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ORIGINAL ARTICLE

The place of local/regional perforator flaps in complex traumas of the forearm

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Abstract
Background Our aim was to conduct a retrospective study regarding the advantages of doing the all-in-one reconstruction in the same step with the debridement, and the possibility of using the local/regional perforator flaps to cover the tissue defects.
Methods We reviewed a series of 137 cases from 1999 until now, for acute traumas with tissue defects of the forearm. We performed a regional perforator flap in 16 cases, and a local perforator flap in 121 cases. These flaps were used for both simple and complex defects coverage, including 26 cases with fractures and devascularization.
Results The follow-up was between 2 months and 2 years. In all the cases the extremity was salvaged and an useful functional recovery was obtained. A very good evolution, with complete survival of the flap was recorded in 133 cases. We completely lost only one flap, and registered minor complications in three cases.
Conclusion The local perforator flaps represent a good and safe indication for small and medium defects in the forearm.

Keywords Complex forearm traumas · Emergency all-in-one reconstruction · Free flaps · Local/Regional perforator flaps

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Introduction

Most of the traumas of the upper limb are located in the forearm, and in their great majority they are very complex, involving skin, bones, muscles/tendons, vessels and/or nerves. These complex traumas result mainly from different engines, but especially from circular saw, and so they are susceptible to be severe contaminated, with disruptions of functional elements and, sometimes, associating multiple mechanisms as crush, entrapment, avulsion, torsion [1, 2]. Because of the local conditions in such traumas (extensive destruction, necessity of fasciotomy, and so on), it is generally accepted that the best method in covering the tissue defects is the free flap transplantation [3–11]. More, in case of defects involving also the vascular bundles, the use of some axial flaps as flow-through flaps in the attempt to solve both the coverage of tissue defect and the revascularization in the same time, proves to be a very useful method [12–15]. The same flow-through flap principle can be used also in cases with very large defects or with defects located at some distance, when two flaps are needed to solve the problem; in such cases, one of the flaps will be revascularized by the pedicle of another flap [8].

The new achievements in flaps surgery, with the development of the perforator flaps, allowed the possibility to minimize some of the disadvantages of the classical free flaps, referring especially to the donor site morbidity [16–21]. In the attempt to improve the results, especially regarding the reconstruction by replacing like with like, some surgeons started in the last time to use more and more the local or regional perforator flaps [22–32]. Of course this type of flaps can not be used in all the cases, because of the extension of the lesions, the need to perform the fasciotomy, and so on [6]. However, in very well selected cases, when the extension of the lesion is limited, and especially for the lesions in the distal third of the forearm, the use of such flaps can be successful.

This paper will present the possibility of using local perforator flaps in complex trauma of the forearm, even in cases with devascularization.

Patients and methods

From 1999 until now, more than 137 cases were treated in our service for acute traumas with tissue defects of the forearm. The age of the patients was between 4 and 87, and 85 were males and 52 females. A regional perforator flap (island fascio-cutaneous flap based on a fascio-subcutaneous pedicle vascularized through perforators from the radial and posterior interosseous artery) in 16 cases was performed. In the remaining 121 cases, a local perforator flap was performed: anterior interosseous perforator flap in 5 cases (Fig. 1); posterior interosseous perforator flap in 23 cases (Fig. 2); radial perforator flap in 59 cases (Fig. 3); ulnar perforator flap in 34 cases. Regarding the local flaps, those were used as V–Y advancement flaps in 5 cases, as transposition flaps rotated for less than 180 degrees in 38 cases, and as propeller flaps in 78 cases. The defects were: simple – with only bone or tendons exposure in 5 cases; complex, but without fractures or devascularization in 106 cases; more complex, including fractures, devascularization, and so on in 26 cases.

All the cases were solved in emergency as an immediate procedure, by performing the all-in-one reconstruction in the same operative step with the debridement.

The postoperative rehabilitation was started very early after surgery, allowing the obtaining of a good functional recovery.

Results

The follow-up was between 2 months and 2 years. In all the cases the extremity was salvaged and an useful functional recovery was obtained. A very good evolution, with complete survival of the flap was recorded in 133 cases. We completely lost a local radial perforator flap. Minor complications were registered in three cases with local perforator flaps: a partial distal necrosis, which solved by secondary epithelialization, and a superficial necrosis in two cases which was managed until granulation and then was grafted.

Case reports

Case 1

Circular saw injury in the middle third of the dorsal aspect of the forearm, in a 34-year-old man, with muscular and tendons disruption. After debridement and reconstruction of all damaged elements, the defect of 12/7 cm was covered with a 90° rotation transposition flap based on a perforator of the posterior interosseous artery; the donor site was covered with free split thickness graft. The postoperative evolution was very good, under very early passive and active, under control, mobilization. Complete rehabilitation in 6 weeks (Fig. 1).

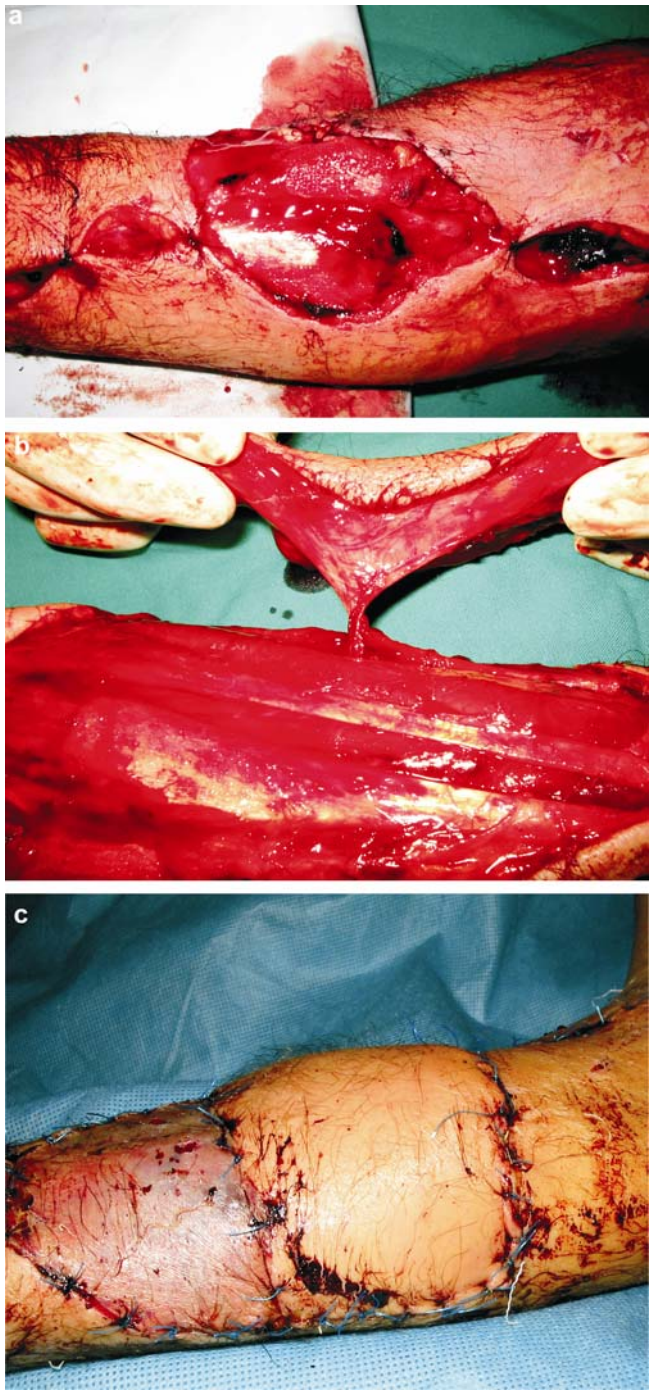

Fig. 1 Circular saw injury in the middle third of the dorsal aspect of the forearm, in a 34-year-old man, with muscular and tendons disruption: **a**. aspect of the remaining defect after debridement and reconstruction; **b**. harvesting of a posterior interosseous perforator flap based on a single perforator; **c**. 7th day postoperative aspect

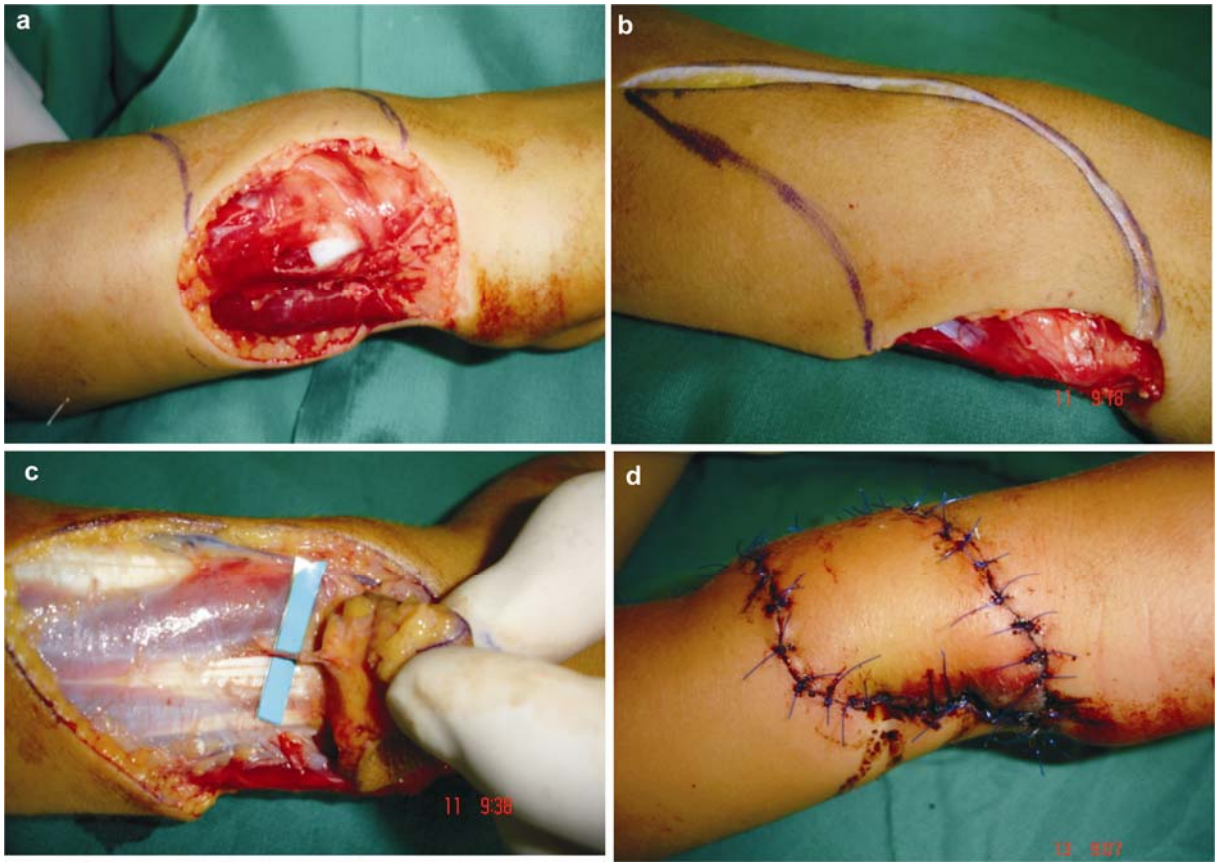

Fig. 2 Crush injury in 4-year-old boy, skin loss and exposure of the fractured ulnar process: **a**. remaining defect after debridement; **b**. the flap is harvested on a single perforator of the anterior interosseous artery; **c**. one week postoperatively

Case 2

Crush injury in 4-year-old boy, skin loss and exposure of the fractured ulnar process. After debridement, the defect was covered by using a VY advancement perforator flap based on a perforator of the anterior interosseous artery. The evolution was simple, with complete rehabilitation in 14 days (Fig. 2).

Case 3

Circular saw injury in the distal third of the anterior aspect of the forearm in a 27-year-old man with flexor tendons and median nerve disruption. After debridement, tendons' reconstruction and median nerve neuroraphy, the skin defect was covered by using a radial perforator flap. The flap was designed in the middle third of the forearm and was based on an intermuscular perforator of the radial artery. A skin bridge was kept between the donor and recipient site, and the flap was rotated 180° (propeller flap) and passed through the defect under this bridge. The donor site was split thickness skin grafted. The complete integration of the flap and skin graft, the rehabilitation program started very early, and the very good reinervation allowed the social reintegration of the patient after 4 months (Fig. 3).

Case 4

Subtotal amputation by circular saw in the forearm distal third in a 56-year-old man, with rheumatoid arthritis; the disruption of all flexor tendons, both the radial and ulnar arteries and both the median and ulnar nerves, cominutive fracture with defect of 5 cm of the distal ulna, partial fracture of the distal radius with a defect of 3 cm on its anterior aspect, and a skin defect of 12/8 cm was recorded. After eschilectomy (it was not possible to reconstruct the distal ulna, and so we abandoned it), the defect of the radial bone was grafted by using one of the ulnar eschiles as a small vascularized pedicled osteomuscular flap. All the tendons were reconstructed and the microsurgical suture of both arteries and nerves was done. The skin defect was covered by using a propeller flap based on a perforator of the ulnar artery, emerging from this one 2 cm proximal from the level of the arteriorraphy. The passive and active mobilization under control was started

2 days after surgery, and continued for 6 months, with the recovery of more than 80% from the hand functionality (Fig. 4).

Fig. 3 Circular saw injury in the distal third of the anterior aspect of the forearm in a 27-year-old man with flexor tendons and median nerve disruption: **a**. preoperative picture; **b**. after debridement and reconstruction of all elements, a radial perforator flap based on a single perforator is harvested; **c**. 3rd day postoperative aspect; **d**. two weeks postoperative picture

Discussion

Because of their great frequency and gravity, the forearm traumas have a big social impact. Generally, the mechanism of the injury is sufficiently aggressive (crush, entrapment, avulsion, torsion) [1, 2] to determine very important damages of the anatomical elements, with possible negative impact from functional point of view.

Despite the fact that nowadays the abdominal pedicled flaps are used only in few situations (contraindications related to the general status of the patient, thrombosis of the recipient vessels induced by the trauma itself), sometimes it is still possible to use these methods as salvage procedures [33].

It is admitted that, if the lesions are very extensive, with complex tissue defects, the single way to cover the defects and reconstruct all damaged anatomical elements is the use of a free flap transfer [3–11]. These flaps can be used for coverage purposes only or for coverage and vascular improvement of a devascularized segment or revascularization of a second consecutive flap (flow-through flap principle) [8, 12–15], but also as functioning transfers.

The use of perforator flaps in the last 25 years improved very much the results in free tissues transplantation, especially from the donor site point of view [16–21], but do not solve other means, as the sacrifice of a main vascular pedicle at the recipient site, the replacement of like with like and the shortening of the evolution and recovery period [26]. From this point of view, the local or regional resources respond better to most of these features, especially if they are used as the most recently described perforator flaps, which avoid the sacrifice of a main artery [26]. These flaps, especially if they are used as local transposition or advancement flaps, need a microsurgical dissection of the perforator but do not need microvascular sutures, and so they can be defined as 'microsurgical non-microvascular flaps' [26].

The vascular basis of these flaps is represented by the septal perforators (direct or septocutaneous) and muscle perforators (indirect or musculocutaneous) [21, 36], which are generally of little interest, excepting the brachioradialis branch derived from the radial recurrent artery. In the extremities the dominant blood supply is through the direct cutaneous vessels, which can be considered synonymous with the septocutaneous vessels [36]. The arterial perforators are accompanied by one or two venae comitantes with a lot of communicating branches between them; they realize a very rich venous plexus which drains into both the superficial and deep systems of veins [27, 29, 31, 32, 35, 37, 38]. The venous drainage in local perforator flaps is realized through direct flow.

These flaps were initially used as regional flaps, so as pedicled flaps, consisting in an island of skin based on fascio-subcutaneous pedicle [23, 26, 28, 32], or in only

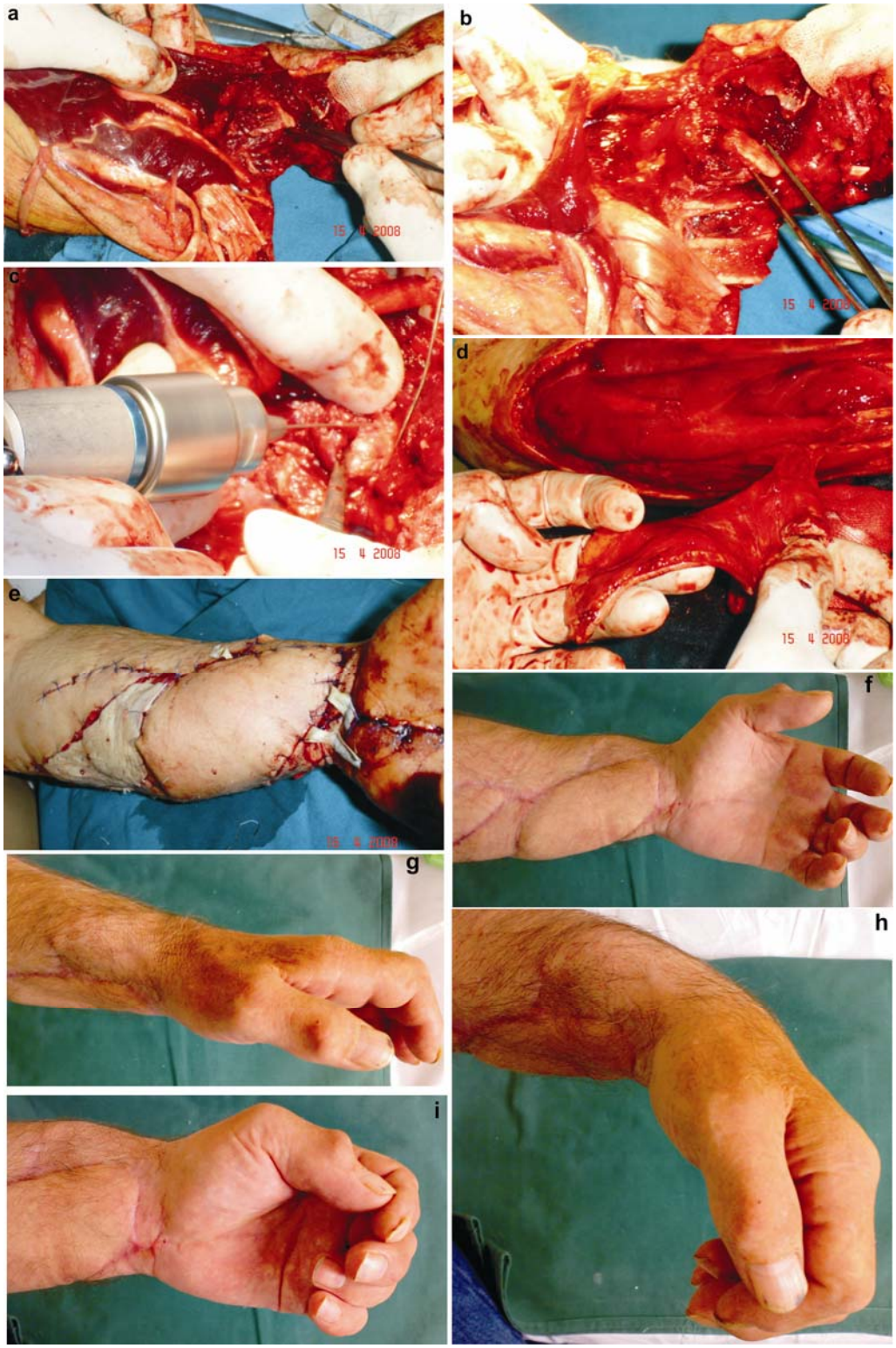

Fig. 4 Subtotal amputation by circular saw in the forearm distal third in a 56-year-old man, with rheumatoid arthritis: disruption of all flexor tendons, both the radial and ulnar arteries and both the median and ulnar nerves, cominutive fracture with defect of 5 cm of the distal ulna, partial fracture of the distal radius with a defect of 3 cm on its anterior aspect, and a skin defect of 12/8 cm: **a**. the debridement; **b**. a bone segment from the ulna is prepared as an osteo-muscular flap; **c**. the vascularized bone is placed on the radius fracture; **d**. after reconstruction of all damaged elements, an ulnar perforator flap based on a single perforator is prepared and harvested; **e**. 2nd postoperative day picture; **f**, **g**, **h**, **i**. degree of functional recovery after 4 months

the fascio-subcutaneous tissue [26, 27, 29–31] blood supplied through perforators originating from the distal part of the main arteries of the forearm, and which proved to be very successful in covering the tissue defects of the hand.

Later on, it was proved that based on perforators originating from the four main arteries of the forearm can be also harvested local transposition or advancement perforator flaps, very useful in covering the forearm defects [24, 26, 34], but in the same time for hand [24–26] and elbow [26, 32] defects. It was proved that these perforators blood supply not only the skin, but also the anatomic sector spanning between the skin and bone, which are well known as angiotomes [39] or angiosomes [40] and allow the use of composite flaps.

The question is if the local perforator flaps can be used in complex traumas of the forearm in which, sometimes, we are confronted with extensive involvement of the soft tissues and in which generally it is mandatory to perform a fasciotomy. Based on our experience, we consider that if the lesions are not very extensive and especially if they are located in the distal half of the forearm, a local perforator flap can be done, even in case of devascularized distal segments. Regarding the skin incisions and the fasciotomy, if we think to the possibility of performing such a flap, we have to do these accordingly with the design of the future flap.

Because of the well known variability in the position and size of the perforator vessels, another question can appear: is it useful to perform a preoperative detection of the perforators? A lot of methods were developed for this purpose as Doppler ultrasound [41], Doppler flowmetry [42], magnetic resonance imaging [43], thermography [44], color-flow duplex scanning [45], scanning laser Doppler imaging [46], but in the limbs, and especially in the forearm, because the main vessels are superficial situated, the results can be false positive or negative. More, in acute opened traumas, it is easier to identify and isolate the perforators through a minute dissection then to perform such investigations [26].

So, in conclusion, we think that the local perforator flaps represent a good and safe indication for small and medium defects in the forearm but, even for largest defects, and especially for those in the distal third of the forearm; the main condition is that the lesions are not very extensive, and if incisions and fasciotomy are to be performed, these should be very attentive planed. The main advantages of local perforator flaps are: the same operative field, the replacement of like with like, the respect of main vessels, the possibility of harvesting of such flaps even based on disrupted and/or sutured vessels.

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