"Our Definition of Propeller Flaps and Their Classification"

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ABSTRACT

The term propeller flap was introduced for the first time by Hyakusoku to define an island flap, based on a subcutaneous pedicle hub, that was rotated 90 degrees to correct scar contractures due to burns.

With the popularization of perforator flaps, the propeller movement was applied for the first time to a skin island vascularized only by an isolated perforator and the term propeller and perforator flap were used together.

Thereafter the surgical technique of propeller flaps evolved and new applications developed.

With the "Tokyo consensus" we proposed a definition and a classification schema for propeller flaps . A propeller flap was defined as an "island flap that reaches the recipient site through an axial rotation". The classification included the Subcutaneous Pedicled Propeller (SPP) flap, the Perforator Pedicled Propeller (PPP) flap and the Supercharged Propeller (SCP) flap. A recent update added a new category, the axial propeller flap (APP).

Here we propose our updated and comprehensive classification of propeller flaps, taking into account the previous classification and subsequent publications. Based on their vascular pedicle, we consider 5 types of propellers: 1.Subcutaneous pedicled propeller flap, 2.Perforator pedicled propeller flap, its subtype 2a.Supercharged Perforator pedicled propeller flap, 3.Axial pedicled Propeller flap, 4. Muscle Propeller flap, 5. Chimeric Propeller flap.

The variables that can be taken into account in the classification are: Type of nourishing pedicle, Degrees of skin island rotation, Position of the nourishing

pedicle, Artery of origin of the pedicle, Flap shape.

Key words: Propeller flap, definition, classification, update

INTRODUCTION

The term propeller flap was introduced for the first time by Hyakusoku to define island flaps, based on a subcutaneous pedicle hub, that were rotated 90 degrees to correct scar contractures due to burns. **(1)** With a better understanding of the angiosome concept,**(2,3,4)** and the superior role of perforator vessels in skin flap perfusion **(5)**, new applications using pedicled or local perforator flaps were soon developed **(6)**, including the propeller movement. **(7)**
Based on this anatomical knowledge, Hallock applied the propeller movement of a skin island vascularized only by an isolated perforator, over the adductor compartment of the thigh, using the term propeller and perforator flap together for the first time. **(8)**
The subsequent work of TC Teo was of great importance in popularizing the use of propeller flaps for soft tissue reconstruction. **(9)**

The presentations in propeller flaps sessions during subsequent perforator flap courses or instructional meetings contributed to an exponential increase in interest in this concept. Concurrently, a few scattered publications started to appear in the English literature describing the propeller flap experiences of different groups, in the lower limb, **(10,11,12, 13)** and in other parts of the body(14, 15), from the upper limb **(16,17),** to the face **(18,19,20,21,22)** and to the trunk. **(23, 24)**

At the First Tokyo Meeting on Perforator and Propeller Flaps, in 2009, faculty and colleagues gathered from all around the world to present their experiences. On that occasion they proposed both a definition and a classification schema for propeller flaps, as this was absent until then. **(25)** This was known as the "Tokyo consensus," and stated that a propeller flap can be defined as an "island flap that reaches the recipient site through an axial rotation". This classification included three kinds of propeller flaps that differed on the basis of the nourishing pedicle: the Subcutaneous Pedicled Propeller (SPP) flap, the Perforator Pedicled Propeller (PPP) flap and the Supercharged Propeller (SCP) flap.

A recent paper proposed an alteration of this classification of propeller flaps, to include new flap variations that have evolved. **(26)** One new category was called the "axial propeller flap", (APP) and included island flaps that rotate on their pedicle 90 to 180 degrees. Instead of being nourished by a perforator or by a subcutaneous "random" pedicle, these are vascularized instead by a recognized axial vessel. **FIGURE 1.**

A slightly different classification concept was proposed by Ayestaray, et al, in 2011. **(27)**

According to their schema, four subtypes are differentiated on the basis of their unique vascular pedicle: perforator-pedicled (PPP flaps), subcutaneous-pedicled (SPP flaps), muscular–pedicled (MPP flaps) or vascular axial–pedicled (VPP flaps) perforator flaps.

An overview of these salient points has led to our updated classification of propeller flaps :

1. subcutaneous-pedicled propeller flaps (SPP flaps)
2. perforator-pedicled propeller flaps (PPP flaps)
    a. supercharged propeller flaps,
3. axial–pedicled (VPP flaps).
4. muscular–propeller flaps (MPP flaps)
5. chimeric propeller flaps

FIGURE 2. TABLE 1.

CLASSIFICATION OF PROPELLER FLAPS BASED ON THEIR VASCULAR PEDICLE

The source of the nourishing pedicle to the given propeller flap is probably the most important variable for their classification.

Subcutaneous pedicle propeller flaps

This type of propeller flap has limited usefulness depending on specific conditions and anatomical sites. For example, burn contractures of mild or sometimes even moderate severity, especially if involving the axilla or elbow, can be released and covered with these flaps using remaining unburned skin, as was originally described by Hyakusoku. **(1)** Several variations of this technique may be applied to better optimize the result. For more information, see references **(28,29,30)**

The perineum is another region where this subtype of propeller flap is most useful as exemplified by the "lotus flaps" **(31)** In some instances, propeller flaps of the facial artery are also better raised with this technique, especially when the arterial perforator and the venous perforator lie at some distance from one another, as is characteristic.

Perforator pedicled propeller flaps

The majority of flaps in the literature that are called "propeller flaps" belong to this category. Their range of rotation can reach 180 degrees, as long as the perforator pedicle is followed and isolated enough towards the main source vessel. The most popular perforator pedicled propeller flaps arise in either the trunk, such as those based on Internal Mammary Artery Perforators (IMAP) (**32)**, Lateral InterCostal Artery Perforators (LICAP), or Lumbar perforators, or on the lower extremity (**33, 34**) as based on posterior tibial and peroneal perforators. (**10**,**11,12**)
As recognized in the Gent consensus and subsequent updates **(35),** perforators can reach the skin either directly, via a septum or indirectly through muscle or some other tissue medium. Thus, perforator pedicled propeller flaps can be further subcategorized:

1. axial or direct cutaneous type [eg. SCIP]
2. septocutaneous type [eg. radial forearm]
3. musculocutaneous type [eg. thoracoacromial]

Supercharged Perforator pedicled propeller flaps

This subtype is rarely used, and that mostly for prevention of complications. A microanastomosis is required so this makes the overall procedure much more complicated. The size of the flap can be extended to include the next perforasome by arterial supercharging **(36).** Venous superdrainage may be required for perceived flap congestion, but is also used routinely for some flaps or surgical settings as a preventive measure to lessen the risk and thereby also to avoid the need for a hospital admission **(37).**

Axial pedicled Propeller flaps

This is a newer category that includes only island flaps that are based on an axial vessel that enters the flap perpendicular to its surface, without ever being a deep fascia perforator. Reach to the recipient site is with a propeller or rotation movement. To reiterate, the pedicle it is not a perforator nor subcutaneous tissues, but a clearly isolated vessel.

Prior propeller flaps that have been described in the literature and are considered to fall into this category are the STAAP (supratrochlear artery axial propeller) and the DLAAP (deep lingual artery axial propeller) flap. **(26, 38)** This inclusion is not without criticism. For example, the propeller flap based on the Supratrochlear artery is considered by some colleagues to be no different than any other perforator-based propeller flaps, as the nourishing vessel pierces the corrugator and frontalis muscles before entering the subcutaneous layer, and therefore in fact is a musculocutaneous perforator.

It is certainly more difficult to classify a propeller flap as described on the deep lingual artery. First, the flap consists only of muscle and mucosa; and secondly, the deep lingual vessel enters the flap in a perpendicular fashion without ever perforating any other tissue such as fascia. Thus, we must accept this flap variation to be part of a different class of propeller flaps, ie. the axial propeller flaps as proposed.

Muscle Propeller flaps

Although in the beginning of propeller flap history all propeller flaps were skin flaps, over the years propeller flaps that are comprised of other tissues have been described. Because the Tokyo consensus defined a propeller flap as an "island flap that reaches the recipient site through an axial rotation," not only skin island flaps but also island flaps of fascia, subcutaneous tissue, mucosa , and even muscle can be called propeller flaps if rotated on their axis as exemplified by the already cited deep lingual artery propeller flap. **(38)** An example of the muscle pedicled propeller flap would be the trapezius muscle propeller flap **(39**), where a portion of the trapezius muscle was rotated 160 degrees on the axis of the Dorsal Scapular Artery (DSA) pedicle of the muscle.

Chimeric Propeller flap

This is an evolution of the chimeric flap concept, which itself is defined as being composed of multiple independent tissues, and connected only via branches of the same main vessel. When one or more of the components of the flap have a movement of rotation on the axis of their specific pedicle, but without a complete dissection back to the source vessel, then that part can be considered a propeller flap and the entire complex can be named a chimeric propeller flap. Probably the first description of this variation was by Cavadas, et al, who called this a "razor flap." **(40)**

The advantage of the chimeric propeller flap is even greater freedom of movement of the different components to allow simultaneous coverage of different defects or parts of the same defect, with tissues having different attributes (i.e. more malleable muscle to fill a deeper defect, and then skin to facilitate superficial wound closure). **(41)**

CLASSIFICATION OF PROPELLER FLAPS BASED ON NON-VASCULAR VARIABLES

Sometimes other characteristics of a propeller flap need to be described to allow a more complete understanding of how the flap was designed and transposed to insure that the methodology is sound, reliable, and safe. **Figure 3**

Degrees of skin island rotation
The degree of rotation of a propeller flap may vary up to 180 degrees, and the actual amount will depend on the position of the perforator in relation to the defect. This rotation will also depend on how the skin island is designed, which usually will be according to the expected distribution of the perforator branching pattern in the involved subcutaneous and subdermal tissues. **(42)**

Position of the nourishing pedicle
The nourishing vessel usually enters perpendicular to the undersurface of the flap, either in the center (typically as would be a subcutaneous pedicled propeller flap for scar contractures); or, more frequently, in an eccentric position. The latter would be the more advantageous for local soft tissue reconstruction, as the larger portion of the skin island can be used to cover the defect while the minor paddle is either discarded (as in a 90 degree rotation) or used to resurface a portion of the major paddle donor site.

Artery of Origin of the pedicle
In most cases, according to the body region and our knowledge of the normal vascular anatomy, the artery of origin of the perforators of that area could be reasonably hypothesized for each propeller flap. This is generally true for the perforator based propeller flaps; but less precisely so for subcutaneous pedicled

propeller flaps. In other anatomical areas, the contiguity of multiple source vessels, since usually the origin of several perforators, makes it difficult to precisely specify the vessel of origin of a given observed perforator. An example of this difficulty is the thoracic region in proximity to the axillary lines, where perforators of the intercostal vessels, thoracodorsal vessels, serratus branch, circumscapular, or lateral thoracic may easily be confused one with the other (although not always having negative clinical consequences when harvesting a propeller flap).

Flap shape

As a consequence of the usually reliable perfusion of propeller flaps, the shape of the skin island may often freely mimic the shape of the defect. Thus the flap configuration may vary from an ellipsoid island, be multilobed, or completely custom-made to each defect.

CONCLUSIONS

This brief introduction has been intended to reiterate the historical development of the propeller flap as we have each witnessed. An updated definition of this concept and a classification schema that distinguishes both new and old variations of propeller flaps will surely open multiple points for discussion that hopefully will lead to even better improvements that can only enhance its versatility.

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LEGENDS to FIGURES and TABLES

FIGURE 1. Tokyo Classification updated

Four types of propeller flaps are classified on the base of their nourishing pedicle: 1. Subcutaneous pedicle propeller flaps, 2.Perforator pedicled propeller flaps, 3.Supercharged Perforator pedicled propeller flaps, 4.Axial pedicled Propeller flaps

FIGURE 2. New comprehensive Classification of Propeller Flaps

Five types of propeller flaps are classified on the base of their nourishing pedicle: 1.Subcutaneous pedicle propeller flaps, 2.Perforator pedicled propeller flaps, its subtype 2a.Supercharged Perforator pedicled propeller flaps, 3.Axial pedicled Propeller flaps, 4. Muscle Propeller flaps, 5. Chimeric Propeller flap

FIGURE 3. Classification of propeller flaps based on all the variables: Type of nourishing pedicle, Degrees of skin island rotation, Position of the nourishing pedicle, Artery of Origin of the pedicle, Flap shape

TABLE 1 New comprehensive Classification of Propeller Flaps