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PERFORATOR FLAPS IN HAND RECONSTRUCTION: THE EFFECT OF BLOOD VESSEL TWISTING

FILIP ARDELEAN[1], MAXIMILIAN MUNTEAN[1], DINU DUMITRASCU[2], STEFAN STRILCIUC[3], ALEXANDRU VALENTIN GEORGESCU[1]

[1]Department of Plastic and Reconstructive Microsurgery, Clinic of Plastic and Reconstructive Microsurgery, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania
[2]Department of Anatomy, Clinic of Plastic and Reconstructive Microsurgery, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania
[3]Department of Health Policy and Public Health, Babes-Bolyai University, Cluj-Napoca, Romania

Abstract

Background and aims. *Perforator flaps increasingly find acceptance and use in hand reconstructive surgery. A propeller flap is an island flap that moves from one orientation to another by rotating around its vascular pedicle. It is now possible to design propeller flaps based on a single perforator, so-called "perforator-based propeller flaps," but they are more prone to vascular impairment when twisted more than 90°.*

Methods. *We present a prospective study conducted in the Plastic and Reconstructive Surgery Department of the Rehabilitation Hospital over 17 months. All perforator-based propeller flaps that were used for hand reconstruction were analyzed. The parameters studied included the size and location of the defect, the size and shape of the flap, the perforator (length and location) that was used, the degree of twisting of the perforator, the degree of perforator dissection, the management of the donor site, and flap survival area.*

Results. *In this study we investigated the circulatory impairment induced by twisting of the pedicle on a true perforator flap. All flaps survived completely with the exception of partial skin necrosis in few cases. Some of these cases required debridement and skin grafting.*

Conclusions. *Perforator-based propeller flaps provide a reliable option for covering small- to medium-size hand complex tissue defects. They have the advantages of using similar tissues in reconstruction, not damaging another area, they do not require main vessels sacrifice, and the donor site can be generally directly closed.*

Keywords: perforator flaps, hand reconstruction, perforator vessel

Background and aim

Hand injuries and iatrogenic soft tissue defects are disturbing for the patient either from a functional or from an esthetic point of view. They should not be neglected and must be treated in time, as soon as possible. When "vital" functions such as feeling, holding or grasping are affected, flaps offer a helpful option on the reconstructive ladder [1]. Through better knowledge of the cutaneous vascularization, reconstructive surgery made considerable progress over the past thirty years [2].

According to the definition established during the Consensus Conference of Gent in 2003 [3], perforator flaps are constituted by cutaneous and subcutaneous tissue areas nourished by perforator arterial branches originating from major vascular bundles with an intramuscular or intraseptal

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Address for correspondence: maximilian.muntean@gmail.com

course. Based on experimental studies, Saint-Cyr M. et al. [4] reported that a single perforator may safely supply its proper perforasome and up to the half of vascular territory of the adjacent perforator. This possibility is favored by vascular adoption directed towards adjacent perforasomes that occurs by means of increased vascular pressure in the perforator artery after ligature of collateral subcutaneous and intramuscular arterial branches.

The concept of propeller flap belongs to Hyakusoku et al. [5], who described in 1991 an adipo-cutaneous flap designed as a propeller; he raised a random subcutaneous pedicle flap and rotated it 90°. The term was used for the first time to define a perforator flap based on a skeletonized perforator vessel and rotated 180° by Hallock [6] in 2006. A detailed description of the surgical technique in harvesting propeller perforator flaps was presented by Teo [7] in 2006. The ultimate definition and terminology of propeller perforator flaps was given by an Advisory Panel of the First Tokyo Meeting on Perforator and Propeller Flaps in 2009 [8].

While this new concept of intentionally twisting the perforator introduced new possibilities into the reconstructive surgeon's armamentarium, safety concerns remained an obstacle to its widespread adoption. Although many successes with this technique have been reported, determinants of perforator patency under such conditions have not been defined [9].

To reduce the risk of vascular complications due to torsion and buckling of the pedicle, Wong et al. [10] suggested that a perforator of 1 mm diameter should be dissected for a length of at least 3 cm. Probably the main way to diminish the complications rate is the ability to establish during surgery the safe vascular limits of a perforator flap, in other words the real potential dimensions of the flap [11]. A method which seems to be accurate is represented by the indocyanine green near-infrared angiography [12-14].

There is an extensive polymorphism in hand soft tissue defects and samples may not be representative of the parent population. Although hand, wrist and fingers are "the most commonly mentioned body sites for injuries" [15], it appears legitimate to redefine the characteristics of the patients first. Second, we will try to establish correlations between the characteristics of the flaps used with the case's evolution and their hospitalization length of stay. Better knowledge of the influence of these parameters may help to decrease the need for re-intervention and the hospitalization length of stay and therefore reduce the costs and the risks related to a prolonged length of stay. After that we will focus on the possible influence of the flaps types, size and applied rotation to the post-surgical evolution.

Patients and methods

Our study is a prospective study conducted in the Plastic and Reconstructive Surgery Department of the Rehabilitation Hospital over 17 months from April 2013 to August 2014. The inclusion criteria were: patients admitted in our department with acute and chronic soft tissue defects of the hand and fingers; patients that benefited from perforator flap transfers. The exclusion criteria were: lost cases that were transferred to other departments or died and whose evolution could not be followed up; cases with severe co-morbidities likely to interfere with the study results.

We gathered a sample of 30 cases, 24 men and 6 women, aging from 7 to 77 years old, with a mean average age of 40 years old and standard deviation of 16 years old. We collected the data from the patients' files. The sample contains 6 types of flaps, in 3 different zones:

- On the forearm, flaps raised on the radial artery (RA) perforators, ulnar artery (UA) perforators and distal carpal perforating branches.

- On the dorsal hand, flaps raised on the commissural perforators.

- On the fingers, simple or bilobed flaps raised on the digital arteries perforating branches.

The following data were collected from the patient's files: the age, the gender, the site of soft tissue defect, the mechanism leading to the soft tissue defect, the type of flap used for reconstruction, the perforator vessels size and length, the donor site location, the donor site closure type, the flap dimensions, the rotation applied to the flap, the hospitalization length, the evolution, the need for re-intervention.

Our study aims at investigating the correlation existing between 1) the flap types, size and rotation and 2) the hospitalization length of stay and the evolution (favorable, stationary or reintervention).

For this, we used the following software: Microsoft® Office Excel® 2007 (12.0.4518.1014) and Minitab 17.1.0, statistical analysis software developed by Minitab Inc.

First, we studied our sample doing repartitions and distributions. Second, we focused on the characteristics of the soft-tissue defects of our cases. Third, we exposed the parameters (variables) of our interventions. Then, we studied the response to our intervention through evolution and hospitalization length of stay. Finally, we aimed to establish correlations between the variables and the response, through distributions and repartitions inside the variable groups, scatting plots, Pearson correlation coefficient for quantitative variables and a statistical analysis in principal component to determine the influence of our variables on the length of stay.

Results

Our sample is composed of patients admitted to the department between April 2013 and August 2014. All age groups are represented, but patients in the working age range (21-50 years old) represent two-thirds of our study population. This may be explained by the fact that hand soft tissue defects are produced in a significant proportion by

work accidents. Probably by their terminal position, their numerous functions and their increased exposure, fingers are involved in 9 of 10 hand soft tissue defects.

Concerning the tissue defect site, the fingers are the main site. Concerning the donor sites, the fingers are also the main site in 40 % of flaps. Acute traumatic injuries and burns are the most frequent mechanisms, representing 23 of 30 cases. In absolute percentage, it appears that two-thirds of the donor sites were closed primarily versus one-third skin grafted. By doing repartitions, we realize that 100% of the forearm donor sites were skin-grafted; 100% of the hand and 92% of the fingers donor sites were closed primarily (this is certainly because of the flap sizes). Indeed, in our study, flaps from forearms were twice as large as those raised on the hand, which were twice larger than those raised on the fingers (Figure 1).

Concerning the hospitalization length of stay, 40% of patients were at the hospital longer than our average duration of 13 days (Figure 3).

Using Minitab, a multivariate analysis in principal component of the hospitalization length of stay, the rotation degree, the flap dimension and the flap type lead us to this loading plot graphic (Figure 4). By applying basic statistics the following results were obtained:

1. A Pearson correlation coefficient of 0,565 for the hospitalization length of stay with the dimension, with p=0.001, which is statistically significant.

2. A Pearson correlation coefficient of 0.371 for the hospitalization length of stay with the rotation, with p=0.043, which is also statistically significant.

The principal component analysis we performed shows that the factor most likely to influence the hospitalization length of stay is the flap dimension, followed by the flap rotation and the flap type.

The Pearson correlation shows a 56% correlation between the flap size and the hospitalization length and a 37% correlation between the flap rotation and the hospitalization length.

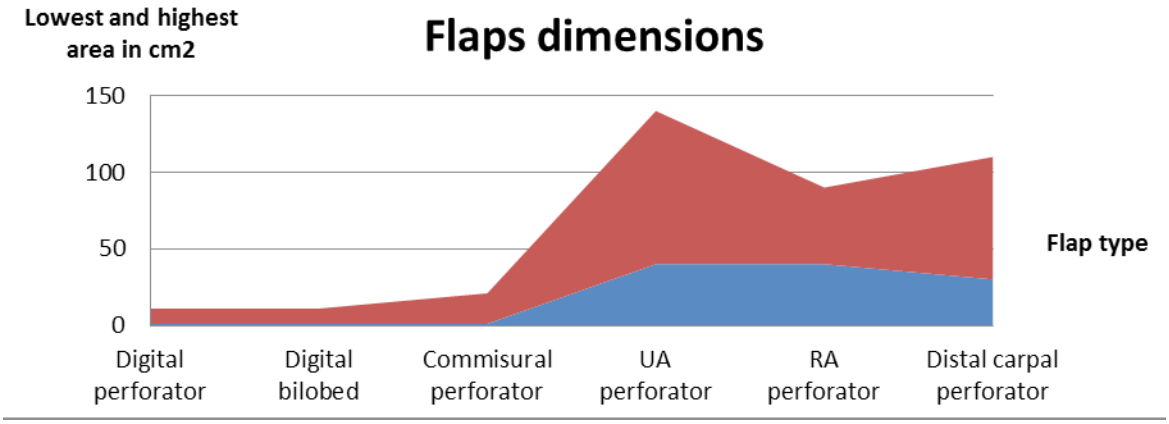

Figure 1. Flaps dimensions.

About the flap rotation, we observe that 90° rotations were only performed on the hand and fingers, and that 180° rotations counted for two thirds of forearm flaps.

We noticed the absence of rotation values between 120 and 160°. We created three groups, one for the flaps rotated 90°, one for the flaps rotated between 90° and 180° (both excluded) and one for the flaps rotated 180° (Figure 2).

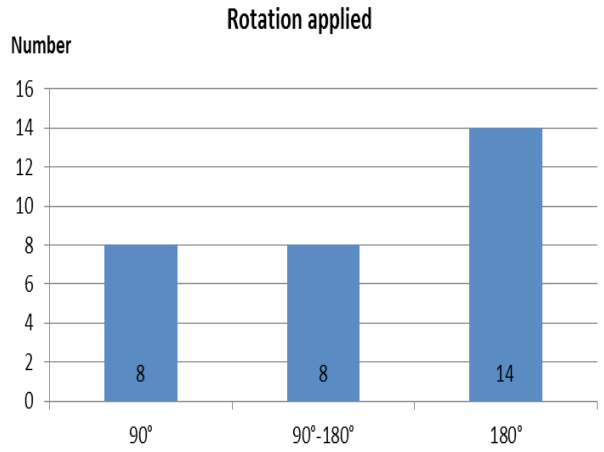

Figure 2. Flaps pedicle rotation.

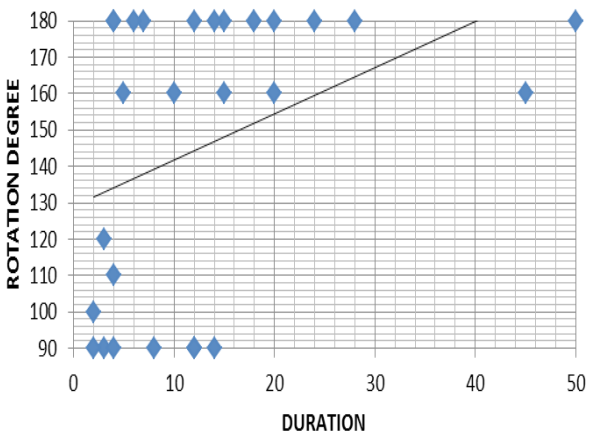

Figure 3. Scatterplot of the hospitalization length with the pedicle rotation.

By studying the repartitions of our flaps evolutions, we remark that 95% of the flaps rotated 90° and 72-74% of the flaps rotated over 90° registered a favorable evolution.

The stationary evolutions are mostly blistering, just requiring a skin graft, and distal necrosis requiring advancement and skin graft.

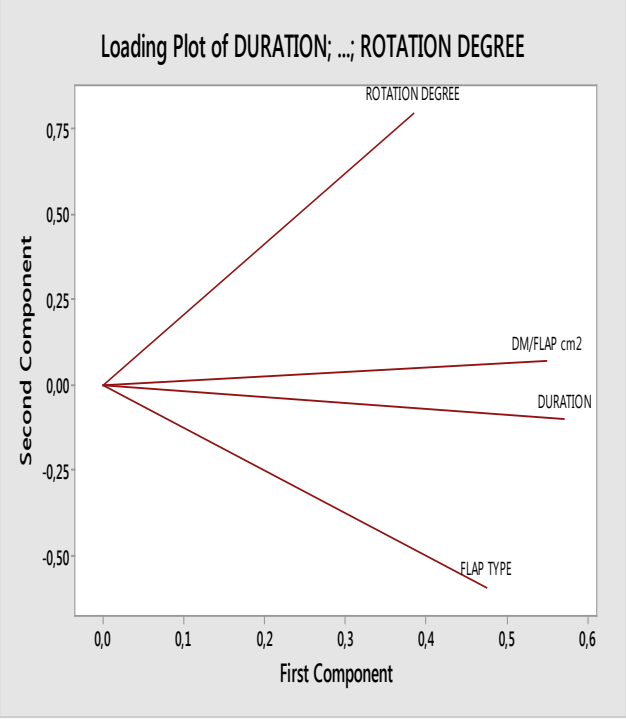

Figure 4. Loading plot of hospitalization length/flap type, rotation degree and flap dimension.

Discussion

Perforator-based propeller flaps provide a reliable option for covering small- to medium-size hand complex tissue defects [16-18]. They have the advantages of using similar tissues in reconstruction, not damaging another area, they do not require main vessels sacrifice, and the donor site can be sometimes closed directly [11]. Another advantage of the procedure is that it does not require microvascular sutures [19].

In the study led in 2008 called "Simulations of blood vessel twisting in Propeller Flaps for Surgery" [9] it was demonstrated by engineering models that arteries could be twisted up to 180° without any sign of buckling. Therefore, the rotation over 90° acts more on veins that have a thinner wall and a low-pressure regimen and so collapse more easily altering venous return, and the resultant venous insufficiency precipitate complications [10].

A perforator flap failure may be due to a true venous insufficiency or insufficient arterial flow that can damage the venous retour. As a result, it is very important to diagnose early if the arterial or venous insufficiency occurs. Venous insufficiency can be prevented by venous supercharge [20], and the insufficient arterial intake - by arterio venous anastomosis or by delaying the flap rotation[21,22]. The simulating studies [9,10] showed that it is technically possible, and our research also demonstrated that the propeller perforator flaps which are rotated more than 90° have a good evolution, which means this option is worth considering.

During perforator flap interventions we are trying to position the flap closer to the defect to avoid large rotation angles and tension on the vascular pedicle. This is especially important if the vascular pedicle length is very short [10].

The digital flaps may have had favorable evolutions despite wide rotations because of their small number of perforasomes, with low blood supply requirements. The subcutaneous tissue which is usually preserved around the vascular pedicle protects the vessels and provides a contribution of nerves which ensures well innervated flaps.

In case we fail to identify the appropriate perforator vessels in the vicinity of the defect, we can use perforator flaps with fascio-subcutaneous pedicle which ensure a high arch of rotation. The flap can be based on a known vascular network , such as carpal vascular network, or it can be a perforator plus flap. Even if these fascio-subcutenous pedicle flaps based on perforator arteries are rotated more than 90°, we can argue that their favorable evolution can be due to the fascio-subcutaneous tissue that protected the vessels from collapse and spasm.

Concerning propeller ulnar and radial artery perforator flaps, in the case where there is an urge to rotate up to 180° a flap with large surface (including many adjacent perforasomes) and short pedicle, we propose we could use near-infrared fluorescence angiography to predict the area of skin perfusion and tailor the skin flap dimensions accordingly. Furthermore, this imaging system aids in precise diagnosis of venous or arterial insufficiency and the decision of augmenting perfusion through an additional microvascular procedure with a distal end-to-end anastomosis.

Conclusion

Soft tissue defects of the hand are very frequent and mostly work or housework related. The most frequent etiology is acute trauma or burn. They should not be neglected and should be treated in time due to their functional, esthetic and psychological impact. Our study demonstrates that the propeller perforator flaps rotated more than 90° have a good evolution, which means this option is worth considering. The main risk of using flaps that are rotated over 90 degrees is the venous insufficiency which may increase in the following circumstances: with greater rotations, with wider flap surface (>80 cm²), with a decrease in perforator vessels size and length, with the tension over the flap and pedicle, or with pressure from

neighboring tissues (hematoma, bony structures at the joints).

Intra-operative identification of the insufficient arterial intake or venous congestion using indocyanine-green angiography could enable the surgery plan adjustment, adding secondary arterial or venous anastomoses when necessary or delaying flap rotation.

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