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Hand/Peripheral Nerve

The Number of Perforators Included in Reversed Flow Posterior Interosseous Artery Flap: Does It Affect the Incidence of Venous Congestion?

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Background: The purpose of this study is to decrease the incidence of venous congestion occurring in the reversed flow posterior interosseous artery flap used for coverage of hand defects.
Methods: This may be achieved by studying the incidence of venous congestion in flaps including only 1 perforator and comparing the results with others including more than 1 perforator both in small and large sized flaps.
Results: This study showed that inclusion of only 1 perforator in the flap decreased the incidence of venous congestion with complete flap loss in flaps to 5%. Also, it decreased the incidence of venous congestion with partial flap loss in flaps to 10%.
Conclusions: The small sized reversed flow posterior interosseous artery flap should be less than 40 cm^2 and should include only 1 perforator to decrease the incidence of venous congestion with partial and complete loss of the flap. The level of evidence for this study is the type II prospective comparative study. *(Plast Reconstr Surg Glob Open 2016;4:e1162; doi: 10.1097/GOX.0000000000001162; Published online 22 December 2016.)*

The reversed flow posterior interosseous artery (PIA) is a regional flap for coverage of hand defects. It has many advantages as skin grafts take well. The dorsal forearm skin is less bulky,[1,2] preserves the lymphatics on the volar forearm,[3] is raised as an osteocutaneous flap,[4] and is able to reconstruct multiple subunits as a bipaddle flap.[5] Despite these advantages, this flap is not popular because of its tedious dissection, so it should be done frequently to lessen the operative time and make surgical dissection easier.[6]

Venous congestion is the main cause of the PIA flap failure. The incidence of venous congestion of the PIA flap with partial or total flap loss in the literature ranges from 3% to 37%.[1,2,7–9] The venous congestion may be caused by the narrow width of the pedicle, inadequate venae comitantes, or because of the tight subcutaneous tunnel subjecting the thin venae comitantes in the pedicle to inadvertent injury and external pressure.[10] The size of flap and number of relevant perforators are also contributing factors.[8,11,12]

The senior author proposed that inclusion of only 1 perforator in the base of the flap may decrease the incidence of venous congestion through decreasing the blood inflow through the flap and thus decrease the venous blood flow subsequently and decrease venous congestion. This applies for flaps with large or small surface area. This is a novel technique. The authors also used the previously described racquet-shaped design to avoid tunnelling of the flap and add more superficial veins.[13]

MATERIALS AND METHODS

This study was conducted on 43 patients in 2 institutions. Approval by the institutional review board and patient consent were obtained. These patients had hand defects because of different etiological factors. Three patients were excluded at the very beginning; the first was because of the absence of PIA, as detected by the preoperative color Duplex, and in the other 2 patients, the PIA suffered intraoperative inadvertent injury. Hand defects of the remaining 40 patients were reconstructed by the reversed flow PIA flap in the period between June 2010 and June 2014 and were divided equally according to the number of perforators and the size of flaps into the following groups:

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Group I flaps (20 patients) including only 1 perforator.

Group II flaps (20 patients) including more than 1 perforator.

The choice of the number of perforators included was judged intraoperatively according to the available perforators entering the base of the flap, so in case of finding more than 1 perforator in the flap, the choice of a sizable perforator that enters the base of the flap and sacrifice of other perforators were done in group I, whereas in group II, there was no sacrifice of the other perforators raising the flap on the available perforators.

Each group was further subdivided into 2 subgroups according to the size of the flap. Subgroup a included flaps with surface area less than 40 cm^2. Subgroup b included flaps with a surface area more than 40 cm^2.

Preoperative Evaluation

All patients were examined thoroughly. Preoperative Color Duplex (Logic 9 pro series scanner GER, Milwaukee, Wis.; with multifrequency probe up to 10 mHz) was used routinely to detect the patency, diameter, peak systolic velocity, and resistance index of the PIA and to detect any abnormalities in the artery.

Surgical Steps

Debridement, creation, and measurement of the defect size were done in each case (Fig. 1). PIA flap was designed as mentioned by original authors.[1] Another additional modification is the inclusion of the skin bridge of the flap (racquet shaped), about 1.5 cm centered over the PIA marking from the ulnar styloid process to the base of the flap[13] (Fig. 2).

After tourniquet elevation, harvesting of the flap begins by exploration of the PIA and the anastomosis between the anterior interosseous and posterior interosseous arteries at the level of the wrist joint. Once adequacy confirmed, proximal dissection was performed (Fig. 3).

The flap was dissected preserving the septum containing the PIA (Fig. 4). Detection of the perforators was done, and skin paddle design may be changed to allow the capture of sizable perforator (Fig. 5). Care was taken to avoid injury of the vessel itself and the posterior interosseous nerve.

Ligation of the PIA was done. To check the flap vascularity, the proximal end may be clamped.[10] The number of perforators to include in the flap was an intraoperative decision. In case of more than 1 perforator in the flap, the choice of a sizable perforator entering the base of the flap and sacrifice of other perforators were done in group I, whereas in group II, there was no sacrifice of the other perforators.

The flap was then transposed to the defect after incising the skin bridge (Fig. 6). The racquet-shaped paddle of the flap was sutured to the edges of the lay open tunnel. The donor sites were either skin grafted or closed primarily.

Analysis of data was done using SPSS (IBM SPSS statistics, version 12) as follows:

Description of quantitative variables as mean, SD, and range.

Description of qualitative variables as number and percentage.

Chi-square test was used to compare qualitative variables between groups.

Unpaired *t* test was used to compare 2 groups as regard the quantitative variables.

One-way analysis of variance test was used to compare more than 2 groups as regard the quantitative variables.

Spearman correlation coefficient test was used to rank different variables positively or inversely versus each other.

The *P* value was calculated and correlated to the variants and considered insignificant if more than 0.05, significant if less than 0.05, and highly significant if less than 0.01.

Postoperative Evaluation

The postoperative follow-up of the flap was done as follows: clinical evaluation of the flap. Color Duplex and laser Doppler devices (O2 CLEA Medizintechnik GmbH,

Fig. 1. Palmar and first web skin defect.

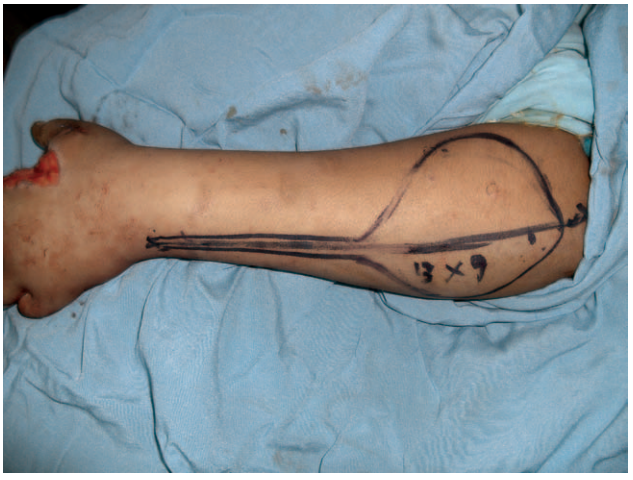

Fig. 2. The racquet-shaped flap design.

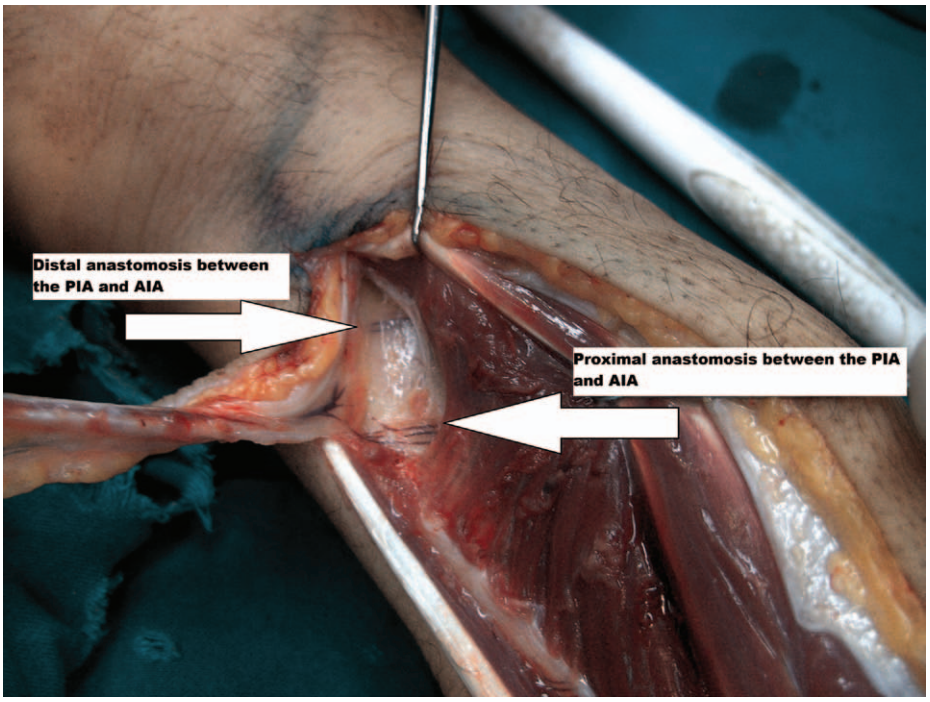

Fig. 3. Distal and proximal anastomosis between the anterior and posterior interosseous arteries at the level of the wrist joint.

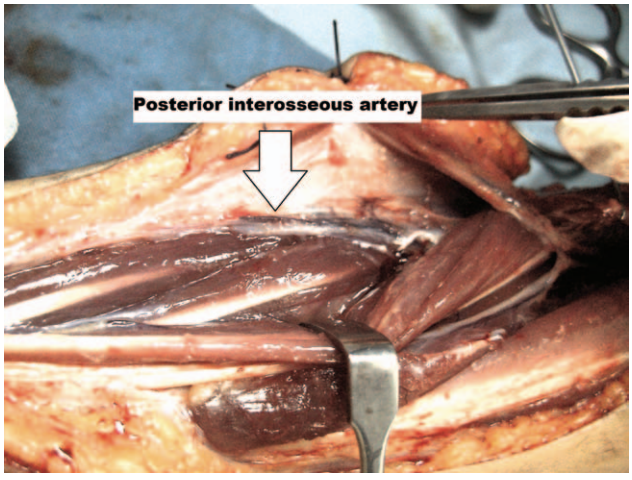

Fig. 4. Dissection of the PIA with the flap attached to the septum.

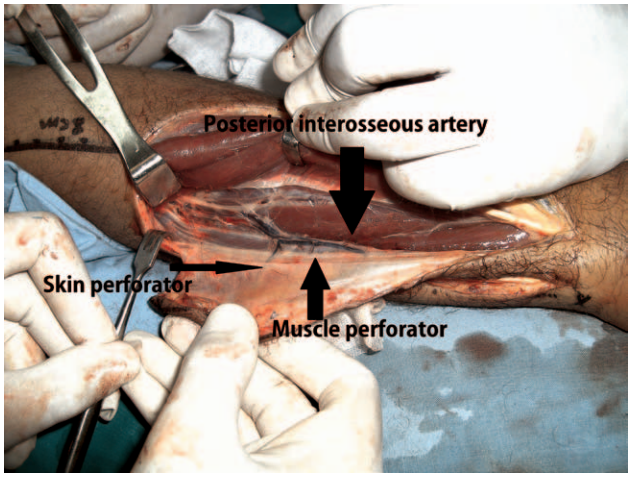

Fig. 5. The posterior interosseous artery passing through the septum with a skin perforator passing through the septum to the skin paddle and another muscle perforator passing to the ulnar side of the septum.

Winchesterstr, using multifunctional probe) were used on day 2 postoperatively.

RESULTS

Forty three patients were included with average age 28.8±13.17 years. PIA was constantly found in all cases except in 1 case in which it was interrupted, and this was a preoperative finding. In 2 other cases, the PIA was inadvertently injured, and these 3 patients were excluded from the study. The study was conducted on the remaining 40 patients. In 1 case, double PIA was found, one larger artery running as usual anastomosing with the anterior interosseus artery and another smaller artery lateral to it, so the flap was raised on the larger artery.

The anastomosis between the AIA and the PIA was found consistent within 1cm from the wrist joint. The proximal perforator in the upper one third of the forearm (as described by Zancolli and Angrigiani[1]) was found consistently at a distance of 6.1 to 11.9cm from the lateral epicondyle. This perforator in the proximal one-third of the forearm is commonly included for coverage of hand defects to increase the arc of rotation. The chart in Figure 7 shows the total flaps' outcome in the whole study. The chart in Figure 8 shows the results of each subgroup. The chart in Figure 9 shows the outcome of flaps in relation to the subgroups. The clinical outcome of flaps is shown in Figures 10 to 12.

Fig. 6. Flap inset with simple sutures to the left and on the right side; eventual flap loss was because of ischemia.

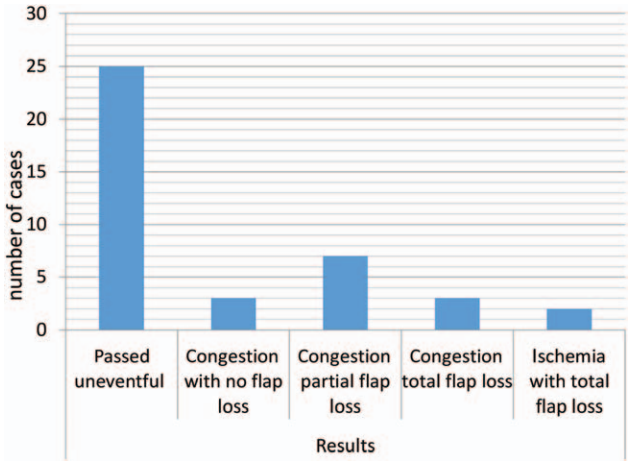

Fig. 7. The chart showing the results of 40 reversed flow PIA flaps.

Congestion with partial and complete loss of the PIA flap occurred more in group IIa than in any other subgroups (3 and 2 cases, respectively; 30% and 20% of the cases). Inclusion of 1 perforator really had its influence on the venous congestion in the small sized flap as its incidence decreased in subgroup Ia (small flaps with 1 perforator) dramatically when compared with subgroup IIa. The results were statistically significant when comparing the incidence of venous congestion followed by partial and complete loss between subgroups Ia and IIa (Table 1). The result of the groups I and II is as follows: when compared with each other, no statistical significance was found as regard the incidence of venous congestion followed by partial or complete loss of the flap, as shown in Table 2. The surface area, the length, and the width of the flaps showed no statistical significance in relation to the incidence of venous congestion (Tables 3 and 4).

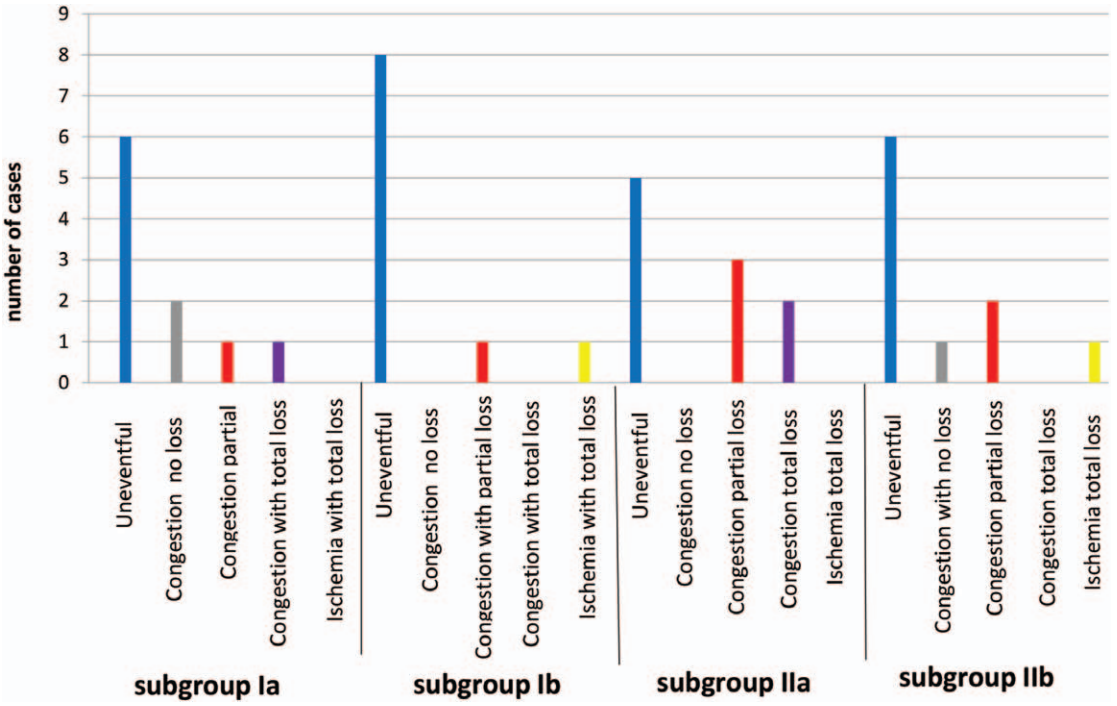

Fig. 8. The results of each subgroup.

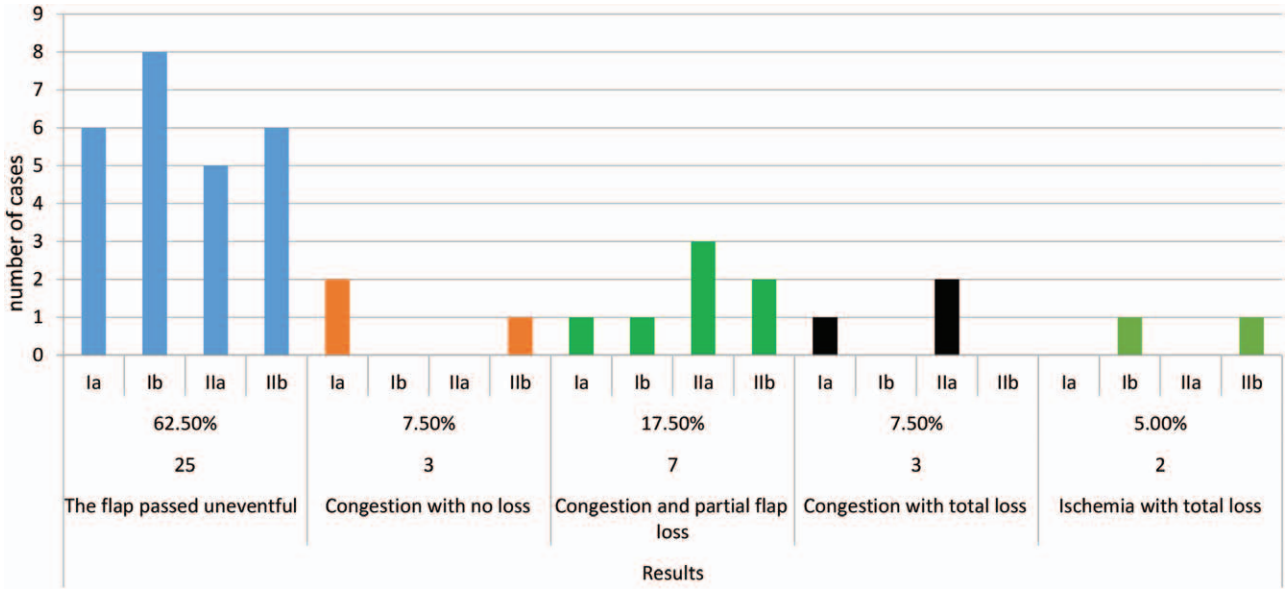

Fig. 9. The outcome of flaps in relation to each subgroup.

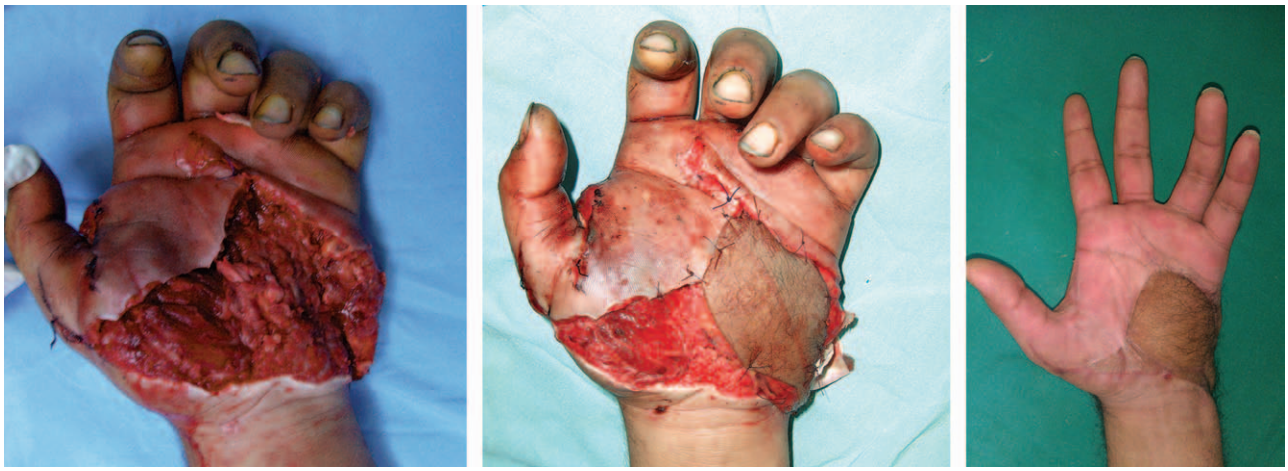

Fig. 10. An example of reversed flow posterior interosseous artery flap on the hand that passed uneventfully. A, Skin defect, (B) flap, (C) late postoperative period showing complete healing of the flap with applied skin graft beside the flap on the remaining defect.

Color Duplex and laser Doppler studies were done on the second day. The average preoperative diameter for all cases was 1.45±0.4, and the average postoperative diameter for all cases was 1.03±0.4.

DISCUSSION

Venous congestion in reversed flow flaps is a well-known complication. The incidence of venous congestion in the reversed flow PIA flap followed by partial or total flap loss in the literature ranged from 3% to 37%.[1,2,7–9] Lin et al[14] suggested that the venous return "skips" between the venae comitantes to bypass the valves. They range from 1 up to 3 mm in diameter. Timmons and Harvey[15,16] suggested that valve incompetence occurs to allow regurgitated flow. Pinal and Taylor[17] then proved the existence of macro- and microvenous connections.

Because the PIA flap was described, many modifications were done to decrease the incidence of venous congestion. These modifications include hyperextension of the wrist,[4] harvesting a wide fascial strip with the septum,[18] inclusion of a cuff of subcutaneous tissue with the distal segment of the pedicle to add some of the superficial veins,[8] performing an additional venous anastomosis,[19] exteriorizing the pedicle,[20] inclusion of the least number of perforators, and the racquet-shaped design to avoid tunnelling of the flap and to add more superficial veins.[13] All the previous studies tried to solve the problem of venous congestion by modifications aiming to increase the venous drainage of the flap. In this study, another concept was studied, which is to decrease the congestion by decreasing the inflow in the flap by decreasing the number of the included perforators. This concept was tried before.[8] The study compared the results of using flaps based on 1 perforator (group I)

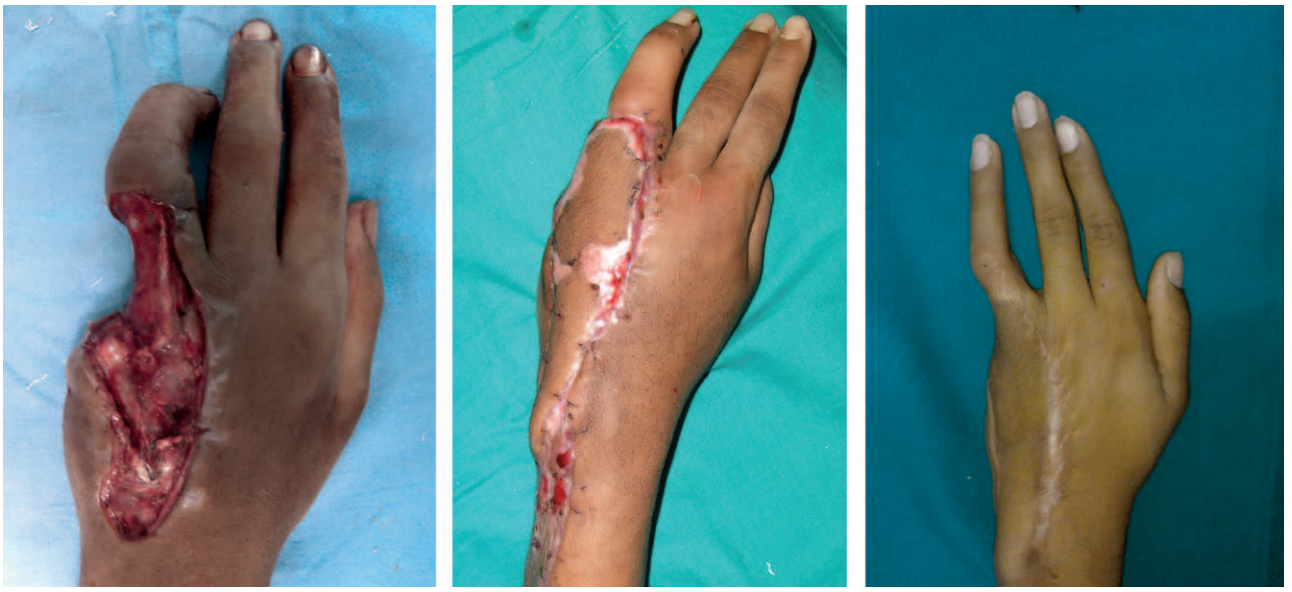

Fig. 11. Flap suffered from moderate congestion (A) and then partial loss (B), followed by complete healing after a month and a half (C).

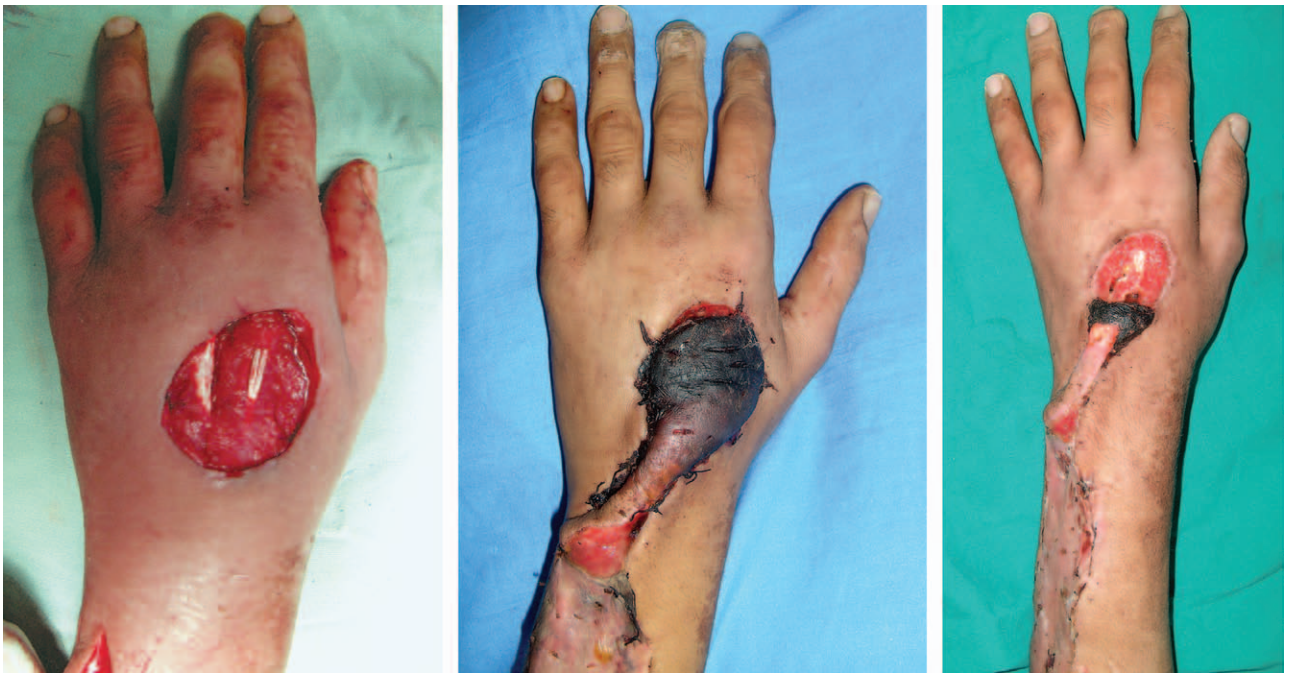

Fig. 12. Flap suffering severe venous congestion (A) with complete flap loss (B).

and flaps based on more than 1 perforator (group II). In each group, this concept was tried in a small sized flap less than 40 cm^2 (subgroup a) and large sized flaps more than 40 cm^2 (subgroup b) to study also the effect of flap size on the incidence of congestion. On doing statistical analysis, we compared the incidence of venous congestion with partial loss and complete loss between all subgroups. We found that venous congestion with partial and complete loss was the highest in subgroup IIa and correlated it with the incidence of venous congestion with complete loss in subgroup Ia as both have the same surface area less than 40 cm^2. It was found that the incidence of venous congestion with complete flap loss was higher in flaps in group IIa than in group Ia with statistical significance ($P < 0.05$), indicating that inclusion of only 1 perforator in small sized flaps yielded better results (Table 1). The incidence of venous congestion followed by partial and complete loss in large groups I and II were compared with each other and were found statistically insignificant ($P > 0.05$ by using chi-square test; Table 2).

Regarding the size of the flap and its effect on the incidence of venous congestion, it was proved statistically that the congestion was not affected by the surface area, the length, or the width of the flap (Tables 3 and 4), and so the

Table 1. Comparison between the Studied Subgroups in Regards to the Outcome of Flaps

Results	Group Ia (n = 10), n (%)	Group Ib (n = 10), n (%)	Group IIa (n = 10), n (%)	Group IIb (n = 10), n (%)	X^2	*P* Value
Uneventful	6 (60)	8 (80)	5 (50)	6(60)	12.6	>0.05
Congestion without skin loss	2 (20)	0	0	1 (10)		(NS)
Congestion with partial loss	1 (10)	1 (10)	3 (30)	2 (20)		
Congestion with complete loss	1 (10)	0	2 (20)	0		
Complete because of ischemia	0	1 (10)	0	1 (10)		
Conclusion	Ia vs IIa, $X^2 = 3.4$ and $P < 0.05$ (S) Other subgroup relations to each other are > 0.005 (NS)					

Flap congestion with partial and total loss were more frequent among subgroup IIa with significant difference in comparison to subgroup Ia, and also, no statistically significant difference between the other studied subgroups and the outcome of flaps was found by using chi-square test. n is the number of patients in every group. X^2 is Pearson x-square test.
NS, statistically insignificant; S, statistically significant.

Table 2. Comparison between the Studied Major Groups (I and II) in Regards to the Results

Variables	Group I (n = 20), n (%)	Group II (n = 20), n (%)	X^2	*P* Value
Uneventful	14 (70)	11 (55)	3	>0.05 (NS)
Congestion without skin loss	2 (10)	1 (5)		
Congestion with partial loss	2 (10)	5 (25)		
Congestion with complete loss	1 (5)	2 (10)		
Complete loss because of ischemia	1 (5)	1 (5)		

No statistically significant difference between the studied groups was found by using chi-square test. n is the number of patients in every group. X^2 is Pearson x-square test.
NS, statistically insignificant.

Table 3. Relation between Results Versus Dimensions Among Group I (1 Perforator Only Including All Sizes)

Variables	Congestion	No Congestion	*T*	*P* Value
Length of flap	8.5±3	8±1.7	1.3	>0.05 (NS)
Width of flap	5.3±1.6	5.8±1.9	0.4	>0.05 (NS)
Area of flap	37±15	38.2±17	0.7	>0.05 (NS)

No statistically significant relation between results and dimensions was found in group I by using unpaired *t* test. Results are shown in mean ± SD.
NS, statistically insignificant.

Table 4. Relation between Results versus Dimensions among Group II (More Than 1 Perforator Only Including All Sizes)

Variables	Congestion	No Congestion	*T*	*P* Value
Length of flap	10±2	8±3	1.6	>0.05 (NS)
Width of flap	5.6±1.8	5.4±1.3	0.9	>0.05 (NS)
Area of flap	44.7±19	36±15	1.2	>0.05 (NS)

No statistically significant relation between results and dimensions was found in group II by using unpaired *t* test. Results are shown in mean ± SD.
NS, statistically insignificant.

number of the perforators is the only variant that is related to the incidence of venous congestion of the PIA flaps. The addition of Duplex and laser Doppler study to flaps was intended to estimate the effect of inclusion of 1 or more perforator on the flap outcome quantitatively. Laser Doppler was very useful as it detected any circulatory compromise in the flap postoperatively early.[21]

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