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Research Article

Ergonomics and Biogeometry of Free Style Pedicled Perforator/Propeller Flaps in the Reconstruction of Soft Tissue Defects of Lower Limb

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Abstract

Background: Lower limb soft tissue defects with exposed bones, joints, tendons and hardwares require a flap cover. A wide range of local, regional as well as free flaps have been described and were used routinely. In the past few years free style pedicled propeller/perforator flaps (FSPPPFs) have become increasingly popular. However, the bio geometry or the ergonomic factors governing these flaps have not been studied extensively.

Aim of the Study:

1. To define biogeometry of FSPPPFs in two different categories-those that were undergoing 180 degree rotation and in those where the rotation was less than 180-degree rotation.
2. To find reliable ergonomics factors in choosing the single best perforator (SBP) for FSPPPFs.
3. To find the maximum safe dimension of the flap that could be harvested on the SBP.

Materials and Methods: This retrospective study was conducted from March 2012 to March 2016 in single centre. A total of 115 patients (78 males and 37 females) (age was ranging from 20 years to 68 years with median age being 45 years) were included in this study. First author operated all cases. Only those with post traumatic or post excisional defects of the lower limb were included. 115 FSPPPFs in 115 patients were done based on SBP from 18 different source vessels in the lower limb.

Results: Author had clearly defined the steps of bio geometry for safe harvest of FSPPPFs in the lower limb with varying degrees of rotation. Bilobed flap design was recommended for the 180° rotation and tri lobed flap design was recommended for less than 180° rotation. Dissection should always begin with exploratory non-delineating incision of the flap. On an average 2.0 cm of the length of pedicle must be dissected to prevent the torsion and kinking during the primary movement of the flap. We have also defined ergonomics in choosing the SBP. Further refined steps of bio-geometry were based on the location of single SBP. Overall size of the SBP in our series was 1.5 mm and average length of pedicle was 2.2 cm. But we could not find any significant relationship between the size of SBP and safe surviving dimension of flap. By statistical analysis we have come to useful conclusion that one third of segment circumference as the breadth of the flap and one third of the length of the lower limb segment as the length of flap could be the maximum safe dimension of FSPPPFs based on the SBP.

Conclusion: By this study we have answered the baffling question as to what is the maximum safe size of the FSPPP flap that can be harvested on SBP. Characters of SBP and steps of biogeometry for safe harvest of the flaps were defined. And we have found out that up to one third of segment circumference as the breadth of the flap and one third of the length of the lower limb segment as the length of flap could be the maximum safe dimension of FSPPPFs based on the SBP.

Keywords: *Bio-Geometry; Ergonomics; Free Style Pedicled Perforator/Propeller Flaps; Single Best Perforator; Safe Maximum Dimension of Free Style Perforator/Propeller Flaps*

Introduction

Reconstruction of soft tissue defects in the peninsular lower limb is quite challenging as reconstructive surgeons have to steer through paucity of loose tissues available for reconstruction, decreased blood supply, scarcity of locally available flaps, poor wound healing and need for prolonged immobilization [1-3]. Though the armamentarium of plastic surgeon is well equipped with local flaps, various muscle/ and free flaps, the need for the flaps with least donor site morbidity and good aesthesis at reconstructive site is a long felt need. With robust vascularity and least donor site morbidity the free style perforator propeller flaps have become the first choice in the lower limb reconstruction [4]. Lower limb was considered by the author as a sanctuary for perforators and each one had the potential of being used as the vascular basis for the free style pedicled perforator flaps. Saint-Cyr M., *et al.* [5-8] established by their extensive study the presence of multiple potential perforosomes in the lower limb. In June 1983, Asko-Seljavaara [9] for the first time introduced the idea of a freestyle free flap at the Seventh Congress of the International Society of constructive Microsurgery, New York. He also suggested that any skin island could be harvested when a supplying vessel is correctly identified, dissected, and incorporated into the skin island flap design. The freestyle concept evolved further as refinements were made in the use of perforator flaps. Raising a skin flap in a freestyle method envisage preoperative localization of perforators with the use of a handheld Doppler device or by other means. The perforator flap is then harvested by performing retrograde dissection until a sufficient pedicle length and size have been achieved, regardless of anatomic variations of the vessels. Advancements in microsurgical techniques, improved understandings of the integument blood supply and the flap physiology in connotation to the perforator flaps have made the harvest of freestyle flaps a practical reality. After identification of perforators using a handheld Doppler device, a flap can be sited, designed, constructed and transferred in any region of the body to suit the unique characters of the defect. The value of this free style concept lies in its ability to overcome anatomic variations of perforator pedicle. However, limitations such as small perforator size and its anatomical variations can make flap harvest and flap inset challenging. Till this date the biogeometry or the ergonomic factors governing these flaps have not been studied extensively. Maximum safe dimension of the FSPPP flaps based on the single best perforator (SBP) is one such factor explored in this article.

Aim of the Study

This retrospective study was conducted to establish the following factors:

1) To define the bio-geometry of FSPPPFs in two different categories-those that were undergoing 180-degree rotation and those where the rotation was less than 180-degree.
2) To find reliable ergonomic factors in choosing the SBP for FSPPPs.
3) To find the maximum safe dimension of free style pedicled perforator/propeller flap that can be harvested in each segment of lower limb based on the SBP.

Inclusion criteria

Only post-traumatic and post-excisional defects in the lower limb were included.

Exclusion criteria

Patients with following co morbid illnesses were excluded.

1) Diabetes mellitus
2) Collagen vascular diseases
3) Smoking or nicotine consumption in any form
4) Vasculitis
5) Uncontrolled hypertension with cardiovascular instability

6) Immune compromise
7) Ulcers due to vascular insufficiency
8) Flaps harvested on more than one perforators
9) Extensive degloving injuries and crush injuries
10) Post excisional defects with the positive margins declared by paraffin sections.

Patients and Methods

This retrospective study was from March 2012 to March 2016 in the Department of Plastic surgery in a single institution and was conducted after the approval of Institution Ethical Committee.

A total of 115 patients were included in this study. Among them 78 patients were males and 37 were females. Age was ranging from 20 years to 68 years with median age being 45 years. Same surgeon (first author) operated all the cases. Perforators flaps based on 18 different source vessels (Table 1) were included. Among 115 patients post-excisional defects were 15 and rest were post-traumatic delayed primary and secondary cases. In each segment of lower limb minimum of three different source vessels for SBP were included in the study.

A thorough clinical examination, reinforced with hand held Doppler examination was performed in all delayed primary and secondary posttraumatic defects. Following were wound selection criteria followed for the FSPPPFs cover:

1) Raw area must have minimal or no edema with healthy flat granulation.
2) Good epithelizing front from the margin of the wound as shown by WBR edges. From external to center direction there must be white-blue-red colored edge of the wound and this was considered as the emblem of "bacteriological balance of the wound" (White ring was due to epiboly healing front of epithelium with maceration; Blue ring was due to thin epithelium with underlying vasculature; Red ring was due to centripetal granulation).
3) Qualitative analysis of wound biopsy showed no beta hemolytic streptococcus
4) General and locoregional factors favoring the flap cover.

There was thorough evaluation of patients undergoing excision for the malignancies in the form of intraoperative consultation for completeness of excision.

Technique of raising FSPPPs

Those patients were examined with hand held 10mHz pencil Doppler, with 45-degree angulation towards onward flow. Perforators were preferably located adjacent to the defect (Within 1 - 2 cms of the defect). Ideally, they should be away from the zone of injury. From the presumed single best perforator based on availability of the loose tissue the greatest dimension was projected in any direction and provisional marking of the flap was done.

If multiple perforators were located, the one with strong tri-phasic or biphasic signal was provisionally chosen. Local scars, vascularity, availability of loose tissues were also taken into was finally chosen by exploration through non-delineating incision.

In situation where the perforator overlies the underlying source vessel, where it was technically impossible to pick up the perforator by hand held Doppler preoperatively, we explored the perforators by single non-delineating incision and we chose the single best perforator (SBP) by the following criteria:

1) With visible pulsation and prominent venae comitantes.
2) Perforator passing through wide fascial defect (wider the fascial defect better the perforator passing through it).
3) Larger size perforator at fascial level after 2% lignocaine spray and waiting for 10 minutes.
4) Finally, when we encountered equal size perforators, one that perfused the whole extent of the flap and closer to the defect was chosen. Perfusion was checked by trial microvascular clamping of the perforator after isolation of perfusion to the skin paddle by applying intestinal clamps (needed further dissection) in approximating manner at the non-delineated intact side. Then the assessment of perfusion of flap by dermal stab at the farthest area of the non-delineated flap was done for choosing the best perforators.

These were the steps for the identification of single best perforator (SBP).

In our experience, only in the gluteal region and especially in females the situation of the perforators intra operatively differed from preoperative Doppler marking by an average of 1.5 cm. This is related to postural variation and flabby fatty gluteal skin. The direction of these perforators that were running in the subcutaneous plane were relatively long distant, directed downward and laterally especially in the gluteal region that accounted for this variation.

In rest of the areas in the lower limb, perforators were located within and nearby at the preoperatively marked site. Considering this variation and to locate all perforators, we always began the surgery with single non-delineating exploratory incision. After identification of all the perforators, using the above criteria, we chose the single best perforator and then rest of steps of bio-geometry of the perforator propeller flap were completed. After choosing the single best perforator, the hemostatic clipping of all side branches from the perforator and peri perforator dissection was carried out leaving only thin cytoskeleton of connective tissue over the perforator pedicle. This peri perforator dissection was continued until the length of the pedicle (of SBP) reached a minimum of 2 cm to 2.5 cm to avoid kinking. This length avoided acute twisting and torsion of the pedicle during the propeller primary movement. Author found out in their study, the common cause for the venous congestion was the residual fine fascial sling left on the SBP. Now based on the location of the SBP the dimension of the flap was adjusted and flap was raised by completing the final delineating incision. These steps were adopted for all the segments of the lower limb.

Bio-geometry of free style pedicled perforator propeller flaps

The farthest edge of the defect (after debridement of post traumatic defect and excision of tumor) from the location of the SBP was measured, to which 1.5 cm was added as an allowance for the primary contraction of the flap-this was the dimension of primary blade. Then 0.5 cm was added to the breadth of the primary defect -this was the breadth of the flap (for the similar primary contraction allowance). Thus, based on the intraoperative location of SBP the dimensions of the flap could be adjusted and this was facilitated by initial non-delineating exploratory incision. All flaps are oriented longitudinally based (especially in thigh, leg and foot segments) on the anatomical axial orientation of direct and indirect linking vessels between the adjacent perforosomes.

The large blade of the flap was away from the defect whereas the small blade was adjacent to the defect. After the final inset the smaller blade of the flap came to lie on the pedicle and part of the secondary defect adjacent to the primary defect. This step relieved the pressure over the pedicle and also facilitated closure of the secondary defect where it was feasible. Flap was designed, as tri lobed flap when the rotation needed was less than 180 degrees. Wherein the secondary lobe of the flap would come to lie in the part of the secondary defect of primary lobe. Whereas the tertiary lobe of the flap would come to lie in the secondary defect of the secondary lobe and this biogeometric arrangement reduced the tension over closure and tension was also partly dissipated by the secondary movement of inter lobar skin (Figure 1 and 2). 4x loupe magnification was always used during elevation and preparation of the pedicle (periperforator dissection).

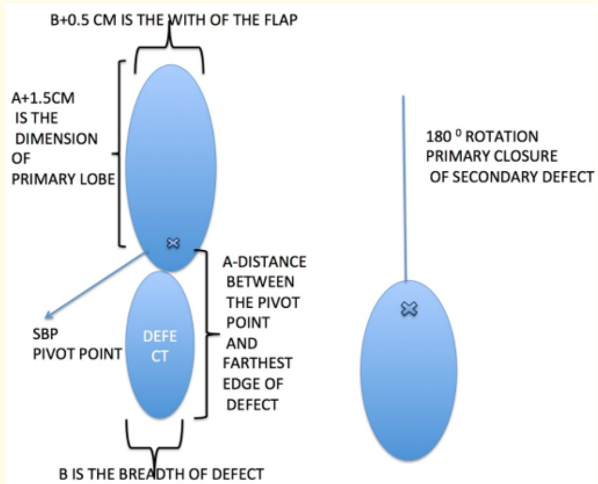

Figure 1: *Biogeometry of conventional free style pedicled perforator propeller flap through 180 degree rotation.*

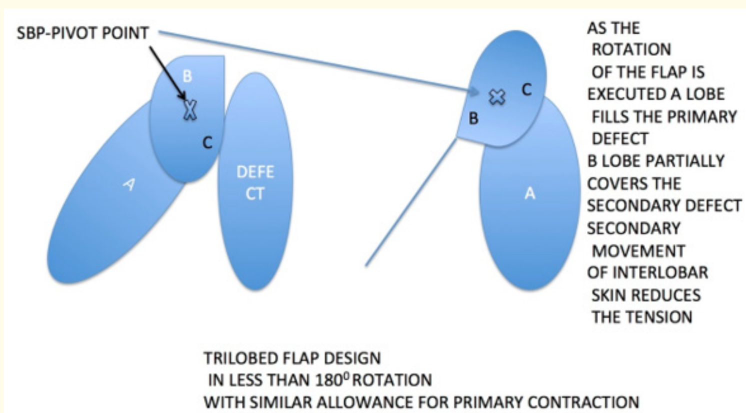

Figure 2: *Biogeometry of trilobed free style pedicled perforator propeller flap through less than 180 degree rotation.*

Periperforator dissection was done around the cytoskeleton, which carried the perforator bundle (artery, vein, lymphatics and possibly nerve twig).

For primary thinning if required, removal of the yellowish layer globular supra facial pad of fat and maintaining the granular whitish sub dermal fat with aim of protecting undulating direct and indirect linking vessels of the perforosomes were done [10]. Primary thinning was done under loupe magnification with diligent care for protecting the undulating veins of direct and indirect linking vessels. This important anatomical step paved way for 1. Rapid recruitment of adjacent potential perforosomes on the SBP and 2. Harvest of congestion free flap.

We used hemostatic clips for the control of and subfascial and intramuscular branches of SBP branches. After satisfactory skeletonization and mobilization of the perforator, the flap was propelled towards the defect.

The critical assessment of clockwise/anticlockwise rotation was done in all propeller flaps. The direction causing the venous congestion was found out after releasing the tourniquet and trial inset of the flap. The final inset of the flap was given after checking whether any kinking, torsion of perforator pedicle. Author found out by his experience that the venous congestion did not occur in one direction either clock or anti clockwise direction. We spent 15 minutes for assessment of venous congestion in any one direction with trial inset. After determining satisfactory direction and no kinking/tension on SBP the final definitive inset of flap was given. In the trilobed flap design shortest rotation was the safest.

Measurements and data collection

At the end of each operation the corresponding lower limb segment's greatest (usually the length of the segment except in the gluteal region it was the transverse dimension) and other orthogonal smallest (usually the circumference at the level of the SBP except in the gluteal region where it was cranio caudal dimension) dimensions were measured and recorded. The greatest (length) and the smallest (breadth) dimensions of the free style pedicled perforator/ propeller flap were also noted. Dimension of the SBP was recorded in each case.

Statistical Analysis and Results

Among 115 cases only 4 cases had collections beneath the flap, in the immediate postoperative period, that were drained uneventfully. Superficial epidermolysis encountered in three cases, but healed well with conservative measures. There was only partial necrosis-less than 10 % of flap size on an average in all cases where the necrosis was encountered. There was no complete loss of the flap in any of the cases. But for the purpose of statistical analysis those cases where the partial necrosis occurred were treated as "necrosis". Any flap in which even one of the flap dimensions was exceeding corresponding segmental dimensions was considered as flaps exceeding the "thirds dimension of the segment" of the lower limb. Hence for the purpose of the analysis "one third" of the greatest dimension of the segment (which is usually the length of the segment in all segments except in gluteal region where it was transverse dimension) and "one third" of the smallest dimension of the segment (which is usually the circumference in all segments except in gluteal region which was the vertical dimension) were considered as "thirds" dimension. Based on these definitions the flaps were stratified into 4 categories as follows:

A. Those flaps exceeding the "thirds dimension of the segment" with necrosis-15 cases.
B. Those flaps exceeding "thirds dimension of the segment" without necrosis-18 cases.
C. Those flaps within the "thirds dimension of the segment" but with necrosis-2 cases (included those flaps where its dimension were same as thirds dimension of the segment of the lower limb).
D. Those flaps within the "thirds dimension of the segment" without necrosis-80 cases (included those flaps where its dimension were same as thirds dimension of the segment of the lower limb).

The odds ratio analysis of the above data was 33.3, which means that when the flap dimensions exceed the "thirds dimension of the corresponding segment" of the lower limb there was 33.3 times more chance getting the partial necrosis complication.

All the patients attained pain free walking with stable healing in an average of 7 months following surgery.

Overall size of the SBP in our series was 1.5 mm (measured 10 minutes after, 5ml of 2% lignocaine spray and measured at fascial level) and average length of the pedicle was 2.2 cm. There was no significant relationship between the size of the pedicle (width of pedicle measured by calipers at fascial level) and the size of the flap survived.

The distribution of the perforator propeller flaps in the various segments of the lower limb and details of source vessels were detailed in the table 1.

Name of the lower limb and total number of flaps in each region	Name of the source vessels for SBP (18 different source vessels)	Number of perforator/ Propeller flaps done in this segment and illustrated in figure number	Total number of flaps exceeding the "thirds dimension" with necrosis (A) (total 15 cases)	Total number of flaps exceeding the "thirds dimension" without necrosis (B) (total 18 cases)	Total number of flaps within the "thirds dimension" but with necrosis (C) (total 2 cases)	Total number of flaps within the "thirds dimension" without necrosis (D) (total 80 cases)
Gluteal region (29)	(1) Superior gluteal artery	10 (Figure 3)	2	2	0	6
	(2) Inferior gluteal artery	10	0	2	0	8
	(3) Internal pudendal artery	9	0	0	0	9
Thigh (28)	(4) Superior medial geniculate artery	9	0	1	0	8
	(5) Saphenous artery	7 (Figure 4)	0	1	0	6
	(6) Medial branch of descending branch of lateral circumflex femoral artery	6	1	0	0	5
	(7) Transverse branch of lateral circumflex femoral artery	6	2	1	1	2
Leg (35)	(8) Anterior recurrent inter osseous artery	6	1	0	0	5
	(9) Anterior tibial artery	5 (Figure 5)	1	2	0	2
	(10) Posterior tibial artery	6	1	1	0	4
	(11) Peroneal artery	4 (Figure 6)	1	1	0	2
	(12) Superficial peroneal nerve artery	5	1	2	0	2
	(13) Descending branch of ramus perforans	4	1	1	0	2
	(14) Inferior medial geniculate artery	5	1	1	0	3
Foot and ankle (23)	(15) Arcuate artery	6	1	1	1	3
	(16) First dorsal metatarsal artery	5	1	0	0	4
	(17) Medial plantar artery	6	0	1	0	5
	(18) Lateral calcaneal artery	6 (Figure 7)	1	1	0	4

Table 1: *Showing distribution of 115 free style pedicled perforator/propeller flaps based on the single best perforators originating from various source vessels in the lower limb.*

Figure 3: *Free style pedicled pedicled propeller flap based SBP from the superior gluteal artery for sacral pressure sore (top left) pre-operative picture sacral pressure sore. (Top right) 9 months late postop. (Lower) Intraop picture free style harvest.*

Figure 4: *Free style pedicled perforator propeller flap based on SBP from the saphenous artery at the lower third thigh region for the post burn unstable scar defect on medial aspect of knee. (Top left) pre-operative picture of unstable scar after excision. (Top right) Intraoperative picture of free style harvest based saphenous artery perforator. (Lower right) late 8 months post-operative picture. (Lower left) intraoperative picture.*

Figure 5: *Free style pedicled trilobed perforator propeller flap based SBP from the anterior tibial vessels at the lower third leg region for posttraumatic defect. (Left extreme) trilobed flap design. (Middle) intraoperative picture of free style harvest. (Extreme right) late 10 months post-operative picture.*

Figure 6: *Free style pedicled perforator propeller flap based on SBP from the peroneal vessels at mid third leg region for posttraumatic lateral malleolar defect. (Extreme left) preoperative picture showing exposed hardware and lateral malleolar fracture fragment. (Middle) Free style harvest of flap based on the peroneal perforator. (Extreme right) late 6 months postoperative picture.*

Figure 7: *Free style pedicled perforator propeller flap based on SBP from lateral calcaneal vessels (LCV) for tendoachilles post traumatic unstable scar. (Extreme left) pre-operative unstable scar on the posterior calcaneum region. (Middle) free style harvest of flap based perforator from the LCV. (Extreme right) late 10 months post-operative picture.*

Discussion

Raw areas in the lower limb pose considerable challenge for the reconstructive surgeon [1-3]. We are now living in the era of customized tailoring to fit flap reconstruction. The big stride in the evolution of flap reconstructive surgery happened in 1989 when Koshima., *et al.* and Kroll., *et al.* separately described perforator flaps and perforosomes and their applications [11,12]. The study by Geddes., *et al.* showed great potential in harvest of perforator flaps for lower limb defects [5]. Ever since the perforator terminology was introduced, there was a growing interest in the perforators as well as in its popular modification the propeller flaps. Though the perforator/propeller flaps are a recent addition in the armamentarium of the flap reconstructive surgery it has become the first choice as predicted by Fu Chan Wei., *et al* [13]. Perforator flaps were defined in various ways [14-16]. The Author defines the perforator flap in more anatomical way; as cutaneous paddle with or without fascia harvested on a direct cutaneous or septo-fasciocutaneous cutaneous perforator which were rendered direct by peri-perforator dissection carried either partly or fully down to the source vessel. Perforosomes were vasoneuro-histosurgical units supplied by the perforator vessels arising from the source vessel. Extensive studies were done on the lower limb perforators by Saint Cyr.M., *et al* [5-8,17]. In June 1983, Asko-Seljavaara [9] for the first time introduced the idea of a freestyle free flap at the Seventh Congress of the International Society of reconstructive Microsurgery, New York. He also suggested that any skin island could be harvested when a supplying vessel is correctly identified, dissected, and incorporated into the skin island flap design. The freestyle concept evolved further as refinements were made in the use of perforator flaps. Raising a skin flap in a freestyle method envisage preoperative localization of perforators with the use of a hand-held Doppler device or by other means. The perforator flap is then harvested by performing retrograde dissection until a sufficient pedicle length and size has been achieved, regardless of anatomic variations of the vessels. Advancements in microsurgical techniques, improved understandings of integument blood supply and flap physiology in connotation to perforator flaps have made harvesting the freestyle flaps a practical reality. After identification of perforators using a handheld Doppler device, a flap can be sited, designed, constructed and transferred in any region of the body to suit the unique characters of the defect. The value of this free style concept lies in its ability to overcome anatomic variations of perforator pedicle. However, limitations such as small perforator size and its anatomical variations can make flap harvest and flap inset challenging. Hyakusoku introduced propeller flaps in 1991 [18]. The Propeller flaps have two unequal blades (skin paddles) centered on the skeletonized perforator vessel and rotated on the single best perforator to the primary defect and the secondary blade potentially filling the secondary defect reducing tension on the perforator pedicle [19,20].

Despite all these publications, there remained a paucity of lucid principles in four areas 1. Biogeometry of free style pedicled perforator/propeller flaps in varying degrees of propeller primary movements 2. Ergonomics in selecting the SBP 3. Relationship between the size of SBP and dimension of free style pedicled perforator/propeller flaps 4. The safe maximum dimension of the SBP based free style pedicled perforator/propeller flaps that can be harvested in the lower limb where these flaps were frequently used.

Though Teo., *et al.* [20] described the bio-geometry of perforator propeller flaps but detailed operative approach towards the perforators and selection of the single best perforator were not elicited. This article defines the steps of the bio-geometry for the perforator propeller flaps.

Author recommends that when the primary movement of propeller flap was less than 180°, trilobed flap design was suitable for tensionless closure of secondary raw areas and for no resultant pressure on the pedicle. Conventional bilobed flap design was useful for the 180 degree primary propeller movements.

Considering the variations in the intraoperative location of perforators coupled with inability to precisely locate the perforator preoperatively author recommends the non-delineating incision as a first step in the exploration of the perforator/propeller flaps. This approach provided the leeway and flexibility for adjusting the dimensions of the flap after securing the SBP. In a related publication by the author [21], this was the recommended and preferred approach for securing the perforator propeller flaps in the lower third leg where the perforators and source vessels lies over each other, thereby negating the efforts of preoperative mapping by the Doppler. Although this free style approach with one initial exploratory incision was found in various other publications [22-29], the lucid step-by-step approach is given in this article. Author generalizes this free style safe approach to all segments of the lower limb for the following four reasons 1. The need for adjustment of dimensions of the flap according to the location of secured SBP arose in every case 2. Anatomical variations of perforators were found in all the lower limb segments (more so in the gluteal region as pointed out earlier). 3. Simple hand held Doppler cannot distinguish the perforators acoustic signal from the source vessels especially in the lower third leg. The number, size, course, branching pattern and all the anatomical details of perforators can be elicited with 90% accuracy by the MDCT scan but this gadget may not be available uniformly. 4. Acoustic Signal intensity of hand held Doppler poorly locates the presumed SBP preoperatively.

Donor site morbidity was greatly reduced as in most cases it can be closed primarily. This was possible, as the bio geometry of propeller flaps facilitates the freedom of choosing the flap adjacent to the defect in any direction subject to the availability of loose tissue so that they could be closed primarily. Lower limb was considered by the author as a sanctuary of perforators and each one had the potential of being used as the vascular basis for the perforator flaps.

The ergonomics of choosing the SBP close to the primary defect is defined step by step. Combination of anterograde and retrograde periperforator must be the essential step in defining all the perforators. Dissection can be supra or subfascial. But when the suprafascial dissection is done, it is safe to include the cuff of fascia around the perforator by prudent changing of plane of dissection after seeing the tree pattern of branching of perforator. Criteria for choosing the SBP are described lucidly. To avoid acute twists and kinks while executing the propeller movement following are recommended by the author 1. Complete skeletonization of the pedicle leaving no residual fascial slings 2. On an average 2cm pedicle length is enough to facilitate the gracious turn of the pedicle. 3.choose one direction of rotation that has facilitated the gracious turn of the pedicle during propeller movement without any acute kinking or twisting. 4. The perforator shall be located in the midway between the initial delineating and non-delineating incision as far as possible. These ergonomics are not defined in any of the currently available literatures [30].

Overall average size of the SBP in our series was 1.5 mm (measured 5 minutes after, 5ml of 2% lignocaine spray and measured at fascial level) and average length of pedicle was 2.2 cm. There was no significant relationship between the size of the pedicle (width of pedicle measured by calipers at fascial level) and the safe surviving dimension of flap.

Milton., *et al.* [31] had proved in their study that it was fallacy to conclude that safe length of the flap can be increased by increasing the pedicle width in peninsular pedicled flaps. This study repudiated the age-old canons, which governed the random flap dimensions [32-35]. So it was the mean arterial pressure of the source and perforator vessel that determines the safe maximum dimension of the flap. The "inversion phenomenon" described by Rubino., *et al.* [36] explained the hyperperfusion of these flaps and how it effectively recruited adjacent potential perforosomes through direct and indirect linking vessels. How effectively the adjacent potential perforosomes can be recruited on the index SBP was dependent on the mean arterial pressure of the source and perforator arteries. Panse., *et al.* [37] studied in the leg segment and found that there was six times more chance for necrosis of flap if its length exceeds one third of leg segment length. But in this study, we have examined all four segments of the lower limb -gluteal, thigh, leg (including knee) and foot (including ankle). Perforator/propeller flaps enjoy a homogenized high vascularity. This is due to wide undermining and staging of the flap during the harvest itself leading to sympathectomized status contributing to increased blood supply. It has got the benefits of the musculo cutaneous flaps minus the muscle. All steal phenomenon due to undesired components like muscle, fascia, and fat were eliminated. This also contributes to the increased blood supply. But till this date the baffling question remains is "what is the safe maximum dimension of perforator/propeller flap that can be harvested on a single best perforator?" In our series partial necrosis (on an average less than 10 % of flap surface area) had occurred in 15 out of 33 flaps (46%) with dimensions exceeding the "thirds dimension of the lower limb segment". Partial necrosis (one flap 5% necrosis and another one 4% of surface area) also occurred in 2 out of 82(2%) flaps within the "thirds dimensions of the lower limb segment". The odds ratio analysis of the above data was 33.3, which means that when the flap dimensions exceed the "thirds dimension of the corresponding segment" of the lower limb there was 33.3 times more chance of getting the partial flap necrosis complication.

Complication like necrosis increases from 2% to 45% when the flap dimensions exceeded the thirds dimension of the corresponding lower limb segment. Therefore, the maximum safe dimension of the perforator/propeller flap in any lower limb segment harvested on SBP should not exceed the 'thirds dimension of the corresponding segment'.

Propeller flaps decrease the morbidity of the donor site by providing the small blade of tissue for partial reconstruction of the secondary defect. Also, the standing cones and the reclining cones of the wide closing angles and unequal side respectively were not encountered in propeller flaps that increase the aesthesis of the local reconstruction. It had all the benefits of local tissue with good color, thickness and texture match. Propeller flaps are microvascular flaps minus the microvascular anastomoses. This considerably decreases the operating time [38-40]. This factor was comparable to the local fascio cutaneous flaps. Donor site morbidity was greatly reduced, as in most cases it can be closed primarily [41]. This was possible as the biogeometry of propeller flaps facilitates the freedom of choosing the flap adjacent to the defect in any direction subject to the availability of loose tissue so that they could be closed primarily. Even the donor site source vessel and nerves were preserved.

Unlike the free flaps, perforator propeller flaps are local flaps, which unlikely fail fully. If at all necrosis occurs it would be partial over critical areas. Therefore, the resultant raw areas either can be skin grafted or allowed heal by secondary intention.

Conclusion

Following were four conclusions arrived by the author:

1. When the primary movement of propeller flap was less than 180 degree, trilobed flap design was suitable for tensionless closure of secondary raw areas and there was no resultant pressure on the pedicle. Conventional bilobed flap design was useful for the 180 degree primary propeller movements.

2. To avoid acute twists and kinks while executing the propeller movement following are recommended by the author A. Complete skeletonization of the pedicle leaving no residual fascial slings B. On an average 2 cm pedicle length is enough to facilitate the gracious turn of the pedicle. C. Choose one direction of rotation that has facilitates the gracious turn of the pedicle during propeller movement without any acute kinking or twisting. D. The perforator shall be located in the midway between the initial delineating and non-delineating incision as far as possible.
3. Overall average size of the SBP in our series was 1.5 mm and average length of pedicle was 2.2 cm. There was no significant relationship between the size of the pedicle (width of pedicle measured by calipers at fascial level) and the safe surviving dimension of the flap.
4. Maximum safe dimension of the free style pedicled perforator/propeller flap in any lower limb segment harvested on SBP should not exceed the 'thirds dimension of the corresponding segment' (one third of segment length as length of flap and one-third of segment circumference as breadth of flap could be the safe maximum dimensions of perforator/propeller flaps, which were being harvested on SBP) of the lower limb. This would avoid the partial necrosis complication of the perforator propeller flaps.

Perforator/propeller flaps were conceived in the refinements of musculocutaneous, fasciocutaneous flaps and born out of constant desire of reconstructive surgeons for reducing donor area morbidity. The bio-geometry, ergonomics and safe dimensions elicited by this study shall usher the reconstructive surgeon for the desired and safe outcome with free style pedicled perforator propeller flaps.

Conflict of Interests and Financial Support

None declared.

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