Elbow defects reconstruction using pedicled perforator flaps

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Abstract

Soft tissue defects around the elbow are a real challenge in the field of reconstructive surgery. This anatomical region is passed by superficial noble anatomical structures (arteries, veins, nerves) that are often exposed in post-traumatic or post-excisional defects. The elbow joint has a high tendency to stiffness or ankylosis even after short immobilization. The pedicled perforator flaps, based on source vessels from the anatomostic arcades of the elbow seem to be an efficient and reliable reconstructive choice. The flap offers a good local coverage, replacing “like with like”, has minor donor site morbidity and contrary to the free flaps, allows the very early beginning of physical therapy starting with the first postoperative day. This paper represents a review of the literature concerning this problem.

Keywords: elbow reconstruction, propeller flap, elbow arterial supply.

Introduction

The elbow reconstruction represents a demanding procedure for the plastic surgeon [1]. This region is covered by thin and mobile tissues that respond to its increased mobility [2]. In addition, in the cubital area lie an abundance of noble anatomical structures: arteries (brachial, ulnar, radial), veins (cephalic, basilica, median cubital) and nerves (median, ulnar, radial). The elbow joint beneath has an increased tendency to stiffness or ankylosis.

In order to have a good coverage of the elbow, there are two demands. The first is to use good tissue to protect the noble structures, replacing “like with like”. The second is a fast postoperative rehabilitation in order to prevent joint stiffness. Over the last decades, surgeons were in search of an ideal flap that would be able to respond to these requirements. Excepting the skin graft that has limited use in the elbow, random, axial and free musculocutaneous flaps [7]. Free musculocutaneous flaps [7]. Mcgregor & Jackson described the axial flap, which offered an increased length with cost of sacrificing the main artery [5]. Another step forward was realized by Orticochea, when he described the musculocutaneous flap [6]. The best results in this area were achieved with free musculocutaneous flaps [7]. In 1989, Koshima & Soeda [8] described the first perforator flap as a free tissue transfer flap. Since then, a large variety of local and regional perforator flaps were used. However, at the sharp end of reconstructive surgery are the pedicled perforator flaps. The first tentative was published by Hyakusoku et al. [9] in 1991, which described a random pattern propeller flap. Hallock first reported a 180° rotation of a pedicled perforator flap around its pedicle [10]. Only late, in 2009 “1st Tokyo meeting on perforator and propeller flaps” settled the definition of a propeller flap: a skin island blood supplied by a perforator pedicle that has to rotate through at least 90° to 180° [11]. Georgescu et al. called the pedicled perforator flap a microsurgical non-microvascular procedure [12] to reinforce two goals of the technique: first, the difficulty of pedicle dissection demanding high microsurgical skills and second the absence of microvascular anastomosis. This absence of arterial and venous anastomosis is the main benefit of the pedicled perforator flaps by reducing dramatically the intraoperative time and by allowing physical rehabilitation from the first postoperative day [11, 12]. For the coverage of small, medium and even in some cases, big soft tissue defects of the elbow [1] the propeller pedicled perforator flaps have to be harvested from the arm or the forearm. The “mother vessels” [13] of the perforators’ pedicles has to be the brachial, the radial, the ulnar artery or the arterial anatomostic arcades of the elbow.
Vascular anatomy of the elbow

The brachial artery, which lies on the medial aspect of the arm, arrives in the cubital fossa. Here, it divides in the radial and ulnar arteries. The radial and ulnar arteries (as well as its branches: common, anterior and posterior interosseous arteries) form the main bundles of the forearm [14]. Between these main vessels, three anastomotic arcades are described: the medial, the lateral and the posterior [15]. The medial arcade is formed by the anastomosis of four arteries: the superior and inferior ulnar collateral arteries on one hand and the anterior and posterior ulnar recurrent arteries on the other hand. The lateral arcade is the result of the anastomosis between radial recurrent and the terminal part of profunda brachii. The posterior arcade is formed by the anastomosis of the recurrent interosseus and the collateral branch of the profunda brachii [14–17].

Cutaneous arterial territories of the elbow region

Taylor & Palmer made a significant step forward in understanding the vascular perfusion of the integument by developing the angiosome theory [18]. The angiosome is a block of soft tissue (situated between the periost and the integument) that is supplied by the same arteriovenous source. This arteriovenous source is a perforator bundle formed by a perforator artery and usually two concomitant perforator veins. In some cases, there were described from one to six concomitant veins for a single artery [8]. The adjacent angiosomes are all linked deep by a source vessel and superficial by a network of “choke vessels” [18, 19]. The understanding of the concept gave the possibility of harvesting larger flaps. In 2009, Saint-Cyr et al. reconsidered the angiosomes, concentrating more on perforator vessel as on the source vessel [19]. On experimental studies, Saint-Cyr et al. delimited the vascular territory of a single perforator and denominated it “perforasome”. Using angiomicro-CT scans “linking vessels” were identified between neighboring perforasomes [19]. The direction of the linking vessels for the upper limb was found to be axial, respecting the direction of the source vessel. In the proximity of joints, the blood flow in the linking vessels is centrifugal, while for the perforasomes located central in a limb segment the blood flow is bidirectional [19]. The linking vessels are susceptible to preferential filling when they have a common source vessel, compared to linking vessels connecting perforator pedicles arising from different source vessels.

In the harvesting of propeller flaps, when only one perforator pedicle is preserved, the perfusion in this perforator will increase. The increased blood pressure in the supplied perforasome will open the linking vessels in an axially direction [20]. This mechanism of integument vascularization explains the possible large dimensions of some flaps [20].

A challenge for both anatomist and plastic surgeon was to map the perforasomes of the human body. Imagistic and cadaveric studies in the elbow region found constant perforator pedicles that arise from the following sources:

1. The brachial artery (BA) sends from two to 10 perforators for the skin above the medial bicipital groove, from the deltoit muscle to the cubital fossa [11, 12, 14, 18, 19]. The profunda brachii artery (PBA) brings an important perfusion to the posterior aspect of the arm. It sends from two to six perforators [11, 12, 14, 18, 19]. The posterior radial collateral artery is the main branch of the profunda brachii. It sends two important perforators for the skin of the infero-latral aspect of the arm [11, 12, 14, 18, 19]. The superior ulnar collateral artery sends two to three perforators for the medial aspect of the arm [11, 12, 14, 18, 19]. The inferior ulnar collateral artery sends one to three perforators for the medial aspect of the elbow [11, 12, 14, 18, 19].

2. The radial artery (RA) supplies the lateral aspect of the forearm. It is one of the plastic surgeons preferred artery because it offers a wide range of free and pedicled flaps. It sends numerous perforators starting from the cubital fossa until the radial styloid process [11, 12, 14, 18, 19]. Saint-Cyr et al. demonstrated that these radial perforators are group in two distinct clusters: one proximal, another distal [21]. The proximal group sends perforator vessel (either muscular or septocutaneous) that vascularize the proximal third of the forearm. Cormack & Lamberty first described the inferior cubital artery (ICA). It is a large, constant perforator artery (originating in 70% of the cases direct from the radial artery) that can supply flaps extending up to 10 cm inferior to the cubital fossa [22].

The radial recurrent artery anastomosis with the radial collateral artery. It sends two strong perforators used as flap pedicles [11, 12, 14, 18, 19].

3. The ulnar artery (UA) supplies the medial aspect of the forearm. Despite its large diameter, it only sends from two to eight perforators, penetrating de flexor carpi ulnaris muscle [11, 12, 14, 18, 19], situated on a line that joins the pisiform bone and the medial epicondyte. Sun et al. identified to perforator clusters situated in the proximal third of the forearm [23, 24]. The common interosseous artery has a short course (approximately 1 cm) and gives no perforator branches [12, 13]. The anterior interosseous artery (AIOA) only gives a dorsal perforating branch distally, at the level of pronator quadratus muscle. This perforator has no use in the coverage of the elbow [11, 12, 14, 18, 19]. Both the posterior interosseous artery (PIOA) and the interosseous recurrent artery supply the posterior aspect of the elbow as well the superior-posterior aspect of the arm by three to six perforators [11, 12, 14, 18, 19]. Since the AIOA vascularize the distal dorsal aspect of the forearm as well as the wrist, the PIOA sends four to six perforators that supply the proximal third of the dorsal forearm. The anterior ulnar recurrent artery sends two to three perforators for the medial aspect of the elbow. It anastomoses with the ulnar inferior collateral artery [11, 12, 14, 18, 19]. The posterior ulnar recurrent artery sends three to four perforators for the upper medial aspect of the arm and eventually anastomosis with the ulnar superior collateral artery [11, 12, 14, 18, 19].

All these perforators are able to vascularize a viable perforator flap. It comes to the nature of the defect and the surgeons experience to choose the most convenient flap. Figures 1 and 2 show cadaveric studies with identifications of perforator pedicles having arterial sources the anastomotic arcades of the elbow region.
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- **Pedicled perforator flap harvesting technique**

  The surgeon should not overlook the possible variation in vascular anatomy. In the preoperative routine clinical tests, as well as paraclinical examinations should be considered. Always a second therapeutically option should be treated [25].

  The use of preoperative Doppler sonography for perforator identification is still debated [21, 25]. Some surgeons rely on intraoperative dissection to identify the vessels [21, 26]. Firstly, only one incision, on one edge of the future flap is performed. Under loupe magnification and blunt dissection, all the perforators are identified. The most convenient perforator is chosen according to its caliber and location. Only after choosing the perforator bundle, the flap design is concluded, respecting the axial orientation of the linking vessels. The perforator is further dissected towards the source artery until a minimum length of 2 cm (for arm and forearm) is reached. Then, the flap is transposed or rotated 90° to 180° to cover the defect, with great attention not to kink the perforator. Closer under tension on both recipient and donor site should be avoided in order to prevent ischemia. As an alternative, the donor site can be covered with a skin graft when is wider than 4–5 cm [10, 13, 21]. Figure 3 shows postoperative results in a 39-year-old male patient suffering from a large soft tissue defect on the posterior aspect of the elbow. After debridement, the defect was covered with a pedicled perforator flap that was rotated with 90°. The donor site was covered with a skin graft (Figure 3).

- **Which flaps should we use?**

  On a search on PubMed, with the keywords *elbow* and *flap*, 521 results were found. When we tried to search the free flaps for elbow reconstruction, 162 results were obtained. Only 12 articles dealing with the propeller flaps for elbow reconstructions were found.

  Even the benefits of the propeller flaps are clear it seems that not many surgeons prefer this technique. We consider this is partially because its novelty and partially because the demanding perforator skeletonization during the dissection.
From the articles we were found relevant data, we searched which source vessels were used for the flaps, the rotation of the flap, the closure method of the donor site and the survival rate.

Aslan et al. presented seven cases of elbow defect coverage. The source of the bundle was not specified. All the flaps were rotated with 90° and no necrosis occurred [27]. A flap published by Ayestaray et al. was harvested based on a perforator from the radial collateral artery (RCA) and rotated with 180° over the defect. No complications occurred and donor site was closed with direct suture [28]. Boucher et al. [2] and Chaput et al. [29] both presented each a clinical case based on profunda brachii (PB) respectively on radial collateral (RCA) perforators flap. Mateev et al. reported a series of 12 posterior ulnar recurrent artery perforator flaps (PURA) that were rotated with 180° [30]. Murakami et al. used the RCA flap in two cases [31]. Hyakusoku et al. reported a case of post-burn contracture that was excised and then covered with BP based flap [32]. A group of nine cases with flaps based on the RCA was published by Wettstein et al. in 2014 [33]. Zang et al. used the BP perforator flap in two cases [34]. Georgescu also used the BP perforator flaps with rotation between 90° and 180°. The table below shows the complete results [27–34] (Table 1).

Table 1 – Propeller perforator flaps in the elbow. Arterial source, flap rotation, complications and donor area closure

<table>
<thead>
<tr>
<th>No.</th>
<th>Cases</th>
<th>Source artery</th>
<th>Flap rotation</th>
<th>Flap necrosis</th>
<th>Donor site closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>7</td>
<td>–</td>
<td>90°</td>
<td>No</td>
<td>DS</td>
</tr>
<tr>
<td>2.</td>
<td>1</td>
<td>RCA</td>
<td>180°</td>
<td>No</td>
<td>DS</td>
</tr>
<tr>
<td>3.</td>
<td>1</td>
<td>PB</td>
<td>180°</td>
<td>No</td>
<td>DS</td>
</tr>
<tr>
<td>4.</td>
<td>1</td>
<td>RCA</td>
<td>180°</td>
<td>No</td>
<td>DS</td>
</tr>
<tr>
<td>5.</td>
<td>1</td>
<td>RCA</td>
<td>180°</td>
<td>No</td>
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<td>6.</td>
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<td>RCA</td>
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<td>No</td>
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<td>7.</td>
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<td>PB</td>
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<td>No</td>
<td>Skin graft</td>
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RCA: Radial collateral artery; PB: Profunda brachii; PURA: Posterior ulnar recurrent artery; DS: Direct suture.

The pedicled perforator flaps for elbow reconstruction are a very reliable option for the plastic surgeon. In the data published in the literature, no flap necrosis was reported which source vessels were used for the flaps, the rotation of the flap, the closure method of the donor site and the survival rate. Aslan et al. presented seven cases of elbow defect coverage. The source of the bundle was not specified. All the flaps were rotated with 90° and no necrosis occurred [27]. A flap published by Ayestaray et al. was harvested based on a perforator from the radial collateral artery (RCA) and rotated with 180° over the defect. No complications occurred and donor site was closed with direct suture [28]. Boucher et al. [2] and Chaput et al. [29] both presented each a clinical case based on profunda brachii (PB) respectively on radial collateral (RCA) perforators flap. Mateev et al. reported a series of 12 posterior ulnar recurrent artery perforator flaps (PURA) that were rotated with 180° [30]. Murakami et al. used the RCA flap in two cases [31]. Hyakusoku et al. reported a case of post-burn contracture that was excised and then covered with BP based flap [32]. A group of nine cases with flaps based on the RCA was published by Wettstein et al. in 2014 [33]. Zang et al. used the BP perforator flap in two cases [34]. Georgescu also used the BP perforator flaps with rotation between 90° and 180°. The table below shows the complete results [27–34] (Table 1).

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Conclusions
The wide interest for this relative new technique in reconstructive surgery demonstrates its efficacy. The pedicled perforator flap in elbow coverage is an optimal alternative to the free flaps. It offers excellent cosmetic and functional results and shorter operative time.

Conflict of interests
The authors declare that they have no conflict of interests.

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References
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