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Experimental Studies of the Effects of Abnormal Venous Valves on Fluid Flow

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The effects of variations in the venous valve anatomy are studied experimentally using an artificial system that mimics the bicuspid valves normally found in veins in the lower extremities. The artificial valves are constructed from thin-walled, latex tubing and polyurethane film. The experimental variables in the study are the gap width between the leaflet attachments at the vein wall and the ratio of the sinus depth to vein diameter. The results show that the antegrade mass flow rate is not affected to the same degree when compared to retrograde flow by the various valve configurations examined in this study. The results also indicate that increases in the gap width, which serve to increase the degree of imperfect wall attachment, have less effect on retrograde mass flow rate in valves with deeper sinuses.

1. Introduction

Initial arthroscopic investigations of in vitro human veins by visualization methods reveal that physical differences in venous valves occur naturally from one individual to the next and within an individual. One of the observed differences is the attachment of the valve leaflets to the vein wall. While most of the valve leaflets meet at a specific point in the vein wall, it was observed in some specimens that the leaflets attached to the vein wall in such a manner that a gap appeared between the leaflets. Gaps may be found at either one or both ends of the leaflets. Since the occurrence of these gaps is infrequent, gaps between the leaflets are considered an abnormality for the purposes of this study. **Hypothesis:** It appears that when there are variations in the geometry of the venous valve, flow behavior and ultimately valvular competency are not only dependent on the surface area of contact between the two halves of the leaflets but also on the gap width between the two halves at the site of attachment to the vein wall.

Other natural variations include the depth of the sinus behind the valve that may vary as a result ofcongenital under- or overdevelopment of the venous system (*1*). The anatomy and physiological function of the venous valve play key roles in the overall performance of the venous system in returning blood from the extremities to the heart (*2*).

It is well-known that conditions such as deep venous thrombosis and chronic venous insufficiency are related to poor performance of the venous vein and valve (*3*). This motivates a study to quantify how structural differences such as gap sizes and sinus pocket depths affect valvular competency and ultimately retrograde and antegrade flows. Since real veins and valves carry different histories of their hosts (neurological, histological, and chemical effects), isolating the effect of these physical variations requires samples that share a similar distribution, i.e., samples that share the same history. Biological specimens cannot be guaranteed to have the same history, and thus this study employs an artificial venous valve and vein system to avoid unknown variability. The design and construction is described in section 2.2. To distinguish between the artificial system and the real venous system in subsequent discussions, the artificial vein will be termed the collapsible tube and the artificial venous valve will be termed a membrane with two halves. Each half of the membrane represents the venous valve leaflet. Figure 1 illustrates some important differences between the real vein and venous valve and the artificial ones.

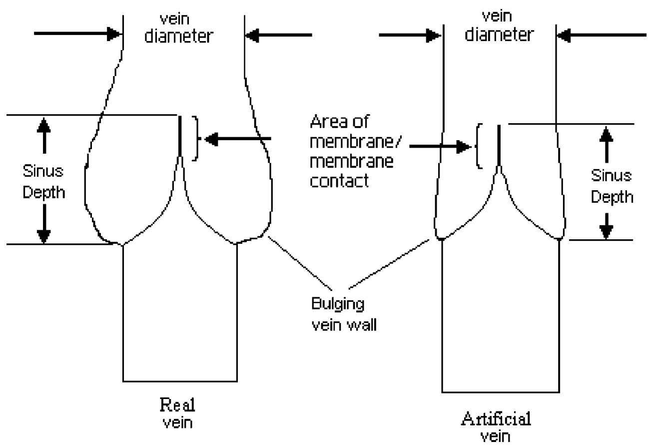

Figure 1. Comparison between the natural valve and vein (left) and the artificial system (right). The extent of bulging by the artificial system is less. Greater sinus depth gives more membrane to membrane contact, reducing retrograde flow at the expense of increasing the resistance to antegrade flow.

Previous experimental research has shown that valve closure and column segmentation are central concepts in venous physiology (*4*). Thus, static and dynamic studies are required to characterize the properties of the valves and to confirm valve behavior under various conditions. Raju et al. (*4*) conclude that the collapse of the tube below the valve is the primary pressure regula-

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