Biomechanical Comparison between Mono-, Bi-, and Tri-cuspid Valve Architectures

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Introduction: An understanding of the relationship between venous valve design and associated fluid and solid mechanical forces will undoubtedly advance prosthesis design and treatments. The objective of the current study was to compare three valve designs (mono-, bi- and tri-leaflet) and the implications of these designs on the fluid and solid mechanics of the valve leaflets. The hypothesis is that the bileaflet valve has the lowest mechanical cost, defined as the ratio of leaflet wall stress and fluid wall shear stress (WSS), for the venous environment as compared with mono- and tri-leaflet valves.

Materials and Methods: To address this hypothesis, fully coupled, two-way Fluid-structure Interaction (FSI) computational models were developed and simulated for the three types of venous valves.

Results and Discussion: It was found that the mean fluid WSS of bi-leaflet valve was generally higher than tri-leaflet valve which was further higher than mono-leaflet valve. The mean solid wall stress of bi-leaflet valve was lower than tri-leaflet valve which was further lower than mono-leaflet valve. Therefore, the mechanical cost which was defined as solid wall stress/fluid WSS of bi-leaflet valve was the lowest.

Translational Impact: The lower mechanical cost may be a reason why the bi-leaflet valve is the dominant design in the venous system. This knowledge may also provide guidance to the design of novel venous prosthetic valves and shed light on venous valve disease.

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