Rev esp cir ortop traumatol. 2011;**55(4)**:248-256

Revista Española de Cirugía Ortopédica y Traumatología

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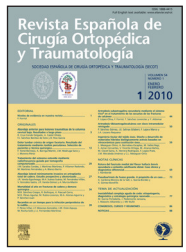

ORIGINAL ARTICLE

Experience with posterior interosseous flaps: a cases series

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Received December 10, 2010; accepted April 6, 2011

KEYWORDS
Posterior interosseous flap;
Hand wounds;
Reconstruction

Abstract
Objectives: To describe 10 patients treated for traumatic wounds or scar tissue retraction with reversed pedicled posterior interosseous flaps.
Material and methods: Ten consecutive patients, operated on for wound coverage between March 2007 and April 2010, were retrospectively reviewed in terms of demographic factors, etiology, wound location, flap dimensions, final outcome, and complications.
Results: One patient was excluded due to anatomical variations. From the remaining nine patients, full flap survival was achieved in seven; partial survival (10% flap loss at the distal end opposite to the pedicle) was achieved in two. Slight to moderate venous congestion was observed in the three first patients of this series, but this did not affect the final outcome.
Discussion: It is our preference to avoid the use of free flaps in order to decrease the operation time and to avoid complications related to the anastomosis technique. The addition of a large subcutaneous vein dissected with subcutaneous tissue, which we started in the fourth case, solved the problems related to edemas and venous congestion. Split thickness skin grafts on the donor area can lead to aesthetic complaints.
Conclusion: Posterior interosseous flap was shown to be a reliable and effective alternative for wound coverage within the range of its pedicle, unless there are anatomical variations, which is not common.

PALABRAS CLAVE
Colgajo interóseo posterior;
Heridas mano;
Reconstrucción

Experiencia con el colgajo interóseo posterior: serie de casos

Resumen
Objetivo: Se describen diez pacientes intervenidos para coberturas de heridas traumáticas y retracciones cicatriciales las cuales se realizaron con un colgajo interóseo posterior.
Material y método: Diez pacientes consecutivos, que fueron programados para coberturas de heridas entre marzo de 2007 y abril de 2010, se revisaron retrospectivamente en

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cuanto a factores demográficos, etiología, localización de las heridas, dimensiones del colgajo, resultado final y complicaciones.
Resultados: Se descartó un paciente por encontrarse variaciones anatómicas. De los nueve restantes, la supervivencia fue total en siete y parcial (pérdida del 10% de la extremidad opuesta al pedículo) en dos. En los tres primeros casos de la serie se apreció una congestión venosa leve a moderada que no comprometió el resultado final.
Discusión: Es nuestra preferencia prescindir del uso de colgajos libres para disminuir el tiempo de intervención y evitar complicaciones derivadas de la realización de anastomosis. La incorporación de una vena subcutánea de gran calibre disecada con tejido subcutáneo realizada a partir del cuarto caso solucionó los problemas de edemas por congestión venosa. El injerto de piel parcial en la zona donante puede llevar a quejas estéticas.
Conclusión: El colgajo interóseo posterior demostró ser una alternativa fiable y efectiva para cobertura de heridas que se localicen en el rango de alcance de su pedículo, a menos que se encuentren variaciones anatómicas, lo cual ocurre en pocos casos.

Introduction

Integument loss in the hand presents a great challenge to the surgeon that is dealing with this. From the tissues available to cover it, the solutions most commonly used include carrying out skin grafts and free or pedicled flaps taken from the forearm. The ideal flap used for closure should be thin and not too large; at the same time it should sufficiently durable, must allow the tendons to glide and preferably have good aesthetic results. Posterior interosseous artery flap (PIA) has many of these qualities and was concomitantly described in 1986 by Zancolli and Angrigiani[1] and by Masquelet and Penteado.[2] Its popularity has increased, becoming a valuable flap for loss of substance accessible to its arc of rotation, due to its safety and low morbidity. The initial indication for reverse-flow posterior interosseous artery flap is to cover dorsal defects of the wrist and hand above the metacarpophalangeal joints. However currently it is also a procedure used successfully in serious defects and burns situated on the volar of the hand and wrist, as well as in the first web space. Unlike the radial artery flap, its main advantage is that it does not interrupt any major vascular axis (fig. 1).

Objective

The study's aim is to describe the use of the distal pedicle PIA flap for wound coverage with loss of substance on the back of the hand, first web-space and front of the wrist.

Material and methods

Ten consecutive patients programmed for wound coverage on the back of the hand, first web-space and front of the wrist between March 2007 and April 2010, were retrospectively reviewed in terms of demographic factors, aetiology, wound location, flap dimensions, final outcome and complications.

The demographic data was collected from clinical histories at our centre. The dimensions, the width and length of the flap were measured intra-operatively with a sterile ruler. Venous congestion and flap survival were judged according to clinical criteria.

A total of 10 patients were operated on for posterior interosseous flaps (9 males and 1 female). The average age was 44.8 years old (22-72 years old). The right side was affected in 7 patients and the left side in three. All were right-handed. Aetiology data and wound location are reflected in table 1, and the data on flap dimensions and treatment of the donor area are described in table 2. The mean follow-up time was 21 months (5-43 months).

Surgical technique

The posterior interosseous flap was carried out under brachial plexus block or general anaesthesia. The ischemia was performed with tourniquet placed on the arm without exanguation of the member so as to locate the posterior interosseous artery and its concomitant veins.

Flap planning

A line was drawn on the skin connecting the distal radioulnar joint and the lateral epicondyle with the arm in pronation and the elbow flexed The point of the main perforator was marked 1cm distal of this line's middle point (fig. 2). An acoustic Doppler was used to confirm the presence of the perforator.

The wound dimensions were calculated based on a template made with an Esmarch bandage strip. This template was positioned and centred on a point corresponding to the perforator and the flap was marked with a marker pen. The calculation of the pedicle length needed to reach the receptive area was meticulously planned.

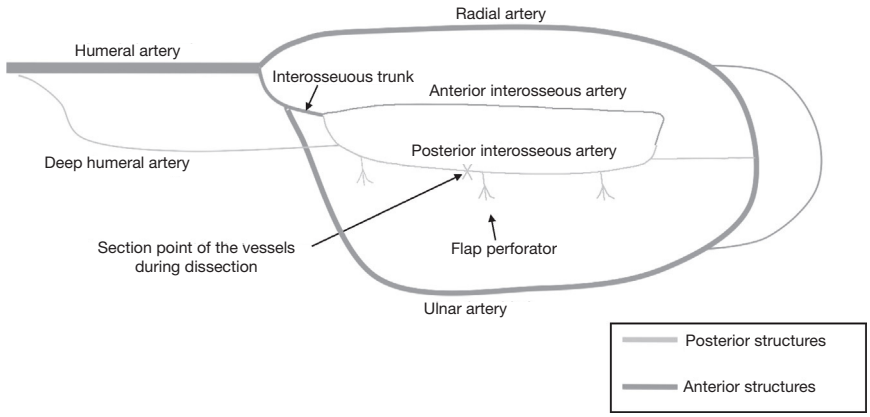

Figure 1 Schematic representation of the vascular axis of the upper limb. The anterior structures are represented in red and the posterior ones in blue. The anterior and posterior interosseous arteries originate from the common interosseous trunk, branch of the ulnar artery. The perforator is highlighted which perfuses the flap and the ligature point of posterior interosseous vessels.

Table 1 Demographic characteristics of 10 patients operated on for wound coverage with posterior interosseous flaps

Case	Gender	Age (years)	Affected hand	Date of operation	Aetiology
1	Male	28	R[a]	13/03/2007	Scar tissue retraction
2	Male	27	L[b]	26/05/2008	Acute post-traumatic wound
3	Male	70	R	31/07/2008	Acute post-traumatic wound
4	Male	72	R	19/08/2008	Acute post-traumatic wound
5	Male	36	R	29/09/2008	Scar tissue retraction
6	Male	69	L	13/11/2008	Scar tissue retraction
7	Male	39	L	26/11/2008	Scar tissue retraction
8	Male	54	R	01/10/2009	Acute post-traumatic wound
9	Male	31	R	15/04/2010	Scar tissue retraction
10	Female	22	R	03/05/2010	Acute post-traumatic wound

a: right; b: left.

Location of distal anastomoses

The first incision is carried out on the vascular axis distally to the flap on the line that was initially traced. With exception of the first three patients, the vein that normally runs in the ulnar direction to the flap axis would be located and dissected. In the first three cases of this series we saw, during the first few days after surgery, a slight venous congestion that made us carry out this stage in all the following cases. This vein, which was generally large, did not have a direct connection to the flap. A ligature would be

Table 2 Flap characteristics in 9 patients operated on for wound coverage with posterior interosseous flaps

Case	Location of the wound	Length of the flap (cm)	Width of the flap (cm)	Treatment of the donor area
1	First web-space	8	5	Direct closure
2	Back	8	5	Split thickness skin graft
3	Dorsal-ulnar	7	4	Split thickness skin graft
4	First web-space	6	4	Direct closure
5	Palmar wrist	5	3	Direct closure
7	Hypothenar region	6	3	Direct closure
8	Dorsal-ulnar	8	5	Split thickness skin graft
9	First web-space	7	4	Split thickness skin graft
10	First web-space	9	5	Split thickness skin graft

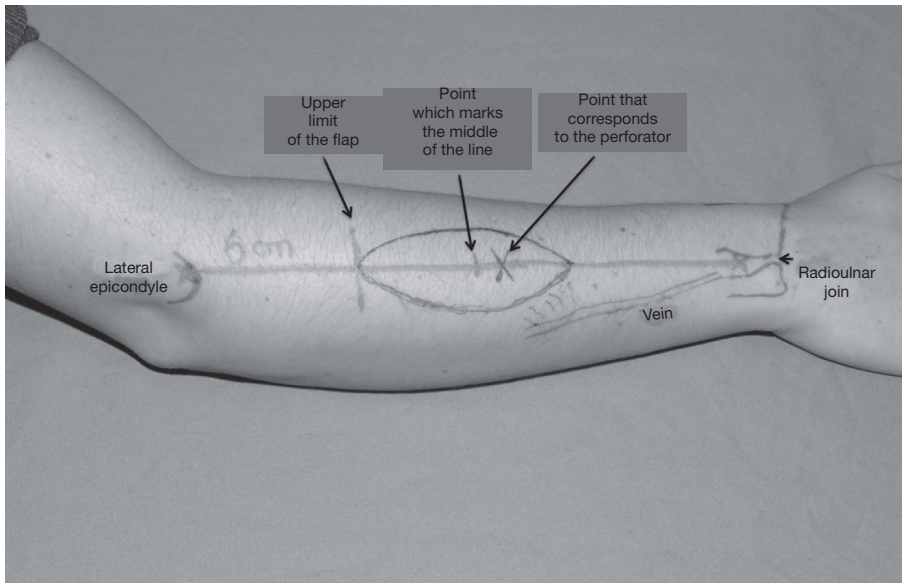

Figure 2 Intra-operatory planning of the posterior interosseous flap. The axis of the posterior interosseous flap vessels are represented on the red line that joins the lateral epicondyle and the point immediately next to the distal radioulnar joint. The perforator is located on this line on a point 1cm distant from its middle. The proximal limit of the flap should not exceed a point that is located 6 cm distally to lateral epicondyle. A superficial vein is also represented that is included to improve venous drainage.

made when this reached the distal third of the flap's ulnar margin, leaving a fatty interstice between it and the flap and along its path (fig. 3).

The second aim was to locate and open the fifth and sixth extensor compartments. After the separation of the Extensor Digiti Quinti (EDQ) and Extensor Carpi Ulnaris (ECU) tendons, the posterior interosseous artery and its concomitant arteries were easily found in the seventh, which runs between those tendons. The anastomosis between the anterior and posterior interosseous vessels was found in all patients proximally to the distal radioulnar joint.

Then the pedicle was dissected from distal to proximal binding all perforators with 5-0 polyglactin (Vicryl, Ethicon, NJ, US.) Once the pedicle was dissected, the radial margin of the flap was sectioned and the incision was deepened to subfascial level. The fascia was then sutured to the subdermal tissue to avoid accidental tears. The course of the posterior interosseous vessels was followed to the central perforator. The branches were bound and the vessels separated from the posterior interosseous nerve. The pedicle was bound to the point immediately proximal to the emergence of the main perforator (fig. 4). No attempt made to include perforators more proximal to this point so as to avoid sectioning the posterior interosseous nerve branch of the long abductor of the thumb.

The incision was then made in the ulnar margin and it would be deepened in the same way as the radial margin.

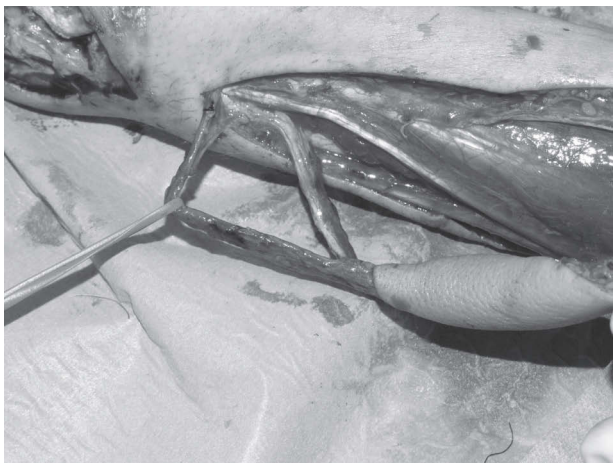

Figure 3 Dissection of a vein in the posterior interosseous flap, with subcutaneous cellular tissue and interstitium.

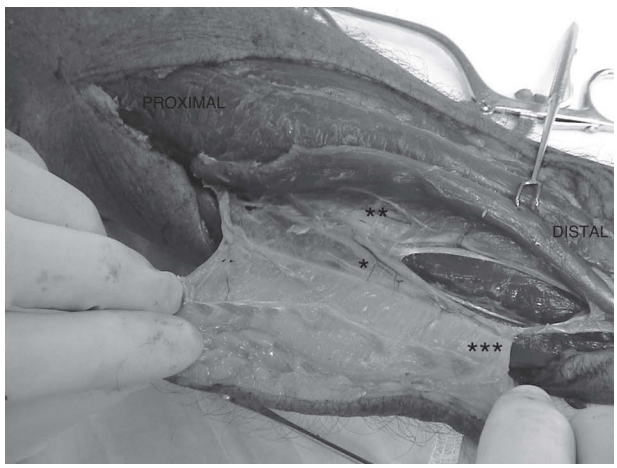

Figure 4 Cadaver preparation of the posterior interosseous flap with its vascular axis. *Ligature point of the posterior interosseous vessels immediately proximal to the perforator that perfuses the flap. **Posterior interosseous nerve. ***Posterior interosseous vessels (pedicle flap).

The flap was lifted from proximal to distal and the most ulnar branches were subsequently bound to the distal anastomoses that maintained flap irrigation. At this level it was important to section the fascial expansions that were connected to the pedicle to allow for greater length.

The ischemic cuff was then deflated to check the flap perfusion. A wide subcutaneous bridge was then dissected between the pivot point and the receptor area. The flap was carefully passed over this bridge until it reached the wound. The perfusion was once again verified to check that the pedicle was free of torsions and compressions.

The flap was sutured with polyamide monofilament sutures 4-0 (Dafilon, Braun, Barcelona, Spain) and the donor area was sutured directly or with a split thickness skin graft. The wrist was immobilised for a minimum of a week during the post-operatory.

Results

Of the nine patients who had a flap, the survival was complete in 7 (figs. 5-7) and partial (10% flap loss on the opposite end to the pedicle) in two patients, which were the first two

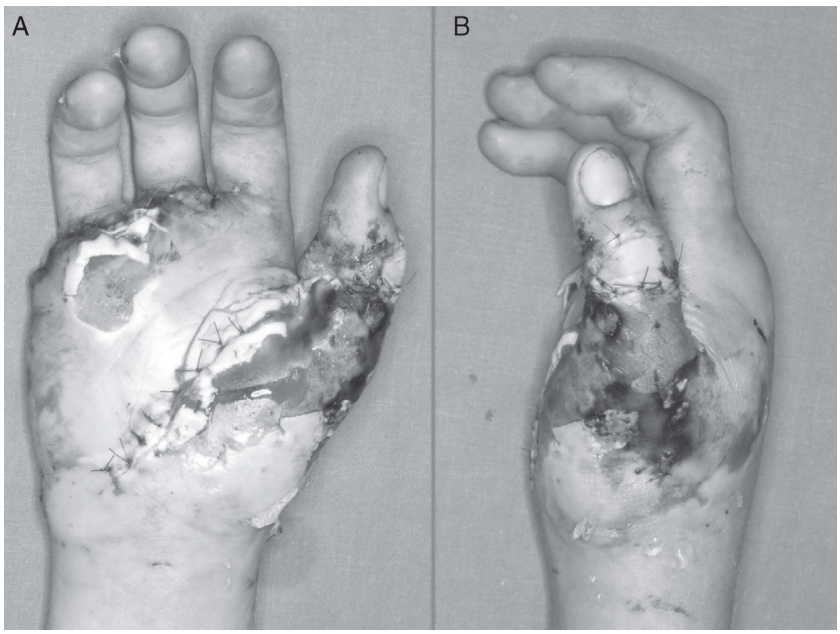

Figure 5 A and B) Wound through a crushed hand (car accident) in a 19 year-old woman. The patient was remitted due to cutaneous necrosis in the first web-space and thenar eminence. The fifth radius had been amputated.

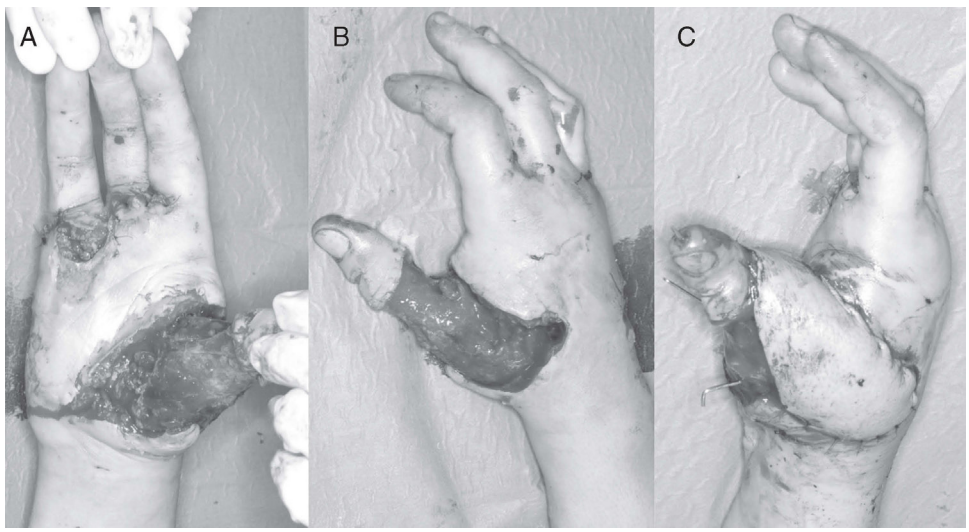

Figure 6 A and B) Intra-operative appearance after debridement. C) Appearance after the transfer of the posterior interosseous flap. A transfer of a free groin flap was carried out at the same time for the coverage of the thenar eminence and the front of the thumb.

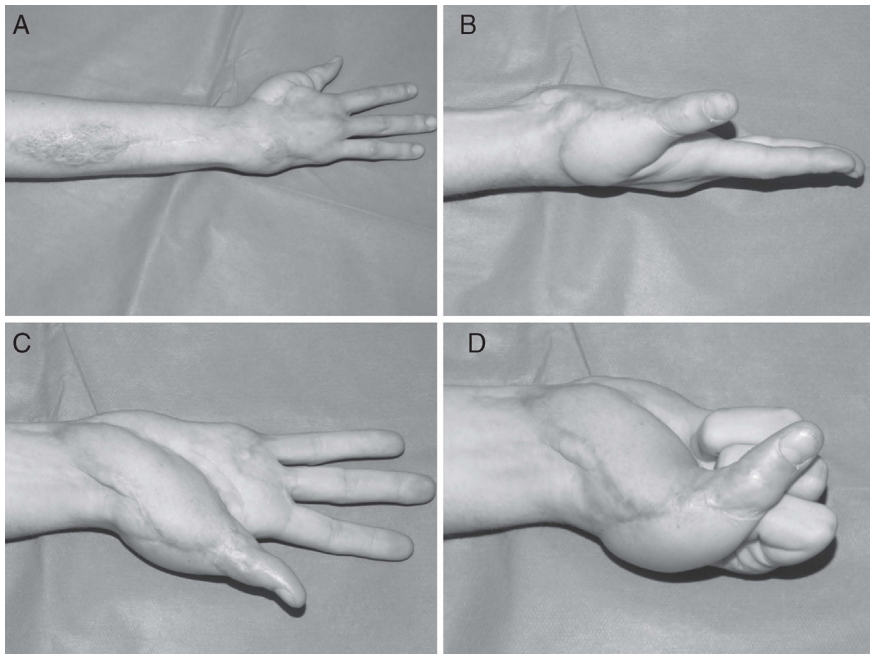

Figure 7 A, B, C, and D) Post-operative appearance 6 months after the reconstruction with a combination of a posterior interosseous flap and a free groin flap.

Table 3 Results for 9 patients operated on for posterior interosseous flaps. Case 6 was excluded due to anatomical variations that impeded a flap to be carried out

N	Survival	Venous congestion	Discomfort in the donor area	Need for slimming
1	Partial	Slight	None	No
2	Partial	Slight	Unpleasant appearance	Yes
3	Total	Slight	None	No
4	Total	Absent	None	No
5	Total	Absent	None	No
7	Total	Absent	None	No
8	Total	Absent	Unpleasant appearance	No
9	Total	Absent	Unpleasant appearance	No
10	Total	Absent	Unpleasant appearance	Yes

cases in the series. In these, we saw suffering flap in the extreme distal of the wound which finally healed without complications and without hypertrophy of the scar.

Slight to moderate venous congestion was observed in the first three patients of this series, but this did not affect the final outcome. One of these patients presented an epidermolysis which healed on its own accord. The results are reflected in table 3.

Four patients were not satisfied with the aesthetic results in the donor area. In these, the closure of the donor area was carried out with split thickness skin grafts. Five patients had no discomfort. In two patients (cases 2 and 10) a slimming of the flap was carried out due to its redundancy after the oedema produced by the initial trauma had subsided. This procedure was carried out 6 and 8 months after the initial intervention.

A patient was ruled out of the final results (case 6) because the course of the posterior interosseus artery during the dissection in proximal direction was directed by the interosseous membrane and had no connections with the perforator. The dissection between the radius and the ulnar was not viable and abandoned without having lifted the flap. This patient had a serious Dupuytren contracture on the fourth finger that had recurred twice in three years. The coverage was finally made with a heterodigital flap based on the dorsal ulnar digital artery of third finger that covered 90% distal of the wound, leaving the most proximal area open for directed healing.

Discussion

The treatment of wounds with loss of substance, where there is bone exposition and of tendons on the front or back of the wrist or the back of the hand, require coverage with flaps. Amongst the options available we have free flaps, the

flaps on a pedicle island and the pedicled groin flap, which is currently not used.

In the cases operated on in this series we did not use free flaps so as to decrease operating time and to avoid complications related to the anastomosis technique. However free flaps should be used in patients where the trauma has injured the continuity of the palmar arch or one of the main arteries in the forearm.[3]

When there is integrity of the radial and ulnar artery there are different forearm flaps described for complex coverages of the wrist and hand. Here we must highlight the radial flap, the dorsal ulnar flap, the anterior interosseous artery flap, and the posterior interosseous artery flap.[4] The ulnar flap unavoidably requires the sacrifice of one of the main arteries in the forearm. The dorsal-ulnar flaps and the anterior interosseous artery have a very short pedicle which limits its indications.

Therefore in the majority of our cases we preferred to use the inverse flap of the posterior interosseous vessels. These vessels generally provide a good blood supply to the skin of the back part of the forearm, allowing the elevation of a flap with sufficient size to cover the majority of defects of the distal forearm, the back and front of the hand, and the back of the wrist. The first web space and the thenar and hypothenar regions are also areas indicated for coverage with this flap. Therefore we consider a distal base posterior interosseous flap as a primary alternative to the radial artery flap and free flaps. Its main advantages are its thickness, texture, and colour, which is suitable for the back of the hand and gives minimum morbidity in the donor area.

The main disadvantage of the posterior interosseous artery flap is the possibility of different anatomical variants, amongst which we must point out, the absence or hypoplasia of the posterior interosseous vessels in the third part of the forearm.[2,5] In case 6 of our series we found that the posterior interosseous artery branched out from the anterior interosseous artery between the middle third and distal of the forearm. In this patient we did not see the connections between the perforator detected by the Doppler (prior to the operation) and the posterior interosseous vessels, which is why the dissection was abandoned. Other anatomical variations described are the direct origin of the posterior interosseous artery of the ulnar artery and the absence of distal anastomoses between the posterior and anterior interosseous artery which constitutes a rotation point.[5] It is our normal practice to start the dissection in the distal part of the vascular axis and initially check if there are any of these anastomoses. We do not indicate this flap n the case of important crushings in this area where the integrity of these vessels is debatable.

We have described the sacrifice of anastomoses with the anterior interosseous artery at the level of the distal radioulnar joint so as to gain more length to displace the flap more distally, basing the flap on very fine vessels of the dorsal carpal. However, these branches are very small, badly defined and not constant.[4] Therefore, if the anastomoses are absent the dissection must be abandoned.

To maximise pedicle length we looked to project the flap as proximally as possible in the forearm with a limit that reaches a point which is 6 cms distal to the lateral epicondyle (fig. 2). Another important measure is to carry out a meticulous dissection at the point of rotation (proximal to the distal radioulnar joint) releasing fascial expansions of the interosseous membrane.

Congestion in island flaps of retrograde flow is described in literature. Mazzer et al[6] described an incidence of 34% oedema and congestion. Imanishi et al[7] studied the mechanism of venous vein drainage of the retrograde flow flaps using a contrast injection, and reached the conclusion that the valves prevent the direct flow path through it, but that the accompanying veins allowed the presence of an indirect flow, which would not be possible any other way. Venous drainage through an added vein in our dissections could obey the same principle, since a sufficient amount of fatty tissue accompanied it.

In the conventional posterior interosseous flap, the retrograde venous drainage can be weak and venous congestion invariably results in the loss of its distal part, which is usually the most important. This congestion is proportional to the length of the flap.[8] The compression of the concomitant veins within the tunnel created to transpose the flap has been signalled as a possible cause for venous congestion.[8] To overcome this problem we advise widening the tunnel and sectioning the fibrous folds that could compress the pedicle. In our three first patients we observed a venous congestion that went away after a week, without the need for an extra intervention. In these three cases we created a tunnel of suitable dimensions and the wrist was immobilised in a favourable position to decompress the pedicle. From the fourth case onwards when we started to include a subcutaneous vein accompanied by subcutaneous tissue during the pedicle dissection, we saw no further cases of venous congestion. Therefore we believe the congestion observed in the three first patients was not due to technical problems in the creation of a subcutaneous tunnel. Therefore the addition of this vein is now our normal dissection practice. In 1986 Zancolli and Angriani[1] and Fujiwara et al[9] in 2003 informed on the addition of cutaneous and subcutaneous veins in the posterior interosseous flap pedicle. As benefits, the authors comment on the prevention of haematoma and flap congestion. Despite that in these publications[1,9] there are no comments on the inclusion of a large callibre vein, its addition in our experience did not compromise a good final outcome. We also cannot deduce from our results that adding the vein is necessary once a proper subcutaneous bridge has been dissected.

With respect to the function of large calibre veins in retrograde flow flaps, Chang et al[10] described a negative effect when it was used on dogs, associating them to a higher percentage of flap congestion. These authors concluded that the inclusion of these veins produces flap congestion and should be bound in their most distal portion. These findings do not correspond with our experience.

The drainage mechanism in these flaps has also been investigated by Pinal and Taylor;[11] their study revealed the presence of an alternative micro-venous system to that of the macro-venous that surrounds the artery and concommitant veins. This system's integrity is fundamental for the survival of these flaps while avoiding

skeletonization of the pedicle. Nakajima et al[12] found valves in the concomitant veins and their communicants, as well as the vasa vasorum. No routes of reverse flow that did not pass through the valves were found, and thus the veins with relatively weak resistant valves became the drainage route.

On the other hand, in an anatomical study of valve presence in the superficial veins of the upper limb, Harunobu et al[13] described the variability in their presence in finding sections of vein that were totally devoid of valves opposed to flow through them. The findings of the authors indicate that valve presence is high in areas of venous confluence and is not so in straight stretches.

Although we have not undertaken studies on cadavers regarding venous flow function on the posterior interosseous flap and our experience is purely clinical, we believe it is probable that a combination of valvular presence variability and flow through the interstice around the vein is responsible for the results that we see in our series of cases. These observations likewise agree with those described by Puri et al[14] who refer that the lesser incidence of cutaneous necrosis and venous congestion in their series of cases, could be attributed to making the flap with a wide band of subcutaneous tissue and fascia that improves its venous return.

Chen et al[8] described carrying out a venous anastomosis to ease venous drainage in cases of initial congestion. This anastomosis was carried out between an initially dissected vein and a tributary one to the cephalic vein near to the defect. The disadvantage was the increase of surgical time of approximately one hour. Based on our experience, we did not think it was necessary to carry out a direct venous anastomosis to rectify the problem of venous congestion. It is important to clarify that in our dissections we did not observe direct vein connection with the flap, but we included a generous amount of subcutaneous tissue around the vein that provided the continuity between the vein and flap.

Despite the flap dissection being described in literature as tedious and technically difficult, we believe there is technical advice that aids it. It is important to start the dissection looking for the seventh compartment amongst the fifth and sixth and not the vessels per se. On finding this seventh compartment, the vessels can be easily visualised running in their most superficial area. The dissection should follow the radial area binding all the branches that are found. The posterior interosseous nerve is found more deeply as the dissection advances and can be easily separated by sectioning the seventh intermuscular between the vascular and nervous axis. The dissection nearer to the selected perforator makes the separation of the vessels and the posterior interosseous nerve more difficult. The posterior interosseous artery should be proximally bound to the emergence of the perforator. The addition of more proximal perforators than those originally planned should be obviated to avoid section of the posterior interosseous nerve branches.[15] With respect to this lesion, Brunelli et al[16] in a series of cases of 113 posterior interosseous artery flaps reported paralysis of the motor branch of the posterior interosseous nerve extensor muscles of the wrist, or fingers in 5% of cases, generally the Extensor Carpi Ulnaris (ECU), Extensor Digiti Quinti (EDQ) or the Extensor Pollicis Longus (EPL), all of them made a full recovery within 6 months of the operation. In our case studies we did not find this complication.

The dissection of a subcutaneous tissue band in the distal part should not be limited to the communication level of the anterior interosseous artery so that there is no loss in pedicle length. The more distal the dissection the easier it will be to accommodate the rotation produced that should be accomodated without closure to the skin tension. In our cases it has not been necessary to place a partial skin graft in this area, but if this were the case we would not hesitate to do so.

There was no precise correlation between the flap width and the need to cover the donor area with split thickness skin grafts. Patients with donor areas with a width of four centimetres required coverage with grafts, whilst in others with a width of five centimetres we proceeded with a direct skin closure. The most important factors regarding the need for coverage with a graft were previous closure to the decompression with ischemic cuff (that varied according to the need of having to carry out associated procedures), the dimensions of the forearm and the oedema level of the limb.

Conclusions

Posterior interosseous flap was shown to be a reliable and effective alternative for wound coverage within the range of its pedicle, unless there are anatomical variations, which is not common. The addition of a large subcutaneous vein dissected with subcutaneous tissue, which we started in the fourth case did not cause problems related to oedemas and venous congestion. Also these complications did not occur when this procedure was carried out, on the contrary to what happened in the first cases.

Evidence level

Evidence level IV.

Protection of human and animal subjects

The authors will declare that the procedures followed were in accordance with the regulations of the responsible Clinical Research Ethics Committee and in accordance with those of the World Medical Association and the Helsinki Declaration.

Confidentiality of data

The authors will declare that they have followed the protocols of their work centre on the publication of patient data and that all the patients included in the study have received sufficient information and have given their informed consent in writing to participate in that study.

Right to privacy and informed consent

The authors must have obtained the informed consent of the patients and / or subjects mentioned in the article. The author for correspondence must be in possession of this document.

Conflict of interest

The authors have no conflict of interest to declare.

References

1. Zancolli EA, Angrigiani C. Colgajo dorsal de antebrazo en isla (Pedículo de vasos interóseos posteriores). Rev Asoc Arg Orthop Traumatol. 1986;54:161–8.
2. Penteado CV, Masquelet AC, Chevrel JP. The anatomic basis of the fascio-cutaneous flap of the posterior interosseous artery. Surg Radiol Anat. 1986;8:209–15.
3. Park JJ, Kim JS, Chung J. Posterior Interosseous Free Flap: Various Types. Plast Reconstr Surg. 1997;100:1186–97.
4. Agir H, Sen C, Alagöz S, Onyedi M, Isil E. Distally Based Posterior Interosseous Flap. Primary Role in Soft-Tissue Reconstruction of the Hand. Ann Plast Surg. 2007;59:291–6.
5. Costa H, Soutar DS. The distally based island posterior interosseous flap. Br J Plastic Surg. 1988;41:221–7.
6. Mazzer N, Barbieri CH, Cortez M. The posterior interosseous forearm island flap for skin defects in the hand and elbow. A prospective study of 51 cases. J Hand Surg Br. 1996;21: 237–43.
7. Imanishi N, Nakajima H, Fukuzumi S, Aiso S. Venous drainage of the distally based lesser saphenous-sural venoneoroadipofascial pedicled fasciocutaneous flap: a dadiographic perfusion study. Plast reconstr Surg. 1999;103:494–8.
8. Chen HC, Cheng MH, Schneebergen AG, Cheng TJ, Wei FC, Teng YB. Posterior interosseous flap and its variations for coverage of hand wounds. J Trauma. 1998;45:570–4.
9. Fujiwara M, Kawakatsu M, Yoshida Y, Sumiya A. Modified posterior interosseous flap in hand reconstruction. Tech Hand Up Extrem Surg. 2003;7:102–9.
10. Chang SM, Hou CL. Role of large superficial veins in distally based flaps of the extremities. Plast Reconstr Surg. 200;106: 230–1.
11. Del Pinal F, Taylor GI. The deep venous system and reverse flow flaps. Br J Plast Surg. 1993;46:652–64.
12. Nakajima H, Imanishi N, Aiso S, Fujino T. Venous drainage of the radial forearm and anterior tibial reverse flow flaps: anatomical and radiographic perfusion studies. Br J Plast Surg. 1997;50:389–401.
13. Shima H, Ohno K, Shimizu T, Michi K, Egawa K, Takiquchi R. Anatomical study of the valves of the superficial veins of the forearm. J Cranimaxilofac Surg. 1992;20:305–9.
14. Puri V, Mahendru S, Rana R. Posterior interosseous artery flap, fasciosubcu-taneous pedicle technique: a study of 25 cases. J Plast Reconstr Aesthet Surg. 2007;60:1331–7.
15. Ege A, Tuncay I, Ercetin O. Posterior interosseous artery flap in traumatic hand injuries. Arch Orthop Trauma Surg. 2003;123:323–6.
16. Brunelli F, Valenti P, Dumontier C, Panciera P, Gilbert A. The posterior interosseous reverse flap: experience with 113 flaps. Ann Plast Surg. 2001;47:25–30.