Computational fluid dynamics of blood flow in the human heart

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ABSTRACT

In this work, we develop a mathematical and numerical framework for the numerical simulation of blood flows in the human heart. In our CFD model, we adopt the Navier-Stokes equations in Arbitrary Lagrangian Eulerian (ALE) framework, in order to account for the endocardium displacement. We use a Variational Multiscale - Large Eddy Simulation (VMS-LES) model [1, 2] to get a stable formulation of the Navier-Stokes equations discretized by means of Finite Element Method and, then, to account for turbulence modeling within the framework of LES; we also aim to consider typical transitional effects of blood flows. We mimic the presence of cardiac valves by means of the Resistive Immersed Implicit Surface (RIIS) method [3]. We propose a computational model on the haemodynamics of an idealized left atrium and we study the role of the VMS-LES model in such transitional flows showing that VMS-LES model is more accurate to predict transitional blood flow indicators than the standard SUPG stabilization technique [4]. We then extend our computational model for the simulation of the whole left heart in physiological conditions, using a realistic geometry and a realistic displacement (obtained suitably extending an electromechanical simulation of the left-ventricle previously run). Our 3D-CFD model is then coupled to a 0D model of the circulation, in order to prescribe more realistic and physiological boundary conditions that are respectful of the closed-loop circulation model of the whole cardiovascular system. Finally, advances regarding the fluid-dynamics simulation of the whole human heart coupled with a 0D circulation model will be introduced and discussed.

REFERENCES


