COMPUTATIONAL FLUID DYNAMICS OF PATIENT-SPECIFIC CORONARY ARTERY DURING STENT TREATMENT

Nur Syuhada Che Amdilah[1], Yu Shi Lau[2], Yih Miin Liew[2], Wan Naimah Wan Ab Naim[1], Mohd Jamil Mohamed Mokhtarudin[1,3]*

[1]*Department of Mechanical Engineering, College of Engineering, University Malaysia Pahang, Lebuhraya Tun Razak, Gambang, Pahang 26300, Malaysia*
[2]*Department of Biomedical Engineering, Faculty of Engineering, Universiti Malaya, Kuala Lumpur, Malaysia*
[3]*Centre for Research in Advanced Fluid and Processes (Fluid Centre), Universiti Malaysia Pahang, Lebuhraya Tun Razak, Kuantan, Pahang 26300, Malaysia*
**mohdjamil@ump.edu.my*

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Abstract

Coronary artery disease is usually treated using stent treatment. However, restenosis is one of the major limitations of using stent. Local hemodynamics can be the main indicator of the occurrence of restenosis. In this project, a computational fluid dynamics (CFD) analysis is performed on a stented coronary artery patient with a 12-month follow-up post stent in order to determine the potential occurrence of restenosis in the patient. An OCT image of the coronary artery is taken and ethically approved from Universiti Malaya Medical Centre (UMMC). Firstly, a 3D geometry of the coronary artery will be developed using image segmentation procedure. The stent structure is smoothened within the coronary artery. Then, the geometry is meshed and CFD analysis is applied. The blood is assumed as a non-Newtonian fluid following a Carreau model of fluid viscosity. The inlet is applied with a velocity waveform, while the outlet is set as zero pressure. Lastly, the time averaged wall shear stress (TAWSS) is calculated. The region with TAWSS < 0.4 Pa is identified as a potential location for restenosis. From our simulations, the location in the middle of the stent shows TAWSS < 0.4 Pa, showing the potential of restenosis in the patient.

1 Introduction

Coronary artery disease (CAD) is the primary cause for worldwide morbidity and mortality [1]. The prevalence rate is also increasing in the developed countries. In spite of having major socioeconomic impact, the mechanism of CAD occurrence is only partially understood. Percutaneous coronary intervention (PCI) is a common treatment for CAD. Every year, hundreds of thousands of patients received stents implanted. Stents are small tube-like devices that are used to keep the blood vessel open. Bioresorbable vascular scaffold (BVS) stents are the latest generation of stents, which can also come in the form of drug-eluting vascular scaffolds that provides transient vessel support with drug delivery capability while avoiding the long-term limitations of metallic drug-eluting stents, such as permanent caging with or without malapposition. BVS are completely absorbed later, lowering the risk of stent thrombosis [2].

Coronary artery disease is caused by the build-up of atherosclerotic plaque within the coronary artery wall. The majority of myocardial infarctions are caused by the rupture of coronary plaques in conjunction with thrombotic arterial occlusions, according to post-mortem analyses published in the literature. As a result, accurate identification of vulnerable plaques is critical for preventing such events. The use of intra-vascular imaging modalities allows for accurate lesion classification by providing a high-resolution image of the plaque composition [3].

The local hemodynamic changes in coronary artery disease and the PCI treatment can be studied using computer simulation [4]. The widespread use of optical coherence tomography (OCT) to visualize the internal structure of the coronary artery has successfully upgraded the patient-specific modelling of stented coronary arteries for local hemodynamic analysis. The combination of both OCT and computer simulation has the potential to improve the understanding of CAD and also improve the PCI treatment planning [5]. Currently, computational fluid dynamics (CFD) has been used extensively to study the local hemodynamics of OCT-based stented coronary artery geometries. Other than using CFD, structural dynamics simulations, in which involving only the stent structure within the artery may also provide further understanding [6]. In order to use the OCT image, it must be pre-processed using a segmentation algorithm to obtain a geometry for the simulation [7]. Then, the geometry is meshed, typically with tetrahedral elements. Finally, the meshed geometry is imported into finite element software and prepared for computer simulation.

In this project, a CFD analysis of a coronary artery with PCI treatment will be discussed. The novelty of this project is the use of coronary artery data taken from an OCT image obtained from the Universiti Malaya Medical Centre (UMMC). The