Simulation of Fluid-Structure Interaction in Arterial Walls Incorporating Nonlinear Anisotropic Material Models at Finite Strains

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ABSTRACT

The computational simulation of atherosclerotic arteries is of high clinical interest to analyze if the plaque is going to rupture and if surgical intervention is required. Therefore, the reliable computation of transmural stress distributions is required which in turn relies on a predictive description of the material behavior which is anisotropic and nonlinear. In addition to that, the wall stresses depend strongly on the behavior of the blood flow as well as its interaction with the solid. In this contribution a framework is presented that takes into account the blood flow, a viscoelastic and anisotropic arterial tissue response as well as their interaction. In order to guarantee existence of minimizers and material stability in the solid, polyconvex strain energy functions are used for the representation of the hyperelastic basic response [1]. A viscoelastic model is considered for the reinforcing fibers, which is not based on a volumetric-isochoric split of the strain energy function, cf. [2]. We recall the equations that model fluid-structure interaction and the monolithic Geometric Convective Explicit algorithm for their numerical approximation, addressing both the cases when the fluid-structure meshes are conforming and nonconforming at the interface [3], [4]. Detailed simulations are presented based on a simplified curved artery comparing different finite element approximations. In addition to the anisotropic viscoelastic model formulated in the finite strain framework, idealized simplifications such as linear material models which are typically considered for FSI-calculations are also investigated.

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