Abstract (Master's thesis, Marco Fedele, EPFL)

A patient-specific aortic valve model based on moving Resistive Immersed Surfaces

The study of hemodynamics in the ascending aorta through computational fluid dynamics simulations is a subject of large interest in medical research for its application in the study of different diseases. The aim of this work is to enrich the numerical simulation with a moving aortic valve model. Closed and open valve surfaces as well as the lumen aorta are reconstructed directly from medical images using a new specific algorithm, allowing a patient-specific simulation. The valve surface is inserted in the classic Navier-Stokes equations adding a dissipative term with a resistance that can be interpreted as a penalization parameter enforcing the condition of null velocity on it. Furthermore, we considered also the movement of the valve between its closed and open position using a reduced zero-dimensional model to compute the valvular angle governed by pressure and flow-rate values in the left ventricle and in the aorta. We describe the valve surface as the zero level of a level-set function defined analytically. From a numerical point of view, this strategy avoids the problem of having bi-dimensional finite elements immersed in the three-dimensional domain consistent with the valve surface. Moreover, in this way the mesh does not have to change at each time step with the movement of the valve avoiding remeshing and high-computational costs. This model can help in a better understanding of the hemodynamics in the ascending aorta; hence it can be used to study aortic and valvular diseases or valvular prosthesis. Furthermore, it can be easily extended to the other cardiac valves, helping in the building of a complete heart-integration model.