Patient-specific 3D hemodynamics modelling of left coronary artery under hyperemic conditions

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Abstract The purpose of this study is to investigate the effect of various degrees of percentage stenosis on hemodynamic parameters during the hyperemic flow condition. 3D patient-specific coronary artery models were generated based on the CT scan data using MIMICS-18. Numerical simulation was performed for normal and stenosed coronary artery models of 70, 80 and 90% AS (area stenosis). Pressure, velocity, wall shear stress and fractional flow reserve (FFR) were measured and compared with the normal coronary artery model during the cardiac cycle. The results show that, as the percentage AS increase, the pressure drop increases as compared with the normal coronary artery model. Considerable elevation of velocity was observed as the percentage AS increases. The results also demonstrate a recirculation zone immediate after the stenosis which could lead to further progression of stenosis in the flow-disturbed area. Highest wall shear stress was observed for 90% AS as compared to other models that could result in the rupture of coronary artery. The FFR of 90% AS is found to be considerably low.

Keywords Coronary artery · Non-Newtonian flow · Stenosis · FFR

1 Introduction

Coronary artery disease (CAD) is the leading cause of death across the world. The primary cause of CAD is atherosclerosis, which reduces the coronary lumen because of the formation of plaque on the inner walls of coronary artery. It is well known that plaques are frequently formed at bifurcations and curvature of vessels [1, 9, 35]. There are many studies that reported a direct link between stenosis and the hemodynamic parameters such as wall shear stress and flow pattern [3, 5, 6]. It is reported that a significantly reduced volumetric blood flow rate was found in >50% occlusion of coronary lumen area [10]. In the region of disturbed flow, high wall shear stress gradient could produce morphological and functional changes in the endothelium and promotes the plaque formation [22, 33]. The anatomical details of arteries can be obtained, and plaques are detectable with high accuracy by using noninvasive medical imaging techniques such as computed tomography angiography (CCTA) [31]. However, this technique is