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How to Design and Harvest a Propeller Flap

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How to design and harvest a propeller flap

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How to design and harvest a propeller flap

ABSTRACT

Propeller flaps are local flaps based either on a subcutaneous pedicle, a single perforator, or on vessels entering the flap in such way to allow the flap to rotate on their axis. Depending on the kind of pedicle and the anatomical area, the preoperative investigation and the harvesting techniques may vary.

An adequate knowledge of skin and subcutaneous tissue perfusion in the different areas of the body is very important in order to plan a propeller flap to be successful.

The surgeon should begin by finding the most suitable perforators in the area surrounding the defect using available technology. The position, size and shape of the flap are planned about this point.

For perforator-pedicled propeller flaps, the procedure starts with an exploration from the margins of the defect or through a dedicated incision to visualize any perforators in the surroundings. The most suitable perforator is selected and isolated, the skin island re-planned and the flap harvested and rotated into the defect. The variations in surgical technique for other types of propellers and in specific anatomical areas are also described.

Compared to free flaps, propeller flaps have the advantage of a simpler, shorter operation, without the need for a recipient vessel for microanastomosis.

Yet from a technical point of view, an adequate experience in dissecting perforators and the use of magnifying glasses are almost always required

Key Words: propeller, technique, propeller harvesting, propeller planning

How to design and harvest a propeller flap

INTRODUCTION

Propeller flaps have been described for soft tissue reconstruction in all areas of the body. These are local flaps with several advantages when compared to traditional flaps both from a functional and a cosmetic point of view. They should be considered for resurfacing a small to medium sized soft tissue defect, as long as the neighboring tissues have been preserved, are expendable, and have sufficient redundancy to facilitate donor site closure. According to the “free-style” concept, as first described by Asko Seljevaara (1), and later in more detail by several other authors especially for perforator flaps, anywhere there is an adequate perforator a local perforator flap can be harvested based on that perforator. (2,3)

The propeller flap adds additional reconstructive options to more traditional local flap movements (advancement, transposition and classical rotation). Flap circulation is typically based on a defined vascular pedicle, consisting in most cases as explained in the classification topic in this issue, of perforator vessels. (4)

Increased certainty of flap perfusion allows the design of skin island shapes that seem impossible, or not advisable with traditional local flaps.

The donor site of a propeller flap can in most cases be closed primarily, or at least partially so, by the minor blade of the propeller. At the pivot point no excess tissue remains, unlike the “dogear” with traditional flaps, as that would impair the rotation of the flap. Overall, tissue redundancy is avoided, as the propeller flap is custom-made for the defect. Thus in general, the residual cosmetic morbidity will be less than with a traditional local flap.

An adequate knowledge of skin and subcutaneous tissue perfusion in the different areas of the body is very important in order to plan a perforator flap to be successful. The angiosome idea (5) and further development from studies that led to the concept of perforasomes (2) have been specifically dedicated to exploring territories nourished by a single perforator. Recent milestone publications have described how a free-style flap can be designed in relation to the presence of hundreds of perforators throughout the body, so that each can be tailored to the defect to be covered (6,7).

Human cadavers and animal models can be used to practice the surgical technique of perforator flaps and propeller flaps. In particular the difficulties and dangers encountered in this kind of surgery in the living pig mimic closely those found when operating humans (8).

PREOPERATIVE INVESTIGATIONS

Preoperative identification of a reliable perforator is essential for the surgical harvest and success of a propeller flap (9).

The simplest method to find a perforator is with the hand-held inexpensive and ubiquitous audible Doppler. Sensitivity is great, but some limitations arise from low specificity due to the frequent impossibility to distinguish perforators from the main vessels themselves. (10-12)

Color Doppler Ultrasound adds the ability to visualize a perforator, and then make a choice based on its size and flow characteristics as well as presence of a comitant vein. (13)

Some drawbacks slowly being overcome include the greater cost, lack of portability, and technical difficulties when in use. (14,15)

Thermography has become a complementary method using thermal cameras to measure skin temperature, where hot spots correspond to the location of perforators. (16,17)

As also a topic included in this issue using SmartPhones, this is now affordable and easily obtainable for propeller flap planning, intraoperative decision making, and postoperative monitoring. (18,19) Preoperative radiological imaging, either by CT angiography or contrast-enhanced magnetic resonance imaging (MRI), have attributes in special circumstances, but are not as readily available. (20-22)

PLANNING

The arborization of perforator branches is, in general, random. But a combination of anatomical studies, prior clinical experience and imaging investigations (2,5,23,24), always helps to increase the probability of positioning a skin island of a propeller flap that will include most of the vascular territory or perforasome of a given perforator. As a general rule, the orientation of the vascular interconnections between perforasomes from the parasternal to the axillary line of the trunk will follow the intercostal spaces in a medio-lateral direction. In the extremities, perforators concentrate around the joints, and their territories extend parallel to the limb's major axis.

FIGURE 1

Within the face, the vascular territories usually overlap those of traditional flaps. The size of flaps here usually are small compared to the enhanced perfusion of this region, so therefore the orientation of the propeller island is less important as regards perfusion than positioning on areas of skin excess or within aesthetic zones. (2)

Following the above principles, begin by finding the most suitable perforators in the area surrounding the defect using available technology. The position, size and shape of the flap are planned about this point.

Probably the most important of these factors is the position of the most suitable perforator in relation to the defect, as it will be the pivot point for rotation of the propeller flap. The position of the skin island also will depend on the location of tissue redundancy or where the donor site defect would be minimal. Another factor determining the best skin island position is that most probable in including the anticipated distribution of the perforator's branching pattern within the subcutaneous and subdermal tissues.

Understand that the position of the perforator and of the skin island in relation to the defect will determine the degrees of necessary flap rotation. It should be the usual practice to perform a reverse planning of the skin island position, to "mark twice, cut once" (**FIGURE 2**). In most cases more than one perforator will be found, and the reverse planning should be performed preoperatively for two or three of them with corresponding skin islands outlined. Especially when a "free-style" technique is used, not only will alternative surgical

solutions thereby be known; but in addition a so-called plan B should be considered, ranging from skin graft to traditional local flap to free flap.

HARVESTING

After the usual preparations and appropriate initial design of the flap, an exploration starts from the margins of the defect to visualize any perforators in the surroundings.

If needed, a skin incision can be added about any pre-operatively located perforators, and it is begun along the outline of the planned flaps (either that of the propeller or plan-B). Any exploratory incision should avoid interfering with alternative flap solutions, and risk of exposing delicate structures that cannot be left without coverage (eg. bone, major blood vessels, nerves). **FIGURE 3a**

Once the suitable perforators are visualized, one must be selected (**FIGURE 3b,c**). The choice will depend on the quality of the vessel, caliber, the presence of a comitant vein, and position relative to the possible skin island that will be based on this vessel. The reverse planning is again repeated to optimally redesign the skin island according to the necessary size, shape, and donor site location. The exact point of emergence of the chosen perforator is marked on the cutaneous surface of the flap. **FIGURE 3d**

The perforator, if already in full view, is then further isolated. Otherwise, it can be completely dissected after full harvest of the boundaries of the skin island, as this could facilitate better visualization (**FIGURE 5a**). Either way, isolation requires following the perforator into the deeper tissues such as the muscle or septum from which it emanates, carefully obtaining hemostasis while dividing all side branches down to the main vessel. Remember that the longer the perforator is dissected, the easier will be flap transposition with a smaller risk of vessel buckling due to torsion. To reduce also the risk of kinking, another important maneuver is to remove all fascial bands and adhesions around both the perforator artery and vein.

After full skin island and pedicle isolation is performed (**FIGURE 4**), the flap can be rotated like a propeller into the defect (**FIGURE 5**). If

a rotation of 180 degrees is required, both clockwise and counter-clockwise directions are tried to find the best one. A key stitch is placed on either side of the flap at the marked location of the perforator so that the flap is not advanced too far that would place excessive tension or compression on the pedicle. Another should join the leading edge of the flap with the most distal margin of the defect. The skin island is then observed for changes in perfusion, the pedicle itself is checked for collapse or engorgement, and then all manipulated for optimal positioning.

If perfusion is adequate, the remaining closure is performed and a drain is positioned. Donor site closure may be by primary intention, partially or totally by the minor blade of the propeller (most commonly after a 180 degrees rotation), or resurfaced as needed with a skin graft.

If adequacy of perfusion is in doubt, the pedicle must be checked again, reversible causes resolved, or the flap is rotated back to its original donor site position. For venous congestion, if an adjunctive subcutaneous vein had been retained during the harvesting phase, this can be used for superdrainage via a microsurgical anastomosis to any recipient vein found suitable nearby the defect.

Harvesting VARIATIONS

There are some conditions when flap perfusion is more predictable, due to one or more of the following reasons:

- a constant location or high density of perforators exists
- a favorable length to width ratio of the skin island
- the known and consistent vascular anatomy of the area

In all these cases the flap can be raised without the need of an audible Doppler or even more sophisticated preoperative investigation.

Subcutaneous pedicled propeller flaps

These flaps are planned in areas of a constant location or high density of perforators, like the lotus flaps of the perineal area that are centered over the emerging area of the pudendal vessels perforators. They are routinely raised without even locating any perforator within the pedicle, but instead leaving a consistent portion of subcutaneous tissue unviolated. (25)

The proposed skin island is incised, and the underlying subcutaneous tissue divided down to muscle deep fascia. The island is harvested starting from the tip towards its base, staying on the deep fascial plane or muscle. This dissection ceases when the flap has enough freedom of movement to be able to reach the defect, usually allowing leaving the subcutaneous fat of the proximal fourth of the flap approximately in continuity with the muscle. (**FIGURE 6a,b,c**).

The subcutaneous pedicled propeller flaps have less freedom of movement compared to a perforator pedicled propeller flap, with an expected arc of rotation limited to around 90-120 degrees. Therefore, when planning and then marking the skin island, it is important to consider the loss of reach of the planned island about its pivot point, although this is not as severe as for a traditional rotation flap (**FIGURE 6**).

Small “Free Style” flaps

In some anatomical areas where a perforator is almost invariably present, it is possible to proceed without any preoperative investigations relying instead on exploring the surroundings through the defect margin (**FIGURE 7**).

In small defects, we initially prefer to design a traditional transposition flap on the skin. Once the defect has been created, exploration of the surrounding area from the wound margin, allows to locate perforators. The traditional flap is then redesigned to include the perforator.

While the traditional flap is raised, the perforator can be better visualized and isolated. If it has a reliable caliber, pulsatility, and presence of a vein, the residual skin bridge can be divided and the flap is now completely islanded on the perforator.

With a propeller rotation about its axis, the flap can now cover the defect (**FIGURE 8 and 9**).

Propeller Flaps of the Face

In some areas like the nasolabial fold, along the course of the facial artery, several perforators can be found. Quite commonly the artery and vein are not coupled together. (26)

Propeller flaps of this area are usually planned as would be traditional local flaps, ie. either random perfusion or axial perfusion flaps. If during flap elevation, both adequate arterial and venous reliable perforators are clearly identified, these are isolated and the flap converted into an island flap as a perforator pedicled propeller flap. If some perforating vessels are seen but not deemed suitable to autonomously nourish a flap, these are not isolated and a larger pedicle of fat surrounding them is left, creating a subcutaneous pedicled propeller flap.

Axial propeller

These propeller flaps are nourished by known axial vessels. The lingual propeller flap is a mucous – muscular flap raised on a hemi-tongue . The dissection starts from the tip of the tongue, towards the base, where the lingual artery is visualized and enters the flap. The flap is then propellered about this axial pedicle. (27) Further details are given in the dedicated paper in this issue. (28)

Muscular propeller

A muscle flap is harvested on its vascular pedicle entering the hilum on its deep surface. This will be the pivot point for axial rotation of the muscle. The size and shape of the muscle included will be exactly as planned in a reverse fashion as would be for perforator pedicled propellers. (29)

Chimeric propeller flap

A Chimeric flap consists of multiple flaps joined only by a single common source pedicle allowing independent inseting of each flap. A Chimeric propeller flap usually will have a cutaneous flap that is first minimally raised on its selected subcutaneous or perforator pedicle until it can be rotated like a propeller flap, while still otherwise in close proximity to the second flap. The latter is most commonly a muscle, but vascularized bone or other tissues would be possible. Then latter are harvested according to the usual macrosurgical technique. Further details can be found in the dedicated paper on this subject in this issue. (30)

POST-OPERATIVE CARE

As with any flap in post-operative management, especially for propeller flaps any tension and pressure must be avoided. If on the lower limb, this should be elevated for the first few days to control swelling. The flap should be kept warm to promote vasodilatation. Dressings must be applied in such a way that the flap can be monitored routinely visually looking for changes at least in color of the skin island and capillary refill. Monitoring of skin temperature, perforator pulsatility by means of an audible Doppler, or bleeding at scratch test, can be used as needed. (18)

In case of observed venous congestion, intervention should be rapid. Release of any undue external tension or removal of sutures are the first maneuvers that can be applied. If needed, an adjunctive venous anastomosis might be made for superdrainage, or the flap can be rotated back to its original position. Leeches are sometimes a good temporary solution to improve venous drainage until a balance between inflow and outflow is gained. This is typically only possible for mild or partial venous congestion, or as a last resource if all else is not an alternative. If started, fear of homeostatic instability due to significant blood loss must always be a concern.

DISCUSSION

The use of propeller flaps in different parts of the body requires anatomical knowledge of the local perforasomes (2); and, accordingly, there will be slight variations of this technique when used as a solution in a wide range of surgical situations. The most commonly used version is the perforator propeller flap, as often an excellent alternative to free flaps or two-staged local flaps, with frequently providing a superior aesthetic result.

Direct visualization of the perforating vessel usually gives a sense of security that an anatomically adequate pedicle is included. Unfortunately, as explained in detail in the dedicated article in this issue (31), perfusion of the flap also depends on the functional behavior of the perforators and the vascular territory nourished by them.

Compared to free flaps, propeller flaps have the advantage of a simpler, shorter operation, and there is no need for a recipient vessel for microanastomosis. Propeller flaps are therefore very useful in anatomical areas where recipient vessels of adequate size are scarce (e.g. the back), are difficult to isolate (eg.scars), risky to use (e.g.radiotherapy), or should not be sacrificed (e.g. a solitary or atherosclerotic vessel in a leg). That said, free flaps should always be considered from the very beginning when choosing a reconstructive plan, for their unlimited size, robust perfusion, origin from distant tissues undamaged from the cause of the local tissue defect, whenever indicated. Yet from a technical point of view, although a vascular anastomosis with the help of a microscope is not needed, an adequate experience in dissecting perforators and the use of magnifying glasses are almost always required.

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LEGENDS to FIGURES

Figure 1

The optimal design of flaps in different parts of the body. The axis depends on the direction of the branches of perforators. Darker pink color with black border: donor site (where the flap should be marked). Lighter/transparent pink with dotted line: recipient site after rotation

Figure 2

- a) A soft tissue defect over the ulna needs coverage. The perforator is located with the hand-held doppler and marked (X in figure)
- b) Reverse planning of the 90° Propeller flap. The shape and size of the flap, needed to adequately cover the defect, is modeled in tissue or gauze using as a pivot the perforator location (X in figure)
- c) Reverse planning of the 90° Propeller flap. The tissue or gauze model is rotated on the pivot point of the located perforator to reach the donor site area, so that the main axis of the flap will collide with the main axis of the limb (as previously said, the safest orientation of the flap)
- d) Reverse planning of the 90° Propeller flap. The margins of the model are marked on the skin (black line), after adding a couple of cm of extra tissue at the tip to account for retraction and possible tissue loss at the pivot. The flap should be a little larger than needed

FIGURE 3

- a) Skin incision over one margin of the planned flap skin island
- b) The perforator is visualized
- c) and partially isolated from its tissue adhesions
- d) Once the exact location of the propeller is seen intraoperatively, the reverse planning is repeated so to optimize the flap skin island position and shape. Since the perforator, intraoperatively, has been found in a slightly different position. Flap markings have been adjusted accordingly

FIGURE 4

The flap is harvested as an island

FIGURE 5

- a) The accurate dissection of the Perforator into muscle or septum down to main vessel is performed
- b) The flap is rotated 90 degrees into the defect.
- c) Donor site is skin grafted
- d) Long term result

Figure 6.

Lotus flap used to reconstruct a perineal defect, as an example of the subcutaneous pedicled propeller flaps. The different steps of the harvesting are shown. Note the bilobed shape of the flap in this particular case, with the advantages of a better fit to the specific defect and reduced tension on the donor site.

Figure 7

- a) A traditional Limberg flap is marked adjacent to the skin lesion to be removed
- b) An internal mammary perforator, well known to have a parasternal intercostal course, is here visualized from the defect margin.
- c) Once the position of the perforator is visualized, the flap is intraoperatively redesigned on the skin (in purple). The cross marks the perforator position. In black ink, the traditional Limberg flap, as marked preoperatively
- d) The perforator propeller flap is completely islanded

Figure 8

Flap is propelled into the defect after a 110 degrees rotation on its axis

Figure 9

Final result at 3 weeks