast, and it has the thickness, texture, and pigmentation of the site that has been lost, replacing with the “like with like” principle¹⁵ (Fig. 1).

In the present study, the main goal was to justify the use of local perforator propeller flaps as a surgical alternative for the coverage of soft-tissue defects of small-medium size in the lower and middle third of the leg, with low morbidity of the donor site and low complications, being reproducible in different hospital centers.

MATERIALS AND METHODS

A retrospective study was made between June 2012 and June 2017 of the perforator propeller flaps done by the authors in different hospitals of Managua, Nicaragua, in patients with soft-tissue defects of the mid-distal third of the

leg. Clinical records of the patients were reviewed with the recollection of the patients’ personal data, diagnosis, perforator flap used, complications, and postoperative results.

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (Institutional and National Autonomous University of Nicaragua) and the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from the patients included in this study.

The sample consisted of 28 patients, in whom a total of 28 flaps were performed for the reconstruction of defects of the middle and distal third of the leg. Patients with concomitant involvement of the proximal third of the leg were not included in the sample.

The information obtained was processed in SPSS 15.0 comprehensive system for analyzing data, for the description of categorical variables, using absolute and relative frequencies [n (%)] and for comparison chi-square test; numerical variables were described regardless of whether they showed normal distribution or not, with median and SD ($M \pm DE$) or with a median and interquartile range [Md (25–75)] and compared with Student’s *t* test or Mann-Whitney *U* test as corresponded. It was considered statistically significant if $P < 0.05$. Simple or complex tables were produced for crossing variables and graphs as appropriate.

The process of selecting the vascular axis of the leg (anterior tibial artery, peroneal or posterior tibial artery), on which to base the perforating vessel of the propeller flap, was done by preoperative auscultation with a Nicolet handheld Doppler with a 8-Mhz probe, with an angulation

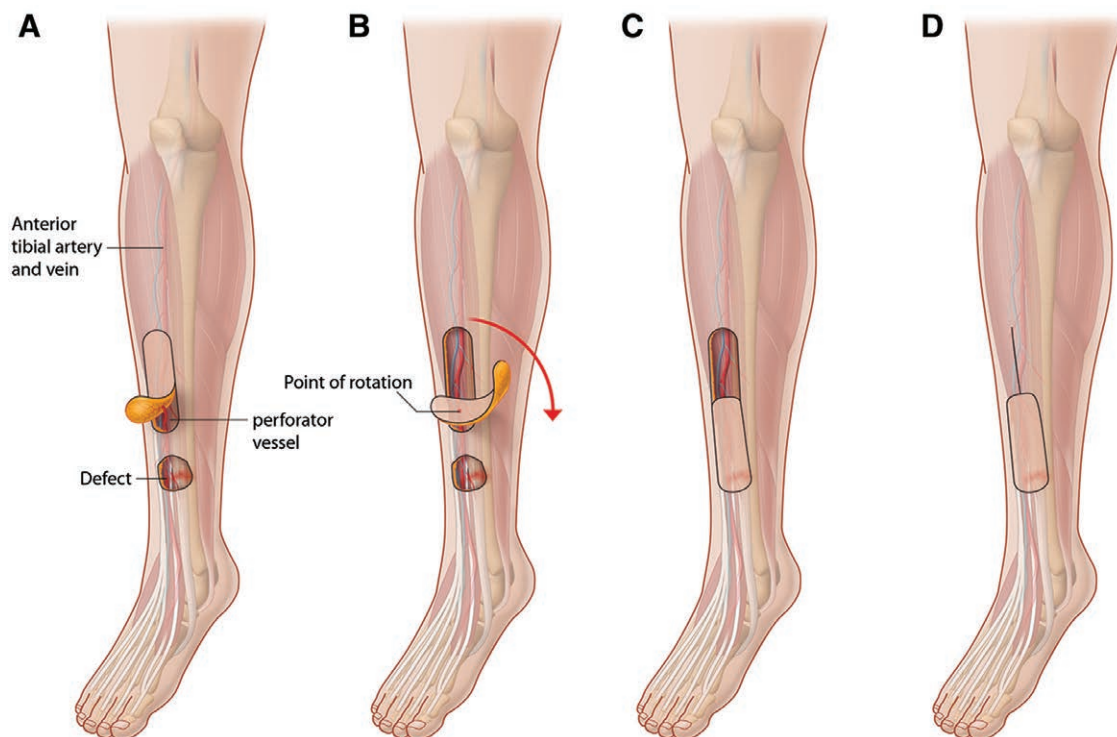


Fig. 1. A, Leg distal third cutaneous defect. B, Flap dissection based in perforator vessel. C, Rotation of the flap 180-degrees over the defect. D, Primary closure of donor site.

of the probe of approximately 45 degrees to the skin surface, according to the location of the defect to be covered. A provisional flap design can be drawn as follows, with the perforator as the pivot point of the flap, as it has been described previously.¹³ First, the distance between the perforator and the distal edge of the defect is measured. This value is then transposed proximally along the axis of the main source vessel, again measured from the perforator, and 1 cm is added. This value forms the proximal limit of the flap. Next, the width of the proximal flap needed to cover the defect is determined by measuring the width of the defect. This value is then used to determine the proximal flap width, adding 0.5 cm to allow for flap contraction and to facilitate its inset without tension. The lateral dimensions are equidistant to ensure that when the flap is eventually rotated around to fill the defect, there is no excessive sideways traction on the perforator during wound closure.

We performed a first longitudinal skin incision on 1 of the margins of the flap to observe the perforator localized preoperatively with the handheld Doppler.

The distance of the perforator from the proximal edge of the defect determined the length of the minor paddle used to cover or partially cover the donor site. If direct closure of the donor site was not achievable, a skin graft was used to close the residual defect.

The elevation of the flap was performed with the patient in supine position, occluding the flow of the leg for 1 minute with digital compression on the popliteal artery, without performing exsanguination of the extremity with an elastic bandage, and at the thigh a controlled tourniquet was placed with a continuous pressure of 250 mm Hg. The flap is dissected, under 2.5× magnification, subfascially or suprafascially, with an axial orientation with respect to the affected limb, always releasing the perforating vessels of all the muscular branches and adhesions, with dissection of the pedicle at least 2 cm as it has been recommended¹⁶ (Fig. 2). Once the pedicle has been dissected, the ischemia is released to assess the irrigation of the flap and before its transposition, it is left in its native orientation for 10 minutes to then corroborate the adequate capillary filling of the borders of the flap. In case of

finding more than 1 vessel, a microclamp is placed on 1 of the vessels to base the flap in only 1 perforator to allow a rotation of up to 180 degrees (Fig. 3).

The area of extension in cm² of the flap transposed, degrees of rotation of the flap, its complications, and the ability to perform a primary closure of the donor site were all evaluated.

RESULTS

In the period of the study, 28 patients were treated in which we perform a total of 28 flaps for the coverage of defects localized at the middle and distal third of the leg, caused by trauma, with a ranging age from 19 to 65 years (mean, 32 years), with an interquartile range of 25 and 42, being the male sex the most frequent in 21 cases (75%). Among the patients, 3 had comorbidities of diabetes mellitus and hypertension (Table 1).

Among the affected areas that required coverage of soft tissues of the leg, in order of frequency, the middle third represented 18 cases (64.3), and in the distal third 10 cases (35.7%).

Flap dimensions ranged from 12 to 156 cm², with an average size of 50 cm² with interquartile range of 30 and 60 cm².

The flap rotation was 180 degrees in 23 cases (82%), 140 degrees in 3 cases (11%), and 160 degrees in 2 cases (7%).

The flaps were based on a single perforating vessel of the posterior tibial artery in 14 cases (50%) of the cases; on the anterior tibial artery in 11 cases (39.3%), and in 3 cases (10.7%), the peroneal artery was chosen.

Complications were present in 14% of the flaps. These included 3 partial necrosis less than a 15% of the flap, which were all based in the posterior tibial artery, and 1 case with an epidermolysis of the flap based in the anterior tibial artery without a statistical difference with respect to the artery used to base the flap. Female patients presented complications in 42.9% with a tendency toward statistical significance ($P = 0038$) according to sex.

Primary closure of the donor site was performed in 24 cases (85.7) of which 16.7% (4) had complications. The registered complications of partial necrosis and epi-

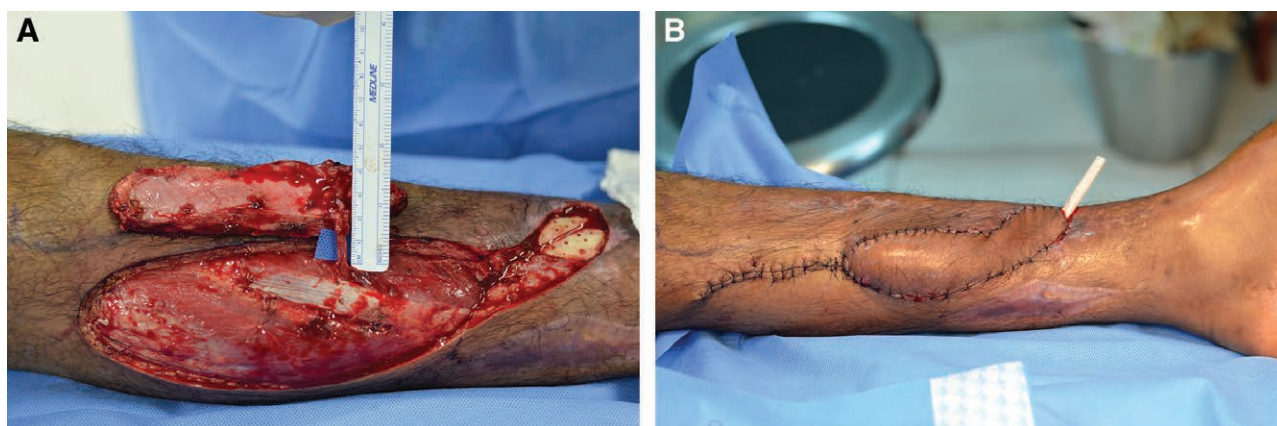


Fig. 2. Case 15. Male 35-year-old patient. A, Posterior tibial artery perforator flap islanded on a single perforator with a 2.5-cm pedicle, for the coverage of distal third tibial open fracture. B, The propeller flap is rotated through 180 degrees, and the donor site is closed directly.

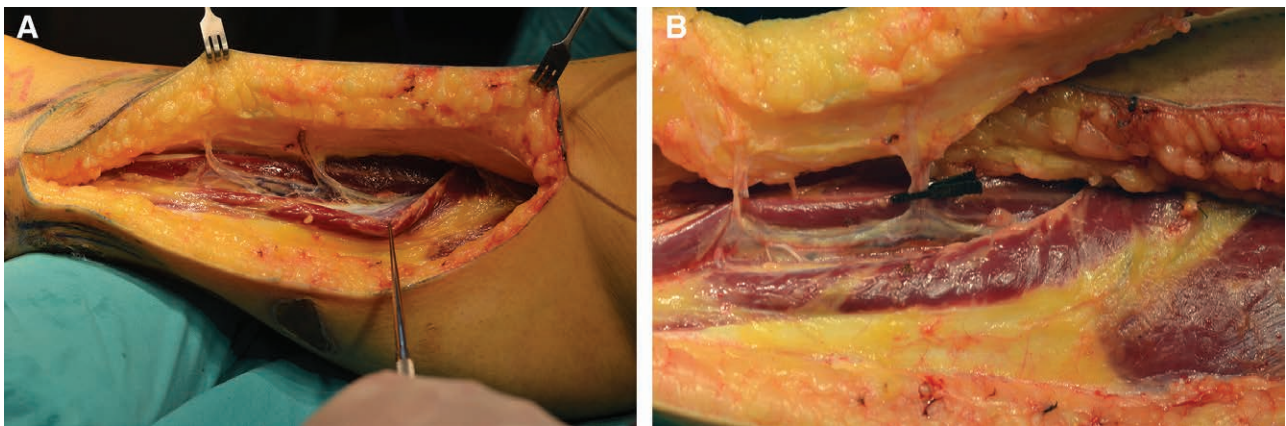


Fig. 3. Case 14. Female 33-year-old patient. A, Dissection of propeller flap, with 2 perforators of the posterior tibial artery. B, Transoperative assessment of perfusion of the perforator, placing a microclamp on 1 of the vessels to base of the flap in only 1 perforator and allow a rotation of 180 degrees.

Table 1. Summary of All Perforator Propeller Flaps In this Series

Case	Age	Sex	Comorbidities	Defect Location	Etiology	Flap Size (cm ²)	Artery	Angle of Rotation (degrees)	No. Perforators	Donor-site Closure	Complications
1	26	M	None	Middle	Trauma	24	ATA	180	1	Primary	None
2	43	F	None	Middle	Trauma	60	ATA	140	1	Primary	None
3	31	M	None	Middle	Trauma	108	PTA	180	1	Skin graft	None
4	22	M	None	Middle	Trauma	45	PTA	180	1	Primary	None
5	61	F	DM	Middle	Trauma	12	ATA	180	1	Primary	None
6	47	M	None	Middle	Trauma	28	PTA	180	1	Primary	None
7	58	F	HTN	Distal	Trauma	40	PTA	180	1	Primary	Partial flap necrosis
8	33	M	None	Middle	Trauma	18	ATA	160	1	Primary	None
9	26	M	None	Middle	Trauma	60	PTA	180	1	Primary	None
10	19	M	None	Middle	Trauma	50	PTA	160	1	Primary	None
11	62	F	None	Distal	Trauma	48	ATA	180	1	Primary	Epidermolysis
12	36	M	None	Distal	Trauma	36	PA	180	1	Primary	None
13	20	M	None	Middle	Trauma	24	ATA	180	1	Primary	None
14	33	F	None	Middle	Trauma	156	PTA	180	1	Primary	Partial flap necrosis
15	35	M	None	Distal	Trauma	60	PTA	180	1	Primary	None
16	41	M	None	Middle	Trauma	48	ATA	140	1	Primary	None
17	30	F	None	Middle	Trauma	30	PTA	180	1	Primary	None
18	27	M	None	Distal	Trauma	56	PA	180	1	Primary	None
19	26	M	None	Distal	Trauma	45	PTA	180	1	Skin graft	None
20	19	M	None	Middle	Trauma	30	ATA	180	1	Primary	None
21	23	M	None	Middle	Trauma	56	PTA	180	1	Primary	None
22	41	M	None	Distal	Trauma	36	PTA	180	1	Primary	None
23	33	M	None	Distal	Trauma	60	PA	180	1	Skin graft	None
24	26	M	None	Middle	Trauma	64	PTA	180	1	Primary	None
25	21	M	None	Middle	Trauma	24	ATA	140	1	Primary	None
26	43	M	None	Distal	Trauma	60	PTA	180	1	Primary	Partial flap necrosis
27	65	F	DM, HTN	Distal	Trauma	105	ATA	180	1	Skin graft	None
28	25	M	None	Middle	Trauma	18	ATA	180	1	Primary	None

DM, diabetes mellitus; F, female; M, male; HTN, hypertension; ATA, anterior tibial artery; PA, peroneal artery; PTA, posterior tibial artery.

dermolysis of the flaps were among the group in which the primary closure of the donor site was treated with a partial thickness skin graft, which had a 100% integration (Fig. 4).

DISCUSSION

Propeller perforator flaps are a reliable option for a stable coverage of mid-distal third defects of the leg, where the design of the flap is based on perforators, in relation to the localization and size of the defect.

Traditional reconstructive tools for the lower limb suggests local flaps for coverage in the thigh and proximal thirds of the leg areas as choice, while microvascular flaps are most useful for the distal third of the leg and foot, due to the paucity of local tissues to base locoregional flaps.^{5,7,14} However, the use of fasciocutaneous local flaps, basing its vascularity on the fascial plexus and not necessarily on the identification of a specific cutaneous vessel in the 1980s by Pontén¹ and Hallock², opened new gates to the reconstruction of the soft tissues of the lower extrem-



Fig. 4. Case 19. Male 26-year-old patient. A, Distal third cutaneous defect, with open fracture of the calcaneus. B, Posterior tibial artery perforator flap of 45 cm², and 180 degrees transposition. C, Postoperative 6-month result, donor-site defect resurfaced with a split-thickness skin graft.

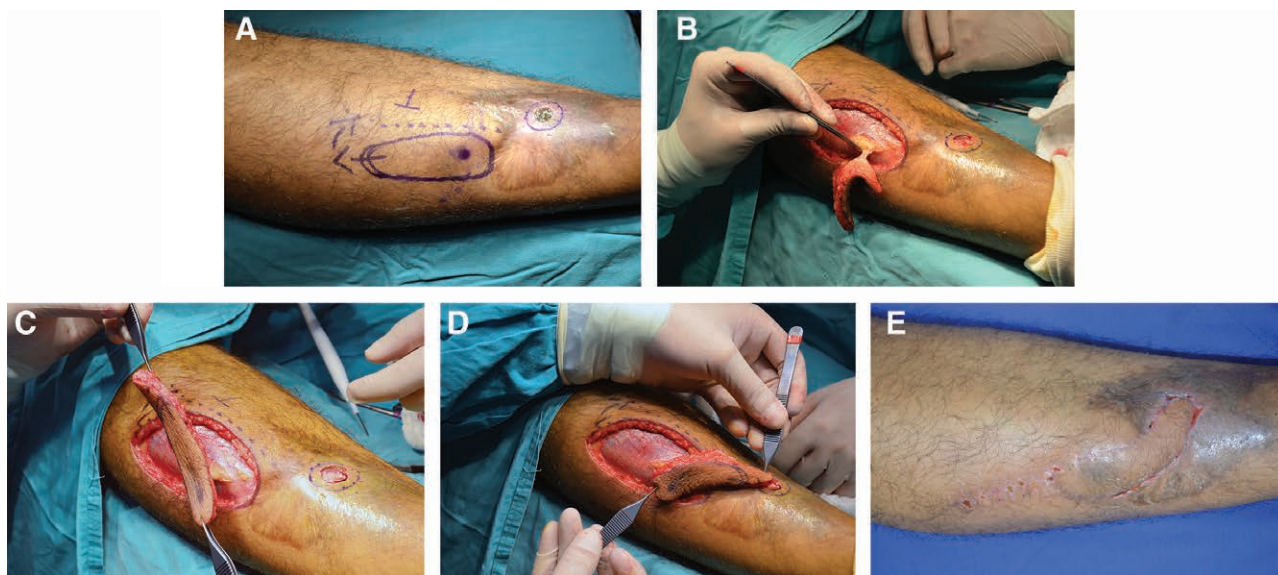


Fig. 5. Case 8. Male 33-year-old patient. A, Middle third posttraumatic tibial exposure of the right leg. B, Anterior tibial artery perforator propeller flap. C, Flap transposed with 160 degrees of rotation to the defect. D, Suprafascial dissection, with no tension of the flap upon transposition. E, Postoperative result at 2 weeks.

ity. Nakajima et al.¹⁰ subsequently demonstrated that this fascial plexus was nourished by deep fascial perforating vessels from the underlying main vessels of the limb.

Refinements for the application of flaps has led to the development of perforator flaps. The perforator flaps have evolved from musculocutaneous and fasciocutaneous to nonutilization of muscle or fascia as irrigation transporters, from the major vessels of the lower extremity, and bearing this in mind has driven our interest in using these flaps with the benefit of providing a similar coverage to neighboring tissues and favoring a primary closure, in small size defects. The flaps made had average dimensions of 48 cm,² which are close to the concept proposed by Morris et al.¹¹, that a perforating vessel of 0.7 cm provides an approximate irrigation of 47 cm² and may even have a broader extension as described by Gir et al.¹⁷ of 67.1 cm.^{2,18}

The ability to rotate the propeller perforator flaps up to 180 degrees, which we performed in 82% of the cases, makes it extremely versatile to reconstruct defects of the

middle and distal third of the leg, as has been reported in other series.^{12,14,17,19}

In our study, we found 4 complications (14%), 3 partial necrosis, and a superficial epidermolysis, which is lower than that reported in the meta-analysis performed by Gir et al.¹⁷, reporting complications of 25.8%, with partial necrosis being the more common in 11.3%. The percentage of complications is similar to that of free flaps, 16–38%, and in terms of total necrosis is lower, because in free flaps it is 4–19%,^{4,5,8} compared with 1.1% in propeller perforating flaps.¹⁷

Another possible described factor that may be associated with partial necrosis of the flaps is the inclusion of scar tissue in the flap design, or excessive tension in the closure of the defect.¹³ This is why sometimes recommended the laminar skin graft for the donor site of the flap, which will always become a more common option as the defect is more distal, due to the lack of displacement of the tissues in the leg, as we did in 14.3% of the cases.

Although no differences have been found in the relationship of flap complications and sex,^{16,17} in the present study it was found that in the female sex there is a certain association with complications, which may be related to hormonal effect on the venous system, although the sample size of female patients was low.²⁰

A useful tool in the planning of perforator flaps is the manual unidirectional acoustic Doppler,^{21,22} in all patients preoperatively as a guide for vessel location and flap design. In our practice, we used a handheld Doppler with a 8 Mhz probe. Khan and Miller²² use a handheld Doppler with 8–10 MHz probes, reporting a sensitivity of 90% with a confidence interval of up to 95%, positive predictive value of 84% with a reliability interval of 74–91%. The transducer is angled approximately 45 degrees to the surface of the skin, because performing it parallel to the skin may increase the possibility than an axial vessel; our source vessel will be selected instead of a perforator.²²

The transoperative confirmation of the position of the perforators allows redesigning the flap, with few modifications, and basing them according to its location in a perforator of the main vessels of the limb,^{9,13,15} so that on 3 occasions we modified the original design, extending proximally to achieve adequate coverage.

Perforator propeller flaps preserve the major vascular axes of the limb and underlying muscle, avoiding the need for a microsurgical anastomosis and the benefit of providing a tissue-like covering. These flaps have a consistent and predictable blood supply, at least 1 perforating vessel greater than 0.5 mm, a pedicle long enough for the required transposition, and ability to close the donor site in a primary fashion¹³ (Fig. 5).

The advantages of the propeller perforator flap include lower morbidity of the donor site, primary closure in most cases, versatility in flap design, and muscle preservation with less functional deficit of the leg.

Its disadvantages are the need to perform a meticulous dissection to isolate the perforating vessels, variability in the position and size of the perforating vessels, and ease of being able to damage the vessels.

CONCLUSIONS

Based on the results obtained in our study, we consider that perforator propeller flaps are ideal in reconstructing small-medium defects of the middle and distal third of the leg, being safe, easy to perform, providing similar tissue in texture and thickness of damaged tissues, with low donor-site morbidity.

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