VI International Conference on Adaptive Modeling and Simulation
ADMOS 2013
J. P. Moitinho de Almeida, P. Díez, C. Tiago and N. Parés (Eds)

VASCULAR RECONSTRUCTION MODELLING OF LUMEN-ADAPTED ARTERIES WITH STIFFENED GRAFTS

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Key words: Shape Optimization, Genetic Algorithms, Biomedical Engineering, ANN Applications.

Abstract. Optimization of prosthetic graft configuration with regard to blood dynamics is the major target of this research. Hemodynamic simulations of idealized arterial bypass systems are acquired using a finite element arterial blood simulator exhibiting the hemodynamic flow changes due to compliance differences of a stiff graft and an elastic arterial wall. An artificial neural network simulating hemodynamic specific conditions is developed in order to reduce computational time. Optimal graft configurations are searched using a multi-objective genetic algorithm. An optimal set of solutions are presented and analyzed.

1 INTRODUCTION

Vascular grafts are special tubes that serve as replacements for damaged blood vessels. When suitable autologous veins are unavailable, prosthetic graft materials are used for peripheral arterial revascularisations. Compliance and calibre mismatch between native vessel and graft contributes towards poor long term patency [1].

The ideal vascular bypass graft would replicate the mechanical properties of native artery perfectly to maximize patency. Research study of dynamic arterial wall properties of large arteries such as the carotid and femoral arteries is becoming more common. Using non-invasive techniques the maximum and minimum arterial diameters and the intima-media thickness (IMT) at the point of maximum diameter and minimum diameter have been determined over the cardiac cycle. Moreover, the arterial diameter and IMT values can be used together with the blood pressure measurements to calculate several standard arterial stiffness indices [2].

Computational approaches have been used simulating blood flow through idealized bypass models [3, 4, 5]. They exhibit particular patterns characterized by the presence of recirculation zones and secondary flows in certain regions. The problem is related with both shape design and flow control that are involved in the simulation of the bypass system. Improving blood flow dynamics in the graft system is an important element for the long-term success of bypass surgeries.

In this project a developed multi-objective genetic algorithm [3] is considered in order to

reach optimal graft geometries for idealized arterial bypass systems of fully occluded host arteries. Genetic algorithms require a large number of computer simulations. So, an artificial neural network (ANN) is developed to efficiently simulate blood flow for specific graft geometries. Input and target data have been acquired using a finite element arterial blood simulator previously developed and tested considering fully unsteady incompressible Navier-Stokes equations and a three-dimensional geometry [6, 7].

2 RESULTS

The minimum carotid artery diameter occurs during the low-pressure end-diastolic cardiac phase and the maximum carotid artery diameter during the peak systolic phase and the IMT has an opposite behavior [2]. On the other hand, the prosthetic graft is stiff and the hemodynamic flow changes due to compliance differences across an anastomosis cause increased shear stress to damage endothelial cells and also reduced shear stress leading to areas of relative stagnation and increasing interaction between platelets and vessel wall. The aim of geometry design is to minimize these disruptive flow characteristics. The optimization process manages to achieve geometries presenting wall shear stress values with the expected variability for the blood behavior in the systemic arterial tree.

Acknowledgments

The authors thank the financial support of FCT Portugal through Unidade de Investigação: 10/225, IDMEC (FEUP) and project PTDC/SAU-BEB/102547/2008, “Blood flow simulation in arterial networks towards application at hospital”.

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