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ORIGINAL COMMUNICATION

Clinical Anatomy of the Dorsal Venous Network in Fingers With Regard to Replantation

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The arterial system of fingers is anatomically well described, and so, usually no difficulties arise during its preparation and the making of anastomoses in replantation surgery. Difficulties may occur, however, during manipulation in the dorsal vascular bed of fingers, known only as a random venous network. There are minimal references to its existence and the location of its valvular apparatus. Using a microscopic preparation, a contrast staining, and a histological assessment, topographic relations and the course of veins of the dorsal venous network, as well as the existence and location of their valvular apparatus, was investigated on 72 three-phalanx fingers. The specimens were either harvested from fresh cadavers or traumatically amputated. We found that veins of rather significant caliber predominantly run along the dorsal aspect of the finger on both the radial and ulnar sides above the proximal phalanx of three-phalanx fingers. Proximally, venous systems of respective neighboring fingers connect in the interdigital space. The valvular apparatus was found at all levels ranging from metacarpophalangeal joints to the distal phalanx. The valves were always located distally from the confluence of two veins. Aside from this confluence, the existence of valves was not observed. The exact description of architecture of this venous system, in practice, contributes to faster orientation, better preparation, and the creation of safer anastomoses of these structures, and thus, to an increased success of replantation. Clin. Anat. 19:000–000, 2006.

Key words: microsurgery; finger replantation; replantation; venous anatomy; venous valve

INTRODUCTION

Replantation microvascular surgery dealing with the anastomoses of arteries and veins of a diameter < 1–2 mm (and in the case of distal finger phalanges, sometimes even as small as 0.3 mm) has a very long history (Buncke, 1986, 1995; Tamai, 1993; Sukop et al., 2004). The actual beginning dates back to 1960, when J. H. Jacobsen and E. L. Suarez from the University of Vermont proved by their experimental work the possibility of suturing veins with a diameter < 1 mm, using a new thin sewing material and a microscope. However, it was not until 27 June 1965, that S. Komatsu and S. Tamai in Japan became the first in the world to perform a successful replantation of a left-hand thumb in the metacarpophalangeal (MP) joint (Komatsu and Tamai, 1968). Nowadays, replantation counts among the routine interventions in amputation hand injuries.

The knowledge of vascular pathways anatomy is one of the prerequisites of such treatment. The finger

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arterial network is described in detail, unlike the venous system (Adachi, 1928). Anatomical textbooks and topographical atlases deal very briefly with this topic; they generally do not characterize any specific topography but merely mention a venous network—*rete venosum dorsale manus*—without providing further details (Davis, 1924; Maksimenkov, 1949; Hamilton, 1956; Sinělnikov, 1965; Feneis, 1996; Platzer, 1996; Petrovický, 2001; Čihák, 2002; Netter, 2003). Other sources purvey only a few studies into this issue (Zancolli and Cozzi, 1982; Moss et al., 1985).

During a finger replantation, namely of its distal phalanges, no difficulties with the arterial supply usually arise, but problems occur upon the reconstruction of venous drainage (Cheng et al., 1985; Sukop et al., 2002). Although it is possible to perform the anastomosis of the dorsal venous system in many cases, sometimes only the anastomosis of the palmar system can be carried out. In some cases it is even necessary to use an arteriovenous shunt to achieve the adequate finger drainage (Fukui et al., 1990; Koshima et al., 1992).

The objective of the present study is to complete and specify the topography of the dorsal venous network in fingers, namely the course of veins on various anatomical levels, including the microscopic and histological verification of the valvular system of the finger veins, with a view to clinical needs and application in finger replantation. The more exact the description of the veins' location, the more able a surgeon is to determine a surgical strategy more easily and to increase the number of successful performances (Matsuda et al., 1993).

MATERIALS AND METHODS

Three-phalanx human fingers were examined. These were divided into two groups by their origin. The first group consisted of fingers amputated from live people by a traumatic mechanism, where the replantation could not be executed, either due to an unsuitable local finding or due to the patient's other serious illnesses, which caused contraindication of the replantation ($n_1 = 10$). The second tested group consisted of fingers amputated from fresh cadavers ($n_2 = 62$). In total, 72 fingers from 21 hands were examined, out of which 16 were index fingers, 18 were middle fingers, 26 were ring fingers, and 12 were little fingers.

The fingers were studied by microdissection under a microscope, by injection of a contrast substance (Indian ink dissolved in a physiological solution 1:1) and by histological examination, with the objective of investigating the dorsal venous system. We observed the number of blood vessels, the diameter of their lumen, and the possible presence of venous valves.

Two different methods were used to detract finger tissue. First, using magnifying lenses, only the skin cover was dissected in the beginning of the examination, so as to preserve the subcutaneous tissue with the venous system for the further injection of veins with the contrast chemical. This type of dissection was very lengthy and fine branches of veins were sometimes damaged, which lead to a misinterpretation of results. For this reason, a new method of tissue removal was developed in which the skin was incised exactly on the boundary of the palmar and dorsal skin along the sides of fingers from the lunula to the MP finger joint. The dissection of fine and thin connective tissue between the subcutis and the extensor proceeded easily and so the examined structures were not damaged. The finger venous bed was then examined from the extensor aspect without the necessity to remove the skin cover.

Forty-two fingers were examined (6 amputated and 36 from fresh cadavers) by a simple dissection under the microscope without using a contrast substance, but rather a normal saline solution, so as to minimize the disruption of the valves. Only the valves that were found were separately stained by Nile blue dissolved in gelatine.

The venous systems of another 32 fingers (4 amputated and 26 from fresh cadavers) were injected with Indian ink dissolved in a physiological solution 1:1. For this purpose, a cannula was inserted in a retrograde direction into a cephalic vein, a basilic vein, or directly into the dorsal vascular pathways at the level of proximal phalanges.

The histological examination was carried out at five standardized levels:

1. The distal interphalangeal (DIP) joint.
2. The centre of the middle phalanx.
3. The proximal interphalangeal (PIP) joint.
4. The centre of the proximal phalanx.
5. The MP joint.

In these 32 fingers, the skin with the whole subcutis was removed. At levels described earlier, small blocks of tissues of 4–5 mm in size were taken vertically to the longitudinal axis of individual fingers.

The tissue was fixed in 4% neutral formaldehyde and then processed by a standard histological technique and embedded into a mixture of paraffin and paraplast. Parallel sections of 5–10 μm were cut off for further histological examination and stained by haematoxylin–eosin. Choice samples containing valves were processed by further standard methods; blue trichrome was used to demonstrate the structure of the vascular wall and Van Gieson staining to prove the

TABLE 1. Number of Blood Vessels of Respective Diameters in the Dorsal Venous Bed in Relation to the Total Number of Vessels on a Given Finger Level

	Examination level[a] (number of examined fingers)				
	A (43)	B (56)	C (56)	D (56)	E (34)
Arithmetic mean of number of vessels on the level in one finger (total number of vessels on the level)	4.16 (179)	5.79 (324)	6.48 (363)	6.20 (347)	5.20 (177)
Ratio of the number of vessels in group I (0.3–0.5 mm diameter) and the total number of vessel on the level (number of vessels in group I)	55.30% (99)	48.46% (157)	50.96% (185)	41.79% (145)	37.29% (66)
Ratio of the number of vessels in group II (0.6–1 mm diameter) and the total number of vessels on the level (number of vessels in group II)	32.96% (59)	38.27% (124)	36.36% (132)	35.45% (123)	35.03% (62)
Ratio of the number of vessels in group III (over 1 mm diameter) and the total number of vessels on the level (number of vessels in group III)	11.73% (21)	13.27% (43)	12.67% (46)	22.77% (79)	27.68% (49)

[a]A, distal interphalangeal joint; B, middle phalanx; C, proximal interphalangeal joint; D, proximal phalanx; and E, metacarpophalangeal joint. Values in parentheses indicate.

presence of elastic fibers. The presence of endothelium was proved by the standard three-step immunohistochemical method (ELISA) using the specific antibodies against factor VIII (von Willebrand factor) and CD 34 (human progenitor cell antigen) (Sigma, St. Louis, MO). Streptavidin–biotin marked with peroxidase (Universal LSAB+, DAKO) and chromogen DAB (Sigma) were used as the detection system (Lukáš et al., 1997). These samples were examined and assessed under a light microscope (Olympus SZ-10J) with a morphometrical gauge, focusing on the number and size of individual vessels and also on the occurrence of venous valves at a predetermined localization.

RESULTS

An ample venous network with steadily repeating patterns of the vascular organization and location of the valvular apparatus was discovered on the dorsal aspects of fingers. The topographical anatomy of the dorsal venous system, including the position and presence of valves, was the same for the second to fifth fingers. It was, therefore, unnecessary to separate each group of fingers. The results were applicable on all three-phalanx fingers.

The average number of vessels on respective finger levels (A: DIP; B: the centre of the middle phalanx; C: PIP; D: the centre of the proximal phalanx; and E: MP) has been further divided into three groups according to the diameter of the vascular lumen (I, 0.3–0.5 mm; II, 0.6–1 mm; III, over 1 mm) (Table 1). Two veins of diameters over 1 mm run along both the radial and ulnar sides of each proximal phalanx, leading to the interdigital space where the veins of neighboring fingers connect. The predominance of the lateral venous system around the proximal phalanx was proved by the comparison of centrally and laterally located vascular trunks, by the measurement of diameters of single vessels, and by the measurement of vessels under the microscope during microdissection. These veins form an arch above a distal third of the proximal phalanx. A dominant venous bed around the middle and distal phalanges is oriented centrally (Fig. 1).

The valvular apparatus was found and verified by the microscopic and histological examinations in all investigated veins at all followed levels (extending from the MP joints to the distal phalanx). The valves were always located distally from a confluence of two veins. The existence of valves outside of this site was not observed (Fig. 2).

The valves had two typical cusps (Fig. 1, zoom). A continuous transition of endothelium to the valve surface was documented at the insertion of the valve into the vascular wall, which was confirmed by the immunohistochemical detection of factor VIII. The valves consisted of elastic connective tissue with sporadic smooth muscle cells (actin, blue trichrome, and van Gieson elasticity) (Fig. 3).

We found no differences in the character of the venous network between the fingers taken from fresh cadavers and those amputated traumatically. The model of dissection applied proved useful both in a de facto healthy terrain and in post-traumatic conditions. Since clinical practitioners carry out blood vessels anastomoses of diameters 0. 3 mm and larger, our study did not concern any smaller diameters of vessels.

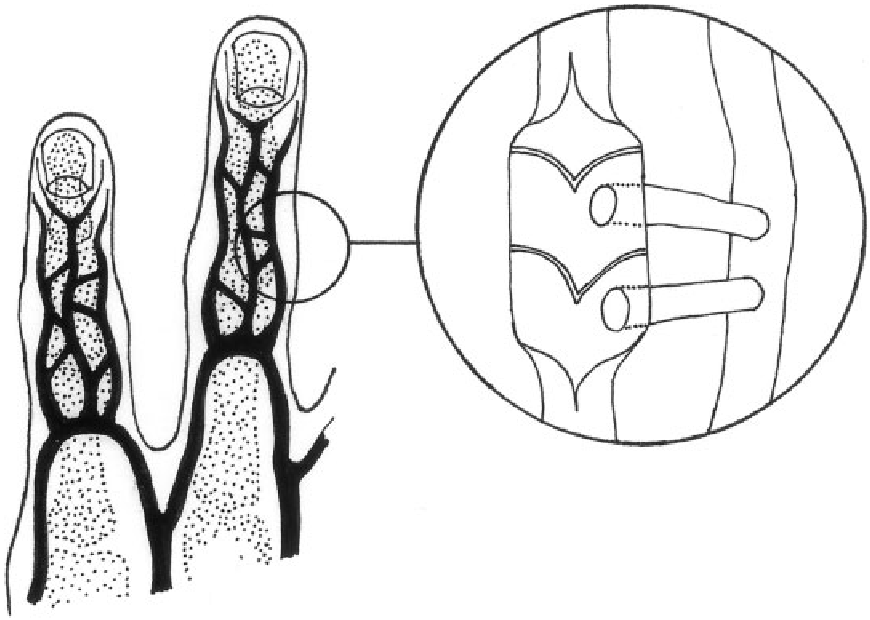

Fig. 1. A diagram of a venous network at the dorsal aspect of a three-phalanx finger. Zoom (1:4) shows a detail of valves in a partly dissected vein. Valves are always located distally from the confluence of two veins.

DISCUSSION

The reconstruction of venous drainage is among the most difficult aspects of finger replantation. This is due to a fine and easily vulnerable venous wall and small calibers of vessels requiring a great deal of skill and special surgical training. At present, the choice of where the preparation takes place largely depends on the surgeon's experience, which may not always correspond with the real situation. Further complications in terms of tissue loss have a negative impact both on hand function and the mind of the patient.

In the dissection of veins on the dorsal aspect of a finger, which is difficult, it is sometimes possible to identify its position based on the venous bleeding following the removal of a vascular clamp from the anastomosed artery. This procedure facilitates better orientation and location of the vein required for anastomosis; however, it often leads to a thrombosis in the anastomosis. The thrombosis develops due to a repeated placement of vascular clamps back onto the artery, which brings about a blood stasis in the artery until the anastomosis to the venous bed is opened. It is optimal to quickly remove the vascular clamps from the artery and vein after anastomosis, one after another, to reduce the possibility of early thrombosis at the place of endothelial continuity broken by the vascular suture.

Unawareness of the existence of the valvular apparatus may cause undesirable complications. For instance, it may be erroneously regarded as a vascular intima damaged and pulled out from a vascular wall, despite a radical resection of a vessel. An incorrect treatment is followed by thrombosis. In our experience, when such complications were surgically revised, valves that had been stitched through were found. Paradoxically, this may happen if prior to performing the last suture, the vessel is filled with a liquid so as to prevent a vascular collapse and a consequent suturing of the opposite vascular wall. The liquid splays off the valves pressed on the vascular wall, and thus, the valves may get caught in the suture, reducing the blood flow and later leading to thrombosis.

The valves are always situated distally from the bifurcation of veins, and therefore, the surgeon is able to locate their position exactly. To avoid difficulties during the anastomosis of veins, which could be connected with later complications (e.g., thrombosis) it is better to resect this part and replace it with a vein graft (Cooley, 1998). This procedure significantly increases the success of the replantation. Most importantly, contused ends of the veins are sufficiently resected, the part containing valves is removed, anastomosis is done safely, and suture is done without tension. For the venous outflow of the replantation of three-phalanx fingers, the dominant dorsal venous system or arteriovenous shunts are used almost without exception. The palmar digital venous system, well described by Nyström et al. (1990) is used only rarely for the delicate vein wall and small-diameter veins.

CONCLUSIONS

We proved on 72 three-phalanx human fingers that more important veins run above the proximal pha-

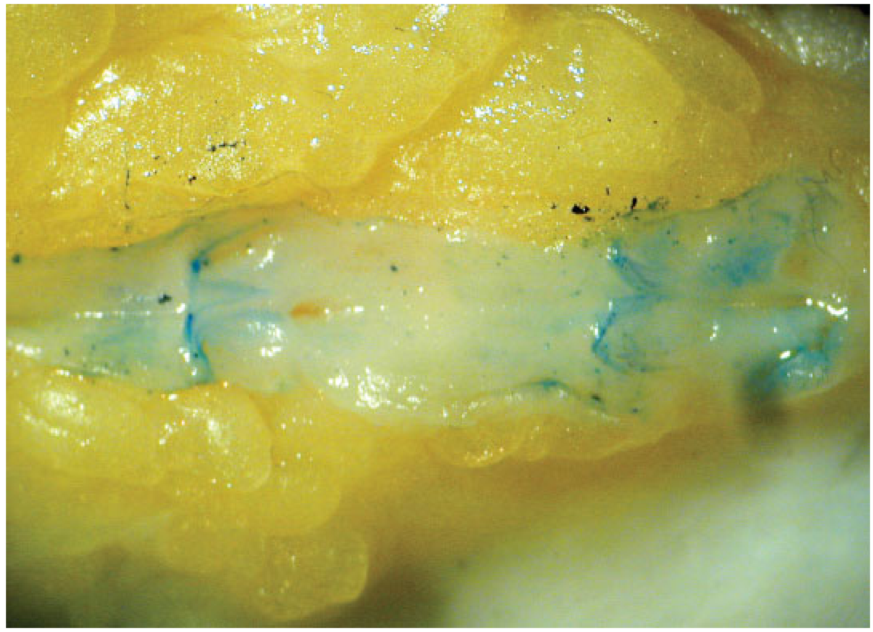

Fig. 2. Detail of the valvular apparatus in the area of the middle finger phalanx.

lanx, predominantly along the dorsal aspect of the finger on both the radial and ulnar sides. Proximally, venous systems of neighboring fingers connect in the interdigital space.

During the examination of the dorsal venous system of 72 three-phalanx fingers, the same topographical relations were found. Above the proximal finger phalanx, on the radial and ulnar sides, there were two veins (one on each side) significantly bigger in diameter. These veins created an arcade in the area proximal to the PIP joint. At the interdigital level, these veins are confluent (the vein from the radial side of one finger connects to the vein from the ulnar side on the adjacent finger). From the venous arcade, the main venous system was situated centrally above the PIP joint and the middle and distal phalanx.

The valvular apparatus was found on all levels ranging from MP joints to the distal phalanx. The valves were always located distally from the confluence of two veins. The existence of valves outside this site was not observed. The clinical significance for the surgeon is that it is possible to exactly localize

Fig. 3. Histological examination of a cross-section of the vein in the dorsum of the proximal phalanx (index finger) with the valvular apparatus (haematoxylin–eosin staining).

the position of the valves according to the confluence of veins. Anastomosis of the veins where the valves are situated should be resected and a vein graft used.

The exact topography and morphology of the venous network is very important for clinical practice because it facilitates a faster orientation and a safer dissection of these very fine and easily vulnerable structures. It thus enables an easier determination of the appropriate surgical strategy and the higher success of microsurgical interventions.

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