Pedicle Perforator Flaps for the Lower Limb

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ABSTRACT

The use of local perforator-based flaps for reconstruction of soft tissue defects of the lower extremity is a simple and safe alternative to the more complex and time-consuming microsurgical reconstructions. This has been made possible through better understanding of the cutaneous circulation and local vascular anatomy and innovations in flap design. This review describes the evolution, technique, and modifications of pedicle perforator-based flaps, particularly in the reconstruction of posttraumatic defects of the lower third of the leg. Attention is focused on the perforator-based posterior tibial, adipofascial, and dorsal foot flaps. We also highlight the concept of the ad hoc perforator flap, a flap that decreases dependence on preconceived designs.

KEYWORDS: Leg, local flap, perforator flap

HISTORICAL BACKGROUND

The pioneers of plastic surgery accepted that flap design that worked well elsewhere on the body commonly failed when applied to soft tissue defects on the leg, especially when these defects were the product of trauma or chronic osteomyelitis. Traditional advice was to avoid local flaps below the knee unless the defects were small or the surgeon was prepared to use special techniques such as delay incisions. Reconstructive surgeons relied on cross-leg flaps and flaps transferred from a distance using the tube pedicle technique. Ger introduced the use of transposed muscle flaps for reconstruction of the leg.¹ Unfortunately, the area least well served by these muscle flaps is the lower third of the leg. The fasciocutaneous flap reported by Ponten showed that long narrow flaps could be safely raised below the knee as long as the deep fascia was included.² Ponten's flaps were not based on specific perforators and therefore could not be islanded.

Following widespread use, it was realized that Ponten's flap was unsuitable for the management of difficult soft tissue defects in the lower third of the leg. Chatre and Quaba reviewed the results of 100 Ponten fasciocutaneous flaps used for lower leg reconstruction

between 1981 and 1986. They reported an overall necrosis rate of 8% but the necrosis rate for flaps raised to cover defects in the lower third of the leg was an unacceptable 25%.³

The advent of fasciocutaneous flaps stimulated great interest in the cutaneous circulation of the lower extremities and in alternatives to traditional, rigid, proximally based flap designs. Of particular significance was the description of the septocutaneous vessels of the leg⁴ and the extension of the concepts of reverse flow and distally based flaps to the leg.⁵ Rather than sacrificing the whole vascular axis in the process of transferring a flap, it was soon appreciated that flaps could be based on a single septocutaneous perforator of the tibial or peroneal vessels.⁶ The circulation in a perforator-based flap remains more physiological compared with a distally based axial vessel-type flap.

PEDICLED PERFORATOR VERSUS FREE FLAPS

Pedicled perforator flaps have several obvious advantages over free flaps. They can be performed expeditiously, and

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this is particularly beneficial in the management of soft tissue defects in multiply injured patients, the elderly, and systemically compromised patients. Additionally, there is no need for special instrumentation and no requirement for transfer of patients to specialist centers. Local flap surgery limits the scars and morbidity to one extremity.

However, pedicled perforator flaps have several potential disadvantages, particularly when used for major posttraumatic soft tissue defects. The principal criticism is that the flap is raised within the zone of injury and that its vascularity could be compromised. Appreciation of the vascular basis of such flaps and adequate assessment

of degloving minimizes this risk. Incorrect raising of local skin flaps can interrupt superficial veins and cutaneous nerves, leading to edema and neuromata. Free flaps can be tailored to suit massive or irregular skin defects, whereas the design of a pedicled flap tends to be limited by the local anatomy and availability of skin and wound orientation. Local flaps can leave a significant cosmetic defect relating to the donor site, which may be difficult to camouflage.

In Edinburgh, the first choice of flap for reconstructing an extremity defect remains a pedicled perforator flap. Free flaps are used for massive defects, particularly those associated with degloving injuries,

Figure 1 Posterior tibial perforator flap. Diagrammatic representation of (A) the approximate site of the two most commonly encountered septocutaneous perforators (8 to 12 cm above medial malleolus). (B) Before islanding and (C) after islanding and inset.

defects requiring composite reconstructions and when donor site scarring, for example in a young female patient, would be unacceptable.

A review of the management of 1000 consecutive open fractures in Edinburgh demonstrated that of the 246 patients who required plastic surgery, only 15 had to have a free flap performed. Thirteen patients had local muscle flaps and 77 had fasciocutaneous flaps, which

were predominantly perforator-based. Skin grafting alone was sufficient for all the other cases.⁷

Pedicled Islanded Flaps Based on the Tibial and Peroneal Septocutaneous Perforators

Fasciocutaneous flaps based on the tibial and peroneal septocutaneous perforators can be safely islanded on

Figure 2 Posterior tibial perforator flap operative sequence. (A) Lower third open tibial fracture. (B) Two possible flap designs outlined. Exploratory incision as a proximal extension of the primary wound. The greater saphenous vein is visible. Note cross corresponding to Doppler signal. (C) The saphenous vein and nerve are preserved. Fascia overlying the deep posterior compartment muscles incised and reflected posteriorly exposing the perforator. (D) The confirmed site of the perforator establishes the pivot point and confirms that the smaller flap design would be adequate to cover the fracture site. (E,F) Flap islanded and transposed 90 degrees. The secondary defect required skin grafting.

one perforator and its venae comitantes, leaving the main vascular axis intact. Suitable perforators are those that pursue a horizontal course through the subcutaneous tissue after an initial vertical course through the

intermuscular septum. Flaps based on these perforators can be transposed up to 180 degrees with the base of the perforator as the pivot point. In our experience, the most versatile and useful pedicled flaps for lower

Figure 3 Perforator-based adipofascial flap. (A) Lower third low-energy open tibial fracture. Zigzag incision outlined on the medial calf. (B) Skin reflected by careful dissection through the subcutaneous tissue leaving a layer of fat on the deep fascia. The adipofascial flap is elevated from proximal to distal. (C) Elevation completed, arrow points to a posterior tibial perforator entering the base of the flap. (D) Flap transposed as an island and covered with split-thickness skin graft. (E) A long-term result of an adipofascial flap reconstruction.

leg reconstruction are those based on perforators of the posterior tibial artery. These emerge through the distal part of the intermuscular septum between the calf superficial and the deep muscle compartments (Fig. 1). The use of this flap in the management of lower third fractures in our practice has been of such importance that its operative technique warrants detailed description.

Posterior Tibial Perforator Flaps – Operative Technique

The flap is raised with the patient in the supine position and under tourniquet control. Preoperative identification of the perforators using a Doppler probe is helpful. The perforators are fairly constant and emerge ~8 to 12 cm proximal to the tip of the medial malleolus, halfway between the Achilles tendon and the medial border of the tibia. These perforators are remarkably well protected and can withstand significant local trauma. However, local degloving should be excluded by digital palpation of the potential flap territory. This

territory lies over the medial calf between the greater and lesser saphenous veins. The flap can extend to within 10 cm of the popliteal skin crease (Fig. 1). Care should be taken to preserve the saphenous veins and accompanying nerves and these should not be included in the flap. The venous drainage of the flap relies on the venae comitantes, which accompany the perforating artery.

After marking the approximate location of the perforator (Fig. 2), an incision is made just posterior to and parallel to the greater saphenous vein. The incision extends down to the deep fascia, exposing the muscles of the deep posterior compartment. The fascia is reflected posteriorly exposing the intermuscular septum where the exact location of the perforator can be verified. There is no need to expose the posterior tibial vessels or to skeletonize the perforator. The dimensions of the flap necessary to cover the soft tissue defect are then established, using basic principles in flap design. Elevation of the flap proceeds at the subfascial level by incising through the posterior and superior margins.

Figure 4 An example of the dorsal metatarsal flap. (A) Hyperextension postburn contracture of the foot. Line of contracture release and flap design shown. The dot at the first web space shows the approximate location of the perforator. (B) Contracture has been released and the flap elevated, preserving the continuity of the dorsal metatarsal vessels and the adjacent nerves. (C) Flap islanded and transposed 90 degrees. Donor site is partially closed. The remaining defect requires grafting.

Dissection proceeds from proximal to distal through the depth of the intermuscular septum until the previously marked perforator is reached. The septum distal to the site of the perforator can also be incised to facilitate transposition. This latter maneuver is usually not necessary with a flap transposition of 30 to 45 degrees to cover defects of the middle third of the leg. However, with 90- to 180-degree transposition,

complete islanding is preferable. It is advisable to release the tourniquet before completely islanding the flap. The donor site usually requires skin grafting. No special flap monitoring is necessary.

A review of the first 66 (first 5 years) islanded distally based fasciocutaneous flaps by the senior author showed that the majority of flaps (53) were used for posttraumatic soft tissue problems.⁸ Of the flaps

Figure 5 Ad hoc perforator flap operative series. (A) Wound breakdown following surgery for osteomyelitis. Note surrounding scarring especially laterally. (B) Exploratory wound extended proximally from the primary wound. Careful subfascial dissection showed a musculocutaneous perforator (C). (D) The perforator establishes a pivot point for a potential flap, which is now surgically outlined (E) but not islanded. (F) Prior to islanding, a soft bowl clamp is applied distal to the identified perforator and kept for ~10 minutes.

Figure 5 (continued) (G) Having confirmed viability of the flap, the flap is transposed and inset. (H,I) Long-term result.

used in the acute setting, 47% were for Gustilo grade IIIb injuries. The overall mean operating time was 1.7 hours. The most frequently used perforator was located ~12 cm above the tip of the medial malleolus. Significant flap necrosis necessitating an alternative reconstruction, either in the form of free-flap transfer or another pedicled perforator flap, occurred in 7.5% of cases. This was mostly encountered in patients with peripheral vascular disease or diabetes or in patients who had unrecognized degloving.

Another report focused on the use of the pedicled perforator posterior tibial flap in the treatment of 26 open fractures of the distal third of the tibia.⁹ There were eight Gustilo type II and 18 Gustilo type III fractures. Intramedullary nailing was performed in 20 cases, and the remaining six fractures were managed by external fixation. Only two flaps underwent edge necrosis, which healed without further surgery. Bone union was achieved at an average time appropriate for the Gustilo grading of the fracture. It was felt that the combination of reamed

intramedullary nailing and distally based fasciocutaneous flaps was an appropriate treatment for open fractures of the distal third of the tibia.

Reducing the Cosmetic Deficit of Pedicled Perforator Flaps

The donor defect created by the transfer of sizeable perforator based flaps, particularly in posttraumatic reconstruction, is of cosmetic significance. Whenever possible, we avoid using this flap in women and in any individual where cosmesis is an issue. The flap itself, being a local flap, provides an excellent color and texture match at the recipient site. Careful tailoring and inset as well as islanding avoid a bulky and unsightly reconstruction. Occasionally, subsequent liposuction helps reduce undesirable bulk. Direct closure of the secondary defect, when possible, avoids the cosmetic deformity associated with split-thickness skin grafting. The propeller¹⁰ and VY advancement¹¹ perforator fasciocutaneous flaps are examples where the donor site can be closed directly. In our opinion these are particularly useful in reconstructing small defects such as those that follow elective excision of skin cancers. Another way of minimizing the cosmetic deficit is by using adipofascial flaps.

The Perforator-Based Adipofascial Flap

This is composed of subcutaneous fat and deep fascia, with preservation of the skin, cutaneous nerves, and vessels (Fig. 3). Several variations have been described according to their blood supply. Early adipofascial flaps were designed as random pattern turnover flaps, most applicable for reconstruction of chronic or subacute defects.^{12,13} Later reports describe both axial pattern flaps¹⁴ and perforator-based flaps.¹⁵

A total of 25 perforator-based flaps were used for a variety of clinical problems including the cover of open joints, exposed internal fixation plates around the ankle, and open low-energy tibial fractures.¹⁵ The flap is ideally suited to children and young women with low-energy injuries resulting in small- to medium-sized soft tissue defects. Caution should be exercised when the defect is large or the injury is complex, requiring secondary procedures such as bone grafting.

The Dimensions of a Pedicled Perforator-Based Flap Are Inversely Proportional to the Number of Perforators in the Area

Larger flaps can be raised on the medial side of the leg compared with the anterolateral aspect. This is due to the fact that perforators arising from the posterior tibial axis, although small in number, are of larger diameter than those from the anterior tibial and peroneal axes, where the converse holds true.¹⁶

The Distally Based Islanded Dorsal Foot Flap

This is a useful flap that can be raised on scar tissue with minimal disruption to the local vasculature and neuroanatomy.¹⁷ The dorsal metatarsal artery flap is based on perforator vessels that arise in the distal web space from the arcade linking the dorsal and planter metatarsal arteries.¹⁸

This flap can be completely islanded and used to resurface defects following release of post-burn hyperextension contractures of the toes. In 14 consecutive flaps, partial necrosis occurred in three flaps, one leading to slight residual contracture¹⁹ (Fig. 4).

The Ad Hoc Perforator Flap

Soft tissue defects, whether postexcisional or following trauma, happen at random. However, most reconstructive surgeons continue to rely on flaps of preconceived designs to provide cover. With increased understanding of the cutaneous circulation, a working knowledge of the regional vascular anatomy, and expertise in raising local skin flaps, the reconstructive surgeon can be released from the constraints of tailoring the defect "to a previously described local flap." Flaps can be based on perforators that have not necessarily been previously described. The term "ad hoc" has been used to describe these flaps.^{20,21} The dictionary defines "ad hoc" as a term for something that is "used on a particular occasion" or something that has "an improvised nature."

Careful Doppler mapping and/or preliminary exploration is performed to identify a perforator adjacent to the defect to be reconstructed. The site of such a perforator is the would-be pivot point of the flap. The wound can be extended in such a way that would make it the leading edge of any potential ad hoc flap. Through this wound, the perforator that was the origin of the positive Doppler signal is sought. Once the perforator is identified, two issues need to be considered. First, the direction the perforator takes after piercing the fascia and second, its potential vascular territory. This is essential for correct planning and design of the flap. Loupe magnification is usually sufficient to identify the direction of the perforator, and in the extremities it is usually safer to design an island flap in which the perforator enters the flap distally. This allows transposition of the flap from proximal to distal. Determining the potential vascular territory of the flap is a matter of fine judgment. Factors to consider include the size of the perforator and also the presence of any other significant adjacent perforators that would, by necessity, be sacrificed to facilitate the transfer of the flap as an island. As mentioned previously, the greater the number of perforators in an area, the less the size of the potential territory of individual perforators. Before completely islanding a flap, it is worthwhile to apply a noncrushing

intestinal clamp at the end of the flap, to make sure that the circulation at this distal margin is adequate. Once this is verified, the flap can be completely islanded and transposed. The defect may be closed directly or with a partial-thickness skin graft (Fig. 5).

CONCLUSION

It is generally agreed that a perforator is a vessel that enters the suprafascial plane through a defined fenestration in the deep fascia.¹¹ Perforator flaps can be divided into direct, indirect septocutaneous, and indirect musculocutaneous based on the type of perforator vessel used.²² We have not endeavored to write an exhaustive review on the use of pedicled perforator flaps in the lower limb. However, we have focused on flaps that the senior author has found to be of use in his practice.

The distally based posterior tibial perforator flap is an example of an indirect septocutaneous perforator flap. It has been a workhorse flap for lower limb reconstruction in our practice. It is particularly useful for lower third defects of the leg where other local options can be limited. With careful selection it can obviate the need for free flap reconstruction.

The adipofascial modification of the posterior tibial perforator flap has also been discussed. It is worth considering in situations where cosmesis is an issue, but only for small- to medium-sized clean defects in low-energy injuries.

The distally based dorsal foot flap is an example of a direct perforator flap. According to current convention, it would be better described as a dorsal metatarsal artery perforator flap. It is useful for correction of post-burn hyperextension contractures of the toes.

The ad hoc perforator flap by definition can be based on any type of perforator. Its concept was first alluded to by the senior author in 1990.²⁰ It is analogous to the "freestyle free flap" concept of Wei and Mardini.²³ It relegates the knowledge and importance of any flap source vessel as irrelevant. It can be based on the suprafascial location of any of the 300 or more major perforators of the body as mapped by Taylor and Palmer.¹⁶ With the ad hoc concept one need not dwell over anatomical landmarks or anatomical variations. The presence of a positive Doppler signal in any potential donor territory adjacent to the defect allows planning and execution of the flap.

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