Blood Flow in a Compliant Vessel by the Immersed Boundary Method

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Abstract

A computational approach to analyze hemodynamics in the aorta is developed which serves as a useful tool in the development of noninvasive methods to detect early onset of diseases such as aneurysms and stenosis of major blood vessels. We introduce a mathematical model which describes the interaction of blood flow with the aortic wall; the model is based on the immersed boundary method. A two-dimensional vessel model is constructed and the velocity profiles at the inlet and the blood pressure level at the outlet are prescribed based on the information from Magnetic Resonance Imaging data measured in the aorta of a healthy subject. The mathematical model is validated by comparing with well-known solutions of the viscous incompressible Navier-Stokes equations, i.e., Womersley flow. The hysteresis behavior in the pressure-diameter relation is observed when the viscoelastic material property of the arterial wall is taken into consideration. A three-dimensional vessel model is constructed, and the velocity profile at the inlet and the blood pressure level at the outlet are prescribed. Normal, dilated, and constricted aortas are considered for the comparison of the flow patterns inside the normal and abnormal aortas.