On the Incorporation of Obstacles in a Fluid Flow Problem Using a Navier-Stokes-Brinkman Penalization Approach

Jana Fuchsberger, Gundolf Haase, Elias Karabelas, Gernot Plank

Patient-specific simulations of the total heart function require computational fluid dynamics (CFD) models of blood flow. To improve validity of CFD tools the incorporation of the heart valves in the CFD simulation is vital. To tackle this challenge a fictitious domain method is realized by extending the Navier-Stokes equation with a Darcy drag term, which results in the Navier-Stokes-Brinkman equations. In this setting rigid obstacles are represented as time-varying regions containing a porous medium with vanishing permeability while the underlying mesh remains unchanged. An Arbitrary Lagrangian Eulerian (ALE) description of the Navier-Stokes-Brinkman model is formulated to facilitate moving background geometries. Additionally we propose a residual based variational multiscale (RBVMS) formulation of the problem to handle numerical stabilization and turbulence modeling.

This allows us to set up a flexible and robust computational technique, that is used to extend the available CFD solver in our cardiac modeling framework CARP (Cardiac Arrhythmia Research Package) without introducing too much additional computational cost.

In order to demonstrate mesh independence we present a mesh convergence study using a three dimensional torus geometry representing a mock model of a human artery tract.