Our Experience in Lower Limb Reconstruction With Perforator Flaps

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Abstract: The application of Taylor's concept about body angiosomes, referred to tissue transfers, has meant that the development of the perforator flaps and muscles is no longer needed as a carrier of skin flap vascularity. In this paper, we revise 59 lower limb reconstructions with local and free perforator flaps performed in the last 5 years, and a basic reconstructive algorithm is also suggested to help with the management of the lower limb soft tissue reconstruction with perforator flaps.

The advantages of the perforator flaps are (1) muscles and their function are preserved; (2) the main vascular trunks are spared; (3) it is possible to make a more specific reconstruction, replacing "like with like" (even performing compound or chimeric flaps); (4) the donor site can often be closed primarily; (5) the general morbidity is reduced; (6) a better cosmetic result can be achieved.

Key Words: perforator flap, propeller, lower limb reconstruction

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The lower limb has always been known for poor wound healing and, since the first steps of the plastic surgery, as a scarce source of flaps. Before the introduction of microsurgery, surgeons had few reconstructive options such as local flaps (random skin flaps, muscular or musculocutaneous flaps) and performed cross-legs, immobilizing the limbs for weeks, to transfer a large amount of skin.[1]

With the introduction of microsurgery, tissue transfers have become one of the main reconstructive options for the lower limb, above all in those areas where there is a scarce availability of local flaps. In the distal third of the leg or in orthopedic problems, a muscular local flap could worsen a significant muscular function.

With the development of perforator flaps,[2,3] newer and more reliable flaps have become available for lower limb reconstruction. Referring to Taylor and Palmer's[4] and Taylor's[5] concept of angiosomes, almost all the tissues of an angiosome can be harvested on 1 adequate perforator vessel. The perforator pedicles of these flaps originate from one of the main vessels of the lower extremity, course through 1 or more muscles or one of the intermuscular septa up to the fascia, and ramify at a suprafascial level in the subcutaneous fat.

Perforator flaps can be used as local or free flaps. Whenever the defect size and the vascular condition of the neighboring tissues allow a reconstruction with local perforator flaps, the surgical intervention and the morbidity ought to be limited to a single body region. The early designs of the local flaps along the vertical axis of the leg or the thigh with a proximal pedicle have been modified by the use of perforator flaps. To transfer a larger amount of tissue rather than random local flaps, a surgeon can carefully isolate the whole course of a perforator vessel and effectively rotate through 180°, like a "propeller," almost all the tissues of an angiosome or more (descending genicular,[6] posterior tibial,[7,8] peroneal[9]). Tissue transfer through a rotation like a propeller was firstly described by Hyakusoku et al[10] in 1991 to release scar contractures of the upper limb by subcutaneous pedicled flaps rotated through 90°. The propeller method applied to perforator flaps becomes a microsurgical technique where the dissection of the pedicle is carried out with binocular magnifying glasses but a microvascular anastomosis is not needed.

When it is not possible to choose a local perforator flap, limiting the morbidity to a single region of the body, free perforator tissue transfers from other regions can be performed. Generally, we use anterolateral thigh (ALT)[11] or thoracodorsal artery perforator (TAP)[12] perforator free flaps. In composite-tissue loss, it is possible to harvest a compound flap, for example, by inclusion of the fascia lata in the ALT to reconstruct a tendon of one of the main joints, or a "chimeric" flap,[13] where each component of the flap can be separately placed because each is supplied by a distinct branch of the common source vessel.

This review, derived from our experience in reconstruction of oncologic and orthopaedic lower limb defects, could suggest the use of local or free perforator tissue transfers in lower limb soft tissue reconstruction and further propose an easy algorithm regarding which would be the most effective for patient rehabilitation.

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MATERIALS AND METHODS

From December 2000 to June 2005, 59 perforator flaps were performed in 35 male and 24 female patients. The mean age was 43 years. Five patients usually smoked more than 20 cig/d. Three patients had type II diabetes. Follow-up time ranged from 5 months to 4 years.

Our series was as follows (Table 1): 35 local perforator flaps, transferred with the propeller method, were performed for soft tissue reconstructions after oncologic resections, traumas, and unstable scars; 19 patients underwent an ALTF for chronic osteomyelitis and oncologic resections; 5 TAPF were used to reconstruct oncologic resections and chronic osteomyelitis.

Among the 59 perforator flaps performed, 2 chimeric flaps and 1 compound flap were carried out. One patient had a bimalleolar fracture of the left inferior limb, with Achilles tendon and bone exposed. A chimeric ALTF with vastus lateralis was performed. Another patient underwent a "chimeric" TAP with latissimus dorsi, used as a razor flap,[14] for chronic osteomyelitis after oncologic and orthopedic surgery. A compound flap was carried out in a patient with an infected rupture of the rotulean tendon after a prosthetic implant and an ALTF flap with vascularized fascia lata were performed.

Patients with chronic osteomyelitis, prior to flap coverage, were additionally treated with preoperative and postoperative culture-specific antibiotics, and an intraoperative radical debridement was performed until only healthy tissue remained in the wound bed. Infected and devitalized bone was removed until active bone bleeding was observed.

Planning a perforator flap, the location of the perforator vessel was defined with the assistance of Doppler ultrasound, but its use is only orientative because of some false positives.[15] It is not possible to study the size and the course of the perforator vessel with Doppler. The right technique to find a suitable perforator is intraoperative assessment carried out with an exploratory incision on one of the flap borders.

In posttraumatic situations, in elderly patients with vascular disease, in uncertain vascular viability, or in free tissue transfers, preoperative arteriography could be useful in determining the degree of patency of the main vessels.

In the last patient, a new technology of perforator mapping was used by the aid of multidetector row-computed tomography (Fig. 1). This technology proved to be very effective and useful in planning perforator abdominal flaps.[16,17] Unfortunately, we cannot yet show the results of its clinical application in preoperative mapping of perforator flaps in lower limb reconstruction because we have not yet a large series.

Our surgical strategy for harvesting a perforator flap is as follows: we perform an exploratory incision of a border of the flap, through the skin, subcutaneous tissue, and deep fascia. With a subfascial approach, the flap is partially raised to identify the location and the size of the perforators. When a perforator vessel of adequate size is identified, we separate it back to the source vessel. If the perforator previously identified by Doppler is not adequate, we look for another suitable perforator vessel and adapt the flap design.[18] Only with the perforator isolated and dissected are the remaining

TABLE 1. Fifty-Nine Local and Free Perforator Flaps Were Performed for Soft Tissue Lower Limb Reconstruction in the Period Between December 2000 and June 2005

	No. Flaps	Sex	Mean Age
Local perforator flaps (propeller method)			
Oncologic surgery	9	2F, 7M	56
Traumas	14	6F, 8M	47
Unstable scars	12	9F, 3M	33
ALTF			
Chronic osteomyelitis	7	2F, 5M	41
Oncologic surgery	10	4F, 6M	52
TAPF			
Chronic osteomyelitis	1	1F	43
Oncologic surgery	3	3M	46
Chimeric and compound flaps			
Traumas	1 ALTF with vastus lateralis	1M	42
Chronic osteomyelitis			
After orthopedic surgery	1 ALTF with fascia lata	1M	53
After oncologic and orthopedic surgery	1 TAPF with LD (razor flap)	1M	20
Total	59	24F, 35M	43

FIGURE 1. An example of a preoperative perforators mapping with the aid of the multidetector row-computed tomography.

borders of the flap incised and is the flap quite easily raised from the underlying muscle.

In the design of perforator flap as a "propeller,"[19] we consider the location of the perforator as a pivot point (Fig. 2). The distance between the proximal border of the flap and the pivot point (A in Fig. 2) has to be a little longer (1.5–2 cm) than the length between the pivot point and the farthest border of the injury zone (B + C in Fig. 2). So, after the rotation of the flap, the suture can be performed without any tension.

In the ALT perforator flap, the patient is placed in supine position. A line is drawn between the anterior superior iliac spine and superolateral border of the patella. The perforators are concentrated in a circle of 6 cm at the midpoint of the marked line. The flap is designed in an elliptical vertical skin island. It is possible to directly close the donor site with a flap width less than 8 cm.[20]

In the TAP flap, the patient is placed in supine position, with the homolateral arm elevated and a little torsion of the thorax. The lateral border of the latissimus dorsi muscle is marked. The perforators are normally about 6–8 cm below the posterior axillary fold and 2–4 cm inside the lateral border of the latissimus. Additional perforators could be identified at 1.5- to 4.0-cm intervals below to the first. The width is determined by the pinch test to determine what can be closed primarily. Flaps up to 25 cm in length have been reported.[21]

RESULTS

Our overall results include resolution of the problem presented in 93.2% of cases (55 of 59); there were 4 flap losses (6.8%). Two losses occurred for a compression of the pedicle by a hematoma not drained quickly enough; 2 losses due to a compression of the flap from incorrect patient positioning in bed. In all these cases, a second operation with a latissimus dorsi free flap was performed. Partial necrosis <20% occurred in 3 propeller flaps (5%) in heavy-smoker patients; partial necrosis >20% happened in 1 propeller flap (1%) in a diabetic patient. All these cases occurred when the flap extended farther than the angiosome territory corresponding to the chosen perforator. The vascular connections between the angiosomes showed themselves to be inadequate to nourish the distal part of the flap, probably due to the microvascular damage caused by smoke and diabetes. Secondary healing was suitable in these cases. Some delayed refinements were carried out to achieve better cosmetic results such as a debulking procedure, liposuction mediated,[22] in a patient where an ALT perforator flap was used to cover a dorsal aspect of a foot.

DISCUSSION

In recent years, perforator flaps have become one of the most useful surgical options in soft tissue lower limb reconstruction. In local flaps reconstructions, the harvesting of a perforator-based flap guarantees a more reliable vasculariza-

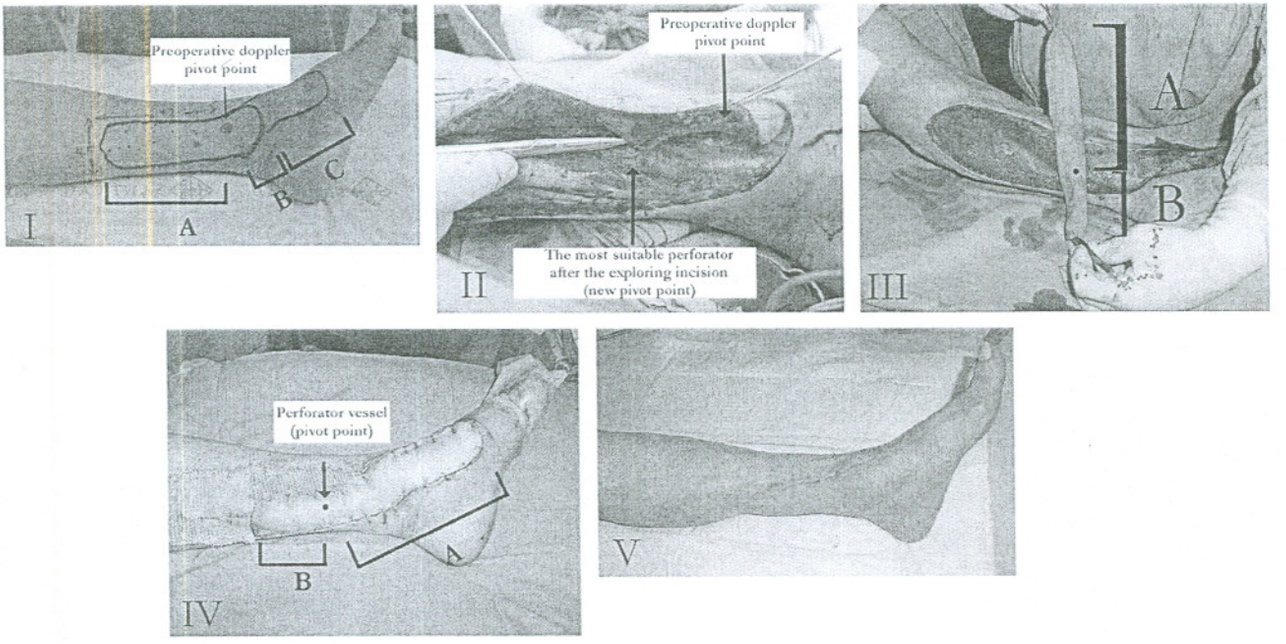

FIGURE 2. Schematic posterior tibial artery perforator flap with the propeller transfer method. I. We calculate the total length of the flap by measuring the distance between the pivot point, identified by Doppler ultrasound, and the farthest border of the injury zone (distance A is 1.5–2 cm longer than B + C, so that, after rotation, the flap is sutured without any tension). II. With the exploratory incision the most suitable perforator is evaluated and the flap design is adapted to the location of the new pivot point. III. The propeller movement of the flap. IV. Flap rotated through 180° to cover the injury zone. V. Two years' postoperative result.

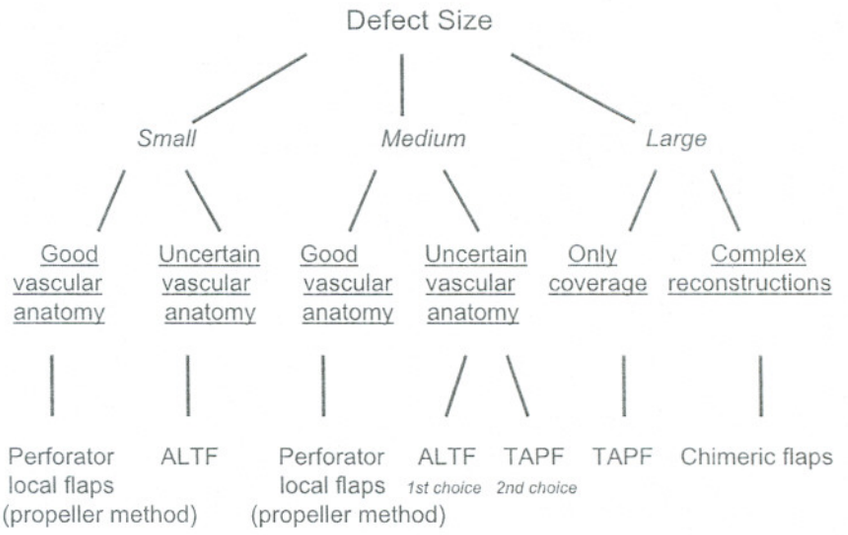

FIGURE 3. Algorithm for lower limb soft tissue reconstruction with perforator flaps.

tion, greater possibility of movement, and a larger amount of available tissue than the classic random flaps. In free-flap reconstructions, perforator flaps have indications (in orthopedic and oncologic surgery, radiodermitis, osteomyelitis, etc) that overlap with musculocutaneous flaps but present reduced morbidity. Free perforator flaps can provide the same amount of tissue and the same vascular supply as a musculocutaneous flap.

Planning a lower limb reconstruction, we evaluate the defect size, the structures involved in the defect, whether the vascular condition of the neighboring tissues is adequate or not, the vascular anatomy of the extremity, the donor-site quality and the vascular pedicle length needed. Whenever possible, the surgical intervention and the morbidity ought to be limited to a single body region.

Our reconstructive strategy is as follows (Fig. 3): (1) In defects of small and medium size, with suitable vascular condition of the neighboring tissues, we select, as first choice, local perforator flaps with a "propeller" transfer method.[10,19] (2) In defects of small and medium size with poor vascular condition of the nearby tissues, ALTF is used as first choice, so the same anatomic body region is the source of a free flap (Fig. 4). When an ALTF is not indicated due to scars that could limit the size of the flap or if the pedicle length required exceeds the ALTF one, we look for another anatomic region as a source of flaps and we prefer the TAP flap, because of its qualities (Fig. 5). (3) In defects of large size, with only a coverage required, the first selected flap is the TAPF; in complex cases, we perform compound or

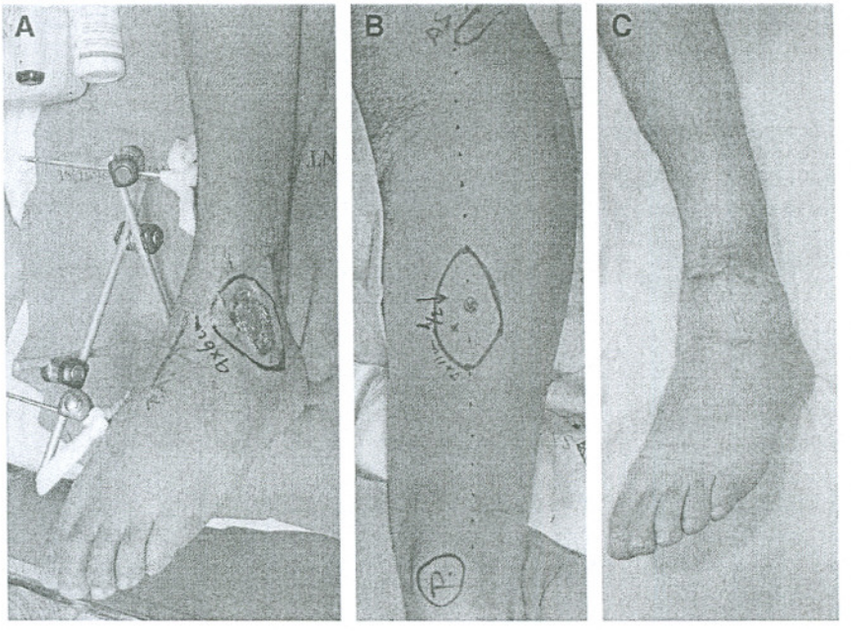

FIGURE 4. A 38-year-old male patient with a traumatic soft tissue loss (9 × 6 cm) of the anterolateral aspect of the left ankle, with osteosynthesis material exposed, underwent surgery. After the removal of the osteosynthesis materials and a surgical debridement, an ALT flap was harvested and transferred to cover the defect. A, The defect; preoperative planning of the flap (B); 2 years' postoperative result (C).

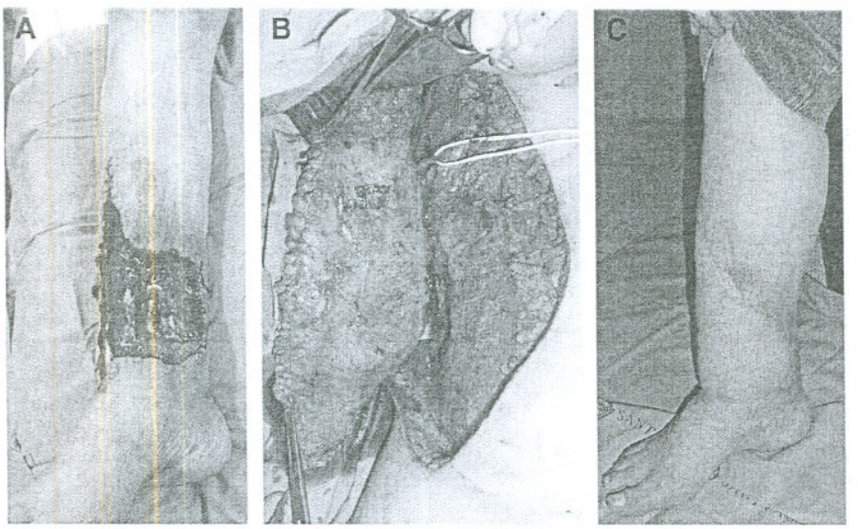

FIGURE 5. A 43-year-old female patient with a chronic traumatic tibial osteomyelitis underwent a radical surgical debridement and specific antibiotic therapy. The defect included the soft tissue of the lower anteromedial leg and devitalized parts of the tibia. A TAP flap was raised to cover the defect. A, The defect; the harvesting of the flap with the perforator isolated (B); 3 years' postoperative result (C).

chimeric flaps either of the thoracodorsal artery (Fig. 6) or the circumflex lateral femoral artery.

As first choice, in defects of small and medium size, with suitable vascular condition of the neighboring tissues, we use propeller flaps. The propellers are reliable flaps that can be performed wherever a perforator vessel of adequate size is encountered. They have skin texture and color very similar to the injury zone. The operation time is shorter than a microsurgical transfer because a microvascular anastomoses is not needed. The surgical intervention can be performed under a locoregional anesthesia. The donor site can be closed in a V-Y shape or with a skin graft.

Small and medium size defects, in patients with an uncertain vascular condition of the local tissues, are generally treated with the ALT perforator free flap.

The anterolateral thigh free flap was first described by Song et al[23] 1984. The cutaneous area of the flap can be relatively large and may include half of the surface of the thigh. The skin is pliable and of good quality. The vascular pedicle is at least 8 cm in length. The diameter of the pedicle is relatively large (2 mm). It is possible to perform a flow-through flap[24] suitable for the reconstruction of ischemic defects of the lower limb. During the harvesting of the flap, the lateral cutaneous femoral nerve can be included to carry out a sensory flap. The donor defect can often be closed directly in flap widths less than 8 cm. Sometimes, the thickness of the flap can distort the contour of the reconstructed region and a debulking procedure is needed. The immediate defatting of the flap,[25] preserving only the pedicle and removing a large amount of the subfascial fat, could improve

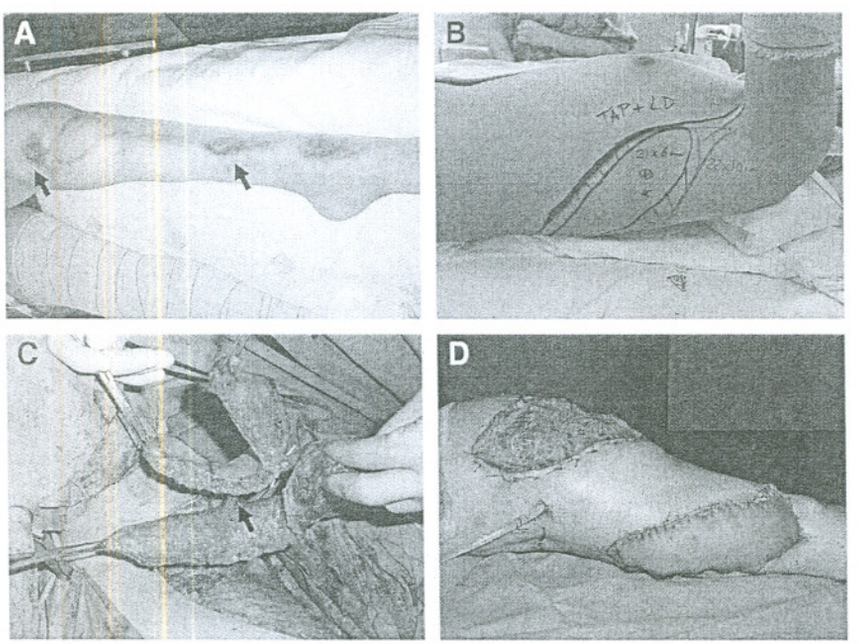

FIGURE 6. A 20-year-old male patient with a recurrent knee prosthesis infection and a tibial osteomyelitis underwent a surgical debridement, removal of knee prosthesis, specific antibiotic therapy, insetting of a joint spacer, coverage with a razor flap. A, The anteromedial aspect of the left lower leg with 2 fistulas (arrows). The patient had been already operated, in another hospital, with a surgical debridement of the medial tibial plate for a prosthesis infection and coverage with a medial gastrocnemius musculocutaneous flap; the preoperative planning of the flap (B); the harvesting of the flap with the perforator isolated (arrow; C); immediate postoperative result (D).

the final shape of the flap but the risk of damaging the vessels, in less skilled hands, is increased. So, we usually wait and perform a delayed defatting of the flap through a liposuction procedure,[22] if necessary.

The ALT perforator flap may be, additionally, raised as a compound flap (including for example the fascia lata) or as a chimeric flap,[13] including rectus femoris muscle, vastus lateralis muscle, etc, for more complex reconstructions (complex defects, tendon defects, etc).

In patients with medium-size defects where it is not possible to limit the morbidity to a single region, due to an insufficient available amount of the ALT perforator flap or the requirement of a longer vascular pedicle, we perform a TAP free flap. We use the TAP free flap even in reconstructions of large-size defects.

The thoracodorsal artery perforator flap, initially described by Angrigiani et al[12] in 1995, can include a thin and pliable skin–soft-tissue paddle up to 14 by 25 cm. The vascular pedicle length is about 18 cm, useful when the anastomosis has to be performed outside a large zone of injury. The TAP can be used as a flow-through flap, and it is possible to include sensory branches of intercostal nerves. The donor site can be closed directly or, rarely, with a split-thickness skin graft. Finally, a chimeric flap with a combined latissimus dorsi flap[14] can be raised.

The advantage of a chimeric free flap[13] is that complex, extensive, 3-dimensional defects can be reconstructed using multiple tissues that are independently moved and inset. The combination of more tissues expands the total surface of the flap and, furthermore, as these kinds of flaps have separate vascular pedicles but a common source vessel, only a single recipient site has to be available.

In our experience, perforator flaps have provided consistent and reliable solutions for soft tissue reconstruction of the lower limb. They are very versatile flaps, allowing us to selectively choose and transfer the tissues of an angiosome that are required for a specific reconstruction, and the morbidity of the donor site is often minimal.

We propose a simple reconstructive algorithm for lower limb soft tissue reconstruction with perforator flaps that could be helpful in choosing the right flap for a specific defect, always focusing on getting the most "like-to-like" tissues; whenever possible, selecting the same anatomic region of the defect as source of flaps; reducing the morbidity; improving the cosmetic results.

CONCLUSION

Perforator flaps are safe and reliable flaps and represent an important step forward in reconstructive plastic surgery of the lower limb. Whenever possible, surgical intervention and donor-site morbidity ought to be limited to a single body region, and the use of propeller perforator flaps can concretely widen the reconstructive options for inferior limb defects. Furthermore, when a free tissue transfer is needed, a perforator flap would be employed because of its undoubted advantages: (1) important decrease in donor-site morbidity, preserving muscles and their functions and sparing the main vascular trunks; (2) specificity in "like-to-like" soft tissue replacement; (3) a better cosmetic and reconstructive result.

REFERENCES

1. Jayes PH. Cross-leg flaps: a review of 60 cases. *Br J Plast Surg*. 1950;3:1–5.
2. Geddes CR, Morris SF, Neligan PC. Perforator flaps: evolution, classification and applications. *Ann Plast Surg*. 2003;50:90–99.
3. Hallock GG. Lower extremity muscle perforator flaps for lower extremity reconstruction. *Plast Reconstr Surg*. 2004;114:1123–1130.
4. Taylor GI, Palmer JH. The vascular territories (angiosomes) of the body: experimental study and clinical applications. *Br J Plast Surg*. 1987;40:113–141.
5. Taylor GI. The angiosomes of the body and their supply to perforator flaps. *Clin Plast Surg*. 2003;30:331–342.
6. Acland RD, Schusterman M, Godina M, et al. The saphenous neurovascular free flap. *Plast Reconstr Surg*. 1981;67:763–774.
7. Koshima I, Moriguchi T, Ohta S, et al. The vasculature and clinical application of the posterior tibial perforator-based flap. *Plast Reconstr Surg*. 1992;90:643–649.
8. Leung-Kim H, Jie L, Pak-Cheong H. Free posterior tibial perforator flap: anatomy and a report of 6 cases. *Microsurg*. 1996;17:503–511.
9. Taylor GI, Pan WR. Angiosomes of the leg: anatomic study and clinical implications. *Plast Reconstr Surg*. 1998;102:599–616.
10. Hyakusoku H, Yamamoto T, Fumiiri M. The propeller flap method. *Br J Plast Surg*. 1991;44:53–54.
11. Wei FC, Jain V, Celik N, et al. Have we found an ideal soft-tissue flap? An experience with 672 anterolateral thigh flaps. *Plast Reconstr Surg*. 2002;109:2219–2230.
12. Angrigiani C, Grilli D, Siebert J. Latissimus dorsi musculocutaneous flap without muscle. *Plast Reconstr Surg*. 1995;96:1608–1614.
13. Huang WC, Chen HC, Wei FC, et al. Chimeric flap in clinical use. *Clin Plast Surg*. 2003;30:457–467.
14. Cavadas PC, Teran-Saavedra PP. Combined latissimus dorsi-thoracodorsal artery perforator free flap: the "razor flap." *J Reconstr Microsurg*. 2002;18:29–31.
15. Blondeel PN, Beyens G, Verhaeghe R, et al. Doppler flowmetry in the planning of perforator flaps. *Br J Plast Surg*. 1998;51:202–209.
16. Masià J, Clavero JA, Larrañaga J, et al. Multidetector-row computed tomography in the planning of abdominal perforator flaps. *J Plast Reconstr Aesthet Surg*. 2006;56:594–599.
17. Voet DVAM, Petrovic M, Masia J, et al. Preoperative planning. In: Blondeel PN, Morris SF, Hallock GG, et al, eds. *Perforator Flaps: Anatomy, Technique and Clinical Applications*. St. Louis: Quality Medical Publishing; 2006.
18. Wei FC, Mardini S. Free-style free flaps. *Plast Reconstr Surg*. 2004;114:910–916.
19. Moscatiello F, Masià J, Pons G, et al. Our experience of the propeller descending genicular artery perforator flap. Abstract Book, 9th International Course on Perforator Flaps; Barcelona, October 5–8, 2005.
20. Mardini S, Lin CH, Wei FC. Lateral circumflex femoral artery-vastus lateralis perforator flap. In: Blondeel PN, Morris SF, Hallock GG, et al. *Perforator Flaps: Anatomy, Technique and Clinical Applications*. St. Louis, MO: Quality Medical Publishing, Inc; 2006:618–633.
21. Van Landuyt K, Hamdi M. Thoracodorsal artery perforator flap. In: Blondeel PN, Morris SF, Hallock GG, et al. *Perforator Flaps: Anatomy, Technique and Clinical Applications*. St. Louis, MO: Quality Medical Publishing, Inc; 2006:441–460.
22. Hallock GG. Conventional liposuction-assisted debulking of muscle perforator flaps. *Ann Plast Surg*. 2004;53:39–43.
23. Song TG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. *Br J Plast Surg*. 1984;37:149–159.
24. Koshima I, Kawada S, Etoh H, et al. Flow-through anterolateral thigh flaps for one-stage reconstruction of soft-tissue defects and revascularization of ischemic extremities. *Plast Reconstr Surg*. 1995;95:252–260.
25. Kimura N, Satoh K, Hsaka Y. Microdissected thin perforator flaps: 46 cases. *Plast Reconstr Surg*. 2003;112:1875–1885.