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Exploring the Microangioarchitecture of the Vasa Vasorum of the Human Great Saphenous Vein by SEM and 3D Morphometry of Vascular Corrosion Casts

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The history of investigation of the general architecture of *vasa vasorum* (VV) started fluently in the 2nd half of the 19th century, when the improved quality of vascular injections enabled the detection of the microvascular bed in practically all organs including the vascular wall [1].
The detailed arrangement of the *vasa vasorum* of the human subcutaneous veins was described, however, during the last decades of the 20th century [2-4]. At that time the higher concern in their morphology was introduced namely by the progress in both the experimental and clinical vascular surgery. The *vasa vasorum* were studied, above all, in the coronary arteries [5-7], and in frame of the investigation of the systemic arteriosclerosis and hypertension [8, 9].
In the veins the *vasa vasorum* were studied on the human great saphenous vein (*Vena saphena magna*, HGSV) from the experimental as well as clinical point of view, e.g. the morphological background for the nutrition of the venous wall during the in situ grafting by the surgical treatment of the obliterative disease of lower extremities, and by harvesting the venous grafts for aorto-coronary bypassing [10-16].
The detailled spatial arrangement of the *vasa vasorum* of the HGSV was demonstrated in qualitative and quantitative terms. Segments of the human great saphenous veins taken from patients undergoing aorto-coronary bypass surgery were studied by scanning electron microscopy and 3D morphometry of vascular corrosion casts. Arterial feeders were found to approach the HGSV from nearby arteries each 15 mm. Feeders branched and formed a rich three-dimensional capillary network within the adventitia and the outer and middle layers of the media in normal HGSVs, while in HGSVs with intimal hyperplasia capillary meshes extended also into the inner layers of the media. Within the media capillary meshes ran predominantly circularly. Postcapillary venules always drained centrifugally towards the adventitial venous vessels which finally merged and formed venous drainers which ran close aside the arterial feeders (Fig.1). 3D-morphometry (M3) of vascular corrosion casts of VV revealed that diameters of (i) arterial VV ranged from 11.6µm-36.6µm, (ii) capillary VV from 4.7-11.6µm, and (iii) venous VV ranged from 11.6-200.3µm. Thus, the dense three-dimensional network of VV within adventitia and media of the HGSV identifies these layers as metabolically highly active tissues which depend on a continuous blood supply. This implies that the VV network must be preserved when harvesting HGSVs for aorto-coronary bypass grafting to foster re-anastomoses of VVs at the implantation sites. VV in the innermost layers of the media of HGSVs are most likely generated by neo-angiogenesis provoked by hypoxia of smooth muscle cells of these layers due to intimal hyperplasia [17].
Measurement of total branching angles and consecutive optimality calculation (Fig.2) showed a clear tendency that venous *vasa vasorum* expresses rather an optimal design in respect to minimum lumen surface and minimum endothelial drag than an optimal design in respect to a minimum lumen volume and minimum pumping power [18].

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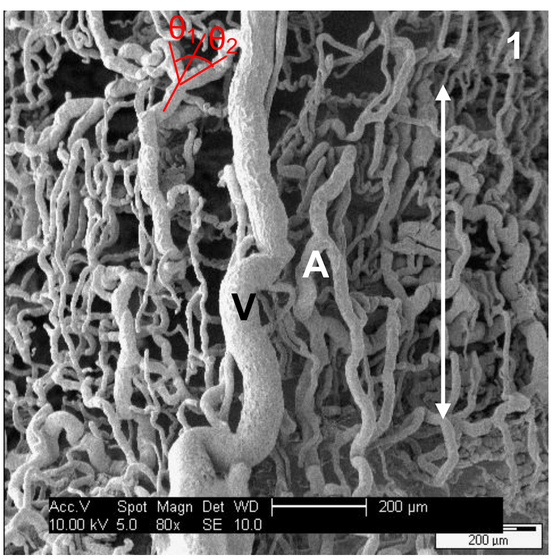

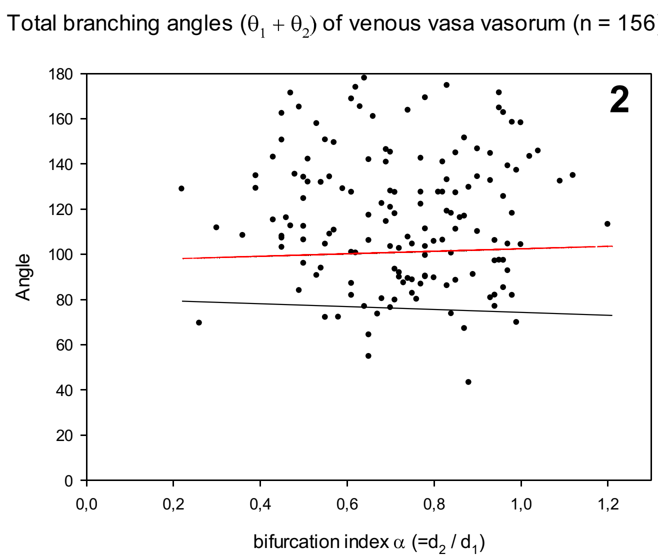

Figure 1. Architecture of the VV of a segment of the HGSV. Adventitial view. Vascular corrosion cast (VCC). Scanning electron microscopic (SEM) image. The white arrow marks the longitudinal axis of the HGSV. A artery, V vein. $\theta_1 + \theta_2$ total branching angle. Bar: 200 µm.

Figure 2. Total branching angles of bifurcations of venous VV plotted against the bifurcation index α (d2/d1). Lower black line: an optimal design in respect to a minimum lumen volume and minimum pumping power; upper red line: an optimal design in respect to minimum lumen surface and minimum endothelial drag.

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