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Shear Stress and Effective Structural Stress Fields of an Atherosclerotic Coronary Artery

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Abstract : A three-dimensional numerical model of an atherosclerotic coronary artery is developed for the determination of high-risk situation and hence heart attack prediction. Employing the finite element method (FEM) using ANSYS, fluid-structure interaction (FSI) model of the artery is constructed to determine the shear stress distribution as well as the von Mises stress field. A flexible model for an atherosclerotic coronary artery conveying pulsatile blood is developed incorporating three-dimensionality, artery's tapered shape via a linear function for artery wall distribution, motion of the artery, blood viscosity via the non-Newtonian flow theory, blood pulsation via use of one-period heartbeat, hyperelasticity via the Mooney-Rivlin model, viscoelasticity via the Prony series shear relaxation scheme, and micro-calcification inside the plaque. The material properties used to relate the stress field to the strain field have been extracted from clinical data from previous in-vitro studies. The determined stress fields has potential to be used as a predictive tool for plaque rupture and dissection. The results show that stress concentration due to micro-calcification increases the von Mises stress significantly; chance of developing a crack inside the plaque increases. Moreover, the blood pulsation varies the stress distribution substantially for some cases.

Keywords : atherosclerosis, fluid-structure interaction, coronary arteries, pulsatile flow
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