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Chapter 2.1

An Anatomical Approach to Arteriovenous Fistula Performance in the Forearm.

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ABSTRACT

Background: Arteriovenous fistulae (AVFs) play a key role for people who rely on chronic haemodialysis. Stenosis in the venous outflow of the AVF will cause an alternative route of the subcutaneous blood flow via the deeper venous pathways by means of side branches and the perforating veins (PVs). The purpose for the present study was to define the number and anatomical localisation of the perforating veins in the forearm.

Methods: Twenty forearms were dissected to study the venous anatomy. The localisation, size and connections of the perforators were recorded and stored digitally.

Results: In total, 189 PVs were defined (mean, 9.5 per arm; range, 6–19), with 60 (32%) PVs connected to the cephalic vein, 97 (51%) connections to the basilic vein and 32 (17%) PVs to the median vein of the forearm. Most PVs originate from the basilic vein and connect with the ulnar venae comitans. The cephalic vein connects equally to the radial venae comitans, interossea veins and the muscles.

Conclusions: The cephalic vein has the fewest PVs and almost a third of them connect to the muscles. This is probably important for the maturation of the AVF, the superficial flow volume and the accessibility for puncture.

INTRODUCTION

Successful access for haemodialysis largely depends on the patient's venous flow in the upper extremity. To ensure vascular access with sufficient blood flow in patients who need chronic haemodialysis, an arteriovenous fistula (AVF) has to be created. Impaired vascular access is the main factor for surgical or radiological intervention.[1] The most distal site for a fistula is the anatomic snuffbox, followed by the Brescia–Cimino fistula.[2] In 15.3% of cases, the radiocephalic AVF fails due to early thrombosis and failure to mature.[3] The maturation depends, among other factors, on sufficient flow, by means of a good inflow pressure and a sufficient upstream resistance.[4, 5] This delicate balance could be easily disturbed, resulting in low inflow pressure or insufficient upstream resistance, caused by alternative routes, such as side branches and the perforating veins or communicating veins. Perforating veins as found in the leg are the connections between the superficial venous system, such as the cephalic, basilic and median vein, and the deep venous system, known as the venae comitans, near the radial and ulnar artery.[6-8] So far, no studies have examined the exact location and amount of the perforating veins in the forearm. It seems likely that they play a role in the direction of flow downstream of an AVF. To assess the relationship between the venous systems in the forearm, an anatomical study was performed to review the number, size and localisation of the perforators on the ventral and dorsal side in the forearm.

METHODS

Materials

In this study, 20 forearms (10 male and 10 female) from human embalmed specimens were dissected. The area of interest was between the styloid process of the ulna and radius and the medial and lateral epicondyl. We were especially interested in the venous pattern of the forearm because of its possible implications of primary AV fistula construction and performance. On the other hand, upper arm fistulae are usually created for secondary autogenous dialysis access.[9] In addition, the group contained 10 left and 10 right forearms. If a forearm showed any signs of surgical intervention or macroscopic signs of vascular disease, it was excluded from the study. We defined a perforating vein as a connection, through the fascia, between the superficial venous system and the deep venous system, as described above. The branches from the superficial system, which did not perforate the fascia, are defined as side branches. At the commencement of dissection, the skin and the subcutis were removed. The cephalic, basilic vein and median antebrachial veins remained attached to the forearm and the perforators were marked by coloured pins.

Computer-Assisted Surgical Anatomy Mapping (CASAM)

All 20 forearms were photographed by using a standardised setting. The camera, a Canon 350D with a Zoom EF-S lens, was placed on a tripod 1 m above the forearms and horizontally aligned, so that all the photographs were comparable. To create an average forearm, all the pictures were marked by using bony landmarks, that is, the styloid process of the ulna and radius, the medial and lateral epicondyl. Magic Morph 1.90 (ITinySoft) software was used to warp 20 forearms into one average forearm. Hereafter, all the perforating vein markers are displayed on the average forearm with Photoshop CS3 to create an overview of the localisation of all perforating veins. In addition, the lumen-size diameter (<1 mm, 1≥ mm) and number of the perforators were identified by using a calliper. Besides the perforators, the localisation and size of the vena mediana cubiti profunda was defined by using the method mentioned above.

RESULTS

Topographic Anatomy

The cephalic veins connect equally with the radial venae comitans and interossea veins on the dorsal side of the forearm. A third of the cephalic vein perforators disappear in the muscles on both sides, in contrast to the basilic perforators, which connect mainly to the interossea veins on the dorsal side and the muscle fibres. The smallest number of perforators from the basilic vein

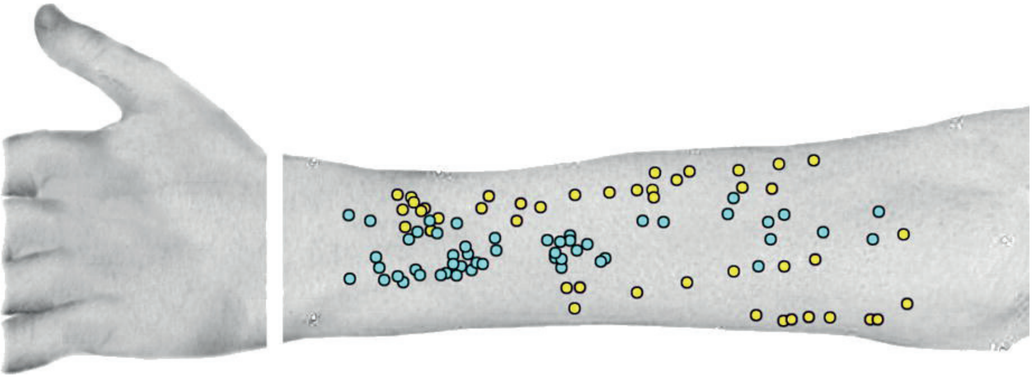

Figure 1. Localisation of the perforating veins at the dorsal side of the upper extremity. Turquoise: PV which connect with the interossea vein, yellow: PV disappearing in the muscles.

connects to the ulnar venae comitans. Similar to the cephalic vein, 31 perforators connected with the basilic vein disappear in the muscle fibres.

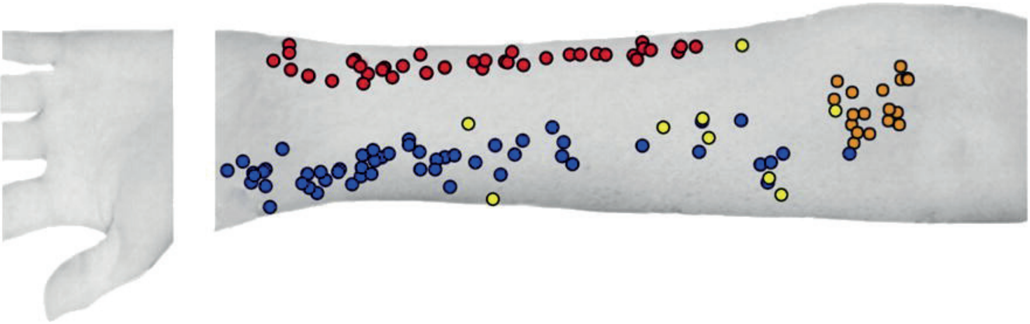

Figure 2. Perforating veins at the ventral side of the upper extremity.
The red dots depict the perforating veins to the a. ulnar venae comitans. Perforating veins that connect to the a. radial venae comitans are colored blue. The yellow dots are the perforating veins that disappear in the muscles and the orange dots are the cubiti media profunda veins.

	Cephalic vein Mean [range]	Basilic vein Mean [range]	Median antebra-chial vein Mean [range]
Perforating vein connections			
ulnar venae comitans	0	1.35 [1-5]	0
Radial venae comiatns	1.05 [0-4]	0	1.15 [0-3]
V. interossea	0.9 [0-2]	1.95 [1-4]	0
Muscles	1.05 [0-3]	1.55 [0-4]	0.45 [0-1]
Total	**3 [1-11]**	**4.85 [1-9]**	**1.6 [0-3]**
Side branches	**4.4 [1-7]**	**4.2 [1-8]**	**3.1 [1-5]**
Size of the perforating veins			
< 1 mm	1.7 [1-3]	3.05 [2-5]	0.9 [0-2]
≥ 1 mm	1.3 [0-2]	1.8 [1-4]	0.7 [0-1]

Table 1. Connections of the superficial venous system with the deeper venous system in the forearm. (Numbers, size and connections of the perforating veins in the forearm).

Median antebrachial veins connect mainly to the radial venae comitans (n = 23) and with a small number to the muscles. Most perforating veins originating from the three veins are <1 mm in diameter. The coordinates of the perforators on the dorsal side of 19 upper extremities are depicted in Figure 1. This diagram shows a more or less organised plot with most connections, based medial of the forearm, to the interossea vein and a higher density at the proximal part of the lower forearm. The diagram of the ventral perforators (Figure 2) of 19 forearms shows a different plot when compared with the dorsal side. Most perforators are located at radial or ulnar side on the ventral side of the forearm. In all 20 forearms, a media cubiti profunda vein was found with a mean diameter of 3.6 (range, 2–5) mm. In 70% of the cases, the media cubiti vein branched off the cephalic vein and 30% are connected to the median antebrachial vein with a connection with the comitant veins. A constant localisation of the media cubiti profunda (Figure 2) has been found at the fossa cubiti. In two cases, the media cubiti profunda vein was divided into two connections.

DISCUSSION

As most complications after AVF formation arise from stenosis or thrombosis of the fistula or the venous outflow of the fistula, the importance of patent venous blood flow in the forearm related to fistula maturation is clear. Similar to the venous circulation in the leg, the perforating veins of the forearm may play an important role in the fragile relationship between deep and superficial venous circulation. However, in contrast to the extensively studied situation of the leg with its well-known Cocket et al.[10] perforating veins, as far as we could find in literature, no study has described the exact anatomic location of the perforators on the dorsal and ventral side of the forearm. Other studies have confirmed the presence of perforators in the forearm, yet have never described the anatomy. An extensive study done by Taylor et al.[11] investigated the venous architecture of the integument and the deep tissues in six total-body human fresh-frozen anatomic specimen. The sites of the venous perforators were plotted and traced to their underlying parent veins that appear to accompany the source arteries. Further, a series of cross-sectional studies were performed to determine the course of the perforators between integument and deep tissue. Valentino et al.[6] confirm the connection between the radial venae comitans and the superficial system, and the presence of valves found in the perforating veins indicates a flow from superficial to deeper venous structures.

In the present study, a similar connection between the ulnar and radial vena comitans and the superficial system was observed. Due to the fact that, in this study, we registered the veins smaller than 1 mm, we found much more perforator veins than expected. Most of the cephalic perforator veins connect with the radial venae comitans and the muscles and on the opposite side, the basilic perforator veins connect mainly with the ulnar venae comitans vein and the interossea vein. Further, half of the connections have a diameter of 1 mm or greater, which probably has a significant role in the venous flow. The cephalic vein has fewer connections with the deeper venous system compared with the basilic vein. Aside from this, most connections are smaller than 1 mm. This can be a factor in maturation of a radiocephalic shunt. The mediana cubiti profunda vein was constant regarding its location and diameter in all arms. This vein was present in all arms, had a mean diameter of 3.6 mm and connected the deep comitant veins with the cephalic vein in 70% and with the median cubital vein in 30% of cases. This perforating vein is used as the anastomotic site with the brachial artery in the brachiocephalic elbow fistula,[12] Perforating veins as ascribed may play a role in the adjustment of the venous flow when the outflow is increased. On the other hand, perforating veins may have a detrimental effect on maturation by diverting blood to the deeper vascular structures. To establish which compensatory mechanisms apply to this situation, it would be useful to investigate the function of perforating veins during the maturation of the fistula. In this study, we therefore attempted to quantify and localise the perforating veins to be able to create a haemodynamic model in the future.

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