Chapter 22

Perforator Flaps

Peter Nthumba

Introduction

Evolution of flaps

Cutaneous flaps have a long history, and have evolved from the random-pattern flaps. Random-pattern skin flaps have significant length: width ratios, and therefore largely limited applications. The concept of axial flaps was introduced by McGregor and Jackson in 1972 with their description of the groin flap. Bakamjian had in 1968 unveiled the deltopectoral flap, an axial flap. Ger and Orticochea described musculocutaneous flaps, while Ponten reported the use of fasciocutaneous flaps, which allowed for the use of flaps with significantly longer length to width ratios. The angiosome concept was introduced by Taylor and Palmer in 1987. After total body studies of the blood supply to the skin and the underlying deep tissues, they divided the body anatomically into three-dimensional vascular territories, “angiosomes”, supplied by a source artery and its accompanying vein(s) that span between the skin and the bone. Each angiosome is linked to its neighbor, in each tissue, by a fringe of either true anastomotic arteries without change in caliber or by reduced-caliber choke (retiform) anastomotic vessels. Each angiosome therefore defines the safe anatomic boundary of tissue that can be transferred separately or combined together on the underlying source vessels as a composite flap.

The perforasome concept and perforator flaps:

The perforasome concept is thus an advancement of the angiosome concept. A perforasome is the vascular territory of a single perforator. Each perforasome is connected to its neighbor both by direct and indirect linking vessels. Freestyle perforator flaps are flaps designed only on the basis of a Doppler signal, in the absence of a known flap. In the absence of a Doppler, a flap may be designed in the area adjacent the defect, beginning with the exploration for the perforator at the base of the potential flap that would form the pivot of the flap. Freestyle perforator flaps should however be designed close to areas with known perforators, such as along intermuscular septae.
Koshima and Soeda reported experience with the inferior epigastric perforator flap in 1989. Since then many perforator flaps have been described, in all regions of the body. Perforator flaps have the advantages of reduced donor site morbidity, reduced recovery time, the ability to contour the flap according to a specific defect, and hence improved aesthetic outcomes. Further, flap harvest is relatively quick, and the recipient site has similar texture, thickness, pliability, and pigmentation to that which has been lost.

The nomenclature remains somewhat controversial, as to what should be called a perforator flap. An attempt at standardizing perforator flaps nomenclature suggested the following:

Cutaneous flaps may be either cutaneous flaps or musculocutaneous perforator flaps.

<table>
<thead>
<tr>
<th>Cutaneous flaps (Direct)</th>
<th>Perforator flaps (Indirect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial, septocutaneous,</td>
<td>Musculocutaneous perforator</td>
</tr>
<tr>
<td>fasciocutaneous</td>
<td>flaps</td>
</tr>
<tr>
<td></td>
<td>Source artery to skin</td>
</tr>
<tr>
<td></td>
<td>arises from and passes</td>
</tr>
<tr>
<td></td>
<td>through the underlying</td>
</tr>
<tr>
<td></td>
<td>muscle</td>
</tr>
</tbody>
</table>

The terms septocutaneous perforator flaps and musculocutaneous perforator flaps are however, the most common in use, describing respectively, cutaneous flaps perfused by a source vessel that passes between two muscles (septal perforator) and those perfused by vessels that pass through muscle.

The author has found perforator flaps most useful in three otherwise difficult anatomic areas: the leg, the hand and the neck/orofacial regions, providing excellent options equivalent to free flaps, yet available feasible in low-tech environments.

**The leg:**

Traditionally, musculocutaneous flaps, principally the gastrocnemius and the soleus have been used for coverage of soft tissue defects of the proximal and middle-thirds of the leg, respectively. High energy lower extremity trauma in sub-Saharan Africa is the result of road-traffic accidents, or gunshot wounds. Inadequate or inappropriate management of the resultant injuries frequently leads to the development of chronic osteomyelitis. The most common reason for
this eventuality is failure to provide an early and adequate soft tissue cover for exposed bone. Anatomically, the distal third of the leg has little or no muscle, with multiple tendons and subcutaneous bones (tibia and fibula). Loss of soft tissue cover of this anatomic region is therefore particularly challenging for the surgeon. Indeed, even in high income environments, soft tissue defects of the lower third of the leg remain a significant challenge to reconstructive surgeons, with sometimes significant free flap reconstruction failure. This varies according to locale, experience of the surgeon, equipment and supplies, etc.

The leg has three source arteries, the posterior tibial, anterior tibial and peroneal arteries, from which perforators arise and supply overlying skin territories. An understanding of the surface markings of the three source arteries is essential for one to raise perforator flaps, especially in the absence of a Doppler for mapping out the perforators.

**Surgical technique**

A Doppler and a pair of loupes are important although not absolute necessities in planning and raising perforator flaps. A Doppler will accurately locate the site of a perforator, and therefore enable rapid designing of the flap, depending on the defect.

In the absence of a Doppler, a flap is designed, with the pivot point placed on the most likely position of a perforator, centered preferentially over an intermuscular septum. Loupe magnification is essential for the identification of the perforator, especially early after trauma, as identification may otherwise be impossible. An incision in made along one side of the proposed flap, down to the fascia, and the flap is raised up to the septum, where a search for a perforator closest to the defect is located, and the flap re-adjusted to suit the new pivot point. Ideally the perforator should be dissected out for a distance of 2 cm. The flap is now raised and inset. High energy trauma presents a number of difficulties, including the fact that the flaps raised may be frequently based on perforators located within the zone of injury, and therefore at a high risk of failure.

In a badly injured leg, it may be impossible to locate a useable perforator, in which case, a contralateral perforator flap is raised as a cross-leg flap, inset, and separated at three weeks (Figure 1-5). Cross-leg perforator flaps have the advantage of enabling comfortable positioning of the two limbs alongside each other, without the need for cumbersome knee flexion, as in traditional cross-leg
flaps. Where cross-leg flaps may be either cumbersome or impossible, flap delay on likely injured perforators within the zone of injury may be performed. These flaps require the use of an external fixator to hold the legs in place.

Fig 1  Fig 2  Fig 3  
Severe lower third leg injury. Initial hemisoleus flap used from Zone of Injury with partial failure. Without availability of other local muscle or fasciocutaneous flap, a cross-leg posterior tibial perforator flap, based on large distal posterior tibial perforator

Fig 4  Fig 5  
External fixator holds legs side by side. Note in Fig. 2, 3 that the legs are not acutely bent as they would be with a traditional cross-leg flap. Division in 3-4 weeks. (Full description below)

Case 1
A 30 year-old male presents with a Gustillo 3B tibiofibular fracture, sustained after a road traffic accident. He was transferred to the author’s institution about 1 week after the accident. Soft tissue in the middle and distal thirds of the leg was extensively damaged in the accident (Figure 1). The orthopedic team performed an initial débridement and stabilized the leg with an external fixator. He also has a compound fracture of the lateral malleolus that was plated (Figure 2). The plastic surgery team was requested to review the patient a week later, to see whether leg salvage was possible.

An initial ipsilateral hemisoleus flap was used to cover the defect; the muscle had been badly damaged, but was still possible to gently dissect out and cover the bone. After a skin graft, a negative pressure therapy dressing was applied. The result was a much smaller defect, but still a challenge (Figure 3). The easiest and quickest option, in the absence of a free flap, which would offer significant challenges in terms of pedicle length, and vessels to anastomose to, and
in the presence of an ongoing low-grade infection, was a cross-leg flap, a contralateral pedicled posterior tibial artery perforator flap was raised, and inset (Figure 4, 5). The flap was divided at three weeks, with all wounds healed on review at 2 months after admission to the hospital.

The posterior tibial artery perforator flap may be designed for any defect, and the propeller flaps may be as small or as large as the defect to be covered (Figures 6-8). Large flaps or those elevated acutely within the zone of trauma may develop tip necrosis (Figure 9-12).

![Fig 6](image1) ![Fig. 7](image2) ![Fig 8](image3)

Posterior tibial perforator flap turned at right angles as a propeller flap after the perforator had been identified (arrow in Fig. 7). Squamous cell carcinoma is located over tibia and periosteum excised with lesion. Outline of propeller flap can be seen to the left in a. (Full description below)

**Case 2**

A 60 year-old female presented with a leg ulcer that was reported as a squamous cell carcinoma on histology. The lesion measured about 4cm x 4cm; (Fig. 6) with a full thickness 6cm x 6cm defect, including tibial periosteum resulted upon excision. A posterior tibial artery perforator flap (Fig. 7) was raised and used to reconstruct the defect, with split thickness skin grafting of the donor site (Fig. 8).

Large flaps or those elevated acutely in within the zone of trauma may develop tip necrosis (Fig.12).
Case 3

A 25 year old female presented with a large chronic ulcer that was clinically suspicious for malignancy (Fig. 9). A wide excision (down to bone), was performed, and the resulting defect covered using a large posterior tibial artery perforator flap (Fig. 10, 11). The large flap developed tip necrosis (Fig. 12).

Schaverien and Saint-Cyr in 2008 in anatomic dissections of the leg found perforators of the posterior tibial, anterior tibial and peroneal arteries in three distinct areas at regular intervals of approximately 5 cm, starting at 5 cm above the intermalleolar line.

The anterior tibial artery perforators were found predominantly between the tibia and tibialis anterior and between the extensor digitorum longus and the peroneus longus within distinct intermuscular septa.

Peroneal artery perforators emerge through the posterior peroneal septum; proximally these emerge through the soleus or peroneus longus muscles, whereas distally they emerge between the flexor hallucis longus and the peroneus brevis. These perforators predominantly emerge 13 to 18 cm proximal to the lateral malleolus.

Posterior tibial artery perforators are found mainly between the soleus and flexor hallucis longus, in three clusters: 4 to 9 cm, at 13 to 18 cm, and at 21 to 26 cm from the intermalleolar line.
Thus posterior and anterior tibial perforators are found at the 4 to 9 cm and 21 to 26 cm intervals, above the intermalleolar line, while at the 13 to 18 cm interval, perforators originate from the posterior tibial and peroneal arteries. Posterior tibial artery perforators are the largest and most consistent, with an accompanying venae comitantes. Chan et al found no posterior tibial perforators in the proximal third of the leg, with clustering in the mostly in the distal third, and the distal part of the middle third, in a largely Asian population. No anatomical studies have been performed in the African population, but the clinical experience of the author suggests a distribution similar to that reported in Caucasian studies.

The perforator flaps so raised may be rotated up to 180°, creating the ‘propeller’ flap. Care must be taken when insetting the flap, that the pedicle is not twisted leading vascular compromise and flap failure. Venous engorgement is often the first event leading ultimately to flap failure. Fifty percent of medial leg perforators may be accompanied by a single vein, often inferiorly placed. Most of the rest had two veins, with three of 40 arteries unaccompanied by a vein.

Reverse sural artery flap is also a perforator flap but the perforators are not carefully dissected out as the flaps in this chapter. This flap is discussed in Chapter 20 and 21.

**The hand:**

Soft tissue defects of the dorsum may result from trauma, including burns, infection or as a result of a surgical procedure, e.g. burn contracture release. When such a defect leaves exposed tendons without peritenon, or will require tendon reconstruction later, simple skin grafting will not suffice, and a flap will be required. In low-income environments, especially in the absence of a reconstructive surgeon, either a groin or an epigastric flap would be most suited; this requires at least two and frequently three procedures. Local/regional flaps have the advantage of being single-staged, while offering tissue similar to what is missing. The pedicled reverse radial artery forearm flap is such a regional flap that however requires the sacrifice of a major artery. The radial artery forearm perforator artery on the other hand, while it is based on the radial artery as a source artery, and provides regional tissue as needed, does not require the sacrifice of the source artery, being based on the distal perforators. A major perforator will usually be found located with 2 cm proximal to the radial styloid process.
Case 4
A 35 year old diabetic male patient presented with tropical diabetic hand syndrome of the left hand. Upon débridement, he had lost the index finger, most of the skin of the dorsum, with exposed tendons. A radial artery perforator flap was used to cover the defect (Fig. 13-15).

![Fig. 13](image1)
![Fig. 14](image2)
![Fig. 15](image3)

Fig. 13-15  Diabetic hand syndrome. Reverse radial artery flap could be used but would sacrifice radial artery in a diabetic patient. Radial artery perforator flap used instead. As long as only superficial fascia is taken with the flap near the wrist, there is skin available to cover possibly exposed tendons. The only drawback is the wide pedicle which will make rotation more difficult than the traditional reverse radial forearm flap. (case below)

Case 5
A 25 year-old man who had suffered burn injuries at age 6 years presented with a dorsal contracture of his right wrist and hand. After the contracture was released and the hand pinned in the position of function, a radial artery perforator flap was fashioned and used to cover the defect (Fig. 16, 17).
The neck and oro-facial region:

Supraclavicular skin is thin and pliable, the perfect source for neck and oro-facial skin, as it closely resembles that of the neck and face. The supraclavicular artery flap has been used both as a pedicled and free flap, for the reconstruction of a large variety of defects around the head and neck, including the neck (for post-burn contractures), face (post-burn scarring and noma), oral, tracheal and sternal defects, as well as palatal and nasal lining. Its use gives results equivalent to or even superior to the use of free flaps.

It has a consistent anatomy, is easy and quick to elevate, with a short learning curve. The origin of the supraclavicular artery may be delimited by a triangle formed by the clavicle, the sternocleidomastoid muscle and the external jugular vein. Safe margins for flap elevation include: (1) anteriorly, the clavicle, (2)
posteriorly, the superior border of the trapezius muscle, and (3) inferiorly, the insertion of the deltoid muscle (Fig.18). Donor sites of flaps 10 cm or less will usually close primarily, unless surrounded by scar tissue, in which case skin grafting is necessary. Common flap complications include flap tip and partial flap necrosis. Scar widening, hypertrophic scarring and keloids may develop in the long term. This flap can be elevated even after oncologic neck dissection.

**Case 7**
A 20 year-old lady suffered severe burns to the face and neck, resulting to a severely scarred face, with ectropion of both eyelid and lip as well as a severe neck contracture with chin on sternum. A contracture release with the use of a left supraclavicular flap, along with release of the eyelid and lip contractures were performed (Fig. 19-21).

**Case 8**
A 15 year-old boy was referred to the author with a history of burns sustained as a child. He was found to have a neck contracture. A contracture release with the defect closed using a left supraclavicular flap was performed, with excellent results (Fig. 22-24).
**Back:**

A perforator flap is the transverse back perforator flap. This flap is based on perforators off of the lumbar artery. It is taken just above the sacrum and can be turned distally to cover large sacral defects as seen in a case below.

Fig 25  Fig 26  Fig 27
Lady developed a large sacral decubitus secondary to radiation. Reconstruction performed with two large transverse back flaps and biceps femoris flap (See Chapter on Pressure Ulcers)

**Conclusion:**

Perforator flaps will definitely be the answer for a number of our reconstructive needs in the future. The editor suggests that surgeons first master the basic flaps. The one perforator flap that can be put into our practice immediately is the posterior tibial perforator flap for immediate reconstruction of lower leg and ankle trauma giving excellent coverage for bone and tendons. The other flap that can also be used for the lower leg and ankle is the reverse sural artery flap which is also a perforator flap. It is discussed in lower extremity reconstruction. Most distal tibial and ankle defects can be covered by one of these flaps. Perforator flaps have given the plastic surgeon many new alternatives for reconstruction of the entire body and especially the distal third of the leg.

(Editor's comments: Dr. Nthumba has been in the forefront in the use of perforator flaps in Africa. Though the perforator flaps include the superficial fascia, the dissections initially extend beneath the muscle fascia in order to identify the perforators. This deep fascia may be included in the flap or a cuff of deep fascia may be taken with the pedicle and the dissection continued superficial to the muscle fascia and deep to the superficial fascia.)
Keystone Island Perforator Flaps:

A new perforator flap design is the "keystone island perforator flap" which takes skin and superficial fascia in a keystone pattern adjacent to the defect that needs to be covered. This keystone flap is trapezoidal in shape and bent in the shape of an arc. The longest side or convex side is designed on the side opposite the defect to be covered. The height of the trapezoidal flap is at least the same height or greater than the defect to be covered in order to capture the perforator blood supply. Ideally the flap lies in the longitudinal axis of the dermatomes. This will help insure the flap will run parallel to longitudinal neurovascular structures and enable inclusion of perforators. By incising completely around this "keystone" flap area, it allows extended mobilization of tissue adjacent to the defect which is supplied by perforators. Careful dissection (often blunt dissection) is carried in a plane beneath the superficial fascia or deep muscle fascia in order to identify the perforators. These are preserved. When the original defect is closed by this flap, then tissue surrounding the "keystone" flap donor area must also be undermined in order to close the secondary defect or a skin graft can be used. The ends are closed in a V-Y manner. In addition, keystone flaps may be placed on both sides of the defect for a midline closure. When using one keystone flap it is important that it be placed on the side of the wound with the most laxity. In the lower leg this is usually medial and posterior.

In Fig 28, B, the width/height of the keystone flap must be equal or greater than A, width/height of the defect to be closed. C, the angle between the defect and sides of the keystone flap should be approximately 90°. D, the convex side of the keystone flap, should be a semi-circle between the ends of the trapezoidal flap and not straight lines as shown in the figure. Red dots indicate perforators. E is the side of the keystone flap nearest the defect and F is the side of the defect opposite the keystone flap. E is sutured to F and D becomes the opposite side of the defect closed by the flap. When the defect is closed by the keystone flap the ends may be closed in a Y-V manner. This narrows the height of the defect. At the end of the case, the closure results in a circumferential suture line around the island flap which is supplied by underlying perforators.
Fig 28

This area is undermined

![Diagram of a defect and donor keystone flap]

Fig 29

Undermined for closure

![Diagram showing V->Y and resulting defect and donor area closed by this island]
There are many applications of the keystone flap and the reader is referred to the book *The Keystone Perforator Island Flap* by the originators of this method of closure, Behan, Findlay and Cheng Hean Lo. The authors are from Melbourne, Australia, and this is an Elsevier publication in 2012 with an ISBN of: 978-0-7295-3971-5.

Conclusion: The surgeon in Africa now has multiple local methods to cover the lower third of the leg. In most cases a microvascular free flap will not be necessary. These new methods include:

1. Posterior tibial perforator flap  
2. Reverse sural artery flap  
3. Keystone island perforator flap  
4. VAC with a secondary skin graft  
5. Cross-leg flap.

In addition, local rotation fasciocutaneous flaps are possible. The decision on which flap or method to use depends on a number of factors including location of the defect, zone of injury, vascular status, presence of an open fracture, age of patient, history of smoking, surgeon’s knowledge and experience with each method of closure, etc.