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OPTIMISING OUTCOMES IN REVERSE FLOW POSTERIOR INTEROSSEOUS ARTERY FLAP FOR HAND RECONSTRUCTION

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OBJECTIVE:

To demonstrate the versatility of the reverse flow PIA flap, and technical modifications for safe execution and enhanced survival of the flap, in a high volume tertiary care center.

PATIENTS AND METHODS:

Between January 2019 and June 2022, 33 patients presented with soft tissue defects in dorsum of hand, first web space, and flexor aspect of wrist region, resurfaced with PIA flaps were included in the study. All flaps were done for reconstruction of post traumatic defects in hand. In Patients with fractures in the hand and tendon loss, fracture fixation and tendon reconstruction followed by resurfacing was done. Patients were taken up for surgery under regional anesthesia, under tourniquet control with loupe magnification. In supine position, flap markings done with elbow and forearm placed in flexed and semi pronated position. Preoperative Doppler was performed for identifying the perforator in the cutaneous paddle marked along the axis. Once the patient is positioned on table, planning in reverse done along the axis and flap was harvested. Flap inset done and donor raw area covered with SSG with immobilization of wrist in 30 degree extension and MCP joints in 60 degree flexion with volar slab. Patients were instructed strict hand elevation for a week. All patients were under clinical observation for 2 weeks. Complications such as infection, venous congestion, donor site SSG loss, and extension lag in fingers were noted. Patients were advised follow up in physiotherapy and later reassessed at the end of 3 months for donor site scar and functional recovery. Patients with major associated injuries and injury to either radial or ulnar artery in the forearm were excluded.

VASCULAR ANATOMY:

The Reverse flow posterior interosseus artery perforator flap is supplied by perforators from posterior interosseus artery that anastomose with anterior interosseus artery. PIA that originates from common interosseus artery or ulnar artery, and enters via interosseus membrane to the extensor compartment of the forearm underneath the supinator at an average distance of 7.4 to 9.8 cm from lateral epicondyle of humerus and

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12.4 to 17cm from ulnar styloid, accompanied by two venae commitantes and running in the fascial septum between EDM and ECU, giving off fasciocutaneous perforators throughout it's length, and musculocutaneous perforators through APL,EPL ,EIP, and periosteal branches to ulna. PIA continues to course caudally in the septum and anastomoses with anterior interosseus artery either as a single branch or two terminal branches at a distance of about 4.5 cm from ulnar styloid. In the distal half of the forearm, posterior interosseus artery is relatively superficial, whereas in the proximal half, the septum lies underneath the extensor digiti minimi and so the vessel is deeply situated. At its origin the artery's external diameter is 1.2 to 2.6 mm and at the anastomotic area the external diameter is 0.8 to 1.4 mm. Deep branch of radial nerve, which pierces the supinator muscle from the cubital fossa, reaches the extensor compartment of forearm as the posterior interosseus nerve accompanying PIA and gives off branches to the long extensors. . The PIA gives of fasciocutaneous perforator throughout its length along the septum between ECU and EDM with three patterns. In Pattern 1: multiple septocutaneous small branches are distributed proximally and distally. In Pattern 2: branches are distributed throughout the septum at 1 to 2cm interval. In Pattern 3: a large perforator arises proximally and multiple minute septocutaneous perforators arise. (2,3)

FLAP MARKINGS:

The following are marked on the extensor aspect with elbow and forearm placed in flexed and semi pronated position over the trunk. A line is drawn between radial styloid and ulnar head and a point is marked at the junction of ulnar 1/3rd and radial 2/3rd of this line (this point represents the distal anastomosis between PIA and AIA). From this point a line is drawn to the lateral epicondyle, which represents the axis of PIA. The PIA originates at around 8cm distal to lateral epicondyle. The pivot point of the flap lies at about 2 to 3 cm from the line joining the radial styloid and ulnar head along the axis of the flap. The midpoint along the axis is marked, which corresponds to the most consistent cutaneous perforators of the PIA which should be included in the flap. The proximal border of the flap to be harvested can be up to 6-8 cm from the lateral epicondyle along the axis.

OPERATIVE TECHNIQUE:

Under regional block/ GA with elbow and forearm placed in flexed and semi pronated position over the trunk, the axis of the flap is marked. After debridement of the defect, planning in reverse is done. Cutaneous paddle of the flap over the mid third of the dorsoulnar aspect of the forearm along the axis is marked. Then, distal to cutaneous paddle, an S shaped incision is marked along the axis so as to raise subdermal flaps with a width of 3 to 4 cm up to the pivot point.

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CASE 1: PIA FLAP for DORSUM AND THUMB WEB DEFECT of HAND

An incision is made along the ulnar border of cutaneous paddle down to the fascia and the fascia is tagged with the skin/dermis to avoid shearing. ECU muscle belly is visualized and the flap is raised subfascially till the septum is visualized on the ECU side. Another incision is made on the radial aspect of the cutaneous paddle down to the deep fascia which is tagged with the skin. On continued subfascial dissection, the EDC muscle belly is visualized. On retracting EDC radially the deeper EDM muscle is visualized along with multiple vessels arising from the PIA artery with its nerve supply. The PIA vessel usually lies ulnar to the PIN in the septum. All the extensor muscles are innervated on the radial aspect

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by the PIN except ECU which receives its innervation from the ulnar side by crossing the PIA. The proximal incision is completed on the cutaneous paddle and the flap is raised along with its septum after ligating the PIA distal to innervation of ECU muscle and proximal to the well-defined cutaneous perforators included in the skin paddle. Cutaneous paddle of the flap is raised along with the intervening septum and PIA.

An S shaped incision is made along the axis, distal to the skin paddle and subdermal flaps are raised for a width of 3 to 4 cm up to the pivot point by carefully preserving all the venous drainage in the adipofascial pedicle. Adipofascial pedicle along with PIA is raised by preserving the PIN carefully. As dissection continues from both radial and ulnar aspect distally, the antero posterior dimensions of the septum is reduced and the vessel runs superficially over the Extensors Indicis, and distally the PIA runs close to the periosteum of ulna. Since the flap is raised in a subfascial plane and an adipofascial pedicle of 4 cm width is raised, we do not routinely visualize the anastomotic arc distal to the pivot point. After elevating the flap it is placed in its position and lignocaine soaked gauze is placed over the pedicle and saline dressing is applied.

CASE 2: PIA FLAP for DORSO-ULNAR DEFECT of HAND

After elevating the hand, tourniquet is released. Wait patiently for 20 minutes and assess the viability of the flap. There should be slow sustained bright red bleeding along the dermal edges of the seam line of flap and moreover, there should not be edema of the flap. The skin bridge between the defect and pivot point is incised and subdermal flaps are raised and the flap is transposed to the defect. SSG is applied over the adipofascial tail. In few cases we raised a flap with a tennis racquet or tear drop cutaneous paddle where there is no need of SSG over the adipofascial tail while transposing the flap

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CASE 3: PIA FLAP for FLEXOR ASPECT OF WRIST

CASE 4: PIA FLAP for THUMB WEB

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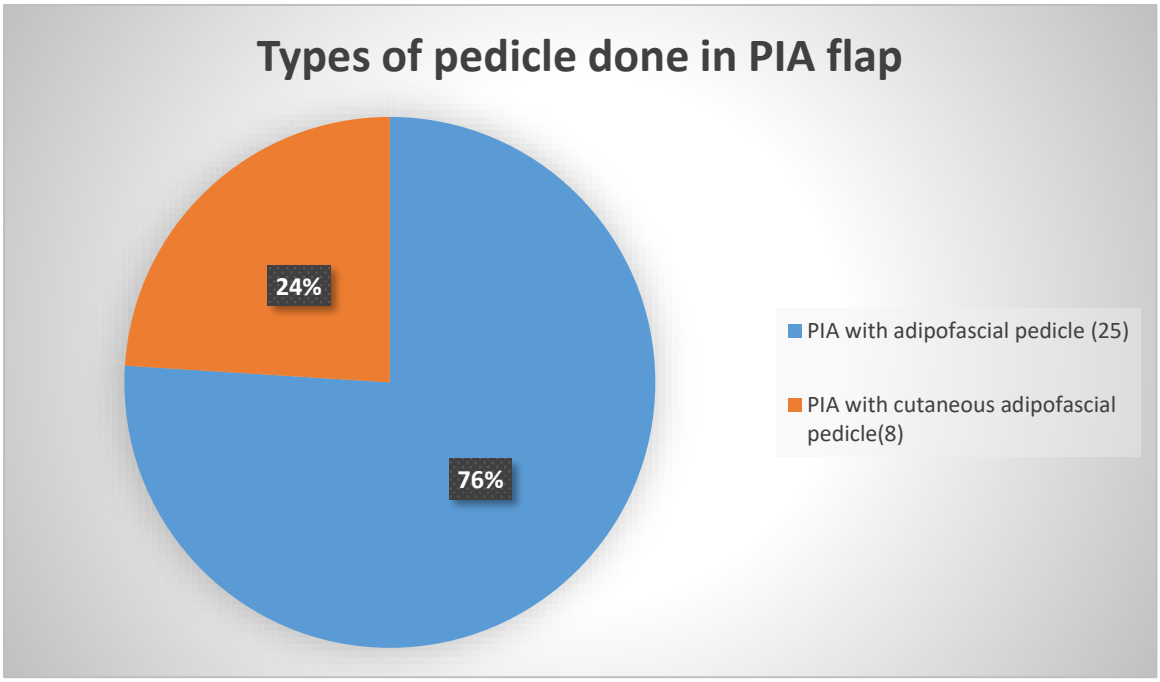
RESULTS:

Out of 33 patients for whom PIA flap was executed, in 25 patients PIA with adipofascial pedicle was done, in 8 patients tennis racquet shaped cutaneous adipofascial pedicle was done (depicted in pie chart 1).



Out of 25 patients for whom PIA flap with adipofascial pedicle was executed, in 20 patients flap and adipofascial pedicle flap was transferred to the defect by splitting the skin bridge between the pivot point and the defect margin, and SSG applied over the pedicle. In 5 patients, flap and adipofascial pedicle were transferred by tunneling through the skin bridge (depicted in pie chart 2).

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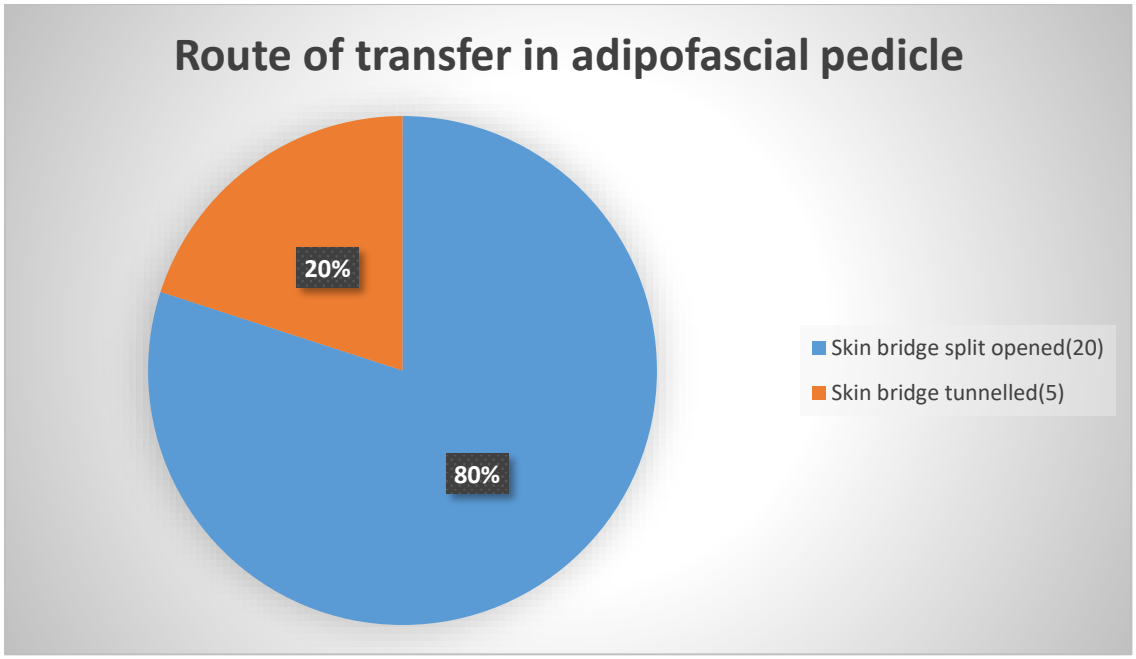
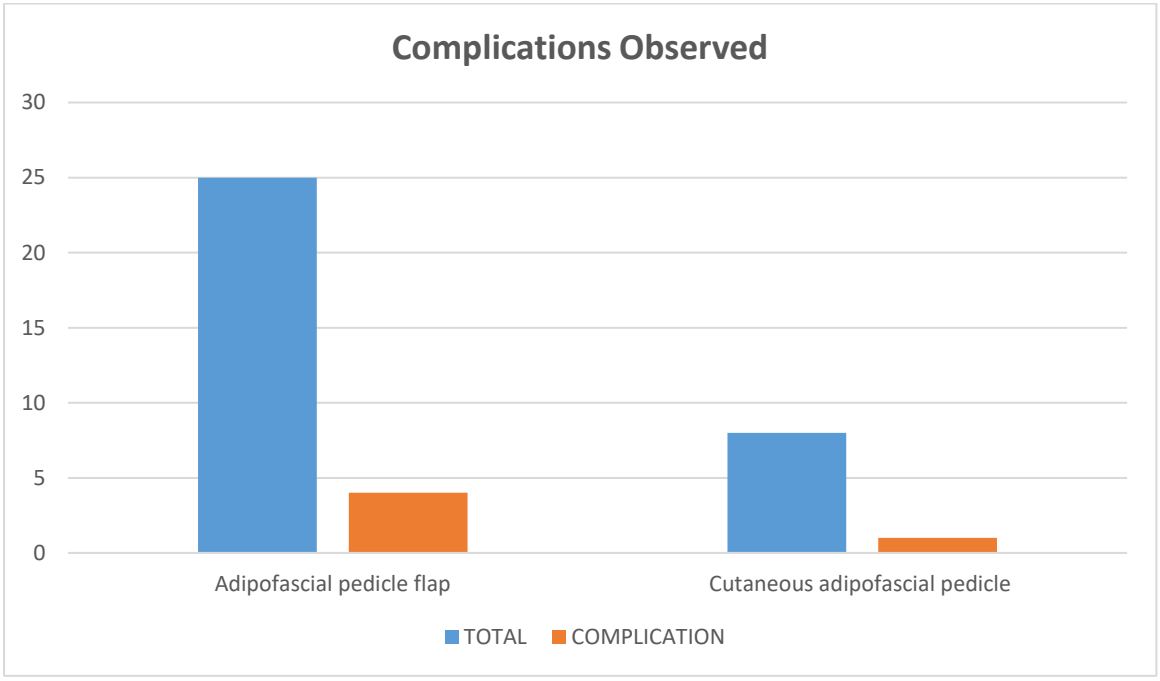


Out of 25 patients where flap with adipofascial pedicle was done, 4 patients had complications, with donor SSG loss in 1 patient, managed with secondary SSG, and mild Extensor lag in little finger in 2 patients. 1 patient had complication of venous congestion, flap edema followed by distal flap necrosis where flap transfer was done by tunneling beneath the skin bridge. Out of 8 patients where tennis racquet shaped cutaneous and adipofascial pedicle was done, 1 patient had complication of infection and flap dehiscence in the 1st web, which was managed conservatively (depicted in Bar chart 1).



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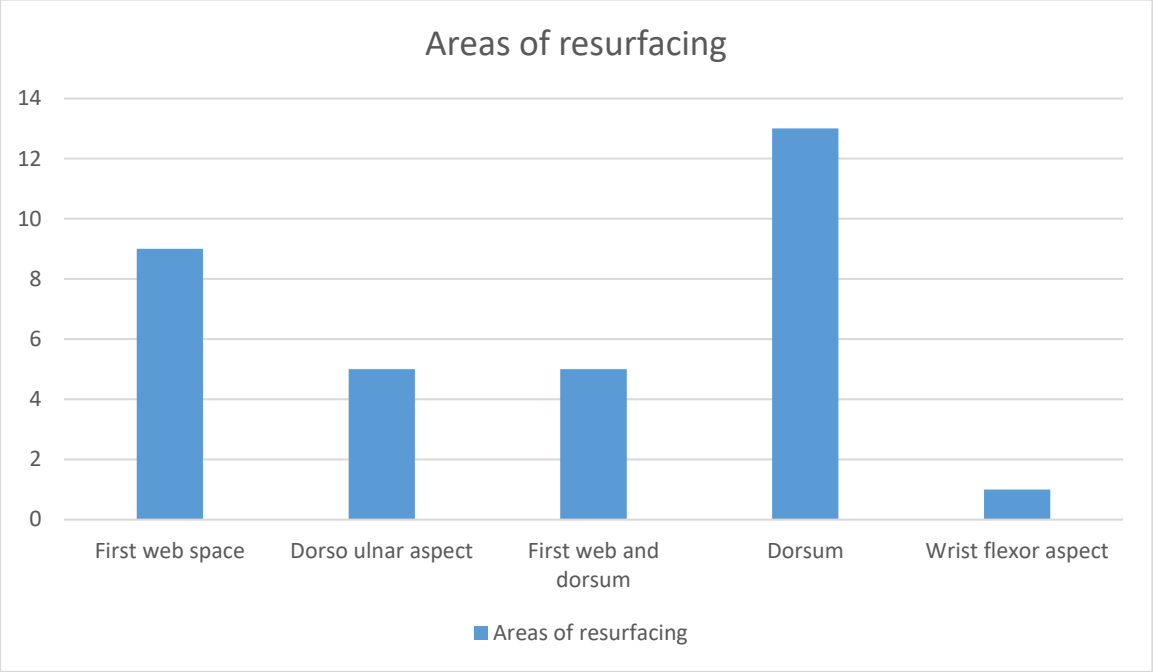
The areas of resurfacing with adipofascial pedicle PIA flap, and tennis racquet shaped cutaneous adipofascial pedicle PIA flap are depicted in Bar chart 2.



DISCUSSION:

Hand defects pose a challenge in reconstruction as one need to restore function and cosmetic outcome. Early wound coverage helps in minimizing soft tissue loss and wound infection thereby aiding in early recovery of hand functions.

PIA flap is one such fasciocutaneous flap based on posterior interosseus artery, which lies invested by fascial septum between ECU and EDM, which spreads on the deep fascia to form longitudinal fascial arcade. The PIA flap based on its perforators' size is restricted to the middle third of the forearm on dorso-ulnar aspect. The advantage of loco regional reverse flow PIA flap as compared with a distant flap is, single stage reconstruction thereby permitting early mobilisation. More over PIA flap provides pliable skin without sacrificing major axial vessels of the hand.

PIA flap described by Zancolli and Angrigiani in 1985, is a robust flap for coverage of soft tissue defects of the dorsum of hand up to MCPJ, first web space and proximo-ulnar aspect of the palm. This reverse flow flap is based on distal communication between anterior interosseus artery and posterior interosseus artery just proximal to the distal radio-ulnar joint. The operation described by Zancolli and Angrigiani begins by making incision in pivot point and after visualizing the communication of PIA and AIA before proceeding for flap harvest. Zancolli and Angrigiani recommend harvesting the flap in the middle third of dorso-ulnar aspect of forearm along the axis.

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The PIA originates from common interosseus artery or the ulnar artery, through the interosseus membrane emerges into the extensor compartment of the forearm underneath the supinator at a distance of around 7.4 to 9.8 cm from lateral epicondyle of humerus and 12.4 to 17 cm from the ulnar styloid. The posterior interosseus artery anastomoses with the anterior interosseus artery underneath the extensor retinaculum mostly by single branch and less likely by double branch just proximal to the ulnar head. At its origin the artery's external diameter is 1.2 to 2.6 mm, and is accompanied by two vena commitantes running in the fascial septum between EDM and ECU, giving off fasciocutaneous perforators throughout its length. It also gives muscular branches to APL, EPL, EIP and periosteal branches to the ulna. At the anastomotic area with AIA, the external diameter is 0.8 to 1.4 mm. Deep branch of radial nerve on piercing the supinator reaches the extensor compartment of the forearm as posterior interosseus nerve and accompanies the posterior interosseus artery and gives off branches to the long extensors.

The PIA gives of fasciocutaneous perforator throughout its length along the septum between ECU and EDM with three patterns. In Pattern 1: multiple septocutaneous small branches are distributed proximally and distally. In Pattern 2: branches are distributed throughout the septum at 1 to 2cm interval. In Pattern 3: a large perforator arises proximally and multiple minute septocutaneous perforators arise (2, 3). The important anatomical considerations is that the fascial septum between the externsor carpi ulnaris and extensor digiti minimi in which the vessel lies, is oriented sagitally. In the distal half artery is relatively superficial but in the proximal half the septum lies underneath the extensor digiti minimi and so the vessel is deeply situated.

Chen et al designed three auxillary procedures to make the flap more reliable, first by additional venous anastomosis when there is congestion, second by converting it to a

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free flap when there is difficulty in harvesting and third by raising the flap with wide base and by incorporating anterior and posterior interosseus arteries.

Rare anatomical variations are described by various authors such as failure of middle third of PIA (Penteado et al), absence of choke anastomosis (Angrigiani et al), hypoplastic PIA in the middle third (Guinta et al), narrowing of the PIA in the middle third (Angrigiani et al), termination of PIA in the middle third of forearm (Coasta et al). In our study we had not come across such variation as noted by Vinita Puri et al. Moreover in our study, we also observed that incorporating 3 to 4 cm width of adipofascial tissue improves the venous drainage, and exteriorizing the pedicle by splitting open the skin bridge between the pivot point and the defect, and covering the adipofascial pedicle by split thickness skin graft reduces venous congestion, pedicle compression and flap failure. (1,2,3)

Designing the flap like a tennis racquet with wide adipofascial cutanueos pedicle with 1cm skin as cutaneous handle in continuity minimize the major complication of venous congestion in the flaps and the intervening skin bridge is incised and reflected in the subdermal plane with a breadth of 1 inch on either side. The cutaneous handle of the racquet shape is inserted into the bridge along with the pedicle. Angrigiani et al raised the flap from distal to proximal in suprafascial plane, Balakrishnan et al raised the flap in subfascial plane. Lu et al described that venous congestion of the distally based PIA flap is due to narrow pedicle and tight subcutaneous tissue, Balakrishnan et al split the skin bridge between the defect and pedicle rather than tunneling to alleviate this. (5)

Venous drainage is from both superficial and deep system; one or two venae commitantes ordinarily follow each of the perforator with communicating branches between the venae commitantes, allowing reverse flow via both cross over and bypass patterns. (6)

Author Angus Keogh with his colleague, in cadaveric dissection, finds a consistent relationship between PIA and PIN and described proximal at risk zone which spans an average of 25mm, intermediate risk zone on an average of 40mm and low risk zone average of 100 mm from the emergence to distal edge of the supinator. In proximal at risk zone there is close intertwining of the small vessels and nerves and the PIN continue deep to the web of the intertwined vessels between 1 to 3 branches of the nerve supplies either ECU or EDM muscle in this zone. In the intermediate risk zone the PIN and PIA separates with an average of 4.3 mm. In the low risk zone the PIN and PIA are markedly separated. The PIA bifurcates and courses around the proximal edge of EPL muscle belly to supply EPL and APL and it variably connects with the dorsal branch of anterior interosseus artery. The PIN continues along the bifurcating arterial branch, giving branches to the EIP and EPL. Knowledge of this interrelationship is clinically important because injury to the PIN in relationship to the harvest of PIA flap described by Brunelli et al and also transient weakness of the extensor of the little finger and ECU encountered commonly was observed by Author Angus Keogh. (7)

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The critical point of dissection in PIA flap is the protection of Posterior interosseus nerve. The motor branch of ECU must be spared; usually the branch to the ECU passes over the artery and necessitates the ligation of artery distal to itself. Perforator vessels nourishing the skin usually runs more distally and ligation does not harm the flap circulation. Costa and Soutar believe that the main artery to the flap arises 1 cm distal to the midpoint between the distal radio ulnar joint and the lateral epicondyle and they suggested that the flap centre should be 9cm from the lateral epicondyle.(8)

Lu et al found that PIA gives off 3 to 9 septocutaneous perforators at the middle third and 2-5 at the distal third of forearm and therefore the middle third of the forearm was called as zone of security of harvesting the skin paddle. Costa and Soutar divided the PIA perforator into three distinct patterns and noted that most common type was as multiple small branches arising in 1 to 2 cm intervals. (9)

Balakrishnan et al modified the method of raising posterior interosseous artery flap subfascially, starting at the proximal half of the forearm at the ulnar border makes it easier to identify the vessels and avoid damage to it during dissection. Modification in the route of transposition by exteriorizing the adipofascial pedicle by splitting open the skin bridge, and modification in the shape of the flap in the form of a tennis racquet, makes it a reliable and versatile option for resurfacing the hand. In our study also we incorporated the modification methods done by Balakrishnan et al, Vinita Puri et al and Acharya et al for optimizing the outcomes. (10)

CONCLUSION:

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Reverse flow PIA flap is a safe versatile option for coverage of hand defects especially over the first web space, dorsum of the hand, dorso-ulnar aspect of the hand and flexor aspect of the wrist, by incorporating the modification methods of raising the flap, incorporating 3-4 cm cuff of adipofascial pedicle and by exteriorizing the route of pedicle transfer.

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