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Regional Perforator Flaps for Coverage of Complex Wounds in Upper Limbs

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ABSTRACT

Introduction: Reconstruction of complex wounds in the upper limbs is a difficult task as multiple structures, including nerves, blood vessels and tendons are arranged in a relatively small soft tissue envelope with limited options available for reconstruction. Early dtection and proper mangemnt of vascular compromise of perforator flaps is key for success of these reconstructive surgeries.

Aim: Evaluating of perferator flaps to cover upper limbs wounds.

Patients and Methods: Twenty-four cases were included in this study. After wound debridement, fasciocutaneous flaps nourished by perforator vessels were used for coverage in these patients. All patients were followed-up for at least 12 months.

Results: Twenty-three patients were males, and one patient was female. The age ranged from 9 to 55 years. All flaps survived completely except one flap which showed partial necrosis. Within 12 hours after surgery, temporary venous congestion was observed in 2 cases. Conservative measures could resolve venous congestion with flaps' survival. Follow-up showed excellent contour of the flaps with stable coverage. Regional perforator flaps included in this study was radial artery perforator flaps (8 cases), ulnar artery perforator flaps (6 cases), posterior interosseous artery perforator flaps (8 cases) and lateral arm flap (one case).

Conclusion: Perforator based flaps provide stable wound coverage with low cost and low morbidity rate for coverage of complex wounds in the upper limb. Careful and meticulous technique and early detection of venous congestion is critical for survival of these flaps.

Key Words: *Ulnar Perforator Flap – Posterior interosseous-Flap – Crushed Wounds – Venous Congestion.*

Diclosure: No conflict of interest.

Ethical Committee: Institutional review board (IRB) approval was obtained.

INTRODUCTION

Reconstruction of complex wounds of the upper limb is a challenge for the plastic surgeon. Machinary injuries **[1]**, road traffic accidents **[2]**, tumor ablation **[3]** and burn scars reconstruction **[4]** are the main causes of complex wounds in the upper extremity. These wounds entails exposure of tendons, bones, nerves or blood vessls and they need flap coverage **[5]**.

There are several flap options. The choice of defined flap needs considering functional and aesthetic factors. Local flaps offeres limited soft tissues. Regional flaps was popular but the division of a major blood vessel is a concern. The versatility of the distant flaps and free flaps make dicison making is more difficult **[6]**.

A perforator-based flap (or perforator flap) is defined as a cutaneous or a fasciocutaneous flap nourished by one or more perforator vessels which orginate from a major deep vessel, pierce the deep fascia and distribute in the subdermal plexus via either intramuscular or intraseptal course **[7]**.

In 1983, The finnish plastic surgeon Asko-Seljavaara developped the first free style flap supplied by any perforator in the body **[8]**. In 1989, koshima and soeda developped a skin flap based only on a perforating vessel of the deep inferior epigastric vessels (DIEP flap) **[9]**. Later, perforator flaps gained popularity in the coverage of skin defects in the extremities **[10]**.

In this paper we present our experience with the use of pedicled perforator flaps for reconstruction of soft-tissue defects in upper limbs focusing on their benefits and limitations.

PATIENTS AND METHODS

This study included twenty three cases suffered from complex wounds in upper limbs. These cases was admitted to Plastic Surgery Department, Mansoura University, Egypt. Institutional review board (IRB) approval was obtained. An informed consent

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was obtained from each patient after explaining the recommended surgical procedure, its benefits, limitations and expected outcomes.

We excluded cases with extreme of age (younger than 10 years or older than 70 years). Cases with sever medical impairments including hepatic failure, renal failure or uncontrolled Diabetes were excluded.

Preoperative preparation including detection of perforators near to the skin defect. The nearest perforator to the defect with the strongest signal detected by doppler ultrasound will be the pedicle for the planned flap. Then, the outline of the proposed flap will be marked on the patient.

All operations were done under general anaesthesia, loupe magnification, aseptic technique and tourniquet control. Hand held doppler was used intraoperatively to localize perforators used as flap pedicle.we started our operation by wound preparation and assesment. Then standard flap elevation was started.

Regional perforator flaps included in this study was radial artery perforator flaps (8 cases), ulnar artery perforator flaps (6 cases), posterior interosseous artery perforator flaps (8 cases) and lateral arm flap (one case).

Radial artery perforator flaps:

The radial artery in the forearm gives rise to 12 skin perforators which run between the Brachioradialis and Pronator Teres (in the proximal forearm) then Brachioradialis and Flexor Carpi Radialis (in the distal forearm). The flap is marked centered over the radial artery with a pivot point 5cm proximal to the wrist crease. The flap width is determined by the defect size. Flap is raised by incising the skin paddle centered over the radial artery while preserving the radial artery perforators.

At the pivot point we preserve the biggest perforator which maintain the blood supply to the flap. Then, we perform an incision between donor and recipient sites to transpose the flap into the defect Fig. (1).

Ulnar artery perforator flap:

The pedicle of this flap is the ulnar dorsal artery which originate from the Ulnar artery about 2-7cm proximal to the Pisiform bone. It moves dorsally deep to the Flexor Carpi Ulnaris (FCU) muscle and divides into a proximal and distal branch. The distal branch is accompanied with the dorsal branch from the ulnar nerve and is a landmark for this vessels Fig. (2). The distal branch descend downward and anastomose with 2 or 3 deep branches below the Abductor Digiti Minimi muscle. The proximal branch ascend in the ulnar aspect of the forearm deep to the fascia toward the medial epicondyle.

The flap designed centered over a line from the Medial Epicondyle Humerus and the Pisiform bone. Flap elevation is started by a longitudinal incision over the FCU muscle tendon about 5cm proximal to the pisiform bone. The dorsal ulnar branch is identified together with its proximal and distal branches. The artery is then ligated as much as near to its origin from the ulnar artery. The flap perfusion is maintained through a retrograde flow from the anastomosis between the distal branch and deep vessels from the ulnar artery in the hypothenar muscles. A perivascular adipofascial tissue should be preserved to protect the pedicle and prevent vessel spasm.

Later, the fasciocutaneous flap is elevated form a proximal to distal fashion with inclusion of the deep fascia together with the distal pedicle. Finally, the flap was rotated in the recipient site without tension Fig. (3).

Posterior interosseous artery perforator flap:

A line that connect the lateral epicondyle of humerus and the ulnar styloid is marked. Distal to the midpoint of this line, the perforator of the posterior interosseous artery is searched for using a Doppler ultrasound. The flap is then marked centered over this line. The pedicle is drawn with a pivot point about 3-6cm proximal to ulnar styloid.

Flap elevation is started by ulnar incision and dissection is started in a supra-fascial plane till the extensor carpi ulnaris was reached. Then, the deep fascia was incised and dissection is continued until the perforator was located. Later, radial incision was done and flap is elevated centered over the perforator. Then a connecting incision was done between the proximal pole of the flap and the pivot point. Complete flap elevation with preservation of the perforator and intermuscular septum is created and the flap was rotated in the defect Fig. (4).

Lateral arm flap:

A line is marked from the lateral epicondyle of the humerus to the insertion of the deltoid muscle indicating the lateral intermuscular septum which contains the pedicle (posterior radial collateral artery). We started flap elevation by posterior incision, developing a subcutaneous plane till the perforators of posterior radial collateral artery were identified. Then, the anterior border of the flap is

incised and dissection advanced posteriorly till the septum is identified. The entire flap borders is incised and elevated based only on the vascular pedicle and the lateral intermuscular septum. Finally, the distal end of the pedicle is ligated and flap is rotated to the defect Fig. (5).

We recorded the following data for each patient: age, sex, cause, site and size of wound defects. We recorded also the type of flap performed and number of perforators detected.

Objective assessments were done by detection of early and late complications of surgery. Subjective assessments were done at the end of the follow-up period (at least 6 months) by assessment of patient satisfaction about the outcome of surgery. Patients were asked about the match of color, thickness and texture of the flap. We asked also about the donor site appearance. A score was formulated where 0 refer to no satisfaction and 5 refer to full satisfaction.

(A)  (B) 

Fig. (1): (A): A preoperative photo of a case with post traumatic skin loss of the dorsal aspect of the right hand with chronic osteomyelitis of the first metacarpal and extensor tendon loss. (B): A one month postoperative photo of the same case. The wound was resurfaced with a radial artery perforator flap.

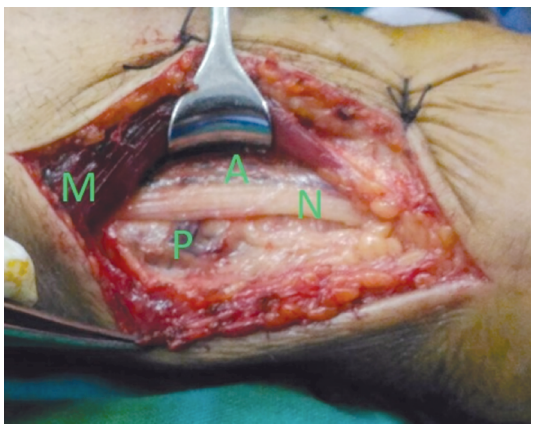

Fig. (2): An intraoperative photo of an ulnar artery perforator flap. M: Extensor carpi ulnaris muscle. N: Ulnar nerve. A: Ulnar vessels. P: Pedicle of the flap which is the dorsal ulnar artery.

(A)  (B) 

Fig. (3): (A): A preoperative photo of a case with post traumatic skin loss of the volar aspect of the left hand with exposed flexor tendons. (B): A two months postoperative photo of the same case. The wound was resurfaced with an ulnar artery perforator flap.

(A)  (B) 

Fig. (4): (A): A preoperative photo of a case with post traumatic skin loss of the dorsal aspect of the right wrist and forearm regions with chronic osteomyelitis of the radius and extensor tendon loss. (B): A one month postoperative photo of the same case. The wound was resurfaced with a posterior interosseous artery perforator flap.

(A)  (B) 

(C) 

Fig. (5): (A): A preoperative photo of a case with post burn contracture scar of the chest wall, axilla, elbow and wrist. (B): An intraoperative view of the donor site of the lateral arm flap. Vessel loop is around the vascular pedicle (posterior radial collateral artery). (C): A one month postoperative photo of the same case. Axillary contracture was reconstructed by Latissimus Dorsi flap, elbow contracture was reconstructed by lateral arm flap and skin graft.

Fig. (6): (A): A preoperative photo of a case with traumatic skin loss of the dorsum of the left hand. There is history of old fracture both bones forearm and the fractures were managed by internal fixation through a dorsal radial approach and volar ulnar approach. So be exclude the rising of posterior interosseous flap and ulnar perforator flaps yet audible perforators can be still detected in these flap territories. (B): 2 weeks postoperative view after elevation of radial artery perforator flap.

RESULTS

In this study, we operated 23 cases, 22 cases (95.6%) were males and one case (4.4%) was female. The range of the age of our patients was from 9 to 55 years (average 32 years). The flap surgery was indicated due to either machinery injuries in nine cases (39.1%), road traffic accidents in twelve cases (52.2%) or after correction of burn scar contractures in two cases (8.7%).

The most affected sites in the upper limb were the dorsum of the hand 43.4% (10 cases), volar wrist region 34.8% (8 cases), palm of the hand 13.1% (3 cases), and elbow region 8.7% (2 cases). The mean size of the wound defects is 35.2Cm^2 (range from 16 to 55Cm^2). The mean number of perforators detected in each flap is 1.88 in radial artery perforator flaps, 1 in ulnar artery perforator flaps, 1 in posterior interosseous artery perforator flaps and 1 in lateral arm flap. Table (1) shows patients demographic data.

Table (1): Patients'demographic data.

Patients' Demographic Data	
Age:	
Mean	32 years
Range	55-9 years
Sex:	
Male	22
Female	1
Defect Characteristics:	
Cause:	
Machinery injury	9
Burn scar release	2
Road traffic accidents	12
Site:	
Wrist region	8
Palm of the hand	3
Dorsum of the hand	10
Elbow	2
Size: (in square centimeters)	
Mean	35.2
Range	55-16
Flap Characteristics:	
Type:	
Radial artery perforator flaps	8
Ulnar artery perforator flaps	6
Posterior interosseous artery perforator flaps	8
Reversed flow lareral arm flap	1
Number of Perforators (mean):	
Radial artery perforator flaps	1.88
Ulnar artery perforator flaps	1
Posterior interosseous artery perforator flaps	1
Reversed flow lareral arm flap	1
Complication Rates:	
Venous congestion	2
Partial flap loss	1

Complications included venous congestion and flap loss. Venous congestion was observed in 2 cases (one case was radial artery perforator flap and the other case was ulnar artery perforator flap). Venous congestion improved over days and minimal flap loss was observed. Secondary sutures was done after one week. One posterior interosseous artery flap showed partial flap loss and was managed conservatively by dressing changes.

Follow-up of our cases ranged from 26 to 6 months (mean: 14.4 months). During the follow-up period, wound coverage was stable without wound rupture or sinus formations. At the end of follow-up period (at least 6 months), overall satisfaction rate was high Table (2). The average scores for color, texture matches and donor site appearance were 2.3, 2.5 and 1.7 respectively.

Table (2): Patients' satisfaction scores.

Serial	Type of flap	Color	Thickness	Donor site
1	Radial artery perforator	2	3	2
2	Radial artery perforator	3	3	1
3	Radial artery perforator	3	2	2
4	Ulnar artery perforator	2	3	2
5	Ulnar artery perforator	2	2	2
6	Radial collateral	3	3	2
7	Radial artery perforator	3	1	3
8	Posterior interosseous	1	2	1
9	Posterior interosseous	1	3	1
10	Ulnar artery perforator	4	5	3
11	Radial artery perforator	3	1	3
12	Ulnar artery perforator	4	3	2
13	Posterior interosseous	1	4	1
14	Posterior interosseous	2	2	1
15	Radial artery perforator	3	1	2
16	Posterior interosseous	1	1	1
17	Radial artery perforator	1	3	1
18	Ulnar artery perforator	3	4	3
19	Posterior interosseous	3	2	2
20	Posterior interosseous	1	1	2
21	Ulnar artery perforator	3	3	1
22	Radial artery perforator	3	4	2
23	Posterior interosseous	1	2	1
Average		2.3	2.5	1.8

DISCUSSION

In this study, we used pedicled perforator flap in reconstruction of complex soft tissues defects in the upper extremity. We believe that this flap options own several benefits including good color and texture match and preservation of the major vascular pedicle of the upper limb is another benefit. These flaps are less bulky than other free or distant flap options and are more suitable to reconstruct

the thin soft tissue envelope at the elbow, wrist and palm regions.

A perforator flap can be defined as a vascularized tissues (named perforasome) supplied by cutaneous perforator vessels which reach the skin through either a septocutaneous, musculocutaneous, or direct course **[11]**. This concept is based on the finding of Taylor who created the principles of the angiosomes or vascular territories which is supplied by deep perforating blood vessels which despite it course, they mainly provide blood supply to the skin **[12]**.

In comparing pedicled perforator flaps to distant pedicled flaps, perforator flaps have the advantage of being a single stage surgery which yield less bulky coverage **[13]**. On the other hand, regional pedicled perforator flap is a simple short surgery in comparison with the free flap options **[14]**. It does not necessitate advanced microsurgical resources, multiple operating teams, prolonged operative time or extended hospital stay **[15]**.

Planning the design of the perforator flap is the corner stone for successful flap elevation **[16]**. Hand held Doppler was used for detection of the suitable perforator around the soft tissue defect **[17]**. The perforator with the strongest audible signal would be chosen for flap elevation. In acute injuries, the presence of degloved flaps or extensive trauma at the perforator site are contraindications for the use of such perforator as in Fig. (6).

There are several other methods for detection of the perforator suitable for flap elevation including computed tomography angiography (CTA) **[18]**, magnetic resonance angiography (MRA) **[19]**, laser Doppler **[20]**, thermal imaging **[21,22]**. We believe that hand held Doppler is an less expensive, easy and practical method to detect the perforator during preoperative planning, intraoperative flap elevation and postoperative monitoring with reasonable reliability and accuracy.

One of the new methods for flap perfusion assessment tools is thermal imaging. It was used for preoperative planning **[23]**, intraoperative flap perfusion assessment **[24]** and post-operative monitoring **[25]** with promising results but more research in this point is still needed for standardization of this non invasive tool.

Early detection of vascular compromise of pedicled perforator flap is mandatory for achieving a successful outcome **[26]**. The early suspicious of venous congestion is of great importance. A well trained ICU nurse in monitoring of flaps check our cases on every 2 hours during the first postoperative day. Progressive changes in the color of the flap into purple and oozing of dark blood at pin brick over the early postoperative hours are alarming signs. When diagnosis was made, bedside removal of the splint and dressing was done followed by Suture removal around the flap. We rechecked the flap perfusion. If definite source of hematoma was noticed, exploration would be done. If no need for flap exploration, we used heparin solution irrigation to the wound edge and changing the dressing every 4 hours. Venous congestion improved over days and minimal flap loss was observed.

Perforator flaps are an integrated part of the learning program in our department where many cases of trauma were treated in a low resource emergency hospital. When microsurgeon or microsurgery resources are not available, perforator flaps can manage difficult cases in an emergency situation. If unsuccessful outcome occurred, refer to the university hospital would be done where advanced microsurgical flaps can be done safely.

Conclusion:

The use of pedicled perforator flaps in reconstruction of complex wounds of the upper limb have the merit of obtaining a reliable flap raised without division of a major vascular pedicle in the upper limb. Hand held Doppler is the minimum required tool for successful perforator detection and dissection. We found perforatorr flaps are a working horse in cases of emergency sitiuation where microsurgical flaps requirements are not available.

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