Hemodynamic effects of "intra" and "supra" deployment locations for bio-prosthetic aortic valves*

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Aortic valve replacement is a surgical procedure to treat aortic valve diseases, such as stenosis and regurgitation. Bio-prosthetic valves, usually made from bovine or porcine pericardial tissue, mimic the natural flow dynamics of the native aortic valve and reduce the need for long-term anticoagulant therapy. However, the positioning of the stented frame relative to the native aortic annulus plays a critical role in determining the resulting blood flow patterns.[1]. Specifically, the supra-annular configuration, characterized by positioning the valve ring superior to the native annulus while extending leaflets into the Valsalva sinuses, seeks to attenuate flow obstruction by circumventing interference with the native annulus. Conversely, the intra-annular approach, which closely mimics the physiological arrangement of the aortic valve, necessitates implantation of a smaller prosthesis with a corresponding reduction in effective orifice area (EOA), thereby potentially reducing hemodynamic performance[2]. This work focuses on the influence of deployment locations of bio-prosthetic aortic valves by examining blood flow characteristics in both intra-annular and supra-annular configurations. Initially, the problem is investigated through in-vitro experiments utilizing a cardiovascular duplicator, where the hemodynamics is assessed using two-dimensional particle image velocimetry (PIV). Subsequently, three-dimensional flow patterns are derived by solving fluid-structure interaction, incorporating the interplay between blood flow and the flexible valve leaflets within a realistic left heart anatomy (see Figure 1). The dynamic and transitional nature of hemodynamics is captured through direct solution of the incompressible Navier-Stokes equations using a staggered finite differences approach. Immersed boundary techniques are employed to address the large valve deformations. Structural mechanics is based on the Fedosov interaction potential method to accurately model the anisotropic and nonlinear mechanical behaviors of biological tissues[3][4]. The numerical model is used to compare Hemolysis, blood residence time and wall shear stress.

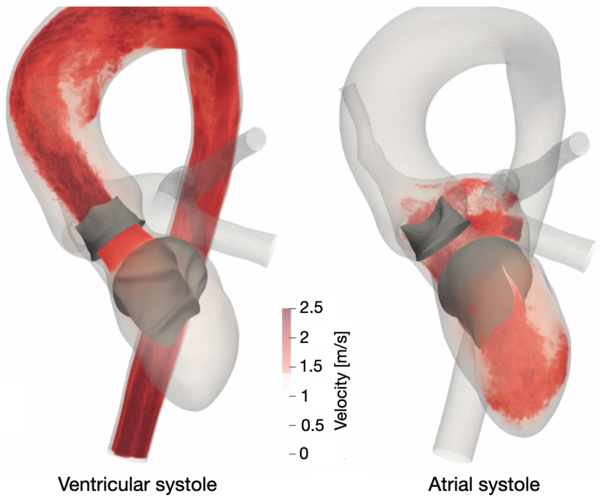

Figure 1: Computational setup.

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[4]Viola et al., *Physical Review Fluids* **8**(10), 100502 (2023).