Hemodynamics of Venous Valve Pairing and Implications on Helical Flow

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\textbf{Introduction:} It has been shown that venous valves have pairing arrangement with specific relative orientation and spacing which contribute to helical flows. The studies to date have not been able quantify the hemodynamic impact of helical flow formation. A computational model allows for various valve orientations and spacing to be studied to better understand the hemodynamic effect of valve pairing.

\textbf{Materials and Methods:} Fluid-structure interaction simulations were performed for paired valves at physiologically relevant spacing and orientations to study the flow features and hemodynamics associated with valve pairing configurations. The wall shear stress (WSS), transit time as well as pressure differential were evaluated for the various valve pairing cases.

\textbf{Results:} It was found that the WSS on the lumen flow side (front) of the leaflet is several times higher than the valve pocket side (back). With rotated paired valves, the WSS at the back side is significantly increased. Helical flow was clearly observed only with orthogonal valve pairing. The transit time was reduced to about half (0.8 vs. 1.5 s) in the orthogonal valve case as compared to the parallel valve case. The further spaced valves (6 cm) had the highest transit time.

\textbf{Translational Impact:} This simulation study shows that helical flow in the veins of lower extremities are strongly dependent on the relative orientation and spacing of the valves. For optimal orientation (~90°) and spacing (~4 cm), strong helical flow is seen which enhances WSS and reduces the flow resistance and flow transit time. These findings demonstrate a structure-function relation that optimizes flow patterns in normal physiology which can be compromised in venous valve disease. The results of this study provide valuable insights that improve the current understanding of blood flow patterns around venous valves, and the design of future multiple paired prosthetic valves.

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