ERGONOMICS OF PERFORATOR/ PROPELLAR FLAPS IN LOWER LIMB

Dissertation submitted to

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CERTIFICATE

This is to certify that the dissertation entitled, "**ERGONOMICS OF PERFORATOR/PROPELLAR FLAPS IN LOWER LIMB"** Submitted by **DR.J.ROMUL DHAYAN RAJA** in partial fulfilment of the requirements for the award of the degree of M.Ch in Plastic & Reconstructive Surgery by The Tamilnadu Dr.M.G.R. Medical University Chennai is a bonafide record of the work done by him in the Department of Plastic Reconstructive & Facio-Maxillary Surgery, Madras Medical College, Chennai, during the academic year 2010 to 2013.

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DECLARATION

I Dr.J.ROMUL DHAYAN RAJA solemnly declare that the Dissertation titled **“ERGONOMICS OF PERFORATOR / PROPELLAR FLAPS IN LOWER LIMB”** has been prepared by me in the Department of Plastic Reconstructive & Facio-Maxillary Surgery, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai. This is submitted to The Tamil Nadu Dr.M.G.R. Medical University, Chennai, in partial fulfilment of the Requirements for the Examination to be held in AUGUST – 2013 for the award of M.Ch. Degree (Branch III) in Plastic & Reconstructive Surgery.

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INTRODUCTION

Tissue defects in lower limb still present a challenge for the reconstructive Surgeon. Various types of flaps have been used in order to cover them. Perforator/propeller flap represent the latest milestone in the evolution of reconstructive surgery in the armamentarium of local flaps. Local flaps reconstruct the defect with good colour match, texture match, thickness match and also with intact sensation.

Since vascular anatomy of perforator vessel has advanced and the availability of microsurgical techniques improved, we have come to recognize the large network of perforator vessels present throughout the body and their potential for flap dissection. This perforator flap are upgraded version of musculocutaneous flaps with complete sparing of muscles and reduced local morbidity and functional disabilities. Even more beneficial and exciting development has been the possibility of using tissue close to or adjacent to the defect as a local perforator/propellar flap.

This technique not only provides a simpler and more expeditious repair, but arguably a superior aesthetic result because of better tissue match. The increased availability of local flap options, a direct result of applied knowledge from perforator flap research, has enabled the reconstructive surgeon to walk down the reconstructive ladder to a simpler, local solution for a problem that in previous years had required a free flap.

To select the perforator flap, factors like dimensions of the defect, surrounding structures involvement, morbidity, functional and aesthetic aspects of the procedures should be considered in each case. Perforator flaps have advantage over free flaps reconstruction in lower limb with ease to perform, single team approach reduced operating time and morbidity.

The questions yet to be answered are perforator blood flow physiology, maximum size of flap that can be harvested on a single perforator, relationship between size of perforator and flap dimention. If its related to size, the yard sticks that can be used for assessing the size of the perforator preoperatively and peroperatively have to be standardized. In propeller flap additional factors incremental for rotation clock wise or counterclock wise has to be determined.

The advantages of the perforator/propellar flaps are muscles and their functions are preserved, the main vascular trunks are spared, reconstruction with like tissue, the donar site can often be closed primarily, the general morbidity is reduced and better aesthetic results can be achieved.

AIM AND OBJECTIVES

1. To design various flaps based on perforators in the lower limb.
2. To standardize the technique of harvest of perforator/propeller flap.
3. To understand the physiology of blood supply to the newly innovated flap.
4. To ascertain the usefulness of these flaps in planning reconstructive surgery.
5. To improve aesthetic and functional outcome and reducing local morbidity.

EVOLUTION OF PERFORATOR FLAPS

For more than 20 centuries the use of skin flaps has been one of the best and most widely used methods of repairing defects all over the body. In 1920 Sir Harold Gillies recognized that tissue transfer was a constant battle between ‘blood supply and beauty’. [1]In 1965 deltopectoral flap was described by Bakamjian. For larger defects, multistaged tube pedicle flaps, first described by Filatov[2] and popularized by Gillies and others, were used. More than 20 years passed before Milton (1969) confirmed Esser's finding that the existence of an adequate vessel in the pedicle is the most important factor in flap survival.

It was the development of the practice of microsurgery by Buncke[3] and others that fueled the discovery of new flaps. The breakthrough occurred when the first cutaneous free flap was reported in Melbourne by Taylor and Daniel.[4]

It was realized that in many regions of the body, the skin obtains its blood supply through the underlying muscles. This finding led to the discovery of many musculocutaneous flaps by Ger, Orticochea, McGraw, and others[5-8] thus greatly expanding the repertoire of the reconstructive surgeon. It was not until 1973 that

McGregor and Morgan, realizing a practical application of Milton's work, first proposed the axial and random flap classification based on their series of deltopectoral flaps.

In 1981 Ponten[9] observed that the inclusion of the deep fascia in extremity reconstruction led to more reliable flaps. These ‘super flaps’ marked the beginning of fasciocutaneous flaps. The classification of muscle and musculocutaneous flaps described by Mathes and Nahai, in 1981, and fasciocutaneous flaps by Cormack and Lamberty, in 1986[10, 11].

The reconstructive ladder was rapidly lengthening, with more options available. The focus then changed to flap refinement. The body of knowledge was further augmented by Taylor and Palmer in1987, [12] who not only rediscovered the largely forgotten works of Manchot in1889 and Salmon in1936,[13-15] but also performed their own extensive injection studies and cadaver dissections.

These investigators further elucidated the arterial, venous, and lymphatic circulation to the skin and its contents, enabling Taylor to propose the ‘angiosome concept’ of interconnecting vascularity of the skin, which greatly helped our understanding of how flaps survive. Taylor’s anatomic dissections divided the body into 40 angiosomes and identified almost 400 good-sized arterial perforators (at least 0.5 mm diameter), which each supplied a volume of skin and therefore were capable of serving as pedicles for perforator flaps and could be detached and transferred as free flaps[16]. This obviously greatly increases the number of flaps available for reconstruction,

It was discovered that in most locations there were set patterns in the way skin obtained its blood flow through direct branches from source vessels that penetrated the fascia, or vessels that first traversed muscle or passed through septa between the muscle groups, or occasionally through vessels that first supply the bone, tendon, nerves, and so forth, giving rise to the concept of perforator flaps.

As a result of these evolution in 1989 Koshima and Soeda's[17] presented their work with a skin flap based only on a perforating vessel of the deep fascia that emanated from the deep inferior epigastric artery. That led to the practical application of perforator flaps. The ‘propeller flap concept’ was described by Hyakusoku et al[18], in 1991 an adipocutaneous flap designed as a propeller, with a random subcutaneous pedicle blood supply and rotated 90^0.

In 2003 Wei and Mardini[19-20] coined the term freestyle flaps to describe the many potential flaps that could be raised on any of these yet unnamed perforating pedicles. In contrast to free perforator flaps, local perforator flaps offer a limited range of flap movement depending on tissue elasticity and perforator vessel length. It can be increased by periperforator dissection into the muscle or the fascia with a propeller design.

REVIEW OF LITERATURE

Koshima introduced the term perforator flaps to differentiate them from fasciocutaneous flaps, as he was convinced that the fascial vascular plexus did not contribute to the vascularisation of the flap but with perforator vessel. Its growing popularity is mainly related to the decrease in donor-site morbidity as a consequence of the preservation of muscle innervations, vascularisation, and functioning donor muscle.

The advantages of harvesting relatively large and thin skin flaps include the presence of long vascular pedicles based on well-known source vessels, the absence of postoperative muscle atrophy as seen in myocutaneous flaps, and the possibility of harvesting sensory nerves with the flap, providing a tool to perform more accurate and precise reconstructions.

[21-24]The main architecture of the skin's microvascular supply includes arterioles, terminal arterioles, precapillary sphincters, capillaries, postcapillary venules, collecting venules, and muscular venules.[25] The arterioles arise from direct or indirect arterial branches to the skin. The vasculature of the skin and subcutaneous tissue is arranged in five vascular plexuses: the subepidermal plexus, dermal plexus, subdermal plexus, subcutaneous plexus, and the fascial plexus

(prefascial and subfascial). Each plexus consists of a fine meshwork of interconnecting vessels that runs in a horizontal sheet at the anatomic level corresponding to the name of the plexus.

Numerous perforating arteries supply the plexus arrangement of vessels above the fascia. These perforators arise from the source arteries below the fascia and approach the skin by passing through muscle and then perforating the overlying fascia (musculocutaneous perforators), or by passing around the muscles through the intermuscular septa (septocutaneous perforators). Both [26] Spalteholz and Salmon defined cutaneous vessels as either direct or indirect.

Overall, the distribution of these two types of vessels in the body is approximately two thirds indirect musculocutaneous and one third septocutaneous. In the extremities, where numerous long thin muscles predominate, septocutaneous perforators are common, winding their way toward the skin by passing around the muscles and through the many intermuscular septa.

Basically, the lead oxide arterial injection technique of Salmon,[27] as modified by Rees and Taylor,[28] added gelatine and developed a new injection technique to study the vascular anatomy. This injection technique is the gold standard for vascular anatomic studies, because it allows simple dissection of the tissues, using a bright orange color to mark the vessels, and also provides excellent angiography. Using this technique the vascular territories of each perforator throughout the body identified. The number of perforators greater than 0.5 mm in diameter supplying the skin is noted. Well defined 61 vascular territories based on the dissection of these perforators are noted. These territories are illustrated in Fig.1

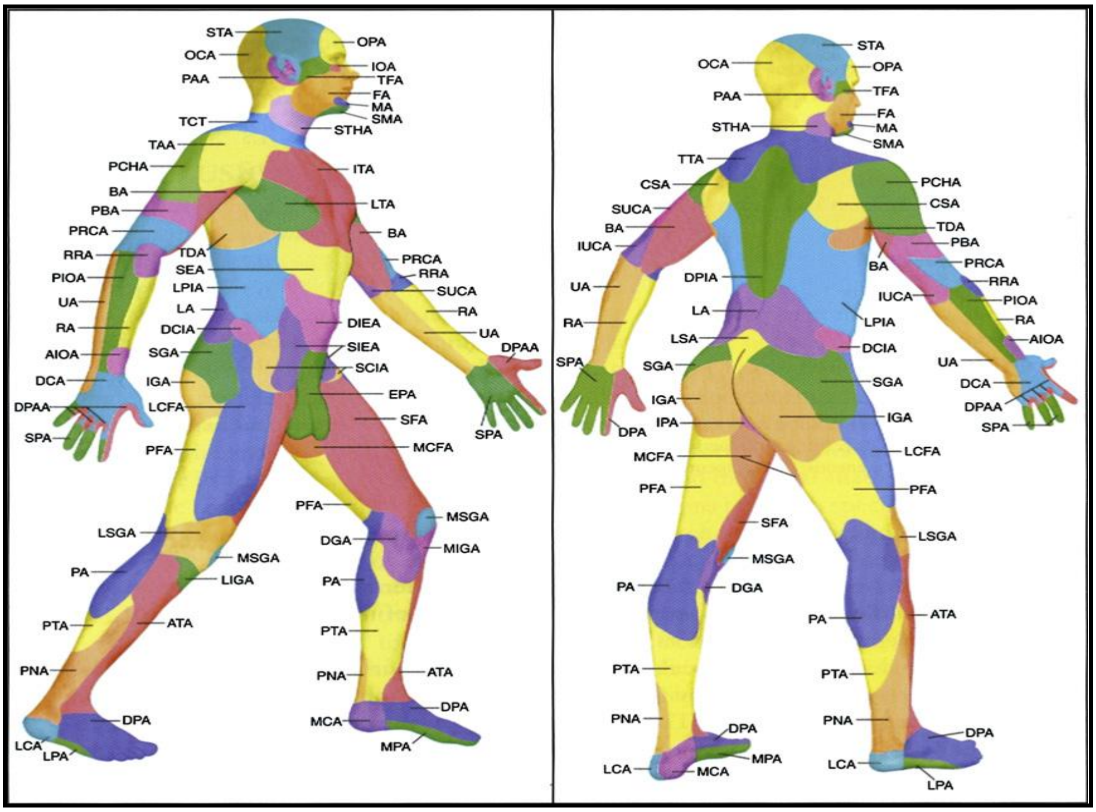


Fig.1. Schematic illustration of the body showing vascular territories that correspond to source Arteries

A perforator is a vessel that has its origin in one of the axial vessels of the body and that passes through certain structural elements of the body, besides interstitial connective tissue and fat, before reaching the subcutaneous fat layer.

Hallock[29] defines a perforator as any vessel that enters the superficial plane through a defined fenestration in the deep fascia, regardless of origin.

Perforators that pierce the deep fascia without traversing any other structural tissue are called direct perforators. All other perforators that run through deeper tissues, mainly muscle, epimysium or septum, are called indirect perforators.

In a perforator flaps, all branching vessels are ligated, except the skin perforator, and therefore, from the origin of the pedicle to the skin there is a single conduit with decreasing diameter. [30]In normal anatomic condition, blood velocity in the perforator is lower, whereas after surgery, i.e. in perforator flap architecture, blood velocity in the perforator is higher than in the corresponding pedicle. In perforator flaps there is an inversion of the gradient of blood velocity between the pedicle and the perforator compared to normal circulation, a phenomenon called the ‘inversion of velocity gradient’. Incresed blood flow is due to surgical sympathatectomy occuring while elevating the flap and ligation of muscle branches during periperforator dissection. According to ‘perforasome concept ‘of [31]saint-cyre et al flap raised on a single perforator will be hyperperfused resulting in increased filling pressure with the possibility of recruitment of the adjacent perforasome territories, explains the large dimension of the flap.

Taylor and colleagues[32] postulated that any flap based on a single perforator can, in addition to sustaining its own composite block of tissue (angiosome), safely supply the angiosome of the adjacent perforator and up to half the territory of the perforator next to it. Beyond that limit, perfusion is deemed to be unreliable and necrosis is likely, especially if the delay technique has not been used.[33] Teo TC observed in many clinical cases that a 1-mm perforator can safely perfuse its own angiosome as well as the tissues of more than 2 vascular territories away. It seems logical to conclude that size of the perforator, its perfusion pressure, and the intra flap axiality of vessel arrangements are the key determinants of the length of flap that can be sustained through a particular perforator.

In 1986, Nakajima et al[34] classified the deep fascial perforators into six patterns of vascular supply very accurately with precise description of the main target of each vessel and its course through the deeper tissues, this complex classification is not necessary. The consensus[35] was reached after terminology consensus meetings held during the Fifth International Course on Perforator Flaps in Gent, Belgium, on September 29, 2001, suggest differentiating among the following five types of perforators (Fig. 2):

1. Direct perforators perforate the deep fascia only.

2. Indirect muscle perforators predominantly supply the subcutaneous tissues.

3. Indirect muscle perforators predominantly supply the muscle but have secondary branches to the subcutaneous tissues.

4. Indirect perimysial perforators travel within the perimysium between muscle fibers before piercing the deep fascia.

5. Indirect septal perforators travel through the intermuscular septum before piercing the deep fascia.

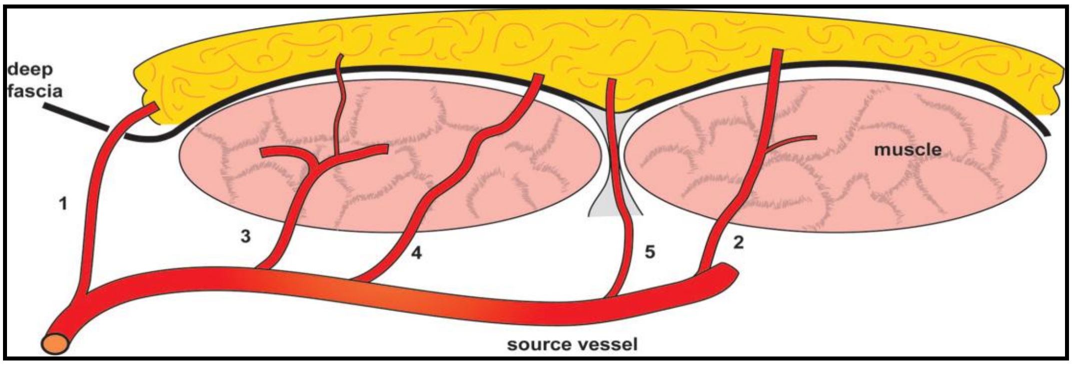


Fig.2. Schematic reprentation of the different types of direct and indirect perforator vessels

Modified definitions from the Sixth International Course on Perforator Flaps in 2002

A perforator flap is a flap consisting of skin or subcutaneous fat. The vessels that supply blood to the flap are isolated perforator(s). These perforators may pass from their source vessel origin either through or in between the deep tissues (mostly muscle).

A ‘‘muscle’’ or myocutaneous perforator is a blood vessel that traverses through muscle to pierce the outer layer of the deep fascia and to supply the overlying skin.

A ‘‘septal’’ or septocutaneous perforator is a blood vessel that traverses only through septum to supply the overlying skin after piercing the outer layer of the deep fascia.

A skin flap that is vascularized by a muscle perforator is called a muscle perforator flap or musculocutaneous perforator flap.

A skin flap that is vascularized by a septal perforator is called a septal perforator flap or septocutaneous perforator flap.

This reduced the classification from five different perforators to three different perforators in 2002 consensus:

1. Indirect muscle perforators (including perimysial perforators) that travel through muscle before piercing the deep fascia.

2. Indirect septal perforators that travel through the intermuscular septum before piercing the deep fascia.

3. Direct perforators that perforate the deep fascia only.

The Proposed Standard Nomenclature for Perforator Flaps are stated by Canadian[36] and European proposal based on source vessel and the perforator.

The nomenclature and abbreviations were very similar in both. The main difference was the use of suffixes to differentiate between muscular and septal perforator flaps. Additionally, the abbreviation of the name of the muscle through which the perforator runs was added to the abbreviation of the source vessel.

Eg: Direct cutaneous / septocutaneous perforator flap

LCFAP – Flap (Source vessel name is the lateral circumflex femoral, Artery Perforator)

Eg: Musculocutaneous perforator flap

LCFAP –*tfl* Flap (Source vessel name is the lateral circumflex femoral, Artery perforator, Muscle name is the tensor fascia lata)

Perforator flaps can be made as free perforator flap, free style perforator flap and pedicled perforator flap which is planned as rotation (Propellar), advancement, or transpositional flaps. The flaps may include one or more perforating vessels. Flaps that include only one perforator offer increased freedom of movement without vascular compromise[37]. Free flap indications are decreasing with emergence of perforator/propellar flaps because it is the ideal flap for local reconstruction which replace like with like tissue.

SURGICAL VASCULAR ANATOMY OF PERFORATORS IN LOWER LIMB

The lower extremity is the largest donor site in the body for perforator flap harvest. The integument of the lower extremity is bound superiorly by the inguinal ligament and iliac crest, and posteriorly by a line between the posterior superior iliac spines. The lower extremity is divided into the following four anatomic subregions: gluteal, hip and thigh, knee and leg, and ankle and foot.

CUTANEOUS VASCULAR TERRITORIES OF THE LOWER EXTREMITY

The superior and inferior gluteal arteries supply the integument of the gluteal region. The branches of the superficial and profunda femoral arteries supply the thigh. Just proximal to the knee, the femoral artery passes to the posterior aspect of the thigh. As the vessel enters the popliteal fossa, it becomes the popliteal artery and continues to supply the integument of the knee.

The popliteal artery ends in the upper part of the leg by dividing into anterior and posterior tibial arteries. These vessels and their branches, including the peroneal artery, supply the integument of the leg. At the ankle, the anterior tibial artery becomes the dorsalis pedis artery, along with the terminal branches of the posterior tibial and peroneal arteries, supplies the ankle and foot.

An average of 93 ± 26 perforators from 21 vascular territories supplied the integument of the lower extremity. The ratio of musculocutaneous to septocutaneous perforators was 1:1.The average diameter and area supplied by a single perforator were approximately 0.7 ± 0.3 mm and 47 ± 24 cm^2, respectively according to cadaver dissection and angiogram (Fig3). The main arteries supplying the lower extremity are listed in Table 1.

Table 1:- Cutaneous Vascular Territories of the Lower Extremity

Superior gluteal artery SGA	Lateral superior genicular artery LSGA
Inferior gluteal artery IGA	Lateral inferior genicular artery LIGA
Superficial circumflex iliac artery SCIA	Medial inferior genicular artery MIGA
(Superficial) femoral artery SFA	Posterior tibial artery PTA
Profunda femoris artery PFA	Anterior tibial artery ATA
Medial circumflex femoral artery MCFA	Medial calcaneal artery MCA
Lateral circumflex femoral artery LCFA	Lateral calcaneal artery LCA
Descending genicular artery DGA	Medial plantar artery MPA
Popliteal artery PA	Lateral plantar artery LPA
Medial superior genicular artery MSGA	Dorsalis pedis artery DPA

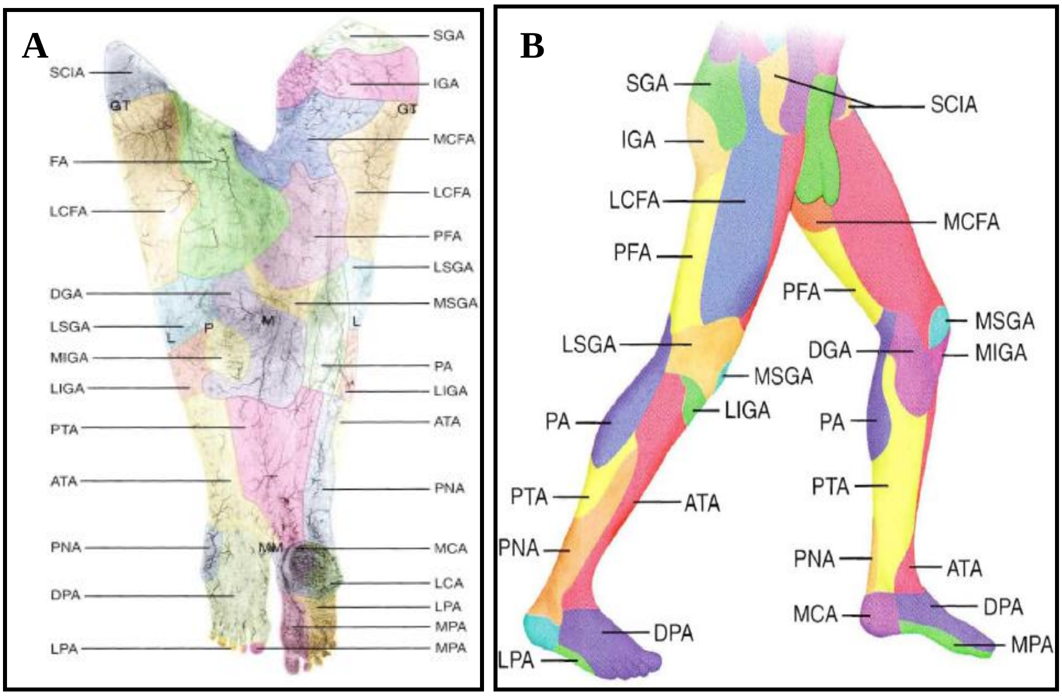


Fig3: A Angiogram of the integument of the lower extremity from a human cadaver specimen injected with lead oxide and gelatine, B Vascular territories

GLUTEAL REGION

The superior and inferior gluteal artries are the two major arteries of this region (Fig.4)

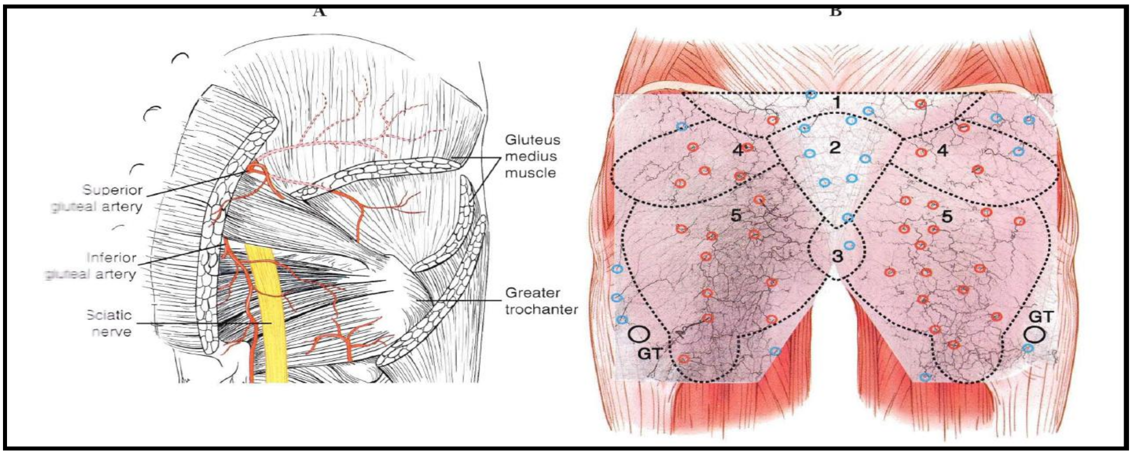


Fig-4A, Deep vessels of the gluteal region. B, Angiogram of the integument from a human cadaver specimen showing Red circles, MC perforators and blue circles SC perforators.

This region has the highest vascular density of all regions of the body.Perforator flaps from the SGA and IGA are useful in coverage of lumbosacral defects as propeller flaps.

SUPERIOR GLUTEAL ARTERY: SGA

The SGA is a terminal branch of the posterior trunk of the internal iliac artery. It courses above the piriformis muscle, where it divides into superficial and deep branches .It supplies a territory approximately198 ± 77 cm^2 via 9 ± 4 musculocutaneous perforators. The average diameter and area supplied by these perforators were 0.7 ± 0.2 mm and 19 ± 5 cm^2. These perforators had a very short superficial course and arborized immediately on piercing the deep fascial layer.

INFERIOR GLUTEAL ARTERY: IGA

The IGA supplies the inferior two thirds of the gluteus maximus muscle and the integument in the region. It originates from the anterior division of the internal iliac artery and enters the gluteal region adjacent to the lower border of piriformis muscle and medial to the sciatic nerve. It supplies a territory that is 221 ± 54cm^2 via 12 ± 3 musculocutaneous perforators that emerge almost entirely through the gluteus maximus muscle. The average diameter and area supplied by these perforators are 0.6 ±0.1mm and 18 ± 3cm^2.

HIP AND THIGH REGION

The integument of the region is supplied by a mixture of musculocutaneous and septocutaneous perforators from six principal source arteries, all originating from the common femoral artery. (Fig5)

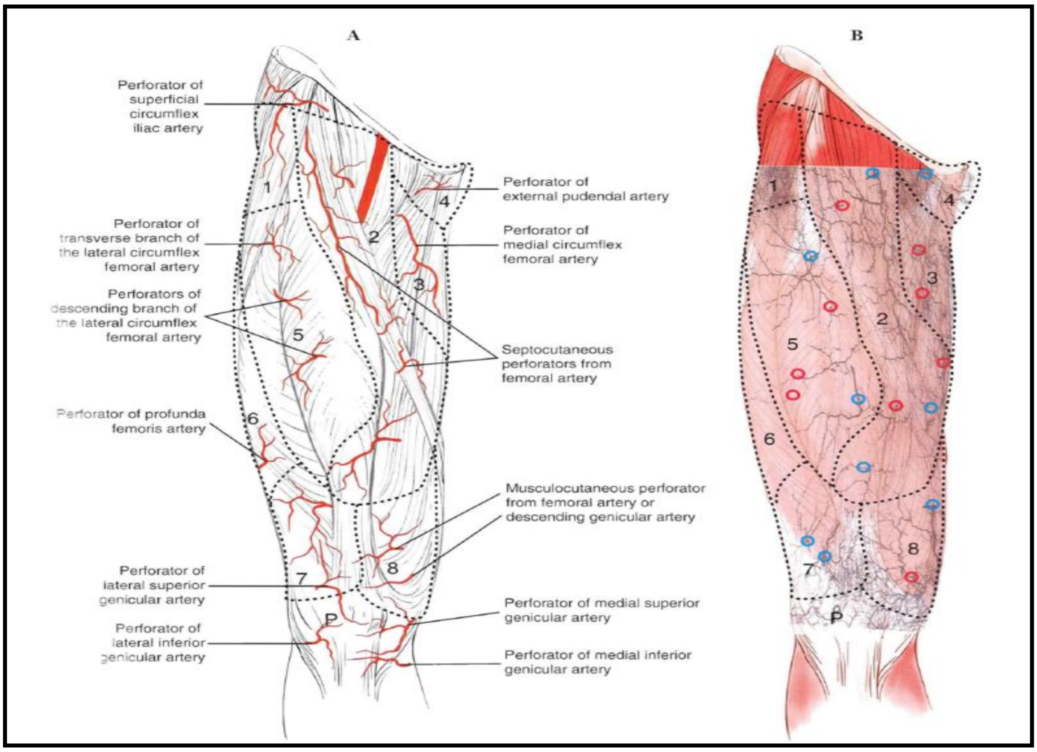


Fig.5A Anteromedial aspect of the thigh showing the principal branches and B- Angiogram of the integument from a human cadaver specimen showing Red circles MC perforators and blue circles SC perforators

The vascular anatomy of the hip and thigh region is divided into four anatomic regions: anteromedial thigh, anterolateral thigh and trochanteric region, posteromedial thigh, and posterolateral thigh. The vascular territories are as follows: the superficial circumflex iliac artery, femoral artery, profunda femoris artery, medial circumflex femoral artery, LCFA, descending genicular (saphenous) artery, and popliteal artery.

SUPERFICIAL CIRCUMFLEX ILIAC ARTERY: SCIA

The SCIA artery arises from the femoral artery and supplies an average area of 66 ± 20 CM^2, usually via one perforator. The average diameter of these vessels is1.0mm.

FEMORAL ARTERY: FA

The FA enters the thigh at the mid inguinal point, and descends to the anterior and medial sides of the thigh. This vessel ends at the middle and lower third junction of the thigh, and passes through an opening in the adductor magnus muscle and becomes the popliteal artery. Within the superior portion of the adductor canal, it gives branches to the sartorius and gracilis muscles. These branches give rise to several small musculocutaneous perforators, none greater than 1.0 mm in diameter. Most of the medial thigh is supplied by two rows of septocutaneous perforators (approx. 8) from the medial and lateral border of the Sartorius muscle, and by musculocutaneous perforators (approx. 6) from two inferior muscular branches to the vastus medialis muscle. It supplies an average area of 427 ± 70 cm^2 in the anteromedial thigh. The average diameter and area supplied by each perforator from the femoral artery are 0.8 ± 0.2 mm and 39 ±12 cm^2.

Several perforator flaps have been described from the femoral artery, including the anteromedial thigh flap FAP-s[38] and the gracilis perforator flap FAP-g.

PROFUNDA FEMORIS ARTERY: PFA

The PFA arise from the femoral artery, 2 to 5 cm inferior to the inguinal ligament. Four deep branches from the PFA, called the first through fourth profunda perforators, pierce the femoral insertion of the adductor magnus muscle, supply the muscles of the posterior compartment, and terminate in the skin as either musculocutaneous or septocutaneous vessels. At the level of the deep fascia, these branches divide and supply an average of 8 ± 7 perforators to the integument of the posterior thigh. Miller et al[39] designed the lateral thigh flap based on the third perforator of the PFA.

MEDIAL CIRCUMFLEX FEMORAL ARTERY: MCFA

The MCFA is the first branch off of the PFA near its origin from the femoral artery. There were approximately 4 ± 2 perforators that supplied a consistent vascular territory (91 ± 52 cm^2) in the superior posteromedial thigh region. The average diameter of the perforators was 0.7 ± 0.2 mm, the only perforator flap described is from these musculocutaneous vessels is the gracilis perforator flap.

LATERAL CIRCUMFLEX FEMORAL ARTERY: LCFA

The LCFA is the branch of profunda femoris artery and is larger than the MCFA. It divides into ascending, descending, and transverse branches. The three branches give rise to musculocutaneous or septocutaneous perforators to supply the integument overlying the anterolateral thigh and trochanteric region. An average of 10 ± 5 perforators with a mean diameter of 0.7 ± 0.3 mm supply the anterolateral thigh and trochanteric region (362 ±121 cm^2).

Superiorly, 3 to 5 musculocutaneous perforators from the ascending branch emerge from the TFL muscle. The majority of perforators from the transverse and descending branches emerge from the anterior border of the vastus lateralis muscle, with a few septocutaneous branches from the intermuscular septum.

DESCENDING GENICULAR ARTERY: DGA

The DGA artery is a branch of femoral artery just before it passes through the opening in the tendon of the adductor magnus muscle. The main trunk divides into a superficial branch (saphenous artery) and a musculoarticular branch. The superficial branch was most commonly a septocutaneous vessel from the femoral artery and had a diameter of 0.8 ± 0.3 mm and supplies a large cutaneous vascular territory (133 ± 39 cm^2).

KNEE AND LEG REGION

The knee region is supplied by musculocutaneous perforators from the femoral artery and septocutaneous branches from seven main arteries (Fig6): the descending genicular artery, medial and lateral superior genicular arteries, medial and lateral inferior genicular arteries, the anterior tibial recurrent artery, and the direct cutaneous branch of the popliteal artery.

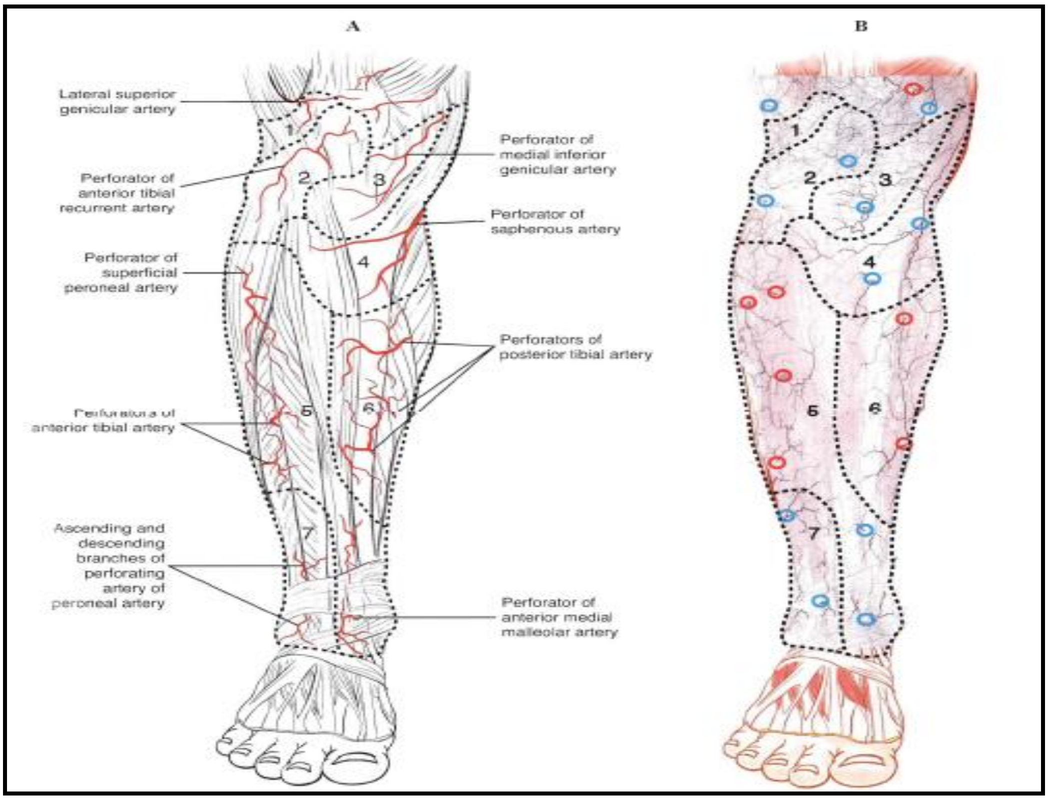


Fig.6.A, Anterior aspect of the leg showing the principal branches and B, Angiogram of the integument from a human cadaver specimen showing Red circles MC perforators & blue circles SC perforators.

There are five vascular territories including the territory of the descending genicular, popliteal, anterior and posterior tibial, and peroneal arteries in the leg region. (Fig.7)

POPLITEAL ARTERY: PA

The PA supplies a large cutaneous vascular territory in the popliteal fossa and the posterior leg by its direct cutaneous branch or sural branches. It supplies an average area of 160 ± 30 cm^2 via an average of 3 ± 1 perforators. The average diameter of these vessels is 0.9 ± 0.2 mm.

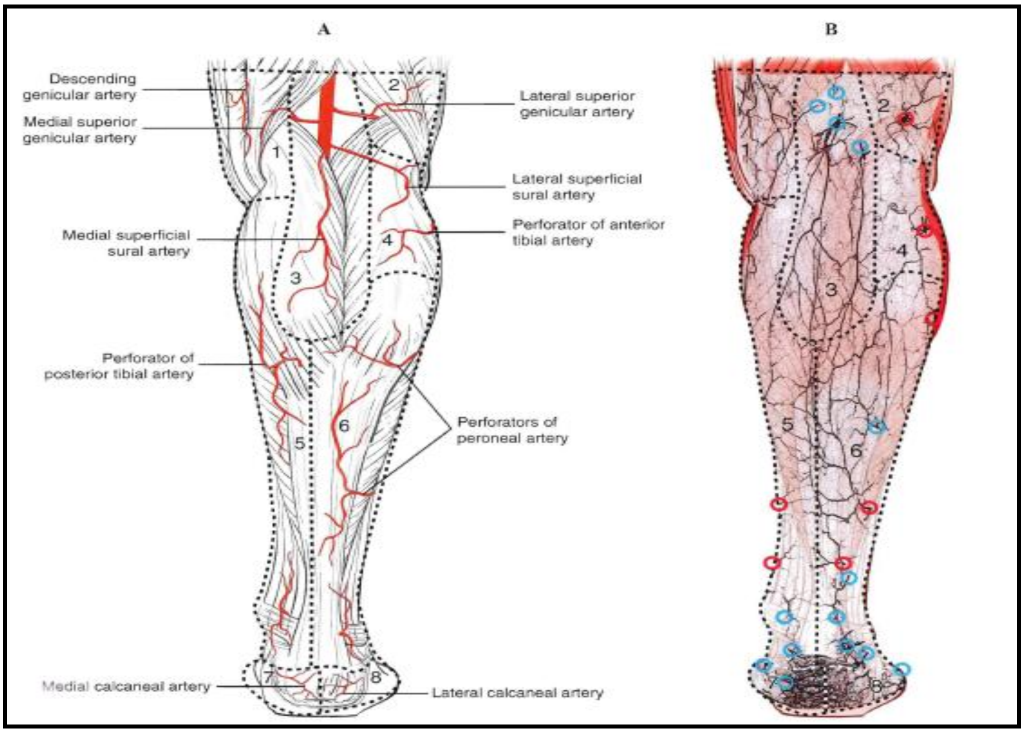


Fig7.A, The posterior aspect of the leg showing the principal branches and B, Angiogram of the integument from a human cadaver specimen showing Red circles MC perforators, blue circles SC perforators

MEDIAL AND LATERAL SUPERIOR GENICULAR ARTERIES: MSGA & LSGA

The MSGA& LSGA arise from popliteal artery, and wind around the femur immediately above its condyles to the anterior surface of the knee joint. The average diameter and area supplied by these vessels were 0.6 ± 0.2 mm and 44 ± 19 cm^2, through one or two perforators.

MEDIAL AND LATERAL INFERIOR GENICULAR ARTERIES: MIGA & LIGA

The MIGA & LIGA arise from the popliteal artery at the level of the knee joint line. Only one cutaneous perforator from each arteries was identified. This vessel has a mean diameter of 0.6 ± 0.1 mm, and supplies an average area of 50 ± 20 cm^2.

POSTERIOR TIBIAL ARTERY: PTA

The PTA is the terminal branch of the popliteal artery. It begins at the lower border of the popliteus, and extends obliquely downward to the medial aspect of the leg and beneath the origin of the adductor hallucis muscle divides into the medial and lateral plantar arteries. Throughout its course, it supplies an average of 10 ± 4 perforators to the skin. A row of four to five septocutaneous perforators that emerge from the intermuscular septum between the soleus and flexor digitorum longus muscles to supply the overlying integument. Three or four musculocutaneous perforators arise through the medial aspect of the soleus, have a diameter of 0.7 ± 0.2 mm and supply a vascular zone of 34 ± 12 cm^2. The best septocutaneous perforator is located 5 cm above the medial malleolus.

ANTERIOR TIBIAL ARTERY: ATA

The ATA begins at the bifurcation of the popliteal artery, at the lower border of the popliteus. The vessel passes forward between the two heads of the tibialis posterior muscle, and through the aperture above the upper border of the interosseous membrane, to the deep part of the anterior leg. The anterior tibial artery then descends on the anterior surface of the interosseous membrane, gradually approaching the tibia, sending an anterior recurrent tibial artery to pierce the deep fascia near the inferolateral border of the tibial tuberosity. It supplies an average of 6 ± 3 perforators to supply the skin over the anterior compartment of the leg. The perforators emerge as two prominent rows. One row is from the tibialis anterior muscle as musculocutaneous or between the tibialis anterior and extensor hallucis longus muscles as septocutaneous. The second row is from the anteromedial septum between the peroneus tertius and peroneus brevis muscles as musculocutaneous and septocutaneous vessels.

An especially large cutaneous perforator from the anterior tibial artery, accompanies the superficial peroneal nerve into the integument.

PERONEAL ARTERY: PNA

The PNA is deeply seated on the posteromedial aspect of the fibula. It arises from the PTA, approximately 3 cm below the inferior border of the popliteus, passes obliquely toward the fibula, and then descends along the medial crest of the fibula. It has deep communicating branches with both anterior and posterior tibial arteries via recurrent branches near the lateral malleolus. Perforators pierce the insertion of the flexor hallucis longus muscle and emerge through the posterolateral septum between the peroneus longus and soleus muscles.. A large constant branch of the PNA pierces the interosseous membrane approximately 5 cm above the lateral malleolus to reach the anterior leg, where it divides into ascending and descending branches. There is an average of 5 ± 2 perforators to supply the integument of the lateral leg, with an average diameter of 0.8 ± 0.3 mm, and each supplied an area of 32 ± 10 cm^2. The PNA anastomosis with the anterior and posterior tibial arteries allows the flap to be distally pedicled to reconstruct the hind foot or to fill dead space in bone and skin to close defects of the tibia or foot[40]

ANKLE AND FOOT REGION

The terminal branches of the anterior tibial, posterior tibial, and peroneal arteries supply the ankle and foot region.

The vascular territories include the medial calcaneal artery, lateral calcaneal artery, medial plantar artery, lateral plantar artery, and dorsalis pedis artery.

MEDIAL CALCANEAL ARTERY: MCA

The MCA arise from the posterior tibial artery just before its division. The medial calcaneal arteries supplied an area of approximately 42 ± 16 cm^2 and had an external diameter of 0.8 ± 0.2 mm.

LATERAL CALCANEAL ARTERY: LCA

The LCA is the terminal branch of the peroneal artery (diameter 0.6 ± 0.1 mm) and supplies 20 ± 9 cm^2 of intugment. After a short descending course, it arborizes into a vast calcaneal plexus that spans posteroinferiorly and anastomoses with the lateral calcaneal branches of the posterior tibial artery.

The LCA island flap is a simple, stable, sensate, and is a versatile and safe flap that can be used to repair defects around the ankle and heel or to cover defects around the lateral malleolus without any delay[41].

DORSALIS PEDIS ARTERY: DPA

The DPA is the continuation of the anterior tibial artery. It gives rise to the arcuate artery, which arches laterally across the base of the metatarsals to anastomose with the lateral tarsal and lateral plantar arteries. It supplies an area approximately 134 ± 42 cm^2 via several perforators. The average perforator diameter is 0.6 ± 0.1 mm.

The perforator size and location is not always constant in all regions of the body. These perforators are potential for propeller flap dissection.

MATERIALS AND METHODS

The study was conducted in the Dept. of Plastic Reconstructive & Maxillofacial surgery, Rajiv Gandhi Government General Hospital, and Madras Medical College over a period of 18 months from October 2011 to March 2013.

CASE STUDIES

All patients with small to large sized soft tissue defects affecting Lower limb except plantar defects were included in the study. The proforma for the collection of data is presented. All the details of the patient, regarding preoperative, surgical, and postoperative and follow up periods were collected and analyzed. Appropriate photographs were taken for documentation.

The patients were explained about the nature of the defect and the various flap options available. The proposed procedure was explained to the patient in detail including its merits and demerits. Informed and written consent was obtained from the patient. The proforma was submitted before the Institution Ethical committee and approval obtained. The study did not incur any added expenditure for the patients or the department.

INCLUSION CRITERIA

1. Patients presenting with post traumatic soft tissue defects of lower limb after 72 hours of injury.

2. Sacral and trochantric pressure sore.

EXCLUSION CRITERIA

1. Patients with peripheral vascular diseases.
2. Gustilo grade IIIC injuries in lower limb.
3. Advancement, transposition perforator flap and Free style free flap.

PREOPERATIVE PREPARATION

WOUND CARE

All patients who required wound care were admitted in the unit and given bed rest and appropriate limb elevation as needed. All wounds were debrided thoroughly on day one. Patients were put on appropriate antibiotics according to culture and sensitivity, if needed. Daily thorough cleaning and sterile dressings and subsequent slough excision if necessary was done.

PATIENT PREPARATION

All co- morbidities (including Type 2 DM) were attended to and appropriate consultations obtained to optimize the patient prior to surgery. Smokers were taken up for surgery after a two weeks period of complete abstinence of smoking.

INVESTIGATION

1. 1.All patients were subjected to routine investigations for anaesthetic fitness

2. A hand held Doppler ultrasound with 8 to 10 Mhz frequency probe is used to mark the dominant perforator artery near the defect in our study. Duplex Doppler or CT-Angiogram were not done.

PERFORATOR MARKINGS

Perforator markings of the following flaps are done with a hand held Doppler.

1. SGAP-gm: Perforator marking is done in prone position.

   A line is drawn from posterior superior iliac spine to greater trochanter. The perforator emerges from junction of the first and second one third of the line.

2. IGAP – gm: Perforator marking is done in prone position. A line is drawn from ischial tuberosity to greater trochanter.

The perforator emerges from the junction of the first and second one third of the line.

3. LCFAP –tfl: Perforator marking is done in supine position. . A line is drawn from anterior superior iliac spine to superolateral border of the patella. The perforator emerges 10 cm below the ASIS on the line.

4. DGAP: Perforator marking is done in supine position. A line drawn from the mid inguinal point to adductor tubercle. In the lower and mid third junction draw another line to mid point of patella. The perforator emerges in the suprapatellar triangle.

5. ATRAP: Perforator marking is done in supine position. A line drawn from mid point of knee joint line and connecting a point 2 cms lateral to tibial tuberosity on this line perforator emerges.

6. SAP: Perforator marking is done in supine position. A 6 cms vertical line four finger breath posteromedial to patella on this line perforator emerges.

7. ATAP: Perforator marking is done in supine position .A line drawn 2cm parallel to lateral border of chin of tibia perforator emerges in the lower two third of this line.

8. SPNAP: Perforator marking is done in semiprone position. A line drawn joining head of fibula and lateral mallelous. In the mid and lower third junction perforator emerges.

9. PTAP: Perforator marking is done in supine position. A line is drawn 1 cm posterior to medial malleolus to the medial border of the tibial plateau, perforators emerges from the lower two third of this line.

10. PNAP: Perforator marking is done in semiprone position. A line drawn joining head of fibula and lateral mallelous, perforator emerges from the lower two third lateral to this line.

11. RFAP: Perforator marking is done in supine position. A line drawn from lateral mallelous to mid point of tibiofibular syndesmosis. Anterior to this line emerges the descending branch perforator.

12. LCAP: Perforator marking is done in supine position. A mid point between lateral mallolues and tendoachilles posterior to lateral mallelous perforator emerges.

13. AAP: Perforator marking is done in supine position. A distal convex line draw from navicular tuberosity to base of fifth toe, perforator emerges on this line.

14. FDMAP: Perforator marking is done in supine position. A line drawn between intermediate cuneiform and first web space, perforator emerges on this line lateral to extensor hallucis longus.

PREOPERATIVE FLAP PLANNING

Preoperative planning is an essential component of perforator flap surgery.

Planning begins with delineation of the anatomic defect to replace ‘‘like with like’’ tissue. The dimensions and constituent parts of the defect like surface area of the skin paddle, the thickness and consistency of the subcutaneous layer, the total flap volume, and any specialized structures need to be considered.

Although the technical aspects of flap dissection are similar for pedicled and free flaps, there are essential differences in flap planning and raising.

The extent of the flap movement depends on the tissue elasticity and perforator vessel length. Longer pedicles are less sensitive to twisting forces, because the length of a vessel is inversely proportional to the critical angle of twisting.[42] Flaps that include only one perforator are likely to have greater flap mobility and can be mobilized in a propeller fashion, 180^0 counterclockwise or clockwise, without compromising perfusion. Flaps with multiple perforators are more suitable for rotational or advancement manoeuvres, depending on the number of vessels preserved. If more than 1 perforator is included, then the vessels must be in close proximity to each other and dissected for a sufficient distance.

The position of the perforator selected depends on the planned movement of the flap.[43] In a propeller flap, a single perforator closest to the defect is chosen to allow the flap to pivot on the vessel and thus increase the potential coverage of the defect. For advancement, transposition, and rotation flaps, perforators furthest from the defect are selected because this provides the longest possible pedicle thereby giving the flap a large arc of motion.

Perforator flap can be elevated as Rotation/ propeller flap, advancement flap or transposition flap according to the defect. Perforating vessels are dynamic structures in constant flux of flow because of varying humeral and neural stimulations. The vessel diameters and the proportionate size of the vessel must be assessed in relation to the flap dimensions. A small flap from the extremities would be well perfused by a perforator of 1 mm caliber. The surgeon must consider not only the main perforating vessel but also the adjacent perforators. Pre and intraoperative delineation of these additional vessels allow the viable boundaries of the flap to be established and thus potentially avoid flap necrosis.

PERFORATOR /PROPELLAR FLAP

The propeller flap is a local island fasciocutaneous flap based on a single dissected perforator. It is designed like a propeller with 2 blades of unequal length with the perforator forming the pivot point so that when the blades are switched, the long arm comfortably fills in the defect. The ability of this flap to rotate any angle up to 180^0 makes it extremely versatile for reconstructing traumatic as well as other defects of all regions in the body. The lower leg is shaped like a cone tapering down towards the lower third and ankle with a paucity of spare tissue in that area for use in reconstructing defects. For this reason a proximally based peninsular fasciocutaneous flap tends to struggle in terms of getting enough healthy tissue into the defect and it risks exposing either the subcutaneous border of the tibia or the Achilles tendon. The propeller flap, pivoted on a single perforator, avoids these problems by importing truly undamaged tissue from the proximal calf into the primary defect. In doing so it simultaneously transfers the secondary defect to an easily graftable area over the proximal muscle bellies.

When the rotation is needed only up to 90^0 it may not matter if more than one pedicle is kept, when the flap is needed to rotate 180^0 it is actually safer to divide all perforators except one.

OPERATIVE PROCEDURE

All patients were operated under appropriate anesthesia (General /Regional). Loupe magnification (4x) was used in all cases. Preoperative Doppler marking of the perforators were done with permanent skin markers (Fig8).

Fig.8 A defect in the lower one third of leg, distally based PTAP Flap marked with two perforator marked (x) adjacent to the defect with a hand held Doppler.

Patients were positioned as per the defect and plan of the flap. Skin preparation done with on table hair clipping if required and Prewash given for the region. Antiseptic skin preparation was done by painting with povidone-iodine solution of the entire limb up to groin and in sacral pressure sore up to lower back. A tourniquet is used, and the leg is exsanguinated by elevation and compression of the popliteal artery for 1 minute. This procedure allows emptying of most of the blood from the leg but retains enough in the perforator vessels to allow for easier identification during exploration in appropriate cases except diabetics and smokers. Parts draped with sterile linen so as to expose the operative area. Wound debrided and edges freshened and thorough wash given.

DESIGN OF THE FLAP

A provisional flap design is drawn, with the perforator as the pivot point of the flap. First, the distance between the perforator and the distal edge of the defect is measured. This value is then transposed proximally along the axis of the main source vessel, again measured from the perforator, and 1 cm is added. This value forms the proximal limit of the flap. Next, the width of the proximal flap needed to cover the defect is determined by measuring the width of the defect. This value is then used to determine the proximal flap width, adding 1 cm to allow for flap contraction and to facilitate its inset without tension (Fig.9). At the pivot point where the perforator pedicle enters the flap, the lateral dimensions are equidistant to ensure that when the flap is eventually rotated around to fill the defect there is no excessive sideways traction on the perforator during wound closure.

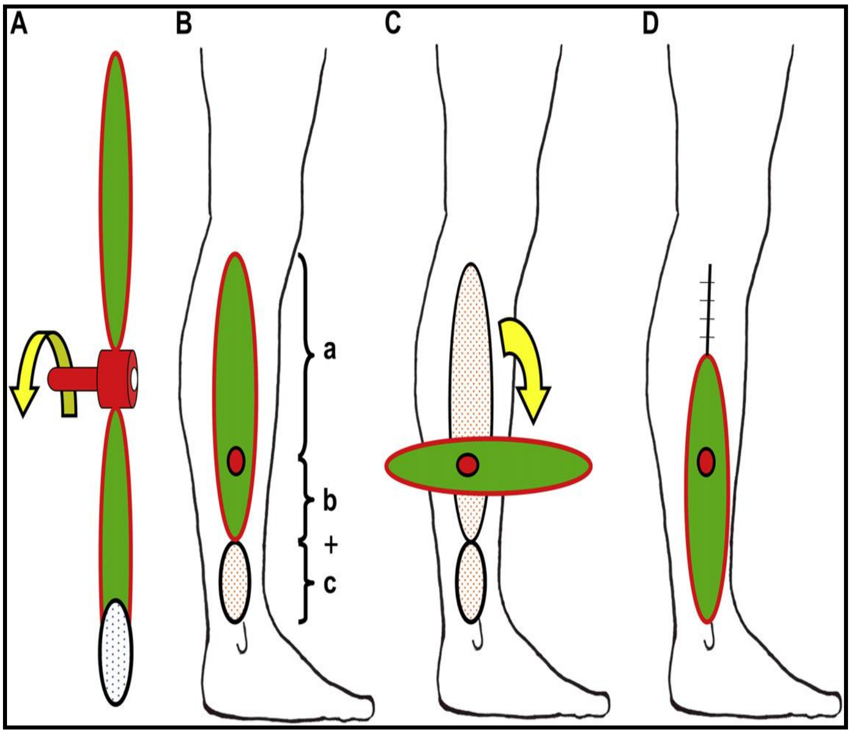


Fig.9 (A) The propeller flap concept, (B) Marking of the flap, (C) Flap elevation and clockwise rotation, (D) Flap inset.

TECHNIQUE OF PERFORATOR /PROPELLAR FLAP DISSECTION

First incision is made at one side of the marked flap liberally and elevated with gentle retraction to locate the marked perforators. The approach to the pedicle could be suprafascial or subfascial. The subfascial approach is easier and safer way to visualize the pedicle.

With this initial incision, several potentially useful perforators are usually exposed and the best is chosen based on its position and size and by microclamping (Fig.10) to asses the flap perfusion. It would be wise to avoid any perforator that is encased in scar or granulation tissue near the edge of an wound because the dissection can prove difficult, with injury to an already fragile vessel more likely. On the other hand, it is best not to choose a perforator too far away from the defect, as this would make the flap unnecessarily long.

When the decision is made, the perforator that is finally chosen for the flap may not necessarily be the one located preoperatively on Doppler and on which the initial design of the flap is based. Once the best pedicle has been chosen, the design of the flap should be rechecked and, if necessary, adjusted. In particular, one should ensure that the proximal edge of the flap, when finally rotated into position, is capable of reaching the distal margin of the defect comfortably and would not place the pedicle under any tension.

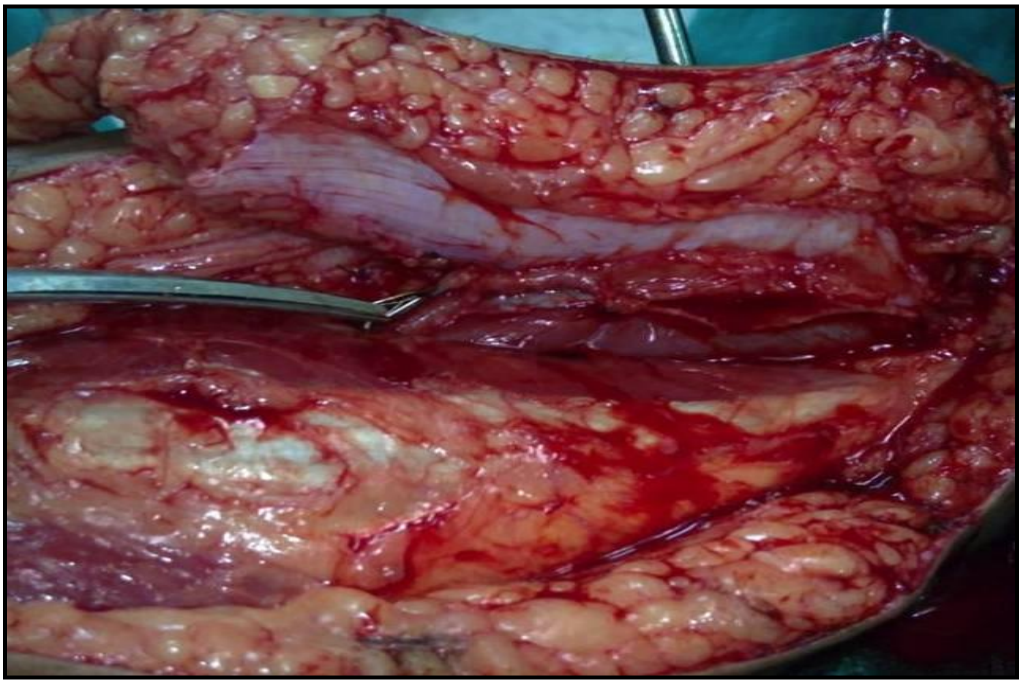


Fig.10. A PTA Perforator is shown with periperforator dissection

The propeller flap should not be based on 2 perforators because, with the rotation of the flap, the 2 pedicles are twisted around each other and this can jeopardize its blood supply. Several intraoperative factors indicate the caliber of the perforator ,the size of the converging branches, whether the perforators have any visible pulsation, and also the extent of the facial opening traversed by the perforator. Larger fascial openings tend to be associated with larger perforators, even if this is not immediately apparent because of vessel spasm. It is crucial to approach the vessels in a blood-free environment because this assists in identifying the converging prefascial branches .Blood-free clean dissection can be achieved by separating the tissue with low-current electrocautery. It is essential to preserve all perforating vessels until a more dominant vessel is encountered. All muscular branches from the chosen perforator is clipped and cut for at least 2 cm. This procedure allows a gentle spiral twist of the pedicle when the flap is rotated through 180^0. When possible, the pedicle is cleaned from its source vessel to the point where it passes through the deep fascia into the flap.

Next, all the fine fascial strands that could potentially compress the vessels once they are twisted should be meticulously divided with microscissors . Particular attention should be paid to those around the venae comitantes, because the relatively low pressure venous system is more susceptible to extrinsic compression once the flap is rotated into position. Once the pedicle is secured, raising the rest of the flap is quick. Then the flap is completely islanded (Fig11), it should be left in its donor area and the tourniquet is released and haemostasis secured. Then the flap is allowed to perfuse and the spasm of the vessels to relax for 10 to 15 minutes before the flap is rotated into the defect.

Fig.11. A PTAP Flap islanded on the perforator is shown

Topical vasodilators, such as lignocaine or papaverine, can be instilled around the pedicle and perforator measured with the caliper.

ROTATION AND INSET OF THE FLAP

Once the flap perfusion is satisfactory, it is ready to be rotated into the defect. The flap is carefully lifted from the wound bed and pivoted around its pedicle. The direction of rotation depends on the angle between the proximal long axis of the flap and the defect. This angle can reach a maximum of 180^0. It is not necessary to rotate the flap beyond 180^0 because it can simply be turned in the other direction. When the defect is at the 6 o'clock position and the flap has to be rotated 180^0, the pedicle is placed under the maximum spiral twist. First turn the flap clockwise into the defect and focusing on how comfortably the venae comitantes are positioned look for any sign of extrinsic compression by residual fascial strands, which will need further division. Then turn the flap counterclockwise and examine the pedicle. The direction of rotation which is the most comfortable for the venae comitantes is selected (Fig12).

Fig.12a A PTAP Flap rotated 160^0 in counterclock wise and (b) Inset given with a drain and donar area closed primarily

Then the flap is secured in position with the first 2 skin sutures placed on either side of the axis of the pedicle. These 2 sutures should be carefully positioned to ensure that the pedicle is not put under any traction either in a proximal or distal direction. A is placed and secured well away from pedicle. Then rest of the flap inset and wound closure done. The donor defect is closed primarily without excessive tension. This produces the best aesthetic result. If unable to close the donor defect skin grafting is done. Sterile non adhesive and loose dressing applied.

CLINICAL APPLICATIONS

Propellar flaps used to cover the following defects in our study (eg. Case 1to14).

1. Pressure sore defects in sacral and trochantric region.
2. Post traumatic soft tissue defects around knee, lower one third of leg, ankle and dorsum of foot.

POSTOPERATIVE CARE

Immobilization of the operated region was ensured with appropriate splinting of the operated site and pressure relieving protocol in pressure sore cases. Limb elevation was given. Appropriate antibiotic cover was given if required. Adequate pain relief, appropriate chest physiotherapy, nutrition support, and symptomatic treatment were given.

Flap monitoring was done once in four hours during the first 48 hours and then once daily through window dressing. Dressing change done earlier if there was soakage. Dressings changed on 2^{nd} POD and drains removed, in case of pressure sore removed on 10th day, II look dressing on 5th POD and complete suture removal by 12^{th} POD. POP immobilization continued for 2 weeks.

All patients observed in plastic surgery ward till the flap had healed. Patients were allowed to ambulate once the flap and graft settled well. Patients with good general condition were discharged and reviewed. Appropriate photographs were taken in the follow up period and documented.

Follow up of all patients every month upto 6 months was done.

Fig.13.A PTAP Flap well settled,
6 moth post operative status is shown

OUTCOME ANALYSIS

The outcomes of flaps were critically analyzed at periodic intervals and at the end of study.

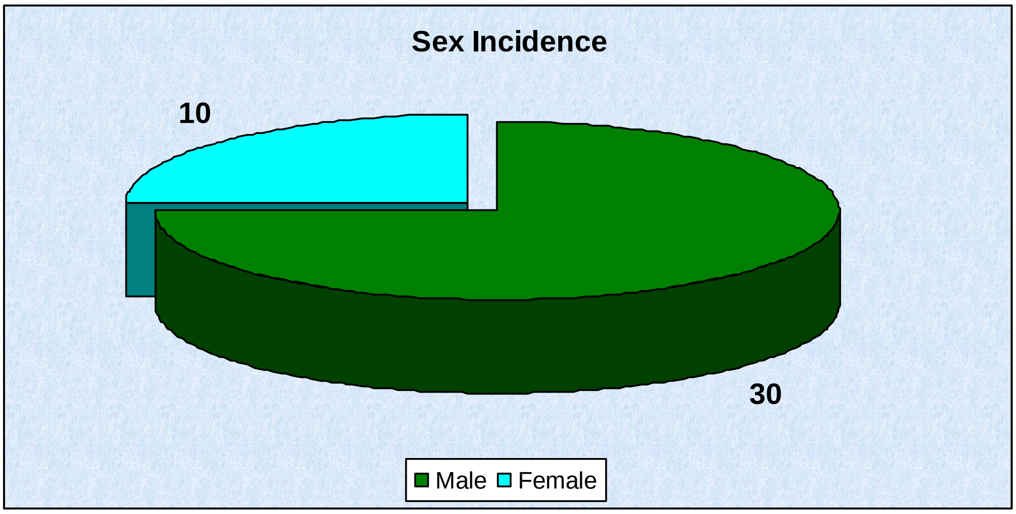
OBSERVATION & RESULTS

Perforator/propellar flaps for reconstruction of soft tissue defects over the lower limb was done in 40 patients (30 males and 10 females). The age of patients ranged from 20 yrs to 63 yrs. (Table.2)

Table 2 – Patient characteristics

Number of Patients	40
Age Range	20-63 Years
Male	30
Female	10

Bar chart-1: Sex Incidence



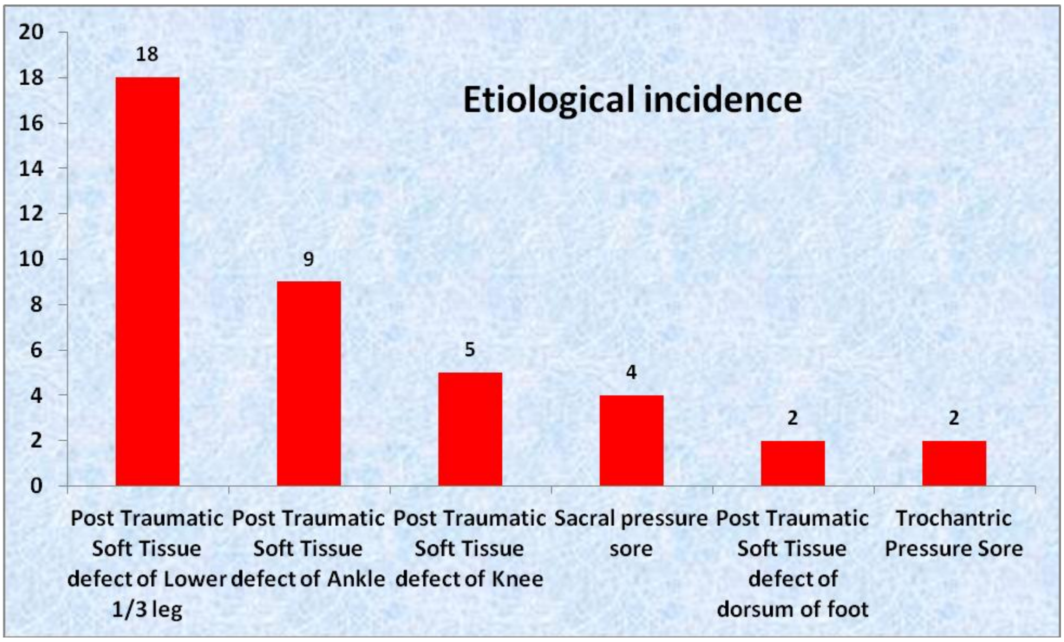
ETIOLOGY

Post traumatic soft tissue defects of Knee, Lower 1/3 leg, Ankle and foot 34 patients, 4 patients were paraplegic with sacral pressure sore and 2patient were paraplegic with trochantric pressure sore(Table3)

Table 3 - Etiological incidence

Post Traumatic Soft Tissue defect of Lower 1/3 leg	18
Post Traumatic Soft Tissue defect of Ankle	9
Post Traumatic Soft Tissue defect of Knee	5
Sacral pressure sore	4
Post Traumatic Soft Tissue defect of dorsum of foot	2
Trochantric Pressure Sore	2

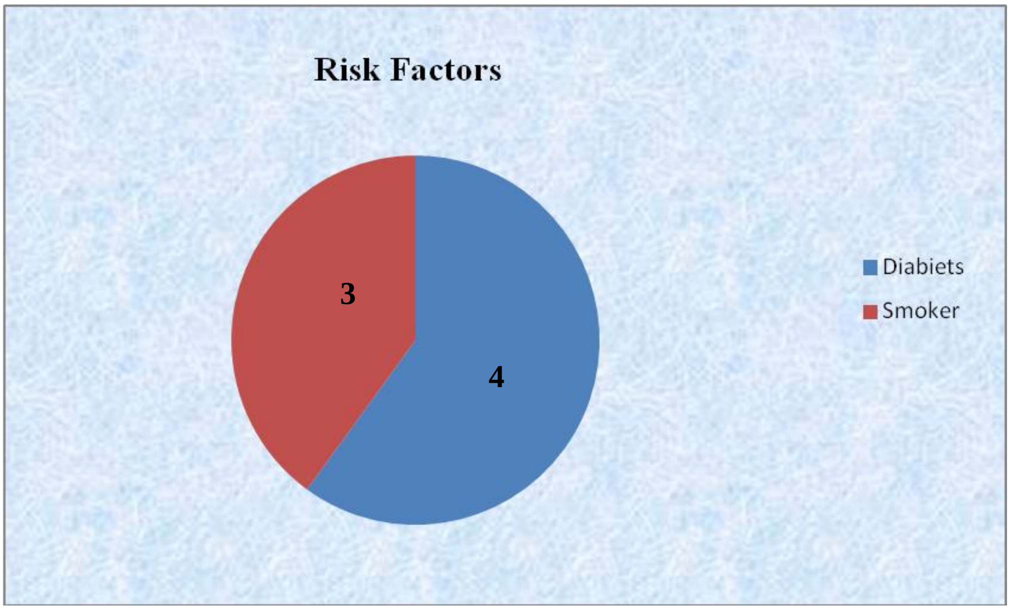
Bar Chart 2– Etiological Incidence



RISK FACTORS

Among 40 patients, 3patients were diabetic, 4 patients had the habit of Smoking.

Chart– 4 Risk Factors



PERFORATOR CHARACTERISTICS

1. Average size of perforator was 1.5mm.

Average distance between perforator and wound margin was 2cms.

FLAP CHARACTERISTICS

In our study Perforator/Propellar flaps were done from 14 source vessel in 40 patients (Table4).

Table 4 - Type of flap

S. No	Name of Flap	Total No. of Flaps	Source Vessel	Average Perforator Size in mm	Max.Flap Dimension in cms	Max.Degree of Rotation In degree	Average Duration of Surgery inminute
1	SGAP-gm	2	Superior Gluteal Artery	1.35	15x8	180	110
2	IGAP –gm	2	Inferior Gluteal Artery	1.8	22x9	180	120
3	LCFAP –tfl	1	Lateral Circum Flex Femoral Artery	1.2	9x5	180	90
4	DGAP	2	Descending Genicular Artery	1.4	16x8	180	100
5	ATRAP	1	Anterior Tibial Recurrent Artery	2.2	6x3.2	100	90
6	SAP	2	Saphenous Artery	1.2	9x4.8	100	90
7	ATAP	4	Anterior Tibial Artery	1.7	15x6	160	110
8	SPNAP	2	Superficial Peroneal	1.5	10x6.5	160	100

S. No	Name of Flap	Total No. of Flaps	Source Vessel	Average Perforator Size in mm	Max.Flap Dimension in cms	Max.Degree of Rotation In degree	Average Duration of Surgery inminute
			Nerve Artery				
9	PTAP	10	Posterior Tibal Artery	1.7	20x8	180	110
10	PNAP	6	Peroneal Artery	1.8	20x8	160	100
11	RFAP	3	Ramus Perforance Artery	1.8	13x5.1	100	90
12	LCAP	3	Lateral Calcaneal Artery	1.2	5x4	140	90
13	AAP	1	Arcuate Artery	1.7	9x4	100	90
14	FDMAP	1	First Dorsal Metatarsal Artery	1.0	6x3.4	180	90

The defect size that were covered ranged from 3 x 3 cm to 18 x 8cm. Skin flap ranges from 5 x 4 to 22 x 9

CASE-1: SGAP – gmx FLAP

DEFECT	FLAP ELEVATION	INSET

CASE-2: IGAP –gmx FLAP

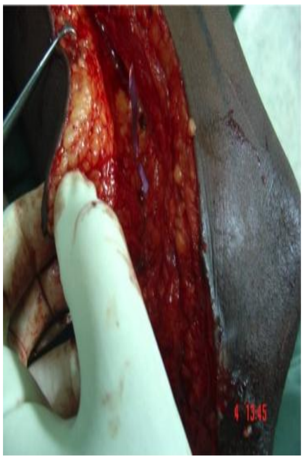
DEFECT	FLAP ELEVATION	INSET

CASE-3: LCFAP –tfl FLAP

DEFECT	FLAP ELEVATION	INSET

CASE-4: DGAP – FLAP

DEFECT	FLAP ELEVATION	INSET



CASE-5: ATRAP FLAP

DEFECT	FLAP ELEVATION	INSET
		

CASE-6: SAP FLAP

DEFECT	FLAP ELEVATION	INSET
		

CASE-7: ATAP FLAP

DEFECT	FLAP ELEVATION	INSET



CASE-8: SPNAP FLAP

DEFECT	FLAP ELEVATION	INSET



CASE-9: PTAP FLAP

DEFECT	FLAP ELEVATION	INSET
		

CASE-10: PNAP FLAP

DEFECT	FLAP ELEVATION	INSET
		

CASE-11: RFAP FLAP

DEFECT	FLAP ELEVATION	INSET



CASE-12: LCAP FLAP

DEFECT	FLAP ELEVATION	INSET



CASE-13: AAP FLAP

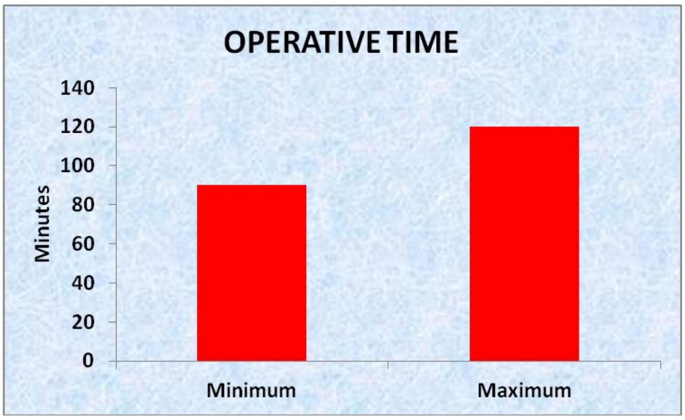
DEFECT	INSET

CASE-14: FDMAP FLAP

DEFECT	FLAP ELEVATION	INSET

OPERATIVE TIME

It depends upon the type of flap dissection and the average time is 90-120 minutes.



COMPLICATIONS

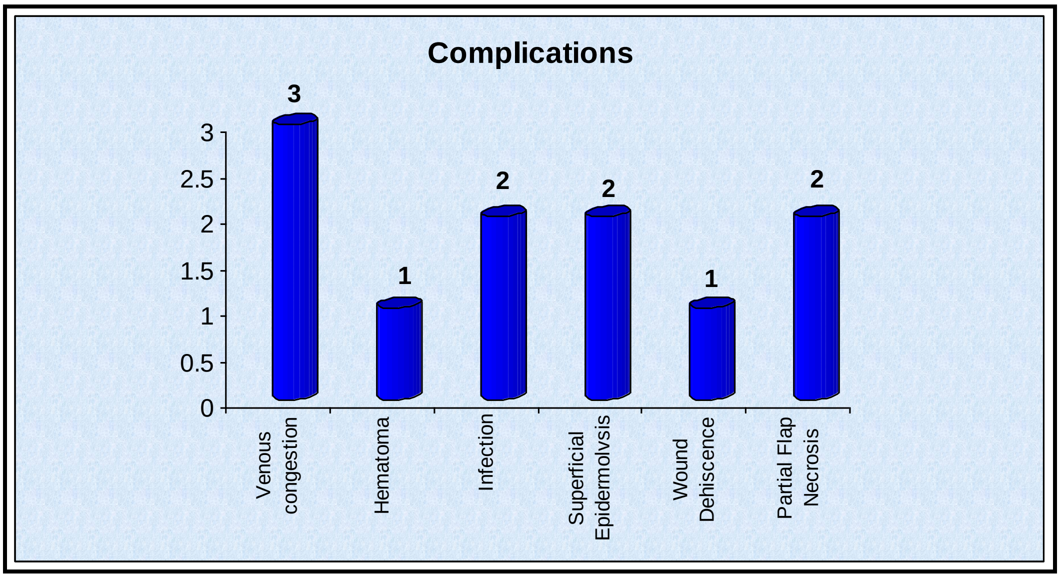
Two PTAP flaps and one SGAP flap had venous congestion and alternate sutures released, flap settled well. One SGAP flap developed haematoma, which was evacuated and flap settled well. One ATAP flap and one PNAP flap patient developed infection with partial loss of graft over the donor site. The patient was managed with bedside debridement, antibiotics and the wound was allowed to granulate and covered with Split Skin Grafting.

One ATAP flap and a SPNA flap in which patient was a smoker had 1 cm superficial dermal necrosis of the flap. Once the scab was removed the underlying flap was healthy that healed by secondary intention with spontaneous epithelialisation. One PTA Flap developed wound dhescience, secondary suturing done. One AAP flap and an ATRA flap had partial flap necrosis, was managed with bedside debridement and SSG.

Table 6 - Complications

Venous congestion	3
Hematoma	1
Infection	2
Superficial Epidermolysis	2
Wound Dehiscence	1
Partial Flap Necrosis	2

Complete flap necrosis was not encountered in our study. All flaps settled well providing a supple, stable skin cover over the defect. The patients were able to walk normally. Donor site scars and graft also settled well with no complications. All patients had retained the sensation. Patient's satisfaction was also good as there were minimal contour deformities.



DISCUSSION

The ultimate aim of our reconstruction is to design various flaps based on perforators/propeller flaps in the lower limb and to improve aesthetic and functional outcome by reducing local morbidity. Both muscle and fasciocutaneous flaps have their limitations and indications for reconstruction of the leg.

Muscle flaps fill complex three-dimensional defects and provide well-vascularised tissue that may have the advantage of controlling bacterial inoculation in heavily contaminated or chronically infected wounds[44.]Fasciocutaneous flaps are indicated to cover shallow wounds and when based on a single perforator, may have enhanced perfusion properties and can restore contour that may be advantageous in controlling local bacterial load[45].

In sacral and trochantric pressure sore propeller flaps cover the defect without tension and secondary defect closed primarly. Reconstruction of the knee, ankle and leg is often problematic because of a lack of local donor tissue. Soft tissue defects in the proximal two thirds of the leg are often covered with local muscle flaps; the distal third is often reconstructed with free microsurgical transfers. In the lower third of the leg, thin and pliable soft-tissue coverage is required to achieve a satisfactory aesthetic outcome.

The advent of perforator flap surgery has created new awareness for the potential of local flaps based on perforator vessels from regional vessels.

Propeller perforator flaps in distal lower leg provide a good option in the reconstructive armamentarium because flap harvest is relatively quick and easy without sacrificing the under lying muscle. Besides the reconstruction can replace like-with-like tissues of similar texture, thickness, pliability, and color, this method also avoids multiple surgical sites and reduce morbidity of the donor site, because the scars are limited to only one region. For defects, <6 cm wide, the donor site closed primarily[48,] but larger defects can be partially closed and skin grafted area minimised. A drawback can be the mild contour deformity related to the donor site.

Propeller perforator flaps are best suited for small to medium sized defects, and in trauma patients for defects without extensive avulsion and degloving injuries. The flap may be rotated through up to 180^0, and the distal perforators in particular can be used for coverage of defects around the ankle and distal two thirds of the tibia, where there have previously been few reliable local flap options. In our study the median angle of rotation of the flap about the perforator was 160^0 (range, 90 to 180 degree) and the average size of perforator was 1.5mm and average operative time is 90-120 minutes. The distance between wound margin and perforator was 2cms.

With perforator anatomical knowledge, it was possible to fashion skin flaps based on single perforator, distally based flaps, islanded flaps and muscle perforator based flaps to cover defect. The reliability of these flaps was proved by the clinical case studies. The flaps were found to be safe and reliable in both young and old patients and in both sexes. Also the flap survival was not significantly compromised by co morbidities like Diabetes Mellitus once they were treated or brought under control. The flaps were also found to be safe irrespective of the etiological factors. The fact that the skin flaps were based on a single perforator allowed for free style design and increased range of reach for the flap that could not have been achieved otherwise .Also these flaps have a good contour and natural appearance and avoid the dog ear problems of the classical flaps.

The unique design of the propeller flap, pivoted around a single cleanly dissected perforator, allows the importation of truly undamaged tissue into a defect for easy closure without tension. In the lower limb this is a luxury afforded to few. Thus the patient satisfaction was much better with less postoperative pain and early recovery.

CONCLUSION

The perforator/propeller flap in lower limb is a truly versatile flap that is safe, reliable, quick to perform and with standard periperforator dissection, gives a good aesthetic result.

The single best perforator contributes to increased influx of blood flow with recruitment of adjacent perforosomes by opening the linking vesssels and larger flap harvest with 95% success rate of flap survival.

In our study nearly one third of segment circumference as breadth and one third of segment length as length of flap can be safely recruited on the single best perforator in lower limb .The ability to base a flap on any perforator found in the vicinity of a wound to be reconstructed gives the surgeon unparalleled freedom when designing local flaps.

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PROFORMA FOR CASE STUDIES

NAME: PS No:

AGE: I.P No:

SEX: D.O.A:

ADDRESS: D.O.S:

D.O.D:

PH NO:

CLINICAL DETAILS:

CO-MORBIDITIES:

PROCEDURE DONE: (with photos)

POSTOPERATIVE FOLLOW-UP:

DOCUMENTATION

Serial No.

Aetiology

Comorbidity

Risk Factors

Defect region

Defect Site

Flap type

Flap dimension

Perforator size

Distance between perforator & defect margin

Flap Outcome

Donor Site Morbidity

Follow up

MASTER CHARTS
DOCUMENTATION OF CASES

Case No	Age/Sex	PS.No	Etiology	Risk Factor	Defect Region	Defect size CM	Flap Type	Flap Size CM	Perforator Size in MM	Distance between perforator & Defect margin in cm	Flap out come	Donor Site Morbidity
1	28/M	2276/10	RTA	-	Lower 1/3 leg	12x5	PTAP	15x6	1.4	2	Flap settled well	NIL
2	40/M	2339/10	RTA	-	Lower1/3 leg	10x5	PNAP	14x6	1.4	3	Flap settled well	NIL
3	40/M	95/11	RTA	-	Sacral Region	15x5	SGAP-gmx	18x6	1.2	2	Venous congesion	NIL
4	36/M	150/ 11	RTA	Smoker	Lower1/3 leg	7x3	ATAP	10x4	1.4	2	Mild Infection	Partial Graft Loss
5	45/F	356/11	RTA	Diabetis Mellitus	Medial Knee	13x8	DGAP	16x8	1.0	2	Flap settled well	NIL
6	41/M	412/11	RTA	-	Lower anterior Knee	4&2.2	ATRAP	6x3.2	1.2	1	Partial flap necrosis	NIL
7	32/M	450/11	RTA	-	Medial Knee	6x3.8	SAP	9x4.8	1.0	2	Flap settled well	NIL
8	56/M	520/11	RTA	-	Anterior Ankle	14x7	RFAP	18x8	1.4	3	Flap settled well	NIL
9	41/M	750/11	Fall from Height	-	Sacral Region	16x7	IGAP	20x8	1.0	3	Flap settled well	NIL
10	30/F	890/11	RTA	-	Lower1/3 leg	15x7	PTAP	18x8	1.0	2	Venous congesiton	NIL
11	45/M	1110/11	RTA	Diabetis Mellitus	Posterior Ankle	3x3	LCAP	6x4	1.0	2	Flap settled well	NIL
12	35/F	1455/11	RTA	-	Anterior Ankle	9x5	PNAP	12x6	1.4	2	Flap settled well	NIL
13	40/M	1564/11	RTA	-	Lower1/3 leg	13x6	PTAP	16x6	1.4	2	Flap settled well	NIL
14	45/M	1698/11	RTA	-	Lower1/3 leg	12x5	ATAP	15x6	1.4	2	Flap settled well	NIL
15	50/M	1869/11	RTA	Smoker	Anterior Ankle	7x5.5	SPNAP	10x6.5	1.2	2	Superficial Epidermplysis	NIL
16	38/F	1985/11	RTA	-	Lower1/3 leg	16x7.3	PTAP	20x7.3	1.0	3	Flap settled well	NIL
17	35/M	2230/11	Fall from Height	-	Sacral Region	12x7	SGAP-gmx	15x8	1.2	2	Haematoma	NIL

18	**50/M**	**2351/11**	**RTA**	**-**	**Anterior Ankle**	**17x7**	**PNAP**	**20x7**	**1.4**	**2**	**Flap settled well**	**NIL**
19	**36/M**	**2458/11**	**RTA**	**-**	**Lower1/3 leg**	**10x4.1**	**RFAP**	**13x5.1**	**1.6**	**2**	**Flap settled well**	**NIL**
20	**63/M**	**2596/11**	**RTA**		**Lower1/3 leg**	**12x5**	**PTAP**	**15x6**	**1.2**	**2**	**Flap settled well**	**NIL**
21	**52/M**	**2920/11**	**RTA**	**-**	**Anterior Knee**	**7x3**	**DGAP**	**10x4**	**1.0**	**2**	**Flap settled well**	**NIL**
22	**42/F**	**3110/11**	**RTA**	**-**	**Lower1/3 leg**	**12x5**	**PNAP**	**15x6**	**1.2**	**2**	**Flap settled well**	**NIL**
23	**20/M**	**3125/11**	**RTA**	**Smoker**	**Lower1/3 leg**	**9x4**	**ATAP**	**12x5**	**1.3**	**2**	**Superficial Epidermplysis**	**NIL**
24	**42/M**	**212/12**	**RTA**	**-**	**Lower1/3 leg**	**10x6**	**PTAP**	**13x7**	**1.4**	**2**	**Flap settled well**	**NIL**
25	**40/M**	**296/12**	**RTA**	**-**	**Anterior Ankle**	**3x3**	**LCAP**	**5x4**	**1.0**	**1**	**Flap settled well**	**NIL**
26	**38/M**	**354/12**	**RTA**	**-**	**Foot Dorsum**	**7x3**	**AAP**	**7x4**	**1.7**	**1**	**Partial flap necrosis**	**NIL**
27	**40/M**	**468/12**	**RTA**	**-**	**Posterior Ankle**	**15x5**	**PNAP**	**18x6**	**1.3**	**2**	**Mild Infection**	**Partial Graft Loss**
28	**28/M**	**493/12**	**RTA**	**-**	**Lower1/3 leg**	**9x4**	**RFAP**	**12x5**	**1.8**	**2**	**Flap settled well**	**NIL**
29	**44/F**	**632/12**	**RTA**	**-**	**Lower1/3 leg**	**15x6**	**PTAP**	**18x7**	**1.2**	**2**	**Venous congestion**	**NIL**
30	**42/M**	**869/12**	**RTA**	**-**	**Medial Knee**	**6x3**	**SAP**	**8x4**	**1.0**	**1**	**Flap settled well**	**NIL**
31	**38/F**	**1282/12**	**RTA**	**-**	**Sacral region**	**18x8**	**IGAP**	**22x9**	**1.0**	**3**	**Flap settled well**	**NIL**
32	**50/M**	**1498/12**	**RTA**	**-**	**Lower1/3 leg**	**13x5**	**PNAP**	**14x6**	**1.2**	**2**	**Flap settled well**	**NIL**
33	**42/M**	**1896/12**	**RTA**	**-**	**Great toe stump**	**4x2.4**	**FDMAP**	**6x3.4**	**1.0**	**1**	**Flap settled well**	**NIL**
34	**42/M**	**2142/12**	**RTA**	**Smoker**	**Trochantric Region**	**6x4**	**LCFA-tfl**	**9x5**	**1.0**	**2**	**Flap settled well**	**NIL**
35	**41/M**	**2354/12**	**RTA**	**-**	**Lower1/3 leg**	**12x5**	**PTAP**	**15x6**	**1.2**	**2**	**Flap settled well**	**NIL**
36	**25/F**	**2695/12**	**Fall from Height**	**-**	**Anterior Ankle**	**7x4**	**ATAP**	**10x5**	**1.3**	**2**	**Flap settled well**	**NIL**
37	**45/M**	**3012/12**	**RTA**	**-**	**Lower1/3 leg**	**13x7**	**PTAP**	**16x8**	**1.3**	**2**	**Wound Dehiscence**	**NIL**
38	**35/F**	**3125/12**	**RTA**	**-**	**Lower1/3 leg**	**11x6**	**PTAP**	**14x7**	**1.3**	**2**	**Flap settled well**	**NIL**
39	**42/M**	**96/13**	**RTA**	**Diabetis Mellitus**	**Lower1/3 leg**	**7x4**	**SPNAP**	**9x5**	**1.2**	**1**	**Flap settled well**	**NIL**
40	**37/M**	**180/13**	**RTA**	**-**	**Posterior Ankle**	**4x4.1**	**LCAP**	**6x5.1**	**1.0**	**1**	**Flap settled well**	**NIL**

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI -3

Telephone No : 044 25305301
Fax : 044 25363970

CERTIFICATE OF APPROVAL

To

Dr.J.Romul Dhayan Raja,
III Year, P.G in Plastic & Reconstructive surgery,
Madras Medical College,Chennai -3

Dear Dr.J.Romul Dhayan Raja,

The Institutional Ethics committee of Madras Medical College, reviewed and discussed your application for approval of the proposal entitled "Ergonomics of perforator/propeller flaps" No.24022013.

The following members of Ethics Committee were present in the meeting held on 05.02.2013 conducted at Madras Medical College, Chennai -3.

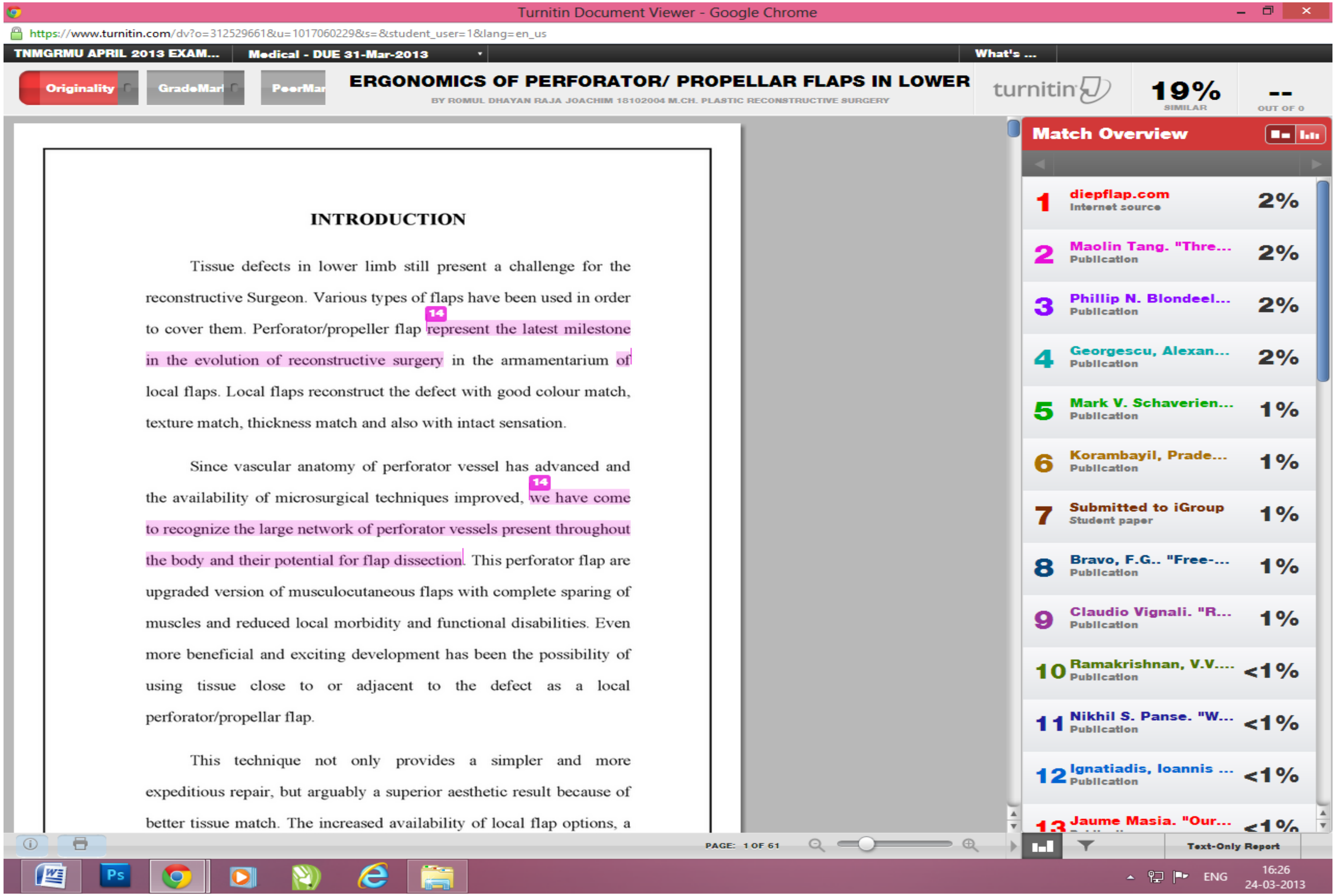
1. Dr.SivaKumar, MS FICS FAIS --- Chairperson
2. Prof. R. Nandhini MD -- Member Secretary
   Director, Instt. of Pharmacology ,MMC, Ch-3
3. Prof. Shyamraj MD -- Member
   Director i/c , Instt. of Biochemistry , MMC, Ch-3
4. Prof. P. Karkuzhali. MD -- Member
   Prof., Instt. of Pathology, MMC, Ch-3
5. Prof. A. Radhakrishnan MD -- Member
   Prof of Internal Medicine, MMC, Ch-3
6. Prof. S. Deivanayagam MS -- Member
   Prof of Surgery, MMC, Ch-3
7. Thiru. S. Govindsamy. BABL -- Lawyer
8. Tmt. Arnold Soulina MA MSW -- Social Scientist

We approve the proposal to be conducted in its presented form.

Sd/ Chairman & Other Members

The Institutional Ethics Committee expects to be informed about the progress of the study, and SAE occurring in the course of the study, any changes in the protocol and patients information / informed consent and asks to be provided a copy of the final report.

R Nandhini 22/2/13
Member Secretary, Ethics Committee



INTRODUCTION

Tissue defects in lower limb still present a challenge for the reconstructive Surgeon. Various types of flaps have been used in order to cover them. Perforator/propeller flap [14] represent the latest milestone in the evolution of reconstructive surgery in the armamentarium of local flaps. Local flaps reconstruct the defect with good colour match, texture match, thickness match and also with intact sensation.

Since vascular anatomy of perforator vessel has advanced and the availability of microsurgical techniques improved, [14] we have come to recognize the large network of perforator vessels present throughout the body and their potential for flap dissection. This perforator flap are upgraded version of musculocutaneous flaps with complete sparing of muscles and reduced local morbidity and functional disabilities. Even more beneficial and exciting development has been the possibility of using tissue close to or adjacent to the defect as a local perforator/propellar flap.

This technique not only provides a simpler and more expeditious repair, but arguably a superior aesthetic result because of better tissue match. The increased availability of local flap options, a