Free Posterior Interosseous Artery Flap for Treatment of First Web Space Contracture: Methods of Venous Anastomosis

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INTRODUCTION

The skin on the dorsal side of the forearm can provide a thin and pliable skin suitable for first web space reconstruction. Although previous reports have described the use of the posterior interosseous artery (PIA) flap as a reverse-flow flap for treatment of first web space contracture, only a few have addressed its use as a free flap for this purpose. The caliber of the concomitant veins accompanying the PIA is usually small, which may give rise to a problem in the treatment.

The caliber of the concomitant veins accompanying the PIA is usually small, which may give rise to a problem in the treatment. There have been reported five articles regarding the first web reconstruction using free PIA flaps. Only three of them mentioned the venous anastomosis method. In this article, we report the first web reconstruction using free PIA flaps, focusing on selection of the type of venous anastomosis.
MATERIALS AND METHODS

1. Patients

Seven patients with first web space contracture were treated with a free PIA flap. All patients were male. The average age of the patients was 48.9 years (range, 35-60 years). In all patients, one hand was damaged. The causes were crush in 2 cases, press injury in 2 cases, degloving injury in a case, incomplete hand amputation in a case, and burn in a case. An average preoperative angle of thumb radial abduction was 31.7° (range, 26°-40°) and that of the palmar abduction was 42.3° (range, 35°-60°) (Table 1).

2. Preoperative evaluation

As an assessment of the recipient site, blood flow of artery and vein in the snuffbox was confirmed with a color Doppler examination.

The patient was in a supine position and the elbow was flexed at a right angle with the forearm pronated. Surface markings were made over the lateral humeral epicondyle and the distal radioulnar joint. The line that joins these two points was the axis of the flap. The flap was designed to include the medial cutaneous perforator, which is the septocutaneous perforator 1 cm distal to the midpoint of the line between the lateral humeral epicondyle and the distal radio ulnar joint, determined preoperatively by a color Doppler examination. The width of the flap was 1.0 to 1.5 cm wider than the defect. The design of the skin paddle was in the shape of a spindle.

3. Surgical procedure

The contracted first web space was released with linear skin incision, and subsequently, fascial contractures were released. Two Kirschner wires were inserted into the first and second metacarpal to keep the web space, and the Kirschner wires were removed 3 weeks after operation.

The procedure of flap harvest was performed using a pneumatic tourniquet without exsanguination for better identification of the posterior interosseous vessels, as they were relatively thin and difficult to identify if the limb was exanguinated.

The dorsal forearm has a large fascial component located anterior (radial side) and posterior (ulnar side) to the intermuscular septum, which itself is within this two-leaved fascial envelope (the posterior leaf is the extensor carpi ulnaris fascia and anterior leaf is the extensor digiti minimi, extensor digitorum communis, extensor carpi radialis brevis fascia) in which the PIA lies. Therefore, the anterior fascia overlies the extensor digiti minimi and extensor digitorum communis muscles.

At first, the skin incision was made from the ulnar side and the flap was initially dissected out under the deep fascia of the extensor carpi ulnaris, and to avoid shearing forces between the skin and fascia, temporary fine stitches were used to fix the fascia and skin while the skin flap was elevated. At this time, an extra 1 cm of fascia was included circumferentially beyond the skin paddle. Next, the skin flap was then elevated from the radial side under the deep fascia of the extensor digiti minimi.

From both ulnar and radial side, the posterior interosseous vessels and septocutaneous perforators in the intermuscular septum were identified. The pedicle was dissected from distal to proximal, ligating the multitude of branches up to the emergence of the vessels under the supinator muscle. The posterior interosseous vessels were dissected proximally while splitting the supinator muscle. Then, the PIA and its concomitant veins were tracked under the supinator muscle until the diameter of the veins increased.

Preserving the motor branch to the extensor carpi ulnaris, located proximal to the medial cutaneous perforator, dissection of the artery should proceed proximally until 1-2 cm distal to the bifurcation from the common interosseous artery. The length of vascular bundle protruding from the intermuscular septum between the extensor carpi ulnaris and the extensor digiti minimi was approximately 3 cm. The vascular pedicle was divided and the flap was transferred to the first web space. With an operating microscope, the PIA was anastomosed to the radial artery in the anatomical snuffbox and the concomitant
| Case No. | Age (yr) | Sex | Lesion site | Cause | Flap size width×length (mm) | Number of anastomoses between pCV and rCV | Number of anastomoses between pCV and subV | Classification of venous anastomosis | Result | Follow-up period (mo) | Preoperative thumb abduction | Postoperative thumb abduction |
|----------|---------|-----|-------------|-------|-----------------------------|------------------------------------------|------------------------------------------|---------------------------------|--------|---------------------|---------------------------|--------------------------|
| 1        | 47      | M   | R           | Incomplete hand amputation | 35×150 | 2                          | 0                                       | Type 1 CS                        | 7      | 34                  | 60                        | 75                       | 80                       |
| 2        | 56      | M   | L           | Degloving injury | 35×150 | 1 (junction)               | 0                                       | Type 3 CS                        | 17     | 32                  | 46                        | 90                       | 88                       |
| 3        | 40      | M   | L           | Press injury, open fracture | 35×155 | 1                          | 1                                       | Type 2 CS                        | 4      | 40                  | 39                        | 70                       | 82                       |
| 4        | 59      | M   | L           | Burn | 40×150 | 0                          | 1 (junction)               | Type 4 CF                       | -      | -                  | -                         | -                        | -                        |
| 5        | 35      | M   | R           | Crush | 40×160 | 2                          | 0                                       | Type 1 CS                        | 10     | 28                  | 39                        | 55                       | 76                       |
| 6        | 45      | M   | R           | Crush | 35×160 | 2                          | 0                                       | Type 1 CS                        | 9      | 30                  | 35                        | 56                       | 70                       |
| 7        | 60      | M   | R           | Press injury | 30×155 | 1                          | 1                                       | Type 2 CS                        | 6      | 26                  | 35                        | 62                       | 68                       |

Type 1: two concomitant veins of PIA were anastomosed to two concomitant veins of radial artery. Type 2: one concomitant vein of PIA was anastomosed to one concomitant vein of radial artery and the other concomitant vein of PIA was done to a tributary of the cephalic vein. Type 3: junction of concomitant veins accompanying PIA was anastomosed to one concomitant vein of radial artery. Type 4: junction of concomitant veins accompanying PIA was anastomosed to a tributary of the cephalic vein. PIA: posterior interosseous artery, pCV: concomitant vein of posterior interosseous artery, rCV: concomitant vein of radial artery, subV: subcutaneous vein, M: male, R: right, L: left, CS: complete survival, CF: complete flap failure, -: not available.
veins of the PIA to that of the radial artery or a tributary of the cephalic vein (Fig. 1). The donor area was closed directly. All patients undergoing surgery have written consent for the use of photographs. As a precaution, the consent forms of these two patients were attached to the email.

RESULTS

1. Representative cases

1) Case 1
A 47-year-old male pinched his right hand in a threshing machine and amputated his right hand incompletely. Ten months after the injury, surgery for the contracted first web space was performed. Following release of contracture, a free PIA flap from the right forearm was created. The PIA was anastomosed to the radial artery in the anatomical snuffbox and two concomitant veins accompanying PIA was anastomosed to two concomitant veins of radial artery. The donor area was closed directly. The flap survived completely, and the patient was capable of returning to his original, farming work (Fig. 1).

2) Case 2
A 56-year-old male sustained a degloving injury to his left palm with a slicer during meat work. Four months after the injury, surgery for the contracted first web space was performed. Following release of contracture, a free PIA flap from the left forearm was created. The PIA was anastomosed to the radial artery in the anatomical snuffbox and junction of concomitant veins accompanying PIA was anastomosed to one concomitant vein of radial artery. The donor area was closed directly. The flap survived completely, and the patient returned to his original, butcher work (Fig. 2).

Six of seven flaps survived completely in our patients. In a post-burn contracture case, venous congestion was noted on the 4th postoperative day, and the flap was lost. Then, skin grafting was performed on the defect site.

The PIA is anastomosed end-to-end to the dorsal branch of the radial artery. There are two choices for the recipient venous pedicle: concomitant veins of radial artery and a tributary of the cephalic vein. In our cases,
there were four types of venous anastomosis as follows (Fig. 3).

Type 1: two concomitant veins of PIA were anastomosed to two concomitant veins of radial artery (Fig. 3A).

Type 2: one concomitant vein of PIA was anastomosed to one concomitant vein of radial artery and the other concomitant vein of PIA was done to a tributary of the cephalic vein (Fig. 3B).

Type 3: junction of concomitant veins accompanying PIA was anastomosed to one concomitant vein of radial artery (Fig. 3C).

Type 4: junction of concomitant veins accompanying PIA was anastomosed to a tributary of the cephalic vein (Fig. 3D).

The venous anastomosis by type 1 was performed in 3 cases, type 2 in 2 cases, type 3 in 1 case, and type 4 in 1 case. In the case of type 4, the flap was lost.

An average postoperative angle of thumb radial abduction was 68.0° (range, 55°-90°) and that of the palmar abduction was 77.3° (range, 68°-88°). An average postoperative increase of the thumb radial abduction was 36° (range, 26°-58°) and that of the palmar abduction was 35° (range, 20°-43°). After surgery, patients were followed 4-17 months, with an average 8.8 months (Table 1).

**DISCUSSION**

Except for one failure case, exhibiting flap failure with late thrombus, six flap survival cases acquired first web space widening. Regarding the cause of the free PIA flap failure, there were reported complete flap failure because of tightness in the donor site closure and 30% flap necrosis caused by late thrombosis. In a free PIA flap, therefore, venous return disturbance seemed to be the cause of flap necrosis.

Anatomically, there were always one PIA and two concomitant veins accompanying the PIA. The caliber of the PIAs ranged from 1.2 to 2.6 mm (mean, 1.7 mm). When the free PIA flap was used for coverage of the first web space, a branch of the radial artery at the snuffbox served as a good recipient artery. The size of the artery matched well with that of the PIA. On the other hand, the caliber of the concomitant veins accompanying the PIA was usually small. The caliber of the large concomitant vein ranged 1.0 to 1.5 mm (mean, 1.1 mm), and that of the small one ranged from 0.8 to 1.2 mm (mean, 1.0 mm). Therefore, venous return disturbance due to the small caliber of concomitant veins should be noted.

Regarding the first web reconstruction using free PIA flaps, the venous anastomosis method was mentioned in three articles. Tonkin and Stern presented a case of first web space contracture treated with a free posterior interosseous flap for the first time. They described one concomitant vein of the PIA was anastomosed to that of the radial artery. To choose the vein for anastomosis in a free PIA flap, Chen et al. selected a large superficial vein in the flap, which is a tributary of the cephalic vein, because the caliber of the concomitant vein of the PIA was small. Cavadas anastomosed the two concomitant veins of PIA end-to-end to two concomitant veins of the radial artery.

In the forearm, there are two systems of venous drainage, i.e., the deep venous system and the superficial/
cutaneous venous system. In a radial forearm flap, the deep venous system consists of the radial concomitant veins, while the superficial venous system was composed of the cephalic, median, and basilic veins. Similarly, in a free PIA flap, the deep venous system consists of the concomitant veins of PIA, and the superficial venous system was composed of subcutaneous veins. In addition, attention was paid to the course of the perforating branches of the intermuscular septum, comprising of ramus communicants of deep and superficial venous system in the forearm. These perforating branches were kept to ensure venous drainage of the flap. Thus, the inclusion of the intermuscular septum is important to secure venous return of the flap.

In our cases, there were four types of venous anastomosis methods. Anastomosis of two veins (type 1, 2) may provide a fail-safe compared to only one venous anastomosis (type 3, 4). Comparing our venous anastomosis method with those of previous reports, we found several key notes as follows. The venous anastomosis method by Tonkin and Stern is similar to type 3. The method by Chen et al., which used only the cutaneous vein without the use of concomitant veins of PIA, does not belong to our classification. Chen et al. emphasized that a large cutaneous vein in the flap should be prepared for venous anastomosis and this cutaneous vein may be much easier for anastomosis than the small concomitant vein accompanying the PIA. Then, the small concomitant veins are not anastomosed. Finally, the method by Cavadas corresponds to type 1.

In case 4 of flap failure, it is possible that venous return in the vicinity of the snuffbox possibly have been already impaired due to burn, although apparent flow disturbance was not detected with a preoperative color Doppler examination. In case 4 and similar cases, the following measures could be taken. Venous anastomosis should be performed using a vein graft to a healthy subcutaneous vein proximal to snuffbox. Alternatively, according to the report by Chen et al., a large superficial vein in the flap should be prepared during flap dissection. When the caliber of concomitant vein of PIA is very small (<1.0 mm), only one vein could be anastomosed using junction like types 3 and 4. This junction was always present in our cases, and its caliber ranged from 1.0 to 1.2 mm. Tonkin and Stern and Cavadas used the concomitant vein accompanying PIA for venous drainage, although the superficial veins in the flap could also be used theo-

![Fig. 3. Types of venous anastomoses. Left panels: before vascular anastomosis, right panels: after vascular anastomosis. (A) Type 1: two concomitant veins of PIA were anastomosed to two concomitant veins of radial artery. (B) Type 2: one concomitant vein of PIA was anastomosed to one concomitant vein of radial artery and the other concomitant vein of PIA was done to a tributary of the cephalic vein. (C) Type 3: junction of concomitant veins accompanying PIA was anastomosed to one concomitant vein of radial artery. (D) Type 4: junction of concomitant veins accompanying PIA was anastomosed to a tributary of the cephalic vein. PIA: posterior interosseous artery, RA: radial artery, SubcV: subcutaneous vein. *Flap.](image-url)
retically. Similarly to the methods by Tonkin and Stern or Cavadas, we did not harvest the superficial vein in the flap, because venous return would be obtained with the concomitant veins accompanying PIA. However we experienced a case of flap failure with late thrombus. As seen in the measures against venous congestion, more venous anastomosis is preferable. Harvesting the superficial vein in the flap as a potential use is desirable.

The following matters can be mentioned as a careful scheme for reliable venous return. (1) The concomitant veins should be tracked and dissected under the supinator muscle until the diameter of the veins increased. When the caliber of concomitant vein of PIA is very small (<1.0 mm), the concomitant veins should be tracked to junction to use it. (2) Two veins should be anastomosed as much as possible. (3) A superficial vein in the flap should be prepared as a lifeboat.

According to the results of our cases and in light of the previous literature, an algorithm on the choice of venous anastomosis was proposed (Fig. 4). As for the choice of venous anastomosis on the flap side, however, we are unable to explain the superiority between two concomitant veins of PIA and one large superficial vein because of lack of experience of the latter.

**CONCLUSION**

Since the caliber of the concomitant veins accompanying the PIA is small, a careful scheme for venous anastomosis is essential in the treatment of first web space contracture using the free PIA flap.

**CONFLICTS OF INTEREST**

The authors have nothing to disclose.

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