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Space-time and ALE-VMS techniques for patient-specific cardiovascular fluid-structure interaction modeling. (English) Zbl 1354.92023

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Summary: This is an extensive overview of the core and special space-time and arbitrary Lagrangian-Eulerian (ALE) techniques developed by the authors' research teams for patient-specific cardiovascular fluid-structure interaction (FSI) modeling. The core techniques are the ALE-based variational multiscale (ALE-VMS) method, the Deforming-Spatial-Domain/Stabilized Space-Time formulation, and the stabilized space-time FSI technique. The special techniques include methods for calculating an estimated zero-pressure arterial geometry, prestressing of the blood vessel wall, a special mapping technique for specifying the velocity profile at an inflow boundary with non-circular shape, techniques for using variable arterial wall thickness, mesh generation techniques for building layers of refined fluid mechanics mesh near the arterial walls, a recipe for pre-FSI computations that improve the convergence of the FSI computations, the Sequentially-Coupled Arterial FSI technique and its multiscale versions, techniques for the projection of fluid-structure interface stresses, calculation of the wall shear stress and oscillatory shear index, arterial-surface extraction and boundary condition techniques, and a scaling technique for specifying a more realistic volumetric flow rate. With results from earlier computations, we show how these core and special FSI techniques work in patient-specific cardiovascular simulations.

MSC:

92C35 Physiological flow
74F10 Fluid-solid interactions (including aero- and hydro-elasticity, porosity, etc.)
76Z05 Physiological flows
92-08 Computational methods for problems pertaining to biology
92C50 Medical applications (general)

Keywords:

ALE methods; cardiovascular fluid mechanics; cerebral aneurysms; fluid-structure interactions; left ventricular assist devices; space-time methods; special techniques; total cavopulmonary connection

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