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Numerical Simulation of Blood-Wall and Blood-Plaque Interaction in Stenosed Artery Using FSI Modelling

Diseased arteries can create high levels of turbulence, head loss, and a choked-flow condition in which tubes can collapse. Most of these diseases are highly focal and must be caused by a local factor acting at a specific site. The stress and mass transfer at the blood-wall interface are important hemodynamic factors that influence biological responses. The formation of a stenosis is the most dire biological response. Hence, complete understanding of the relationship between pressure, flow, and symptoms for cardiovascular stenoses is a highly critical problem.

We want to describe the velocity field and the pressure inside a section of the aorta according to the nature of the arterial layers and the geometry. A problem of this type can be solved using Navier-Stokes equations for the fluid (blood) in an Arbitrary Lagrangian Eulerian framework (ALE). Furthermore we are interested in the dynamic analysis of the aorta.

Many models have been developed based primarily on fluid mechanics under the assumption of rigid wall were allowed to determine the flow characteristics such as recirculation zones and disruption of the flow. The majority of this work focusing on the study of the velocity field did not study the behavior of the wall vessel towards the fluid. There are several difficulties when studying the biomechanics of this structure : the three constituent layers of the tissue (intima, media and adventitia), the variability of the geometry of the arterial wall and their strong interaction with blood flow.

The aim of this work is to study, on one hand the fluid-structure interaction (FSI) between blood and atherosclerotic plaque and on the other hand, the interaction between blood and the arterial wall, in a 2D geometry using a FSI model. The atheroma plaque is composed of a lipid pool covered with a fibrous cap and both are modeled as hyperelastic materials, linear isotropic and elastic material properties are assumed for the vessel wall layers and the blood is supposed to be Newtonian. The parameters used in our simulations are taken from experimental data. We investigate the vessel wall mechanics effects on the recirculations downstream of the atheroma plaque and on the stress over the plaque in different degrees of stenoses.