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Fluid dynamics of the whole human heart: a multiphysics and multiscale computational model

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We introduce a CFD model for the simulation of the whole heart hemodynamics, by accounting for all the physical processes that influence cardiac flows: moving domain and interaction with electromechanics, transitional-turbulent flows, cardiac valves and coupling with the external circulation. We employ the Navier-Stokes (NS) equations in Arbitrary Lagrangian Eulerian (ALE) framework to account for the endocardium displacement, and the Resistive Immersed Implicit Surface (RIIS) method [1] to model the presence of valves in fluid. To impose a physiological displacement of the domain boundary, we use a cardiac electromechanical model [2], obtaining thus a multiphysics one-way coupled electromechanics-fluid dynamics model [3]. To better match the 3D CFD with blood circulation, we also couple the 3D problem to a 0D closed-loop circulation model. We obtain a multiphysics and geometrically multiscale coupled 3D-0D fluid dynamics model that we solve via a segregated numerical scheme [3]. We carry out numerical simulations for a healthy whole heart and we validate our model by showing that significant hemodynamic indicators are correctly reproduced.

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