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A MULTI-VARIABLE ANALYSIS OF TRANSIENT NEAR-WALL HAEMODYNAMICS IN A STENTED CORONARY ARTERY

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INTRODUCTION

Coronary stent implantation can improve blood flow in an artery that has been narrowed by the build up of arterial plaque. Unfortunately, the stented artery is susceptible to restenosis, defined as a greater than 50% re-blockage of the artery. Restenosis is caused by the excessive growth of new tissue in the stented segment of the artery, a process termed intimal hyperplasia (IH). Currently, drug-eluting stents (DES) are implanted to suppress IH by inhibiting the growth of new tissue. This however, leads to an increased risk of late thrombosis [1] and does not address the underlying factors which promote IH.

IH is the arterial response to stent implantation and is stimulated by the injury incurred from the stenting procedure [2] and by the abnormal near-wall haemodynamics due to the presence of the stent [3]. The haemodynamics in the stented artery are commonly modeled using computational fluid dynamics (CFD). In many of these analyses the degree of abnormality of the haemodynamics is often quantified by the amount of tissue area below or above a certain threshold value of a viscous stress based variable. Normalised area below 0.5 N/m² wall shear stress (WSS) and above 200 N/m³ wall shear stress gradient (WSSG) have been commonly used to interpret CFD results [4].

We hypothesise that using this threshold method to assess the abnormal near-wall haemodynamics does not adequately capture the physics of the flow. The current work proposes a robust methodology to assess coronary stents based on these abnormal near-wall haemodynamics that result from the stent implantation. The methodology demonstrates how to obtain the maximum information about the near-wall haemodynamics in the artery. The results reveal how the threshold method may be misleading.

MATERIALS AND METHODS

A transient CFD analysis is conducted on a physiologically realistic geometric model of the stented left anterior descending (LAD) coronary artery. The results are then post-processed to calculate the magnitudes of the time-averaged WSS, WSSG, wall shear stress angle gradient (WSSAG) and oscillatory shear index (OSI) on all surfaces representative of living tissue. A distribution and statistical analysis is then conducted on the full range of these variables to get the maximum information possible about the abnormal haemodynamics near the artery wall. The methodology is applied to Palmaz Schatz (PS) and Gianturco-Roubin II (GR-II) stents as a demonstration.

RESULTS

The mean and standard deviation of the WSS distribution is 0.808 N/m² and 0.387 N/m² for the PS stent and 0.803 N/m² and 0.481 N/m² for the GR-II stent respectively. The threshold method gives 21.6% and 32.4% of area below 0.5 N/m² for the PS and GR-II respectively. The mean and standard deviation of the WSSG distribution is 904 N/m³ and 721 N/m³ for the PS stent and 1542 N/m³ and 968 N/m³ for the GR-II respectively. The threshold method gives 99.6% and 97.7% of area above 200 N/m³ for the PS and GR-II respectively. Further results are omitted due to space limitations.

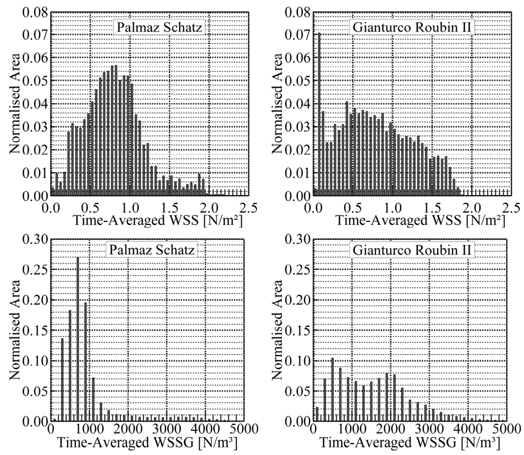

Figure 1: Distributions of time-averaged WSS and WSSG for the PS and GR-II stents. The bars represent the normalised area with variables values bounded by the tick marks on the abscissa.

DISCUSSION

The proposed methodology provides a rigorous analysis of the abnormal near-wall haemodynamics in a stented artery and identifies subtleties in the results which are overlooked with the previously employed "threshold method."

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