Blood Flow Patterns in a Patient Specific Right Coronary Artery with Multiple Stenoses

B. Liu[1]

[1]Department of Mathematics, Monmouth University, West Long Branch, NJ, USA

Abstract

Atherosclerotic lesions preferentially develop in certain regions like bifurcations, branches, and bends [1, 2]. A possible explanation for such a preferential localization of atherosclerosis is that the geometry of the vessel influences the blood flow pattern. It suggests that the arterial geometry plays an important role in determining the localized blood flow information. Thus hemodynamic studies based on patient-specific data are likely to offer insights to understanding the progression of atherosclerosis and may have useful clinical value.

The objective of this work is to obtain a detailed hemodynamic evaluation of disturbed flow and the spatial and temporal flow distribution patterns in human atherosclerotic right coronary arteries using a patient specific model with multiple stenoses. The first stenosis near the inlet has a reduction of 66% approximately in lumen cross-section area and the second stenosis near the outlet has a reduction of 47% approximately in lumen cross-section area. The blood was assumed as a laminar, incompressible, non-Newtonian viscous fluid. The time dependent three dimensional Mass-Momentum equations were used as the governing equations. An image-based model of an atherosclerotic right coronary artery was re-constructed based on the lumen contour curves extracted from an in vivo 3D IVUS dataset covering the plaque region, which was acquired during cardiac catheterization from a patient [3]. The velocity and pressure pulse waveforms imposed at the inlet and outlet boundaries were extracted from on-site blood pressure and flow velocity data.

Computer simulations were carried out using COMSOL Multiphysics® software. The inlet and the outlet of the artery were extended in length by .2 cm in the direction normal to the inlet and the outlet cross sections to reduce the influence of the boundary conditions in the region of interest [Figure 1]. Four consecutive cardiac cycles were simulated to ensure the periodicity of the flow and computations were repeated over different sizes of mesh to confirm the independence of the numerical solutions on spatial mesh. Numerical solutions were validated by comparing the simulated blood velocity and pressure with the acquired on-site blood pressure and flow velocity data from the patient. Based on the computer simulation results, the spatial and temporal patterns of the blood pressure, the pressure drop coefficient, the wall pressure gradient, the blood velocity and the wall shear stress in a stenotic human right coronary artery will be presented.

Acknowledgment: This work was partially supported by a grant from the Simons Foundation

(#210082 to Biyue Liu). The author thanks Dr. Dalin Tang for providing the stenotic right coronary artery data for re-constructing the computational domain and extracting velocity and pressure waveforms at inlet/outlet boundaries.

Reference

1. Friedman MH, Hutchins GM, Bargeron CB, Deters OJ, Mark FF. Correlation between intimal thickness and fluid shear in human arteries. Atherosclerosis 1981, 39:425–36.

2. Myers JG, Moore JA, Ojha M, Johnston KW, Ethier CR. Factors influencing blood flow patterns in the human right coronary artery. Ann Biomed Eng 2001, 29:109–20.

3. Tang D, Yang C, Zheng J, Bach R, Wang L, Muccigrosso D, Billiar K, Zhu J, Ma G, Maehara A, Mintz GS, Fan R: Human coronary plaque wall thickness correlated positively with flow shear stress and negatively with plaque wall stress: an IVUS-based fluid-structure interaction multi-patient study. BioMedical Engineering OnLine 2014, 13:32.

Figures used in the abstract

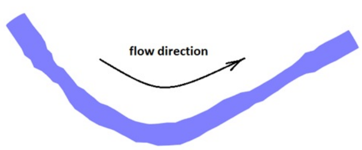

Figure 1: Geometry of the computational domain.