CUTANEOUS VASCULAR TERRITORIES OF THE FOREARM AND HAND

Costache Chertif¹, Alexandru V. Georgescu²

INTRODUCTION

Initially used almost exclusively as free flaps, the perforator flaps have been also used in the last years as local transposition or regional pedicled flaps. However, the use of the perforator flaps has been improved after the description and the understanding of the cutaneous vascularization.

One of the first complete descriptions of the blood supply of the skin was done by Manchot, who described the source vessels and their branches coursing through the muscles to reach the skin, but the first describing also the finer framework of anastomosing vessels within the skin was Salmon, who...
used the lead oxide injection technique.\textsuperscript{1,2}

Despite the numerous studies regarding the blood supply of the skin in various regions of the human body, this is still incompletely understood, necessitating a new development nowadays.\textsuperscript{3-11}

A lot of regional or local flaps are used nowadays in hand and forearm reconstructive surgery, especially as perforator flaps, but the data regarding the overall architecture of arterial cutaneous perforators are still insufficient.\textsuperscript{12-16} Many studies were done in the attempt to find the main perforators able to sustain such flaps, but the method of injecting lead oxide-gelatin described by Salmon and modified by Rees and Taylor seems to be the most reliable.\textsuperscript{2,3,5,6,17,18,19}

The goal of our study was to find the main perforators in the hand and forearm through a series of ten upper extremities from fresh cadavers, injected with lead oxide-gelatin, and to document the number of perforators of sufficient caliber to sustain local/regional perforator flaps.

\section*{MATERIALS AND METHODS}

We have dissected and studied the cutaneous vascularization at the level of the upper limb in 10 fresh human cadavers segments injected with lead oxide and gelatin. (Fig. 1)

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig1.png}
\caption{Angiogram of the skin of the upper extremity: general aspect.}
\end{figure}

The Ethics Committee of the Emergency County Hospital from Baia Mare, together with the Department of Pathological Anatomy, approved this study.

The cadavers with peripheral vascular diseases, poly-traumas of the upper limb or with metastasis at the level of the upper limb were eliminated from the study.

In the first stage, the axillary vascular pedicle was dissected, then the axillary artery was incised longitudinally and a Foley catheter was introduced in its proximal part. A cannula was introduced into the axillary vein. The axillary artery was flushed abundantly with 5-10 l water in carbonated solution (9\% KCl), with continuous pressure until a clear liquid was obtained in the axillary vein.\textsuperscript{17-20} Immediately afterwards the segment was introduced into warm water at 38\(^\circ\)C in order to maintain the mixture of lead oxide – gelatin in liquid state, allowing its spreading throughout the whole vascular system of the segment, without solidifying.\textsuperscript{21-23} After injection, the segment was refrigerated for 24 hours at 4\(^\circ\)C, and then was X-rayed after the important anatomic osseous landmarks were positioned. The areas intended to be studied were X-rayed before dissection in order to have a general image of the respective vascular anatomy. (Figs. 1-3) One must take into account the fact that the angiograms obtained can be confusing to analyze, because of the tri-dimensional overlapping of the multiple vessels visualized. During the dissection that followed, X-ray photographs and sequential digital photographs were taken in order to increase the degree of pointing out the tissue areas to be studied. (Fig. 4) The parameters observed during the study were: the number of perforators, the length and the diameter of the pedicle at the level of the deep fascia, the area vascularized by each perforator, the ratio between muscle-cutaneous and septocutaneous perforators.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig2.png}
\caption{Angiogram of the upper extremity showing cutaneous branches of the ulnar and radial artery.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig3.png}
\caption{Angiogram of the forearm showing cutaneous branches of the posterior interosseous artery.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig4.png}
\caption{The perforators during dissections, sequential digital pictures are being taken. The arrow indicates one of the perforators.}
\end{figure}

\section*{RESULTS}

The length of the superficial pedicle of each perforator was measured directly during the dissection, and the vascular territories were measured directly on the X-ray images by calculating the average value. The diameter of the vascular pedicle was measured directly during the dissection at the level of the deep fascia.
As a result of the study carried out, we have found at the level of the forearm and of the hand nine vascular territories with an average number of perforators of $25 \pm 9$, with a diameter of $0.6 \pm 0.1$ mm, generally vascularizing a cutaneous area of about $30 \text{ cm}^2$. It was evident that the perforators became smaller from proximal to distal.

The septo-cutaneous perforators occur predominantly at the elbow level, in the inferior third of the forearm and in the hand, with a ratio of 4:1, while the muscle-cutaneous ones prevail in the proximal third of the forearm, with a ratio of 7:3. A detailed presentation of the data obtained can be found in Table 1. We compared our results with those obtained by Geddes and al.24 The results are presented in the Tables 2-7.

The great majority of perforators emerging from the same source artery anastomoses longitudinally with

<table>
<thead>
<tr>
<th>Source Artery</th>
<th>Average Number of Perforators with Diameter ≥ 0.5 mm</th>
<th>Superficial Length mm</th>
<th>Diameter mm</th>
<th>Total area cm²</th>
<th>Musculocutaneous/septocutaneous</th>
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<tbody>
<tr>
<td>IUCA</td>
<td>2</td>
<td>28±2</td>
<td>0.7±0.1</td>
<td>45±5</td>
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<td>0.6±0.1</td>
<td>47±10</td>
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<tr>
<td>RA</td>
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<td>28±6</td>
<td>0.6</td>
<td>115±6</td>
<td>4/3</td>
</tr>
<tr>
<td>UA</td>
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<td>20±1</td>
<td>0.4</td>
<td>135±3</td>
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<tr>
<td>PIOA</td>
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<td>AIOA</td>
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<td>0.4</td>
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</table>


<table>
<thead>
<tr>
<th>Nr. of perforators</th>
<th>Pedicle superficial length (mm)</th>
<th>Diameter mm</th>
<th>Total area cm²</th>
<th>Ratio musculocutaneous/septocutaneous</th>
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<tr>
<td>Present study</td>
<td>2</td>
<td>28±2</td>
<td>0.7±0.1</td>
<td>45±5</td>
</tr>
<tr>
<td>Geddes et al²⁴</td>
<td>2</td>
<td>28±2</td>
<td>0.7±0.1</td>
<td>45±5</td>
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<td>4±3</td>
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<td>115±6</td>
</tr>
<tr>
<td>Geddes et al²⁴</td>
<td>5±5</td>
<td>32±25</td>
<td>0.6±0.2</td>
<td>180±68</td>
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<td>20±1</td>
<td>0.4</td>
<td>135±3</td>
</tr>
<tr>
<td>Geddes et al²⁴</td>
<td>7±2</td>
<td>27±14</td>
<td>0.6±0.2</td>
<td>186±58</td>
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each other, and some others anastomose transversely with perforators emerging from other source arteries; this fact is especially true for the radial and ulnar arteries. (Figs. 2, 3)

In the proximal part of the forearm we found mainly perforator branches from the inferior collateral ulnar artery and the radial recurrent artery. (Fig. 5)

At the dorsal aspect of the wrist we found a very nice network—the dorsal carpal arch—formed by perforators emerging from the main axial arteries of the forearm, as follows: type 1 formed by the anastomosis of the dorsal carpal branches of the radial artery with the anterior and posterior interosseous arteries, in 70% of the specimens, and type 2 formed of branches of the ulnar or radial artery, in 30% of the specimens. (Fig. 6)

In the hand we found perforators from the dorsal intermetacarpal arteries, but also more distally, at the level of commissural spaces and the proximal half of the first phalanx, emerging from the arches realized between the volar and dorsal system of vessels of the fingers. (Fig. 7) Also, more distally, at the level of fingers, we found well developed perforators emerging from the collateral digital arteries. (Fig. 7)

**DISCUSSION**

The aim of this anatomic research was to assess the cutaneous vascularization of the forearm and of the hand, with practical applicability in carrying out perforator flaps at this level.
Compared to other studies, we have found less perforators at the level of the forearm and with the superficial length of the vascular pedicle also smaller.\textsuperscript{3,8,10,11,24} It is possible that these differences appear because of the different modality of injecting the contrast substance, but also probably because we could not see the perforating vessels having a diameter less than 0.4 mm during the dissections despite the fact that the dissections were done with a magnifying apparatus. Otherwise, the data obtained overlap those from the literature.

We have found a variable distribution for the perforators at these levels, but relatively constant for each one of the main vessels. Regarding the forearm, other anatomical studies found the same constant distribution for the main vessels, but with overlapping of the adjacent territories of these vessels.\textsuperscript{3,11,24} Similar to Kanellakos et al, we found that the number and diameter of the perforators decreases from proximal to distal, but compared with other studies, we have noticed differences both regarding the number of perforators, the length and the diameter of the vascular pedicle and of the area blood supplied for each perforator.\textsuperscript{11,2,24,26} A comparison between our results and those obtained by Geddes et al is presented in Tables 2-7.\textsuperscript{24}

Based on these results, we found as in other previous studies, that the main arteries of the forearm (i.e., radial, ulnar, posterior and anterior interosseous arteries) are involved in the blood supply of the forearm, with a predominance for the radial artery.\textsuperscript{12,16,27} More, as Geddes et al have shown, there are also perforator branches from the inferior collateral ulnar artery and from the radial recurrent artery.\textsuperscript{24} (Figs. 5,6) At the hand level our finding are similar to other authors: in the proximal half of the long fingers, there is a well represented anastomotic network between the dorsal metacarpal arteries and the palmar common digital arteries and the collateral digital arteries.\textsuperscript{26,30} The perforators emerging from this network give branches which realize longitudinal anastomoses able to blood supply the dorsal skin over the intermetacarpal spaces. Based on these perforators, perforator metacarpal flaps can be designed, which are similar, as design and donor area, with the classical metacarpal flap, but they can be used in covering more distal defects in both palmar and dorsal aspect of the long fingers, and allow an early postoperative mobilization, due to the situation of the vascular pedicle distally to the metacarpophalangeal joint. It is possible to harvest two such types of flaps: (1) fasciocutaneous pedicle flaps and (2) fasciocutaneous transposition flaps. The first ones are very useful in covering the very distal defects in the fingers and the second ones in the reconstruction of the web spaces and first phalanx. Both of them can be used as composite flaps by including small vascularised metacarpal segments.

**REFERENCES**

3. Taylor GI, Palmer JH. The vascular territories (angiosomes) of the