Egypt, J. Plast. Reconstr. Surg., Vol. 37, No. 2, July: 221-229, 2013

Posterior Interosseous Fasciocutaneous Flap: Technical Modifications to Increase its Versatility as a Workhorse Flap for Reconstruction of Hand Defects

AHMED M. ABOUL WAFA, M.D.

The Department of Plastic Surgery, Faculty of Medicine, Ain Shams University, Cairo, Egypt

ABSTRACT

Background: Minimizing the donor site morbidity while maximizing the quality of reconstruction either aesthetically or functionally should be the primary concern when dealing with soft tissue defects of the hand. The aim of this article is to highlight the versatility of the posterior interosseous flap for coverage of large variety of hand defects and to present some technical modifications to increase this versatility.

Patients and Methods: A total of 56 patients of soft tissue defects of the hand of different etiologies underwent reconstruction using distally based reverse flow (PIF) over ten years with some technical modifications. Healing of the flaps was as-sessed clinically at regular intervals with recording of any complications.

Results: The average follow-up period was 13 months. The average age was 36.2 years. The donor area was covered by a split thickness skin graft in 30 patients. All flaps survived without major complications. Flap edema was encountered in eight patients with complete resolution after three months of conservative therapy.

Conclusions: The reverse flow (PIF) is a reliable and safe flap for soft tissue cover to the palm and dorsum of the hand up to the PIP joints, first web space, and thumb distal to the IP joint. Thorough attention to these technical modifications, including primary splitting, in situ fashioning and shifting the skin island of the flap in a more proximal location to create a long pedicle will contribute to the versatility of this flap.

INTRODUCTION

Posterior interosseous flap (PIF) is a fasciocutaneous flap based on the posterior interosseous artery (PIA) and constructed from the posterior aspect of forearm. It was first anatomically described by Penteado et al., in 1986 **[1]** then introduced by Zancolli and Angrigiani in (1988) as a reverse island flap **[2]**.

This flap present a major event in hand reconstruction, as it has the advantage over other available regional flaps in that it does not require sacrifice of any vessel essential for perfusion of hand **[3]** Another advantage is the anatomical basis of the retrograde flow of this flap by the consistent anastomosis between the posterior and anterior interosseous arteries **[1,4-6]** and so even with damage of radial or ulnar arteries or palmar arches this flap can still be used **[7]**. This flap possessed the desirable qualities of both a thin pliable skin island of good texture and excellent circulation through expendable vascular pedicle which is the posterior interossseous vascular system that has extensively been described **[2,4,8]**.

Among of the reconstructive tools for complex soft tissue defects in the hand is the reverse-flow island (PIF) as it provides a vascularized skin to the dorsal region of hand as far as the proximal interphalangeal (PIP) joint level **[2,4,8,9]**. It can also be raised as an osteofasciocutaneous unit, including a vascularized bone segment from the upper third of the ulna for thumb and other metacarpal bones reconstruction **[7,10]**. There little in the literature that highlight the superiority of PIF over the radial forearm flap in reconstructing hand defect. However the distally based radial artery forearm flap is considered at a time to be the workhorse for covering large hand defects **[11]**. It has distinct drawback of sacrifice of a major arterial channel to the hand and it should not be used in badly mutilated hands where the additional loss of the radial artery could compromise hand viability **[12]**.

The aim of the present article is to report the author experience over ten year's period of using

the distally based reverse flow (PIF) with some technical modifications for reconstruction of different hand defects. In view of this series and beside the review of literatures the author highlights the importance of this flap as a versatile tool for reconstruction of different hand defects. Also stresses the great advantages of this flap being a regional distally based fasciocutaneous or osteofasciocutaneous flap with wide arc of rotation that giving it the right to be the workhorse and the first choice for hand reconstruction.

PATIENTS AND METHODS

Over the past 10 years (from 2003-2013), Fifty six patients were reconstructed for hand defects with a reverse-flow distally based PIA flap with some technical modifications. These hand defects were the result of traumatic or burn injuries and their sequelae. The average age of the patient was 36.2 years (range 4-60 years). Fifty two patients were male and four were females. In twenty two (39.4%) patients the defects were in the dorsum of the hand including the metacarpophalangeal (MP) joints and proximal phalanges of the fingers, twenty (35.7%) patients had defects involving the first web space extending to the palm of the hand, eight (14.2%) patients had soft tissue deficiency on the ulnar side of the hand either due to trauma or after release of contractures, and the remaining five (10.7%) patients had extensive soft tissue defect on volar aspect of the thumb. The average follow-up period was 13 months (range 3-24 months). Split thickness skin grafting of the donor area was performed primarily in 30 Patients with excellent take.

All patients were thoroughly examined regarding the donor site, the defect site, size, shape, tissue layers involved and exposure of any vital structure as tendons, bones and joints. Donor site examination is performed to any patient with suspicion injury to the pedicle or communicating anastomosis with anterior interosseous artery (AIA) that may prevent use of this flap using Doppler ultrasound. All patients were operated by the same surgeon and healing of the flaps was as-sessed clinically at regular intervals with recording of any complications.

Surgical anatomy:

The PIA is situated in the intermuscular septum between the extensor carpi ulnaris (ECU) and extensor digiti minimi (EDM) muscles and tendons and its course corresponds to a line drawn from the lateral epicondyle of the humerus to the head of the ulna. It is reported to arise from the common interosseous artery and infrequently from the ulnar artery. The artery emerges in the posterior aspect of the forearm at the junction between the upper and middle thirds of the forearm and it gives off several fasciocutaneous perforators along its course that supplies almost the whole skin of the posterior aspect of the forearm. The PIA anastomoses with the (AIA) about 2.0cm proximal to the distal radioulnar joint (DRUJ), lateral to the ulnar head. The artery runs in a close relation to (PIN) and is crossed by the branches of this nerve to the ECU muscle. The cutaneous territory of the PIA extends from elbow to wrist, centered on a line drawn from the lateral epicondyle of the humerus to the (DRUJ) **[1,2,8]**.

Surgical technique:

All Patients were operated under general anesthesia using the tourniquet with incomplete exsanguinations to maintain visibility of the perforators and small vessels. The markings were done twice, the preliminary one before elevation of the tourniquet to lessen the ischemia time and the final one after preparation, debridement and release of contracture to know the exact dimensions and shape of the flap according to the defect size and shape.

Marking of the log axis of the flap was performed which represents a straight line joining the lateral humeral epicondyle and the DRUJ while the forearm in full pronation and elbow in 90° flexion. This roughly represents the course of the PIA. The pivot point of rotation of the flap lies about 2cm proximal to DRUJ where PIA anastomosis with dorsal branch of AIA was marked (Fig. 1).

The distance from this pivot point to the proximal edge of skin defect was measured and it represents the length of the pedicle. This distance was then transferred to the PIA axis proximal to the pivot point. The flap was centralized over the axis proximal to the pedicle. Using a Loop magnification 3X the dissection was started by exposure of the pedicle at the level of wrist and progresses proximally. It is important to make sure that distal anastomosis between PIA and AIA exists. The skin incision was carried down to the fascia overlying the vascular axis. PIA is very superficial in the distal third of forearm and lies between ECU and EDM. A cuff of deep fascia about 1cm in width

on either side of the septum between ECU and EDM was kept and PIA and accompanying vena comitantes are reliably found in this septum.

Dissection was continued proximally with careful ligation or electrocoagulation of muscular perforators to ECU and EDM using bipolar cautery. The muscular branches of PIN are also carefully avoided.

The flap was then outlined and the incision extended to its lower border and circumferentially to its upper limit through the radial side. The incision was carried down through the deep fascia and radial side is raised subfascially, taking and fixing the deep fascia to the flap to avoid shearing forces between the skin and the fascia. The dissection extended proximally along the septum until a significant cutaneous perforator was seen entering the flap (Fig. 2).

The PIA is ligated proximal to this perforator. The dissection is more critical in the middle third of the forearm as PIA lies deeper and in close proximity to PIN and the nerve should be dissected and preserved carefully. After localizing the major perforator and dividing the PIA, the ulnar skin incision was made with harvesting the ulnar half of the flap in the subfascial plane. The flap was then elevated from proximal to distal. Ulnar retraction of the ECU exposes the pedicle within the septum, which should be dissected from the ulnar shaft.

Once completely detached, the flap was rotated and either tunneled through a large subcutaneous tunnel between the pivot point of the vascular pedicle and the proximal edge of the defect or inset through an open incision depending on integrity of local tissue (Fig. 3).

The flap can reach the dorsal defects directly and along the first web space or ulnar side for volar defects. Then the flap was sutured or stapled at recipient site. The donor site was closed primarily if width is less than 6cm. Split-thickness skin grafts are used for larger defects with two drains left, one under the flap in the recipient area and the other one in the donor site. The wrist was splinted for 7 days followed by active and passive mobilization.

In very distal defects in which a long pedicle is required, the skin island can be moved over the axis of the flap as far proximally as 2cm distal to the lateral epicondyle. This is a technical modification in the flap design that gives two benefits, increase the distal reach of the flap (palm of the hand) and give the surgeon the chance to harvest a large skin paddle (Fig. 1).

Another technical modification during insetting of the flap is the primary splitting. The flap can be splitted longitudinally starting from the proximal edge till the main perforator of the skin island (this splitting is based on the vascular anatomy and length and width ratio of the fasciocutaneous flaps). Usually the proximal half of the flap (which becomes the distal half of the flap after insetting) can be splitted without compromising the blood supply whenever the recipient defect dictates. In situ fashioning of the required design of the flap that matches the exact shape of the recipient defect can also be done.

RESULTS

All flaps survived completely in all patients and the healing was uneventful without major complications as partial or total flap necrosis and loss and patients discharged at third postoperative day after removal of the drain. All flaps provided stable coverage and excellent contour.

The recipient defect dictated primary splitting of the flap during insetting in sixteen patients (Fig. 4).

In situ fashioning of the required design of the flap that matches the exact shape of the defect was done in six patients (Fig. 5).

In sixteen patients the defects were remote with long pedicle that dictate shifting of required skin island more proximally till about 2cm from the lateral epicondyle (Fig. 1).

There were no early complications at the donor site as neurological deficit or vascular disruption in the hand resulting from flap elevation. None of our cases showed any evidence of venous congestion. Flap edema was encountered in the early postoperative period in eight patients in which a very good response to limb elevation and compression therapy was noticed with complete resolution after three months. Smooth healing of all recipient and donor sites was achieved at the time of final evaluation, the flap matched the surrounding skin in color and texture except for palmar defects and the aesthetic result at the donor site was acceptable Fig.s (6-10) show some of the clinical cases.

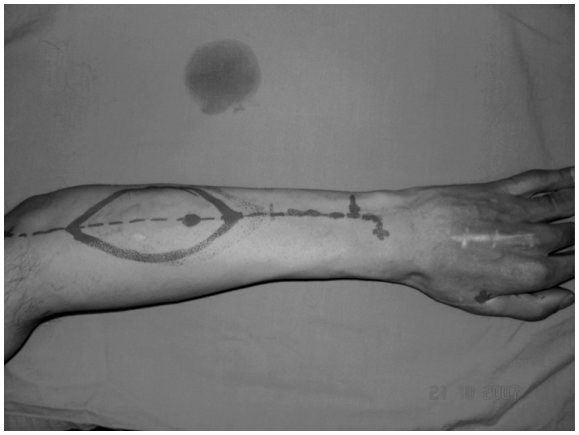


Fig. (1): A 26 year old male patient with posttraumatic contracted first web space and palm of left hand underwent release and reconstruction with the reverse flow (PIF). This is the design of the flap with proximal location about 2cm from the lateral epicondyle.

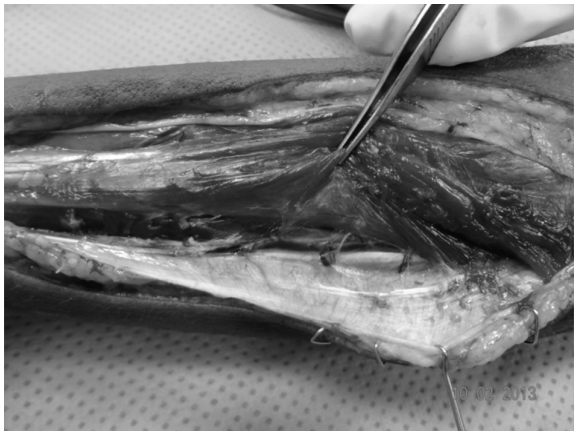
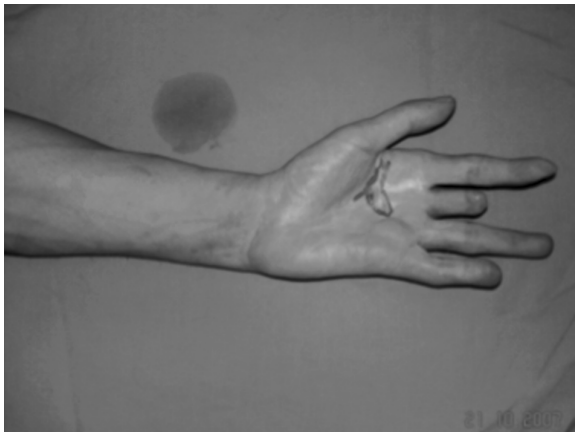


Fig. (2): Dissection of the flap from distal to proximal. The PIA lies in the septum between the ECU and EDM. A cuff of deep fascia about 1cm in width on either side of the septum is dissected. A sizable perforator pierce the deep fascia under the skin island which is dissected subfascially from the radial side is shown.

Fig. (3): Left: Insetting of the flap through tunneling of the pedicle with primary closure of the donor site. Right: About ten days postoperative.



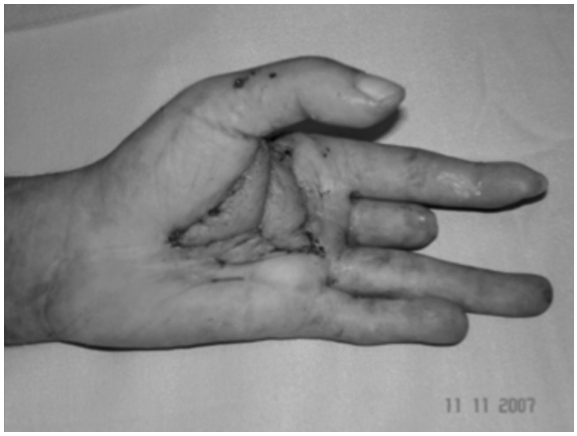


Fig. (4): A 26 year old male patient with posttraumatic contracted first web space and palm of left hand underwent reconstruction with the (PIF). Left: Preoperative showing that the contracture is extended to the mid-palm. Right: The results of the primary splitting after three weeks are evident with complete flap viability.

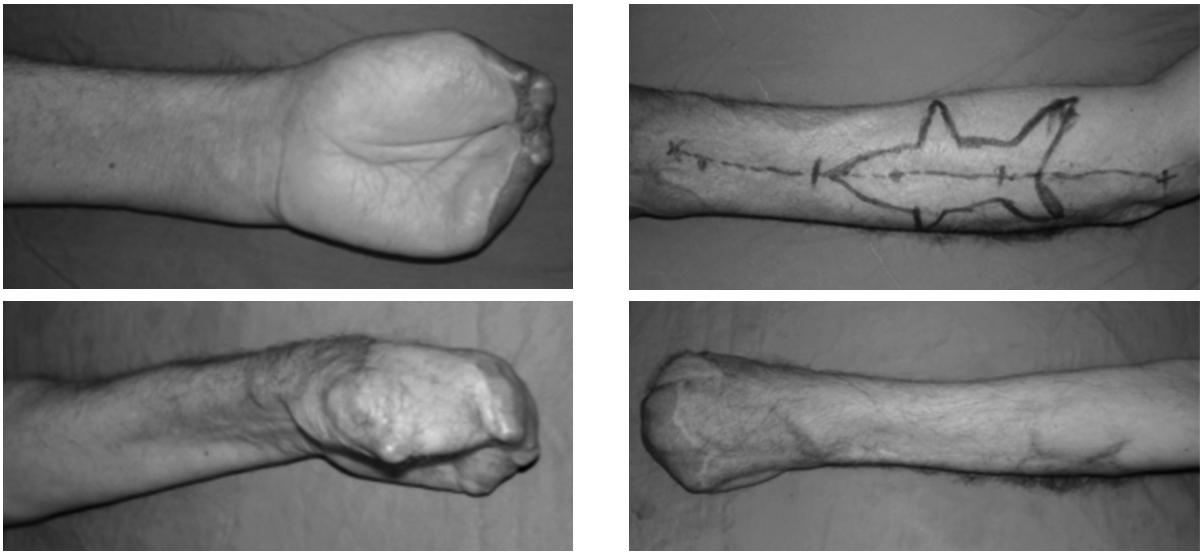


Fig. (5): Above Left: A 48 year old male patients with posttraumatic amputation of the fingers with severely contracted first web space. Above Right: In situ design of the flap is shown with two wings to line the proximal phalanges of the adjacent fingers and two tails to fit the palmar end of the web after release. Below Left: The results of the recipient site after six months shows a generous web with stable coverage. Below Right: The donor site showing fine scar. This web was subjected to more deepening at a later date with satisfactory restoration to the basic pinch.

Fig. (6): Left: A 60 year old male patient with posttraumatic ulnar defect with mild to moderate contracture after ray amputation of left little finger underwent reconstruction with the reverse flow (PIF). Right: The results after about one month have showed that the flap served as functional and aesthetic reconstruction.

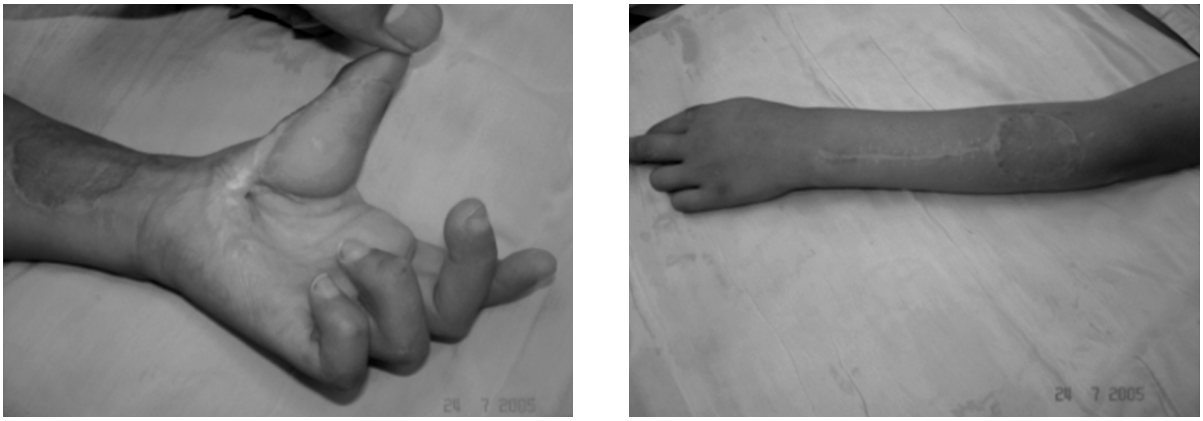


Fig. (7): A five year old child with post-electric injury extensive soft tissue defect on the volar, side of the left thumb underwent reconstruction with the (PIF). The results after about two years showing that the distal reach of the flap go beyond the (IP) joint of the thumb and the donor site is about 2cm distal to the lateral epicondyle with aesthetically accepted graft at the site of the skin island.

Fig. (8): Left: A 23 year old male patient presented with crushed right hand. All extensor tendons were injured with extensive skin and soft tissue laceration and loss. The Patient underwent serial debridement and extensor tendons repair followed by reconstruction of the soft tissue defect with (PIF). Right: About six months postoperative with very good aesthetic and functional results.

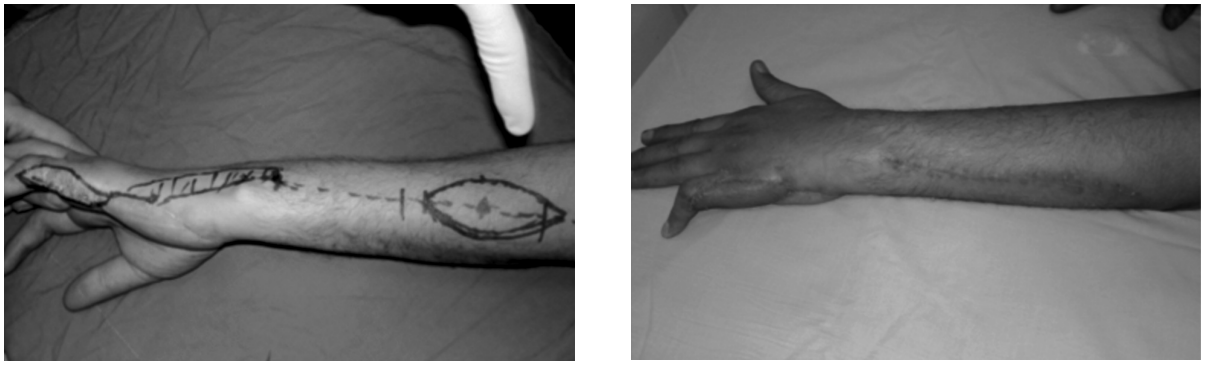


Fig. (9): Left: A 35 year old male patient presented with posttraumatic unstable and contracting scar in the ulnar side of the left hand extending to the PIP joint of the little finger. The design of the flap, the tunnel and the planned excision is shown. Right: Shows the results after about one month with the flap reaches the PIP joint of the finger and fine donor scar.

Fig. (10): A 29 year old male patient presented with adherent scar over the dorsum of right hand. Left: The design of the flap. Right: The results after about two weeks show the distal reach of the flap up to the mid proximal phalanx and second web space. Also it shows the good color and texture match and contour with the dorsal skin.

DISCUSSION

Single stage procedure for reconstruction of soft tissue defects of the hand minimizes infection, allow limb elevation, early mobilization and rehabilitation and guarding against edema with reduction in hospital stay. Regional flaps from the forearm like the radial forearm flap and the ulnar artery flap have been in conventional usage for a long time.

The radial forearm flap has two major drawbacks encountered with this flap. First, one of the two principal arteries of the forearm and hand is

inevitably sacrificed, potentially compromising the vascular supply of the hand and, more importantly, jeopardizing the possibility of additional microvascular procedures in the same hand. The second drawback is the aesthetic appearance of the donor site that is very conspicuous, especially when skin grafting is necessary after harvesting larger flaps. For this reason, the use of this flap should be limited to defects which can be reconstructed in a one-stage procedure and which do not require further microsurgical tissue transfer. These limitations make the indication for this flap should always be made on an individual basis. Even with the Variations of the original technique that have extensively done to address the two main disadvantages, the conspicuous donor site and the sacrifice of the radial artery **[13,14]** this will add more limitations especially in the arc of rotation, size and distal reach of the flap.

The ulnar artery flap is based on the major arterial supply to the hand and sacrificing the ulnar artery is the major disadvantage of this flap.

The reverse-flow distally based (PIA) flap is a thin fasciocutaneous flap with excellent consistent circulation and can be considered to be extremely versatile for coverage of hand defects **[15]**.

Regarding the arc of rotation and distal reach of this reverse-flow (PIF) flap in this small series (56 patients) are the dorsum and palm of the hand, first web space, thumb distal to the (IP) joint and the fingers up to the (PIP) joints.

Our results showed survival of all flaps and the healing was uneventful without major complications as partial or total flap necrosis and loss. In one series of 68 flaps **[15]**, sixty (88.24%) flaps were rated as good result with complete uneventful healing; four (5.88%) flaps developed partial necrosis. In these cases, the authors had relied on a single distally located perforator to supply cutaneous island and four cases suffered necrosis. All of these four failures happened during initial part of their experience with PIF. They tried to isolate the pedicle from its fascial sleeve during their dissection. This skeletonization of the pedicle in their opinion may have contributed to pedicle damage causing complete necrosis.

Coverage of distal defects requires harvesting the skin island more proximally. In our patients the flaps harvested as proximal as 2cm from the lateral epicondyle in sixteen patients. The flaps in those patients only comprise one perforator without any problem in flap viability. In our experience, inclusion of only one sizable perforator supplying the skin paddle would be enough to perfuse the flap and maintain its viability. One sizable perforator located within the skin island this does not mean that this is the only perforator of the flap. There are other perforators along the course of the PIA that perfuse the fascial cuff around the pedicle and minor perforators within the skin island. As the other sizable perforator of the skin island usually located proximal to the nerve to the ECU and harvesting of this perforator require severing and repair of this important branch of the PIN.

Our colleagues in our department used to harvest more than one sizable perforator within the skin island and some of their flaps suffer from early venous congestion (16%) of their series and they also encountered partial flap loss in (11%). When they noticed this they decided to harvest the least number of perforators to restore the balance between the arterial inflow and venous outflow **[16]**. But they did not determine the exact number that restores this balance. In our series, inclusion of only one sizable perforator was done and we did not encounter any congestion or loss whether partial or complete as well as the risk of PIN injury or its branches become minimized.

In sixteen patients primary splitting was done to match the shape of the defects with no effect on the flap survival so long as the splitting did not extend beyond the main perforator of the flap. Also it was found that in situ shaping of the flap did not affect the flap survival so long as the main skin paddle has at least one perforator. The donor site is amenable for primary closure in 26 patients with complete healing with fine scar. Larger donor defects were met in the remaining patients in whom closure with a split skin graft was done with excellent take and aesthetically acceptable results.

The venous outflow of the reverse flow (PIF) is in a retrograde fashion through venae comitantes. It was reported that the edema and congestion of the flap as high as 34% **[17]**. Adding a venous anastomosis when there was congestion after the inset was recommended **[18]**. In our series there is no single case of venous congestion was encountered, this may be in most of our patients the flap comprise only one perforator and that venae comitantes that accompany posterior interosseous artery are adequate for venous drainage even with very large flaps.

Only flap edema in early postoperative period that responded well to conservative management. In our series the technique of subcutaneous tunneling or inset via an open incision did not affect flap

survival. Also, the size of flap did not affect survival as long as at least one perforator is included in the skin paddle of the flap.

There are many described anatomic variations including absence of the PIA-AIA anastomosis or a hypoplastic (PIA) in the middle third that may lead to flap loss in clinical practice. Flap elevation can be tedious and dangerous to the last motor branches of the posterior interosseous nerve and finally the PIA is sometimes more deeply situated between the deep extensor muscles **[19-21]**.

In our patients during dissection of the flaps we did not find any of these anatomic variations and the PIA was always situated between the (EDM) and (ECU) tendons-muscles. Many authors also have not found any gross anatomical variation in their patients **[16,22]**. And others stated that this flap is extremely reliable **[2,6,11]**.

In our experience, the main drawback of the PIA flap is the requirement of a long learning curve to master the flap elevation as the dissection of this flap is usually tedious and time consuming, especially in the proximal area of the pedicle because of the close proximity of the branches of the (PIN) with the PIA and carful dissection is required to separate these branches from the artery and its perforators. With inclusion one perforator make this step much easier and less time consuming.

Conclusions:

The reverse flow (PIA) flap is a single-stage, safe, reliable and very versatile with minimal donor site morbidity for soft tissue cover to the palm and dorsum of the hand up to the PIP joints, first web space, and thumb distal to the IP joint. And now it can be considered to be the workhorse and the front runner for coverage of defects in these areas by its great benefit to preserve both the major arteries to the hand. The inclusion of one sizable perforator in the skin island would be enough for perfusion of the flap and thus minimizes the amount of dissection and the risk of injury of the PIN or its branches. Primary splitting up to the main perforator of the skin island, in situ design of the recipient shape over the skin paddle and harvesting a more proximally located skin island are valuable technical modifications that add too much to the versatility of this flap.

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