Experimental Evaluation of the Physiologic Response of the Venous Valve

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Abstract

There is inadequate understanding of the mechanisms that cause veins and venous valves to fail. Problems related to vein and valve failure include deep venous thrombosis (DVT), chronic venous insufficiency (CVI), leg ulcers, and pulmonary embolism (PE).

The primary objective of this research is to develop a fundamental understanding of the hemodynamics of venous blood flow. To achieve this objective, a fluid flow circuit is used with an artificial vein and valve system to simulate the basic features of biological venous fluid flow. It is widely known that biochemical reactions regulated by blood borne enzymes affect parameters such as vascular geometry, viscosity of blood and elasticity of blood vessels. One of the main benefits of the artificial system is that the experiments give results that are based solely on the mechanical effects of the venous valve geometry and avoids the effects of blood borne enzymes.

This work is a collaboration with the Texas Tech Health Sciences Center. This collaboration has assisted in the design of an artificial system that closely approximates the actual biological system. This collaboration also allows for the validation of the artificial system by comparison with harvested *in vitro* human specimens of venous valves that are tested in the experimental fluid flow circuit.

Current medical imaging technology such as ultrasonic duplex scanning, allows doctors to non-invasively define and characterize the dimensions of deep vein valves *in vivo* [1]. However, there is a gap in knowledge that allows for relating how these dimensions affect the competency of the valves. Competency is a measure of valvular performance and indicates how well a valve prevents retrograde flow, thus regulating venous pressure and assisting the venous system to return blood to the heart from the extremities of the human body.

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Preliminary experimental fluid flow studies indicate that valve geometry has a significant effect on valvular competency of a single valve in a single segment of a collapsible tube [2]. These studies were conducted on artificial, one-way, bicuspid structures that employ thin, compliant, polymer tubes as artificial veins and valves.

The artificial system permits the production of valves with varying degrees of competency and also the ability to investigate valve to valve interactions. These interactions are important because biological systems contain multiple valves. If a particular valve in the venous system is to be characterized, doctors and researchers should know how valves both distal and proximal will affect the studied valve. Experiments are conducted involving two or more valves in series and two or more valves in parallel (occurs when two vein segments come together to form a single vein). These experiments involve a viscous fluid in combination with "micro" particles that act as surrogate blood cells and other particulate matter found naturally in blood. This combination closely simulates the non-Newtonian nature of blood. The particles in the fluid also make it easier to observe flow patterns that occur as the fluid passes through the valve. The visualization provides insight into how the flow patterns change at different positions within the vein, including in the valve sinus, which is where DVT is known to initiate [3].

A fluid flow apparatus is developed represent a venous system with multiple valves and segments. The data collected from the experiments will be used to determine the feasibility and effectiveness of a novel, non-invasive prophylaxis designed to increase blood circulation efficiently and thus mitigate or prevent DVT. The results of the fluid flow experiments will also be used to validate theoretical models of hemodynamic flow in collapsible tubes with internal restrictions. Ultimately, the experiments will provide improved understanding of the behavior of venous valves in the role of venous return to the heart and assist in the prediction and prevention of the development of thrombus and other maladies associated with the venous system

References

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