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Research Paper

Perforator Flaps in Reconstructive Surgery: Report of Our Service's Experience

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Abstract:
Perforator flaps have revolutionized reconstructive surgery by enabling reliable tissue coverage while significantly reducing donor site morbidity. Based on the use of small-caliber perforating vessels, these flaps allow the transfer of cutaneous and subcutaneous tissues without sacrificing muscle. Advances in the understanding of vascular anatomy and the use of preoperative imaging—particularly Doppler ultrasound and CT angiography—have enabled precise planning and safe dissection.
Numerous variants have been developed, including deep inferior epigastric perforator (DIEP) flaps, anterolateral thigh (ALT) flaps, gluteal perforator flaps, and freestyle flaps, each with specific indications and advantages. The emergence of supermicrosurgical techniques, particularly perforator-to-perforator anastomoses, has expanded reconstructive options, especially for distal or complex tissue defects. This article provides a review of the principles, technical aspects, and clinical applications of perforator flaps, highlighting their central role in modern reconstructive surgery.

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I. Introduction:

Flap surgery is based on the transfer of tissue with its own vascular supply from one anatomical region to another. Improved understanding of cutaneous blood supply, along with advances in microsurgical instrumentation, has led to the emergence of the perforator flap concept.

This innovative approach combines enhanced vascular reliability with optimal reconstructive outcomes, while minimizing functional and aesthetic sequelae at the donor site. (1)

Historical Background:
In 1988, Kroll and Rosenfield paved the way for a new approach in reconstructive surgery by proposing the design of flaps based exclusively on perforating arteries. They highlighted the potential benefits of this technique, particularly the reduction of donor site morbidity.

The following year, in 1989, Koshima and Soeda introduced the term *perforator flap* for the first time, describing two cases of cutaneous-adipose flaps vascularized by a paraumbilical perforating artery originating from the deep inferior epigastric artery. (2)

These examples demonstrated the main advantages of this new generation of flaps: a large available skin surface, greater thinness compared to traditional musculocutaneous flaps, and significantly reduced donor site morbidity.

Definition:
A perforator flap is defined as a cutaneous-adipose flap vascularized by one or more perforating vessels that pass through a deep structure—such as muscle, fascia, or an intermuscular septum. These vessels may be **direct cutaneous perforators**, which only traverse the fascia, or **indirect perforators**, which pass through muscle (**musculocutaneous**) or between muscles (**septocutaneous**).

The Ghent consensus conference, led by Blondeel, established six core definitions to standardize the terminology of perforator flaps. First, a perforator flap consists solely of skin and subcutaneous fat, and its blood supply comes exclusively from perforators originating from deep structures, typically muscular.

A **muscular perforator** is defined as a vessel that passes through a muscle to reach the skin, while a **septal perforator**follows an intermuscular path via a septum. Depending on the nature of the source vessel, the flap is classified as either a **muscular perforator flap** or a **septal perforator flap**.

Finally, the nomenclature of perforator flaps is based on the **source vessel** from which the perforator arises, rather than the muscle it traverses. When a single vessel gives rise to multiple perforator flaps, their names should be specified based on anatomical location or nearby structures. (3)

Physiological Principles:

Mastery of the vascular anatomy of cutaneous perforating vessels is a critical step in planning perforator flaps. Taylor made a significant contribution to this understanding by establishing a detailed map of cutaneous vascularization.

He identified 374 dominant cutaneous vessels with a diameter of 0.5 mm or greater. Through his work, he introduced the concept of the **angiosome**, defined as the cutaneous territory supplied by a specific perforator, which communicates with adjacent territories via vascular anastomoses. (4)

This vascular organization allows a single perforator to perfuse not only its own angiosome but also that of a neighboring perforator, provided the latter is ligated. However, including a third angiosome within the same flap generally exceeds the vascular capacity of a single perforator, putting that territory at risk of necrosis. As a result, a reliable perforator flap typically corresponds to the area of two angiosomes, as long as it is supplied by a single adequate perforator.

Perforator flaps offer several major clinical advantages. They significantly reduce donor site morbidity by preserving deep structures such as muscles, fasciae, and nerves. The flap can be precisely tailored to the patient's needs, improving both the aesthetic and functional outcomes of reconstruction.

However, their implementation poses certain challenges. The dissection of perforators through muscle remains a delicate and time-consuming procedure. Moreover, there is considerable anatomical variability in perforator vessels, making their intraoperative identification sometimes uncertain. The risk of intraoperative vascular injury is not negligible, as are the microsurgical complications associated with the long and branching pedicle—particularly vasospasm or thrombosis.

Imaging:

The decision to proceed with a perforator flap must be preceded by a thorough evaluation and control of risk factors that may impair microcirculation, such as smoking, atherosclerosis, hematologic disorders, oral contraceptive use, and certain systemic diseases.

Preoperative planning is essential—both in terms of the tissue defect and the recipient site—taking into account the volume and surface area to be reconstructed. An ideal donor site is characterized by relatively constant vascular anatomy, the presence of at least one perforator of adequate caliber, and a pedicle length sufficient to ensure flap viability.

Color Doppler ultrasound is a valuable tool in the planning of perforator flaps. It allows not only for precise localization of perforators but also for the assessment of their diameter and the velocity of blood flow. This technique is noted for its high sensitivity and positive predictive value, approaching 100%. Its effectiveness is enhanced by the fact that perforators typically follow a perpendicular course relative to the skin surface. This orientation produces a strong Doppler signal, facilitating preoperative detection and mapping.

Magnetic resonance imaging (MRI) offers better contrast resolution than CT angiography, although it has lower spatial resolution. It is particularly effective in visualizing the vascular network in adipose-rich environments.

When performed with contrast injection using appropriate protocols, CT angiography allows for high-quality imaging and three-dimensional reconstructions. Its high spatial resolution enables precise visualization of the location, course, and caliber of perforators—down to vessels as small as 0.3 mm. It is more effective than MRI in evaluating the intramuscular course of vessels.

Radiological assessment is a crucial step in the planning of perforator flaps. Doppler ultrasound enables accurate localization of the cutaneous projection of perforators, which is particularly useful for the design of propeller flaps. CT angiography remains the gold standard for evaluating the intramuscular vascular course—especially in DIEP flaps, which are characterized by a complex intramuscular network.

In cases where CT is contraindicated, or when the clinical context requires it, magnetic resonance imaging is a valuable alternative. Although non-ionizing, MRI provides high-quality visualization of the vascular network, particularly within fatty tissues.

Different Perforator Flaps:

- **Deep Inferior Epigastric Perforator (DIEP) Flap**

The perforators arise from the inferior epigastric vessels, which originate from the external iliac vessels above the inguinal ligament.

First described by Koshima and Soeda in 1989 (5), the deep inferior epigastric artery perforator (DIEP) flap represents a technical evolution of the transverse rectus abdominis myocutaneous (TRAM) flap (6), aiming to preserve the muscle and its aponeurosis to reduce abdominal wall morbidity (7,8).

Perforator detection is performed preoperatively either by Doppler ultrasound or CT angiography. The flap design is adapted according to the indication, considering the variable role of the inferior epigastric artery in abdominal skin vascularization, which follows a mediolateral gradient (Hartrampf zones) (9).

The excision area follows the same landmarks as those used for a TRAM flap or abdominoplasty, allowing the scar to be positioned in the lower abdomen where it remains discreet.

The abdominal flap is elevated in contact with the aponeurosis, with particular attention paid to the paraumbilical perforators, which are critical for flap vascularization. Perforators of suitable caliber, generally one or two, are identified and preserved, while the others are ligated or coagulated.

Dissection usually begins with the largest or most lateral perforator. A vertical incision is made in the superficial aponeurosis aligned with the selected perforator. Intramuscular dissection allows determination of which perforators can be used to vascularize the flap. This step, along with the selection of perforators to preserve, is greatly facilitated by data provided by CT angiography.

Finally, the inferior epigastric pedicle is dissected back to its origin from the external iliac vessels and divided at this point to obtain maximum length and optimal vessel caliber.

When intramuscular dissection of the perforators proves too complex, it may be necessary to include a thin portion of muscle around the pedicle, following the muscle-sparing TRAM technique. Additionally, the presence of a midline subumbilical scar, which prevents crossing the midline in flap design, requires harvesting only one abdominal hemi-flap. In this case, preservation of a well-calibered subcutaneous abdominal vein is essential to ensure adequate drainage and maintain the entire useful volume, while the contralateral hemi-flap is sacrificed.

The main indications for the deep inferior epigastric perforator flap include breast reconstruction, inguinal or thigh reconstruction using a pedicled flap, repair of large tissue defects, and pelviperineal reconstruction. However, certain abdominal scars may represent contraindications by limiting the available donor area.

Among its advantages are the quality of volume and surface contouring, the possibility of secondary reshaping via liposuction, and low donor site morbidity with inconspicuous scars. Nevertheless, this technique has disadvantages, including significant anatomical variability and often lengthy operative times.

- **Anterolateral Thigh Flap**

The anterolateral thigh flap, or lateral circumflex femoral artery perforator flap (LCFAP), is a perforator flap vascularized by septocutaneous or musculocutaneous perforators arising from the descending branch of the lateral circumflex femoral artery. This technique was initially described by Song in 1984. (10)

The harvesting technique of the anterolateral thigh flap involves a design following the line connecting the anterior superior iliac spine to the lateral border of the patella, with identification of the midpoint. Doppler mapping typically localizes perforators within a 3 to 4 cm radius around this point, which should be included in the flap design.

The incision is made along the medial border of the flap down to the fascia of the rectus femoris muscle. The septocutaneous perforators, located lateral to this muscle, are then identified. Dissection continues at the intermuscular septum between the rectus femoris and vastus lateralis muscles, where the descending branch of the lateral circumflex femoral artery is found.

In the absence of septocutaneous perforators, musculocutaneous perforators originating from the vastus lateralis muscle may be sought. Direct closure of the donor site is possible if the flap width is 8 cm or less.

Indications for the Anterolateral Thigh Flap are varied. It is used to cover various tissue defects, often as an alternative to the radial forearm flap, with the advantage of sparing a major vascular axis and resulting in a less conspicuous donor site scar. (11,12)

As a pedicled flap, it is employed in certain phalloplasty techniques. It also allows coverage of perineal defects (13), lower abdominal wall defects, and the knee region. (14)

A bridging flap use is possible, particularly in distal extremities with combined soft tissue and vascular injuries. (15)
This flap can be made sensate if the lateral femoral cutaneous nerve is included during harvest.

Advantages:
- Large, thin flap allows for good resurfacing. (16)

Disadvantages:
- Variability in the origin and course of perforators.
- Difficult dissection.
- Ethnic variability.

Figure 1. Preoperative mapping of the ALT (Anterolateral Thigh) flap with marking of vascular axes and anatomical landmarks.


Figure 2: The harvesting the ALT flap

- **Superior and Inferior Gluteal Perforator Flaps**

Described by Koshima and Allen (17), the gluteal perforator flaps are derived from the gluteal musculocutaneous flaps (18,19) and are based on perforators from the following pedicles:

- Superior gluteal artery perforator (SGAP)
- Inferior gluteal artery perforator (IGAP) (20)

The pedicle originates from the superior or inferior gluteal vessels.
The superior gluteal artery arises from the internal iliac artery, exits the pelvis above the piriformis muscle, and

enters the gluteus maximus muscle at the junction one-third of the distance between the greater trochanter and the posterior superior iliac spine.
The inferior gluteal artery is also a branch of the internal iliac artery. It passes through the greater sciatic foramen below the piriformis muscle. It is accompanied by the sciatic nerve, internal pudendal vessels, and the posterior femoral cutaneous nerve.

- **Superior Gluteal Artery Perforator (SGAP) Flap Technique**

Anatomical landmarks are first marked on the patient in a standing position.
A line is drawn between the greater trochanter and the posterior superior iliac spine, with the emergence of perforators located approximately at the medial third of this line.
Doppler ultrasound is used to identify one or more perforators.
A skin paddle, oriented obliquely upward and outward, is designed around the perforators.
The patient is then positioned in the lateral or prone decubitus position for surgery.
The approach to the perforators proceeds from lateral to medial, with muscle dissection following the orientation of the muscle fibers.
The perforators are isolated, followed by identification and dissection of the superior gluteal vessels.
The average pedicle length ranges from 3 to 6 cm.
The donor site scar may be depressed and often appears less aesthetic than that observed after harvesting an IGAP flap.
This flap is indicated for breast reconstruction when the abdominal excess is insufficient or scarred, and when a moderate to large gluteal volume excess is available. Vascular anastomosis is preferably performed on the internal mammary vessels due to the short pedicle length.
It is also used to cover defects located in the sacral region (SGAP) or ischial region (IGAP as a pedicled flap to achieve adequate pedicle length) (21).
For lumbar defects (22), a pedicled SGAP with a laterally extended skin paddle allows an appropriate arc of rotation.
Advantages of this flap include a longer pedicle compared to gluteal musculocutaneous techniques, sufficient tissue bulk for reconstruction of small to medium-sized breasts, and low donor site morbidity characterized by a discreet scar and minimal functional impairment thanks to the preservation of muscular and neural structures.
However, this technique may have limitations, including difficulty in shaping adipose tissue and the risk of hypoesthesia of the posterior thigh due to involvement of the posterior femoral cutaneous nerve.

- **Thoracodorsal Perforator Flap**

The thoracodorsal perforator flap is a reliable reconstructive option that preserves the integrity of the latissimus dorsi muscle. However, its anatomy remains variable. The thoracodorsal pedicle, originating from the subscapular vessels, divides within the muscle into two main branches: a horizontal branch and a descending vertical branch, the latter giving rise to the largest perforators. These perforators are generally located approximately 8 cm below the posterior axillary fold, 4 cm inferior to the scapular tip, and 2 cm posterior to the anterior border of the latissimus dorsi muscle. (23,24)

Technique:

The patient is positioned in the lateral decubitus position with the arm abducted at 90°. An incision is made along the anterior border of the latissimus dorsi muscle, allowing inclusion of an anterior cutaneous perforator if needed. Dissection begins at the anterior border of the muscle and progresses posteriorly, beneath the muscular aponeurosis, until a perforator of adequate caliber is identified. The procedure is generally facilitated when the perforator arises from the descending branch of the pedicle due to a shorter intramuscular course. When multiple perforators are aligned along the same axis, they can be harvested simultaneously. Dissection continues proximally to the origin of the subscapular pedicle, ligating collateral branches according to the required pedicle length.

The thoracodorsal nerve is systematically preserved.

Finally, the flap is separated from the underlying muscle, and the skin paddle is tunneled through the muscle to its undersurface for transfer.

Figure 3: Surgical steps for harvesting the thoracodorsal perforator flap

Indications:
This flap is indicated in cases where preservation of the latissimus dorsi muscle is essential, particularly in patients who engage in regular sports activities or are exposed to repetitive trauma such as crutch use. It is also useful in breast reconstruction (25,26), especially for correcting localized partial defects in the outer quadrants of the breast. Additionally, this flap can be used as a composite flap, combined with muscle harvest (e.g., serratus anterior muscle) or bone (scapula), to address complex reconstructive needs.

Advantages and Disadvantages:
This flap offers several advantages, including a large skin paddle with reduced thickness compared to the musculocutaneous flap, facilitating aesthetic integration. It also preserves both the appearance and function of the donor site by maintaining the integrity of the latissimus dorsi muscle. Moreover, it provides a pedicle of satisfactory length, which is beneficial for microsurgical anastomoses.
However, certain limitations must be noted: the limited number of large-caliber perforators may compromise the vascular reliability of the flap, and the dissection remains technically demanding.

- **Deep Circumflex Iliac Artery Perforator Flap (DICAP)**

The deep circumflex iliac artery perforator flap is a refinement of the free iliac crest flap.
Anatomy:
The deep circumflex iliac artery arises from the external iliac artery.

Technique:
- The perforator is usually located 1 to 2 cm above the iliac crest and 5 cm posterior to the anterior superior iliac spine.
- The flap design covers this point identified by Doppler ultrasound.
- The long axis of the flap corresponds to the superior border of the iliac crest.
- The skin paddle is harvested based on the perforator. (27,28)

Indications:
The deep circumflex iliac artery perforator flap is used for reconstruction of osteocutaneous defects, particularly in mandibular reconstruction.

Advantages:
- Absence of a muscular component.

Disadvantages:
- Aesthetic sequelae.

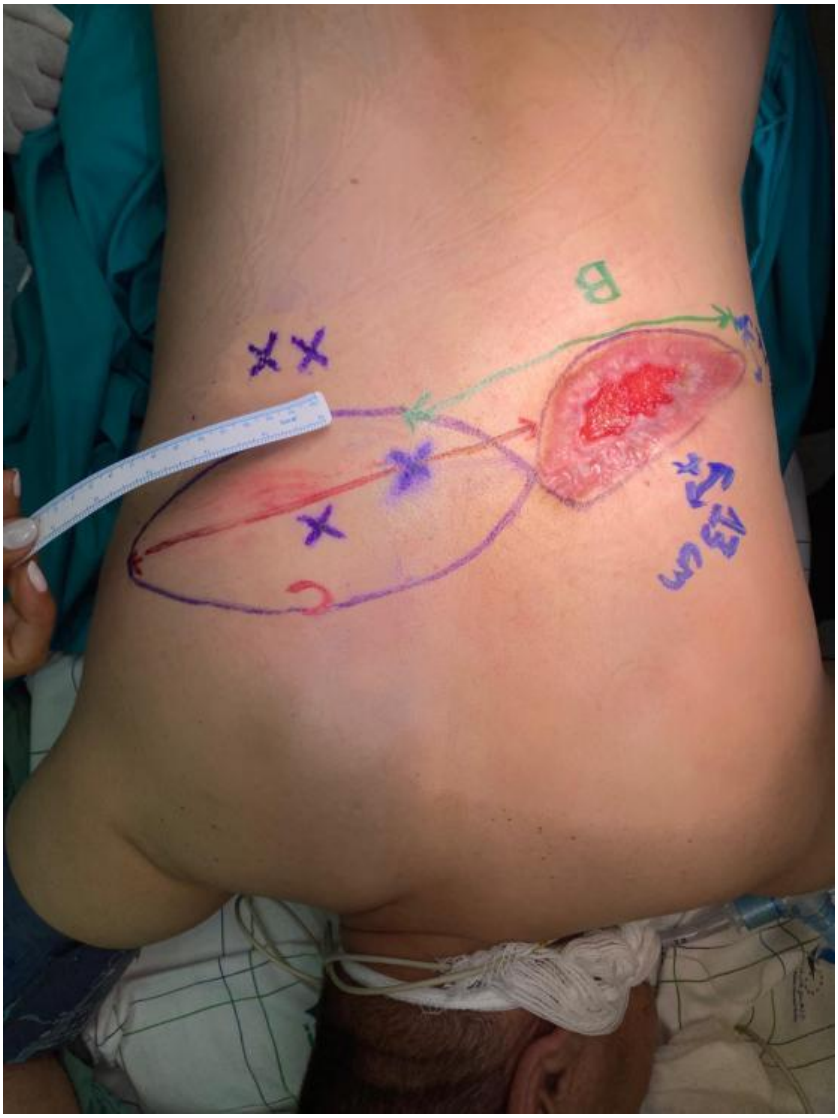

Figure 4: Intraoperative marking of the DICAP flap with identification of perforators for skin coverage of a tissue defect.

Figure 5: The DICAP flap is positioned at its donor site.

- **Perforator Propeller Flaps (29,30)**

Perforator propeller flaps, also known as "propeller flaps," are a local coverage technique based on a single perforator vessel. These island flaps are custom-designed to conform to the defect's topography and then mobilized by rotation up to 180°, similar to a propeller, allowing coverage of the tissue defect.
This approach is particularly indicated for reconstruction of defects in the distal third of the leg and ankle.
A perforator propeller flap is characterized by three essential elements:

- The nature of the nourishing pedicle,
- The degree of rotation,
- The source artery of the perforator.

- **Technique:**

Perforators are localized using Doppler ultrasound (28). The perforator that will serve as the pivot point for flap rotation is identified. The flap is designed along the axis of a second perforator. Its width should correspond to that of the defect, while its length must be at least equal to the sum of the defect length and the distance between the defect and the pivot point.
Once elevated, the flap can be rotated up to 180°, either clockwise or counterclockwise, depending on the configuration of the defect. The donor site is then closed primarily or grafted.

- **Free Style Flaps**

The concept of the “free style perforator flap” is based on the possibility of harvesting a flap from any anatomical region where a perforator of adequate caliber is identified. The required flap characteristics determine the anatomical harvest site, which must match the defect in terms of dimensions, thickness, color, and texture. The ideal perforator is located using Doppler ultrasound. The surgical strategy is defined during dissection and can be adjusted based on intraoperative findings.

Heel Coverage Using Free Style Perforator Flaps: In the article by Herlin et al. (31), the authors report the use of three types of free style perforator flaps (ALT, TD) with microanastomoses in four patients presenting heel defects. The identified causes of these defects included pressure ulcers, trauma, and excision of vascular malformations. Defect sizes ranged from 4 × 5 cm to 6 × 7 cm.
In one reported case, a 45-year-old man had a defect following a road traffic accident. The lesion, located at the heel weight-bearing area, was initially managed by secondary intention healing. However, this area experienced multiple episodes of superinfection and unstable epidermal coverage, resulting in repeated failure of skin grafts.
A radical therapeutic strategy was then implemented, including complete debridement followed by coverage with an anterolateral thigh (ALT) flap harvested from the thigh. To restore some cutaneous sensation, a branch of the lateral femoral cutaneous nerve was used for flap reinnervation.

After exposure of the posterior tibial vessels, a 7 × 13 cm skin paddle was raised. The donor site was closed primarily. Vascular anastomosis was performed in a "T" configuration on the posterior tibial artery at the level of the retromalleolar groove, allowing preservation of distal foot perfusion.
The postoperative course was uncomplicated, with partial weight-bearing resumed on day 11 and full weight-bearing on day 21. At two years follow-up, the functional and aesthetic outcome was considered very satisfactory.

- **Supermicrosurgery and the "Perforator-to-Perforator" Technique**

Supermicrosurgery refers to a highly precise surgical approach allowing vascular or nerve anastomoses on very small structures, typically less than 0.8 mm in diameter. This technique requires the use of ultrafine sutures, specialized microsurgical instruments, and rigorous technical expertise from the surgeon.
In the field of perforator flaps, it finds innovative application through the so-called "perforator-to-perforator" technique, which consists of directly connecting two perforators without dissecting the main deep vascular trunks. This method offers several notable benefits. It reduces operative time by eliminating the dissection step of the principal vascular trunks. It also minimizes donor site morbidity by preserving the deep vascular network. Finally, it provides great technical flexibility, as the harvest can be performed from any perforator of sufficient caliber, depending on the location and characteristics of the defect to be treated.
Its main indications concern the extremities, particularly the hands and feet, where the presence of suitable recipient perforators is frequent. This approach thus enables more targeted, less invasive reconstructions while ensuring optimal vascular safety.

II. Conclusion:

Perforator flaps represent a major advancement in the field of tissue reconstruction. They allow for satisfactory functional and aesthetic outcomes while significantly reducing donor site morbidity by limiting harvest to only the tissues necessary to cover the defect.

However, the implementation of this technique requires rigorous technical expertise, a significant learning curve, and high operative precision to avoid excessively prolonging the procedure or compromising flap viability.

Imaging plays a fundamental role in locating perforator vessels and in meticulous surgical planning. A well-structured and individualized operative strategy is essential to fully leverage the benefits of perforator flaps in modern reconstructive surgery practice.

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