Role of Interosseous Recurrent Artery Perforators in the Posterior Interosseous Artery Flap

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Abstract The Posterior Interosseous Artery flap is a fasciocutaneous flap based on the Posterior Interosseous artery which lies invested by the fascial septum between the Extensor carpi ulnaris and Extensor Digiti Minimi where it gives off septocutaneous branches that spread out on the deep fascia to form longitudinal fascial arcades as well as supply the deep extensors. The conventional flap based on these perforators is restricted to the middle-thirds of the dorsum of forearm. Preservation of the perforators from the Interosseous Recurrent Artery by proximal ligation of the Interosseous Recurrent Artery and by protecting the index septum prolongation carrying the perforators of IRA can help us to recruit larger tissue in the flap. A total of 20 clinical cases and 10 cadaveric dissections were done to objectively define this technique.

Keywords Posterior Interosseous Artery · Interosseous Recurrent Artery · Perforators

Introduction

The PIA flap first described in 1985 by Zancolli and Angrigiani is a reliable flap for coverage of soft tissue defects of hand [6]. Large fasciocutaneous island flaps can be harvested, even when the radial or ulnar pedicles are damaged, sacrificing only vessels of secondary importance to the perfusion of the hand, sparing the axial vessels of the hand [1]. Compound flaps can be dissected based on muscular, musculo-periosteal and fascio-

periosteal branches. Distally pedicled flaps will reach the dorsum of metacarpo-phalangeal joints, the first web space, and proximal and ulnar part of the palm [2]. The posterior interosseous vessels give a significant contribution to the fascial plexus which supplies the skin of dorsum of the forearm [3].

Retrograde perfusion is dependent on an intact distal communicating artery between the anterior interosseous and posterior interosseous artery just proximal to the radio-ulnar joint [4] (Fig. 1). In the conventional technique described by Zancolli, the dissection begins by making an incision along the line proximal to the pivot point to ascertain the distal PIA communication with the AIA and if the vessel was not found satisfactory the surgery was abandoned. The axis of the flap was planned along the line joining the lateral epicondyle and distal radio-ulnar joint. At the mid-point of this axis is the surface marking of the middle perforator of the PIA which was included in the flap. The reliable proximal limit of the flap is 7–8 cm distal to the lateral epicondyle based on this vessel [5].

According to the experience of Zancolli and Angrigiani a more proximal perforator is present arising from the Interosseous recurrent artery but it seems to add little to the viable length of the flap that can be raised. In a large series [6] the authors recommend keeping the flap design distal to the proximal quarter of the epicondylar-ulnar line in order to avoid proximal necrosis, and any further extension proximally is based on a random distribution pattern. The Interosseous Recurrent Artery which arises from the Posterior Interosseous artery gives variable number of perforators to the proximal quarter of dorsal forearm. In our dissections we have observed that the reverse flow in the PIA extends to the Interosseous Recurrent Artery and its perforators and can possibly contribute to a more proximal extent of the conventional

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Fig. 1 Surgical anatomy showing PIA, IRA and their relations

flap (Fig. 2). This study is aimed at objectively defining a technique for safe harvest of a larger flap including the skin over proximal third of the forearm by including the perforators from the Interosseous Recurrent artery. This is done by using the Y configuration of the pedicle as an advantage in improving the transfer of the flap as well as recruiting perforators from the proximal arm of the 'Y'.

Fig. 2 Distal extent of defect covered by flap, proximal extent of flap raised

Surgical Anatomy (Course and Relations of the PIA) (Fig. 1)

The PIA originates from the Common Interosseous Artery or the Ulnar Artery and passes between the oblique cord and interosseous membrane and emerges in the deep extensor compartment of the forearm underneath the supinator at a distance of around 15 to 18 cm from the ulnar styloid. At this point the interosseous recurrent artery emerges and runs proximally deep to the Anconeus giving off fasciocutaneous and musculocutaneous perforators. At its emergence in the deep posterior forearm, the external diameter of PIA ranges from 1.5 to 2.0 mm and it is accompanied by at least two venae comitans running in the septum between ECU and EDM giving off fasciocutaneous perforators throughout its length. Here it gives muscular branches to APL, EPL, Extensor Indices and periosteal branches to the ulna.

The Posterior Interosseous nerve arises from the radial nerve in front of the lateral epicondyle of the humerus in the cubital fossa. It pierces the supinator, winds around the lateral aspect of the neck of radius in the substance of the muscle, to reach the posterior compartment of the forearm. At or after emerging from the Supinator the PIN gives branches to the long extensors.

The nerve lies between the superficial and deep extensors over the posterior aspect of forearm along with the PIA. The branch to ECU passes through the index septum proximal or distal to the most proximal perforator of the PIA.

This is an important surgical relation during flap dissection. The PIA continues in the septum till around 4–5 cm from the ulnar styloid where it divides into two terminal branches: one for the anastomosis to AIA and second for the dorsal carpal arch.

Materials and Methods

Twenty patients (13 male and 7 female) who had defects of dorsum of hand, volar aspect of distal forearm, web spaces and dorsum of proximal phalanges were treated with a Posterior interosseous flap cover from September 2005 to February 2008. Pre-operative Doppler examination was done with a 8 MHz hand held Doppler which confirmed the presence of communication between the Anterior Interosseous Artery and Posterior Interosseous artery [7]. Ten cadaveric dissections (out of which two done in freshly amputated limbs) were performed prior to the commencement of the clinical study.

In all the dissections the flap was raised proximo-distally, based on the distal communication between posterior and anterior interosseous artery. Clinical observations such as location of the artery, Posterior interosseous nerve, site of perforators were measured on a linear scale from a fixed bony landmark (ulnar styloid). Digital photographs were recorded.

Method of Dissection

After outlining the flap dimensions the flap is raised with dissection starting from the ulnar side raising a fasciocutaneous unit. The dissection is continued till the septum between the Extensor Digiti Minimi and Extensor Carpi Ulnaris is reached. From now the flap is dissected from its radial aspect until the septum is reached. During the dissection from the radial side, in all our dissections upon retracting the extensor digitorum communis the extensor digiti minimi is found to be a thin muscle enclosed in a separate fascial compartment (Fig. 3). After making an incision longitudinally over the muscle, disto-proximally the myofibres of the EDM which are attached to the index septum is carefully dissected away ligating one or two muscle perforators from the PIA. Throughout the dissection the attachment of the fascia over Abductor Pollicis Longus and Supinator is maintained. Proximally the dissection is carried

Fig. 3 Clinical case dissection showing perforators from PIA, IRA and relation to PIN

Fig. 4 Flap for post amputation dorsal and palmar defect (FOLDED FLAP)

out under the Anconeus over the Supinator. The Interosseous Recurrent Artery runs through few distal fibres of the Supinator and in some of the cases it runs through the connective tissue between the Supinator and APL. The Interosseous Recurrent Artery runs at the base of the index septum under the Anconeus over the Supinator giving rise to two or three direct cutaneous perforators to the overlying skin [8]. In raising a larger flap we have done proximal dissection and protected the index septum prolongation which carries the perforators from the IRA. Except for one case where there was 0.5 cm distal necrosis, all flaps survived in the entirety. We have successfully included a flap whose proximal limit was at 2.5 cm from lateral epicondyle (Figs. 2 and 4) with no complications. During raising of flap the dissection is carried out on the surface or between fibres of Supinator after dividing and ligating the IRA proximally. In 15 dissections the superficial fibres of distal supinator are divided carefully to reach the Y-stem of PIA after it has pierced the interosseous membrane.

The PIA, the IRA and the PIA proper form a 'Y' or a 'T' where the stem of the 'Y' is the PIA which is perpendicular to the axis of the flap and the two arms – the PIA proper and the IRA are parallel to the axis of the flap which represents the index septum. Hence to harvest the extended flap we need to ligate and divide the pedicle at two places which are in two separate planes and dimensions. This procedure is known as the "reverse-flow YV pedicle extension of a flap" [9]. The idea is to raise a flap distally on a branch of a Y-like vascular bifurcation.

The section of the trunk of the bifurcation turns the Y-into a V-vascular pattern, which allows distal mobilisation of the flap on the remaining branch of the V. The distal range of transposition of the flap can reach twice the length of one bifurcation of the flap. The arterial blood supply is provided by reverse flow through the attached remaining branch of the 'V'. By doing so we also recruit the perforators arising from the IRA making the extended flap robust and reliable. We have ligated the stem of PIA close to the interosseous membrane and the IRA either superficial or in between the fibres of the supinator (Figs. 3 and 5). In our dissections the branch of PIN to ECU passes through the septum proximal or distal to the most important perforator of the PIA (Figs. 1 and 3). This relation of the important cutaneous perforator and the PIN is important in the dissection of the flap to avoid denervation of ECU and preserve flap viability.

Fig. 5 Cadaveric dissection showing Y-V concept

The dissection is continued from both radial and ulnar aspect distally where the antero-posterior dimensions of the septum are reduced and the vessels are superficially running over the Extensor Indices Proprius. We proceed distally by carefully dissecting the sub-epimyseal plane of APL, EPL and EIP.

During the dissection at an average distance of 16 cm from the ulnar styloid process the nutrient artery to the ulna is identified. There were multiple perforators to APL, one to EIP and two to EPL in all our dissections which were ligated during raising of the flap. Distally the PIA runs very close to the periosteum of ulna, radial to the ECU which is situated in the groove on the dorsal surface of ulnar styloid. From there on the ulnar directed smooth arch, the artery runs beneath Extensor Digiti Minimi and Extensor Digiti Communis to make anastomosis with the Anterior Interosseous Artery. In one of our dissections the pulsatile reverse flow was seen upto the proximal end of the flap (in the IRA) after the flap was completely raised from the bed which reinforces the Angiosomal dynamic recruitment.

Observations and Results

1. The axis of the flap was planned on a line joining the lateral epicondyle and Ulnar styloid process.
2. In the clinical study there were 13 male and 7 female patients. The average age of these patients was 32.4 years
3. Cause of defect:

S No	Cause of defect	No of patients
1.	Post chemotherapy infusion necrosis	4
2.	Post traumatic sequelae	10
3.	Post burns sequelae	3
4.	Post Infective sequelae	2
5.	Post- surgical defect	1

4. Site of defect:

S No	Site of defect	No. of patients
1.	Dorsum of hand upto MP joint	6
2.	Proximal phalanx of thumb	3
3.	Dorsum of hand and digits upto PIP joints	3
4.	Volar aspect of forearm	2
5.	first web space adduction contractures	2
6.	post burns defects involving MP joints and Prox phalanx	2

5. Observations during dissection Ref [Appendix](#)

6. Pedicle management in the clinical cases:

Tunneling: 7

Exteriorizing the pedicle and grafting: 8

Skin bridge opened to transfer the flap from pivot point to defect: 5

7. Complications:

Total flap necrosis: NIL

Rim necrosis: ONE (did not need secondary procedure)

Donor site graft loss: ONE

Graft loss over pedicle: ONE

Venous congestion: NIL

Discussion

This study is an attempt to understand the importance of the Interosseous Recurrent Artery, its perforating branches and its relation to the muscles of proximal third of forearm and the PIA proper. These relations may help to evolve a methodology of dissection for safe raising of the Posterior Interosseous Artery flap and recruiting larger tissue from the proximal third of forearm.

The PIA flap has been extensively studied with larger series reporting variations in the anatomy of the PIA such as –failure of the middle third, absence of choke anastomosis, hypoplastic PIA, narrow caliber PIA and termination of PIA in the middle third. None of these variations were found in our dissections and in the clinical cases this was confirmed by use of hand held Doppler. None of our cases were preceded by a test dissection and a patent anastomosis between the Anterior and Posterior Interosseous artery and good reverse flow was found in all our cases.

In all our cadaveric and clinical dissections the vascular axis of the pedicle distally deflected towards the ulnar styloid process [10] as compared to the mid- point of radio- ulnar joint described in the original flap harvest [11].

In all our dissections the origin and course of the PIA has been relatively constant with the PIA originating around 15 cm from the ulnar styloid, giving an average of 3–4 constant septocutaneous perforators, the distal most perforator being given off roughly 6 m proximal to the site of

anastomosis of PIA and AIA. The proximal perforator roughly corresponds to the middle of forearm just distal to its origin. The conventional PIA flap is designed to include this constant perforator. In a large series [6] the authors recommend keeping the flap design distal to the proximal quarter of the epicondylar-ulnar line in order to avoid proximal necrosis, and any further extension proximally is based on a random distribution pattern. But studies by [12] (which includes dye study) are suggestive of the forearm being divided into three angiosomal units or cutaneous vascular territories.

The skin over the middle third of the dorsum of forearm as per the observation made by Zancolli is supplied by 2–3 perforators from the PIA. The skin over proximal third of the forearm overlying the Anconeus also receives 2–3 perforators as per our observation either directly or musculocutaneous through the Anconeus from the IRA [12]. In the distal third of the forearm there are direct cutaneous perforators passing between the Extensor Carpi Ulnaris and Extensor Digiti Minimi [13] which are three in number situated at an average distance of 6, 7 and 9 cm from the ulnar styloid process as per our observations.

Based on the theory that perforators from IRA are relatively constant and could be the source of cutaneous vascularity for the proximal third of forearm and the fact that the anatomic relation of the Posterior Interosseous Artery, the PIA proper and the IRA form a ‘Y’ or ‘T’ – can be utilized in raising a flap that is including the skin over proximal third of forearm. The continuity of the reverse flow into the IRA has been noted in our dissections with even pulsatility seen in one of the dissections.

However, a larger series of clinical cases and dye studies are needed to supplement the observations made in our study. As we had done our cadaveric series prior to the clinical cases, the dissection of the IRA and ligation at the stem of PIA in our case studies were performed with some ease but technically the dissection of IRA within the fibres of supinator may prove difficult for a beginner. The possibility of contribution of the anastomosis around the elbow to the vascularity of the proximal third of the forearm cannot be ruled out but it remains to be seen whether it has any contribution in the reverse flow PIA-IRA flap.

In addition to the direct cutaneous perforators passing between Extensor Digiti Minimi and Extensor Digitorum Communis for the middle third there are two paired venae comitans consistently found in all our 30 dissections running on either side of PIA more definable towards the hilum between the Supinator and the APL. In eight of our clinical cases and four cadaveric dissections there is a dorsal forearm vein running all along the dissection in the subcutaneous plane upto proximal end of the flaps. We have preserved this vein during our dissection distally over the pedicle by subdermal dissection.

Conclusion

Including the IRA and its perforators as a routine procedure during the harvest of the PIA flap may increase the reliability of the conventional flap and a larger flap extending proximally although a larger series with comparative study is needed to definitely prove this theory. Dissection of the proximal part between the fibres of supinator may have a learning curve but does not increase the operating time significantly.

Appendix

Site of entry of PIA in the posterior compartment

	14–15CM	15–16CM	16–17CM
CADAVERIC	nil	3	7
CLINICAL	2	2	16

Number of perforators from the PIA

no. of perf	1	2	3	4	5
CADAVERIC	nil	1	4	5	nil
CLINICAL	nil	nil	3	15	2

Distance of the distal most perforator from the ulnar styloid process

	7.5–8.5CM	8.5–9.5CM	9.5–10.5CM	10.5–11.5CM
CADAVERIC	2	6	2	nil
CLINICAL	7	9	3	1

Site of anastomosis between PIA and AIA from ulnar styloid process

	2.0–2.5	2.5–3.0 cm	3.5–4.5CM
CADAVERIC	9	1	nil
CLINICAL	11	7	2

Origin of IRA

site	oblique cord	APL/Sup
cadaveric	7	3
clinical	11	9

Plane of IRA

PLANE OF IRA	b/w anc, sup	fibres of sup/deeper
cadaveric	7	3
clinical	13	7

Number of perforators from IRA				
	1	2	3	
CADAVERIC	4	5	1	
CLINICAL	7	12	1	
Site of flap				
	MIDDLE 1/3	mid-prox (min ext)	ext to prox1/4	
NO.OF FLAP	3	10	7	
Flap length (vertical)				
length	5–7CM	7–9CM	9–11CM	11–14CM
NO.OF FLAPS	4	9	1	6
Flap breadth (horizontal)				
Breadth	3–4 cm	4–5 cm	5–6 cm	6–7 cm 7–8 cm
NO.OF FLAPS	6	6	4	3 1

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