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ORIGINAL ARTICLE

Hand/Peripheral Nerve

# Improvement of the Rotation Arch of the Posterior Interosseous Pedicle Flap Preserving Both Reverse Posterior and Anterior Interosseous Vascular Sources

Cesare Tiengo, PhD
Erica Dalla Venezia, MD
Matteo Lombardi, MD
Franco Bassetto, MD

**Purpose:** The reverse posterior interosseous artery flap has several advantages, not sacrificing any major blood vessel, but its relatively short pedicle limits the use to cover defects up to the metacarpophalangeal joint. Our purpose is to demonstrate that the ligature of the anterior interosseous artery (AIA), proximal to the communicating branch with the posterior interosseous artery, leads to an improved flap rotation arch, preserving both vascular sources.
**Methods:** Sixteen fresh cadavers with latex perfusion were analyzed before and after our technique of elongation, and the so-obtained measures were standardized in "percentage of elongation of the pedicle." Eight patient with the loss of substance at the dorsal aspect of the hand have been treated with this technique, and results were evaluated in terms of flap survival and complication rates.
**Results:** The medium length of the pedicle in the normal flap was 10.8 cm, and after the section of the AIA, the medium length of the pedicle was 13.6 cm with a medium increase of 2.8 cm. It means a medium increase of 24% of the length of the pedicle. In all patients treated, full coverage of the defect was obtained, and we did not experience major complications.
**Conclusions:** This anatomical study supported by our clinical experience demonstrates that the use of the variant described above permits to reach more distal part of the hand without being afraid to stretch the pedicle because of the connection with the anastomotic arcades of the AIA at the wrist reducing the risk of ischemia of the flap. *(Plast Reconstr Surg Glob Open 2016;4:e794; doi: 10.1097/GOX.0000000000000760; Published online 11 July 2016.)*

Independently described by Penteado et al[1,2] and by Zancolli and Angrigiani,[3] the reverse posterior interosseous artery (PIA) flap (PIAF) has proven to be an excellent solution for the reconstruction of defects of the hand, wrist, and elbow,[4] and it is widely used to resurface dorsal hand defects up to the metacarpophalangeal joint and to reconstruct the first web space contractures.[5–8] Some modifications to the original description, such as addition of bones for use as an osteocutaneous flap[9] or for use as a free revascularized flap[10] have been previously proposed.

PIAF is an island fasciocutaneous flap vascularized by branches of the PIA. Its most common application is represented by the reverse flap to reach tissue defects around the wrist and the dorsal surface of the hand,[11] but it can also be based proximally to repair defects in the elbow region using a direct blood flow.[8,12] The distally based flap preparation depends on retrograde flow coming from the direct connection between the PIA vascular bundle and the vascular network at the level of the dorsum of the wrist (dorsal arterial arch).[1,13] Simultaneously, the existence of an anastomosis of the PIA with the anterior interosseous artery (AIA) through the interosseous septum localized at the level of the distal forearm guarantees to the flap viability an additional vascular source.[14] The identification and the saving of this anastomosis represent a safe distal pivot point of the reverse posterior interosseous flap.

This flap has several advantages, such as providing thin, soft, and pliable skin with good color and texture match and not sacrificing any major blood vessel as in a radial artery or ulnar artery forearm flap. The main disadvantage of the posterior interosseous flap lies in its relatively short arch of rotation, which limits its distal use to cover defects

*From the Clinic of Plastic Surgery, Department of Surgery, Padua University Hospital, University of Padua, Padua, Italy.*

*Received for publication December 8, 2016; accepted April 20, 2016.*



DOI: 10.1097/GOX.0000000000000760

**Disclosure:** *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*

up to the metacarpophalangeal joint or complex first web space contractures.

To obviate this drawback, Büchler and Frey[15] in 1991[15] carried the dissection distally along the transverse anastomotic branch as described by Bayon and Pho.[16] Using this method, they could make the flap reach up to the proximal interphalangeal joint crease. In 2001, Brunelli et al[11] proposed to extend the wrist and to exteriorize the vascular pedicle, allowing a gain of approximately 5 cm in the distal range of the flap, making possible the coverage of the more distal part of the dorsal aspect of the finger. To gain additional length, it would be possible to sacrifice the anastomosis between the anterior and the posterior vascular pedicles, basing the flap only on the fine arterioles of the dorsal carpus.[1] However, these branches are extremely small, poorly defined, and inconstant, representing a potential risk of flap ischemia.

In 2014, Fong and Chew[17] reported 1 case in which the reverse PIAF reached distal interphalangeal joints with the use of fascia extension.

Through an anatomical study, we verified the possibility of stretching the pedicle length of the PIAF, preserving retrograde anterior and posterior interosseous vascular sources. A retrospective analysis of 8 patients treated with this surgical solution was performed to verify its safety in clinical practice.

This study was carried out with respect to high ethical standards and in accordance and in conformity to the World Medical Association Declaration of Helsinki (June 1964) and subsequent amendments.

## MATERIALS AND METHODS

### Anatomical Study

Sixteen fresh upper extremity specimens from male and female cadavers (mean age, 62 years) without any history of trauma or surgery were analyzed in this study. Latex perfusion was performed cannulating the brachial artery and perfusing with red latex under manual pressure until incision within the pulp stained red. The dissection was performed 24 hours after preparation. The instruments used in the analysis included 4.5× loops, a vernier caliber, and a digital camera.

In all the specimens, the dissection was performed after the original technique description,[1] drawing a line that joined the lateral epicondyle and the distal radioulnar joint and assuming that the most proximal perforator of PIA was located just distal to the junction of the middle and proximal thirds of this line. The first incision was made on the posterolateral side of the flap and was extended distally to the radioulnar joint. The pedicle was then exposed, and the intermuscular septum was defined by identification of the septal perforating arteries. The fascia was then sliced on both sides of the septum, and the PIA was exposed by retracting the extensor carpi ulnaris, the extensor digiti minimi, and the extensor indicis proprius muscles.

The presence, location, and the caliber of all the anastomosis between the AIA and the PIA with respect to the distal wrist crease were recorded (Fig. 1). Then, the PIA was ligated proximally to the first perforator vessel, and the PIAF was raised up to the location of the distal communicating branch between PIA and AIA. The length of the pedicle was measured. Then, we proceeded with the opening of the interosseous membrane to perform the ligation of the AIA 5 mm prior to its distal anastomosis and to expose and preserve the distal course of AIA (Fig. 2).

The obtained vascular pedicle of the flap consisting in both retrograde anterior and posterior vascular network was then analyzed (Fig. 3). Those last measurements were standardized in "percentage of elongation of the pedicle" to avoid the bias because of the different length of the arms (Fig. 4).

### Clinical Application

Between 2012 and 2015, in our Clinic of Plastic Surgery, we used modified PIAF in 8 patients who presented tendon or bone exposure of the dorsal hand up to the proximal phalangeal joint or severe scar contracture of the first web space. Demographic data and location of the defect are shown in Table 3. Flap survival rates in terms of venous congestion or peripheral tissue ischemia were evaluated.

## RESULTS

### Anatomical Study

In the 16 specimens analyzed, there were 14 cases in which the PIA originated from the common interosseous

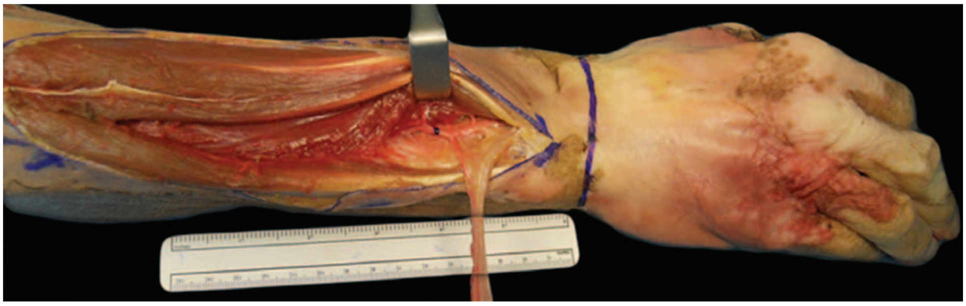

**Fig. 1.** Measurement of the distance between the most distal communicating perforator and the wrist crease. This vessel was constantly found in all the specimens and was located at a medium distance of 6.2 cm from the wrist crease.

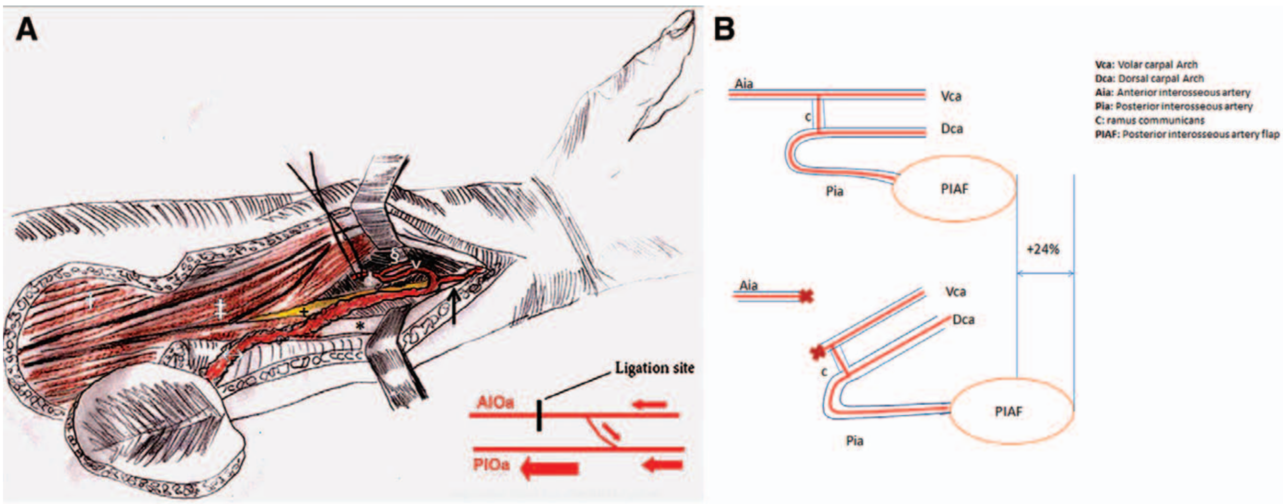


**Fig. 2.** A, Schematic representation of distal anterior interosseous artery (AIOa) (§); anastomotic branch (ᵛ); posterior interosseous artery (PIOa), distal to the anastomotic branch (↑); PIOa, vascular pedicle of the flap (↔); site of legation of the AIOa proximal to the anastomotic branch with the PIOa (wire); extensor carpi ulnaris muscle (*); extensor digiti minimi muscle (‡); extensor digitorum communis muscle (†); and ulna (+). B, Schematic drawing of new technique in comparison with original one.

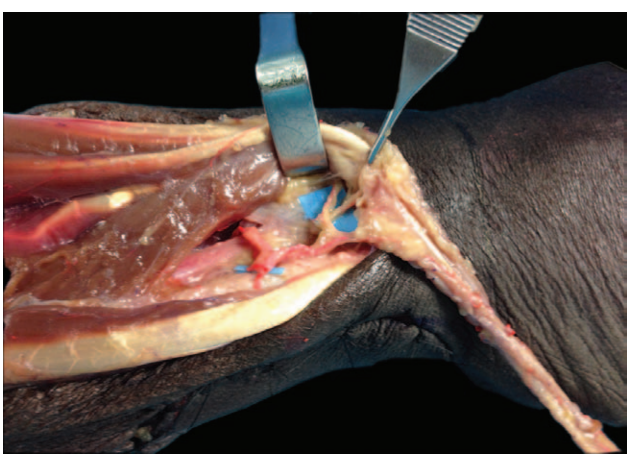

**Fig. 3.** Anastomotic vascular network at the wrist. Note the section of the anterior interosseous artery 5 mm proximal to the emergence of the ramus communicans.

artery and 2 cases in which the artery originated directly from the ulnar artery.

In all the cases, the PIA penetrated the interosseous membrane and emerged in the deep extensor compartment underneath the supinator and the extensoris pollicis lungus. At this level, it always gives origins to the interosseous recurrent artery.

Then, the PIA and its comitans veins and the posterior interosseous nerve formed a neurovascular bundle that flows below the extensor digitorum and extensor digiti minimi and then penetrated constantly in the intermuscular septum between the extensor carpi ulnaris and the extensor digiti minimi. At its origins, the PIA had a medium caliber of 1.5 mm; distally, at the level of the distal radioulnar joint, it had a medium caliber of 1.0 mm.

During its course, it was interconnected with the AIA by several communicating branches that perforated the interosseous membrane. In all specimens, the AIA was constantly identified, nourishing the pronator quadratus muscle branching on the anterior carpus surface.

The medium number of communicating vessels was 6. The mean distance of the last perforator from the wrist crease was taken, and it is reported in Table 1. They had a medium caliber of <0.5 mm, except for the most distal communicating perforator that had a medium caliber of 0.6 mm (Table 2). That vessel was found constantly in each specimen, and it was at a medium distance of 6.2 cm from the distal wrist crease.

After the accurate dissection of the pedicle and the ligation of the PIA proximally to the first perforator branch, the flap was elevated and presented a medium pedicle length of 10.8 cm (Table 1).

Then, we proceeded with the ligation of the AIA 5 mm before the emergence of the ramus communicans; the so-obtained vascular pedicle had a medium length of 13.6 cm with a medium gain of 2.8 cm, which represented a gain of 24% in terms of the length of the pedicle ($P \leq 0.01\%$; Table 2).

**Clinical Application**

In all patients treated with this modification of the flap, we obtained a full coverage of the defect, reaching the dorsal aspect of the PIP. Furthermore, we used this flap to treat 3 patients with the first web space scar contractures that involved also the palmar aspect of the hand in which an original PIAF could not completely cover the loss of substance or inevitably stretch its pedicle. In those patients, we obtained an almost complete restoration of the range of motion of the first finger and a median of 95% of postoperative web space width with 1-year follow-up. None of the flaps suffered with venous congestion or arterial ischemia. None of the patients treated presented clinical signs of infection after the procedure.

A clinical case is shown in Figures 5 to 8. Note the complete coverage of the defect reaching the dorsal aspect of

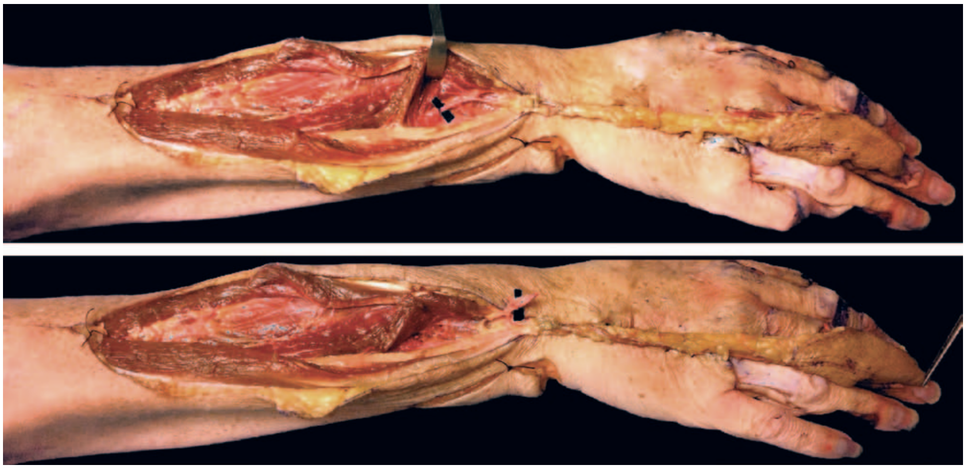

**Fig. 4.** A, Transposition of the flap before the section of the AIOa proximally to the ramus communicans. B, Transposition of the flap after the section of the communicating vessel: note that the increase of length of the pedicle is 24% in this specimen.

**Table 1. Distance of the Ramus Perforans between PIA–AIA and Wrist Crease**

| Specimen | Distance Ramus Perforans between PIA–AIA and Wrist Crease | Pedicle Length, cm | Pedicle Length after AIA Section, cm | Gain, cm | Gain, % |
|---|---|---|---|---|---|
| 1 | 6.2 | 13 | 16.8 | 3.8 | 30 |
| 2 | 6.8 | 14.4 | 17.8 | 3.4 | 25 |
| 3 | 6.1 | 13.3 | 16.7 | 3.4 | 26 |
| 4 | 6.9 | 13.7 | 17.1 | 3.4 | 25 |
| 5 | 5.4 | 11 | 14.4 | 3.4 | 30 |
| 6 | 7.3 | 16 | 19.1 | 3.1 | 21 |
| 7 | 6.3 | 14.1 | 17.7 | 3.6 | 26 |
| 8 | 6.5 | 14 | 17.9 | 3.9 | 28 |
| 9 | 5.5 | 13.5 | 15.5 | 2.0 | 13 |
| 10 | 6.5 | 7.2 | 9.5 | 2.3 | 24 |
| 11 | 6.0 | 11.5 | 13.5 | 2.4 | 15 |
| 12 | 5.5 | 5.2 | 7.5 | 2.3 | 30 |
| 13 | 6.5 | 5.3 | 8.0 | 2.7 | 33 |
| 14 | 4.5 | 6.5 | 8.0 | 1.5 | 18 |
| 15 | 5.5s | 7.5 | 9.0 | 1.5 | 16 |
| 16 | 7.0 | 7.5 | 9.5 | 2.0 | 21 |
| Mean value | 6.2 | 10.8 | 13.6 | 2.8 | 24 |

Pedicle length before and after AIA section. Note the main gain of length of 24% AIA section.
AIA, anterior interosseous artery; PIA, posterior interosseous artery.

**Table 2. Number of Communicating Arteries between AIA and PIA and Caliber of the Last Ramus Communicans**

| Specimen | No. of Communicating Arteries | Caliber of the Last Ramus Communicans, cm |
|---|---|---|
| 1 | 6 | 0.5 |
| 2 | 7 | 0.6 |
| 3 | 5 | 0.5 |
| 4 | 6 | 0.6 |
| 5 | 6 | 0.6 |
| 6 | 7 | 0.7 |
| 7 | 7 | 0.5 |
| 8 | 5 | 0.6 |
| 9 | 6 | 0.7 |
| 10 | 5 | 0.5 |
| 11 | 4 | 0.8 |
| 12 | 7 | 0.6 |
| 13 | 6 | 0.5 |
| 14 | 8 | 0.4 |
| 15 | 5 | 0.6 |
| 16 | 6 | 0.6 |
| Mean value | 6 | 0.6 |

middle phalanx without the need of exteriorization of the pedicle or hyperextension of the wrist.

## DISCUSSION

PIAF is already well known for being very useful in the coverage of tissue loss of the hand without sacrificing any of the principal vascular axis and for small areas where the use of free flaps is not necessary.

Although this flap has several advantages, it also has many drawbacks that make it unemployable in certain instances. Technically, the dissection of the pedicle along its course could present risks of ischemic flap necrosis, venous congestion, and damage to the interosseous posterior nerve. Subsequently, technical modifications have been described to overcome these problems. Recently, Sun et al[18] performed a cadaveric study of the PIA and septocutaneous perforators to provide the anatomical evidence for clinical use of PIA pedicle cutaneous branch–chain

**Table 3. Demographic and Clinical Data of the Patients Evaluated**

| Age, y | Sex | Type of Injury | Site | Flap Dimension, cm² | Minor Complications | Major Complications | Follow-Up, y |
|---|---|---|---|---|---|---|---|
| 33 | M | Posttraumatic tissue loss aspect with tendon exposition | Second finger, left hand: dorsal MCP joint | 21.2 | Flap edema | None | 2 |
| 42 | F | Postburn severe contracture | First web space, right hand | 20.4 | Venous congestion (spontaneous resolution after 24 h) | None | 1.4 |
| 53 | M | Posttraumatic tissue loss with tendon exposure | Third finger, left hand: dorsal MCP and PIP joint | 19.1 | None | None | 1.6 |
| 66 | M | Postoncologic demolition; exposure of extensor tendons | Second finger, right hand: dorsal MCP joint and P1 | 21.5 | None | None | 2.1 |
| 41 | F | Posttraumatic tissue loss | First finger, right hand: dorsal IF joint | 20.7 | Surgical wound infection (resolution after antibiotic therapy) | None | 1.7 |
| 52 | M | Postburn severe scar contracture | First web space, right hand | 19.7 | Bleeding at the harvest site | None | 2.3 |
| 57 | F | Complex hand trauma, residual tissue loss with tendon exposure. | Fifth finger, left hand: dorsal PIP and P2 | 18.9 | Moderate pain | None | 1.8 |
| 62 | M | Postburn severe contracture | First web space, left hand | 20.8 | Mild venous congestion | None | 1.5 |

Note that the area of the flap has been calculated as an ellipse ($\pi ab$ where $a$ is the half of the major axis and $b$ is the half of the minor axis). MCP; metacarpophalangeal. PIP; proximal interphalangeal; P1, proximal phalanx; P2, middle phalanx.

**Fig. 5.** Fifth finger dorsal bone exposure in a posttraumatic crushing.

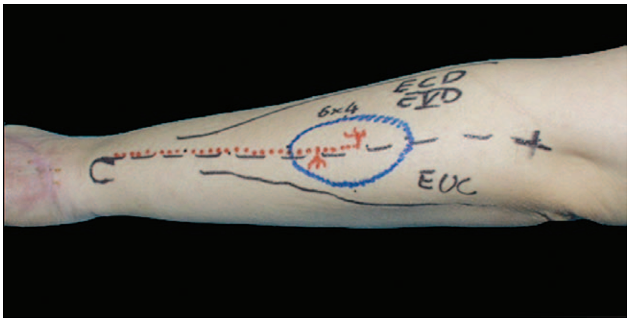


**Fig. 6.** Preoperative marking of PIAF, planning the proposed pedicle elongation.

**Fig. 7.** Long-term follow-up with excellent survival of PIAF.

perforator flap. This technique simplifies the dissection; however, it can be used only for the repair of small hand defects up to the metacarpophalangeal joint on the dorsum of the hand.

Acharya et al[14] proposed to perform a proximodistal flap dissection of the PIAF, avoiding dissection of the anastomotic arc between posterior and anterior interosseous arteries, creating a broad pedicle with a cutaneous handle, and avoiding its tunneling for inset to contribute to prevent venous congestions and increase flap survival.

Regarding the distal reach of the flap, the original version presents the metacarpophalangeal joint on the dorsum of the hand as the distal limit of the PIAF. Various changes in the flap design have been suggested to im-

**Fig. 8.** Good functional outcome after reconstruction with PIAF.

prove the reach of the flap. Brunelli et al[11] in 2001 and Puri et al[19] in 2007 showed that the PIAF could reach the distal interphalangeal joint by exteriorizing the pedicle and keeping the wrist in extension. However, a disadvantage of this technique is the 2-stage procedure.

Moreover, in 1991, Büchler and Frey[15] described another method to increase the distal reach of the PIA flap carrying the dissection distally along the transverse anastomotic branch. By this method, they could make the flap reach up to the proximal interphalangeal joint crease. However, the incidence of partial flap necrosis and major flap necrosis in their series is a little too high to justify such a distal dissection. In 1997, Gupta et al[20] described 1 case of PIA flap in which, to increase the pedicle length, they passed the pedicle through the interosseous membrane to cover a volar wrist defect after an electric burn injury. However, this solution makes the procedure more difficult and laborious.

In this anatomical study, we verify the constant location from the dorsal wrist crease and the reliable caliber of the connecting branch between AIA and PIA, representing an essential vascular supply of the PIAF.

The considerable vascular support of this anastomotic branch to the distal dorsal vascular network convinced us to study a new PIAF pedicle elongation technique preserving its integrity.

The proposed interruption technique of the AIA proximally to its distal communicating branch helps to preserve retrograde flow of both AIA and PIA (Figs. 2A, B). Moreover, the distal opening of interosseous membrane can permit the safe dissection and mobilization of the distal portion of AIA. The elongation of the pedicle constituted by both retrograde AIA and PIA may continue to ensure a valid perfusion to the PIAF and permits to reach much more distal defects of the hand without being afraid to stretch vascular bundle. This preserved vascular flow, through the connection with the anastomotic arcades of the AIA at the volar wrist, may reduce the risk of flap ischemia, overcoming the traditional limit of the arch of rotation of PIAF.

In our short clinical experience, we used this modified flap without encountering adverse events or major complications. Exteriorization of the pedicle or definitive interruption of the perforans between AIA and PIA was not necessary.

So, we advise the use of this technique of elongation of the pedicle every time there is a need for coverage of defects that reach the PIP joint or for severe first web space contracture to prevent the stretching of the vascular pedicle.

***Erica Dalla Venezia, MD***
Clinic of Plastic Surgery
Padua University Hospital
Monoblocco Ospedaliero, 5th floor
2, Via Giustiniani Street
Padova; I-35000, Italy
E-mail: erica.dallavenezia@gmail.com

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