Three-dimensional laminar-turbulent transition mechanisms downstream of a bioprosthetic aortic valve

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During peak systole, bioprosthetic heart valves (BHV) are known to create turbulent flow in their downstream flow field which possibly compromises BHV durability and performance[1]. To identify mechanisms of laminar-turbulent transition and eventually contribute to the understanding of how to suppress turbulent flow, two-dimensional simulations of a parameterized aortic root with inserted BHV are performed. A Direct Numerical Simulation approach[2] for the fluid motion is coupled by a modified Immersed Boundary Method based on variational transfer to a structural solver for the motion of aortic wall and valve[3]. Numerical results from two-dimensional simulations confirm the impact of leaflet flexibility and aortic wall parameters on laminar-turbulent transition and flow patterns in the ascending aorta. After the initial opening of the valve leaflets, a starting vortex is formed which is simultaneously advected downstream as well as moves towards the shear layer in the leaflet wake due to the confinement of the downstream flow field by the aortic wall. The perturbation of the shear layer leads to a Kelvin-Helmholtz-like instability potentially triggering structural leaflet oscillations. Following the identification of basic instability mechanisms with a simplified two-dimensional aortic configuration, we now target the investigation of three-dimensional instability mechanisms contributing to turbulent flow. Therefore, the modeling complexity is increasing by complementing the previously obtained two-dimensional parameterized data set by a highly-resolved three-dimensional simulation of selected parameters. The combination of two-dimensional flow fields for varying aortic wall parameters and a corresponding three-dimensional simulation allows the comprehensive understanding of laminar-turbulent transition past BHV from basic two-dimensional to complex three-dimensional flow patters.

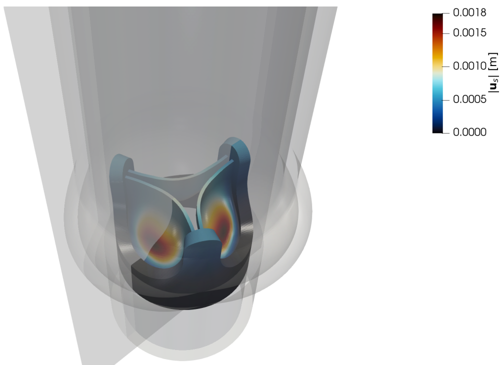

Figure 1: Instantaneous displacement of the aortic valve during the initial opening phase.

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[1]Becsek et al., *Front. Physiol.* **11**, 1 (2020).
[2]Henniger et al., *J. Comput. Phys.* **229**, 3543 (2010).
[3]Nestola et al., *J. Comput. Phys.* **398**, 108884 (2019).