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Effect of Helical Flow on Separation Delay in the Aortic Arch for Different Mechanical Heart Valve Prostheses by Time-Resolved Particle Image Velocimetry

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Abstract : Atherosclerotic plaques are typically found where flow separation and variations of shear stress occur. Although helical flow patterns and flow separations have been recorded in the aorta, their relation has not been clearly clarified and especially in the condition of artificial heart valve prostheses. Therefore, an experimental study is performed to investigate the hemodynamic performance of different mechanical heart valves (MHVs), i.e. the SJM Regent bileaflet mechanical heart valve (BMHV) and the Lapeyre-Triflo FURTIVA trileaflet mechanical heart valve (TMHV), in a transparent model of the human aorta under a physiological pulsatile right-hand helical flow condition. A typical systolic flow profile is applied in the pulse-duplicator to generate a physiological pulsatile flow which thereafter flows past an axial turbine blade structure to imitate the right-hand helical flow induced in the left ventricle. High-speed particle image velocimetry (PIV) measurements are used to map the flow evolution. A circular open orifice nozzle inserted in the valve plane as the reference configuration initially replaces the valve under investigation to understand the hemodynamic effects of the entered helical flow structure on the flow evolution in the aortic arch. Flow field analysis of the open orifice nozzle configuration illuminates the helical flow effectively delays the flow separation at the inner radius wall of the aortic arch. The comparison of the flow evolution for different MHVs shows that the BMHV works like a flow straightener which re-configures the helical flow pattern into three parallel jets (two side-orifice jets and the central orifice jet) while the TMHV preserves the helical flow structure and therefore prevent the flow separation at the inner radius wall of the aortic arch. Therefore the TMHV is of better hemodynamic performance and reduces the pressure loss.

Keywords : flow separation, helical aortic flow, mechanical heart valve, particle image velocimetry
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