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Evaluation of Stent Design Based on the Haemodynamic Effect of Coronary Stenting

Jonathan Murphy
Technological University Dublin, jonathan.murphy@tudublin.ie

Fergal Boyle
Technological University Dublin, fergal.boyle@tudublin.ie

Funder: Department of Mechanical Engineering

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EVALUATION OF STENT DESIGN BASED ON THE HAEMODYNAMIC EFFECT OF CORONARY STENTING

Jonathan Murphy, Fergal Boyle
Dublin Institute of Technology
Mechanical Engineering Department
Bolton St., Dublin 1
jonathan.murphy1@student.dit.ie

INTRODUCTION

Coronary stent implantation can improve blood flow in an artery that has been narrowed by the build up of arterial plaque. However, the haemodynamic effect of stent placement is unclear and may influence arterial restenosis (re-blockage). Stent placement triggers a substantial immunological response from the vessel wall leading to thrombosis, which is the starting point for restenosis. It has been well documented that stent design is a factor in restenosis rates with implanted coronary stents [1]. We hypothesise that flow disturbances influenced by stent design play an integral role in thrombus formation and hence, restenosis.

MATERIALS AND METHODS

In order to assess the haemodynamic impact of coronary stent implantation, three-dimensional computational models of a stented left anterior descending (LAD) coronary artery have been created using computer-aided-design. One model represents the artery implanted with a Palmaz-Schatz (PS) stent and the second model represents the artery implanted with a Gianturco-Roubin-II (GR-II) stent. CFD was used to simulate the flow field of the coronary artery with the implanted stent in each case. Mathematical models were constructed to simulate the fully developed, non-Newtonian nature of the coronary blood flow. Flow disturbances that are known to encourage restenosis such as regions of low wall shear stress (WSS) and high wall shear stress gradient (WSSG) [2] have been identified from both computational simulations. Using data from a recent clinical restenosis trial [3] of the GR-II stent and the PS stent, correlations between flow disturbances and restenosis rates have been investigated.

RESULTS

The results will show the mesh convergence studies, contour plots and graphs of areas of high and low WSS and a graph of the axial WSSG in the vicinity of struts for both stents. Figure 1 illustrates the percentage stented area subjected to WSS below a given magnitude starting from 0.1 Pascals. In comparison to the PS stent, the GR-II stent has more than double the percentage stented area subjected to WSS less than 0.1 and 0.25 Pascals, and 70% more percentage stented area subjected to less than 0.5 Pascals. The GR-II stent also has areas on the stent wires with higher WSS than the PS stent with a maximum WSS value of 4.28 Pascals compared to the PS stent which has a maximum of 3.73 Pascals.

The GR-II stent displays 15% higher WSS on the top of the stent strut than the PS stent leading to a 21% higher WSSG in front of the stent strut and a 44% increase in WSSG behind the strut.

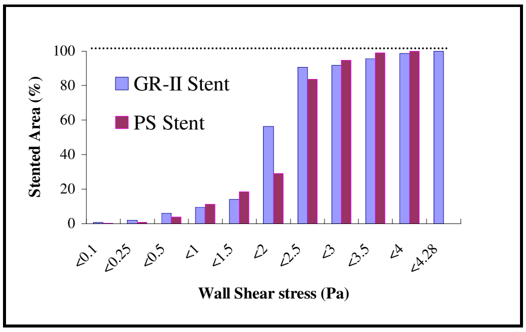

Figure 1: Bar chart illustrating percentage stented area subjected to different degrees of WSS for the GR-II and PS stent

DISCUSSION

In a medical trial conducted to compare the in vivo performance of these two stents, the GR-II stent had a restenosis rate of 47.3% compared to the PS restenosis rate of 20.6% after six months [3]. The medical trial data and predicted CFD results correlate strongly with the hypothesis that coronary haemodynamics due to stent design are a significant factor in whether or not the stenting procedure will be successful. In light of this evidence, future stent designs should strive to reduce restenosis encouraging haemodynamic effects, primarily regions of low WSS and high WSSG.

REFERENCES

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