DEPARTMENT OF BIOMEDICAL ENGINEERING

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Blood Flow Simulations in the Human Aortic Arch in Relation to Obesity

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The global obesity epidemic is worsening with 10% of the world's population now classified as obese [1]. In 2015, obesity contributed to 4 million deaths globally, 41% of which were due to cardiovascular disease. The healthy human aorta has a complex anatomy often associated with disturbed flow dynamics, while in obese individuals structural and functional changes to the cardiovascular system lead to abnormal aortic function [2]. Such changes are also associated with coronary artery disease, hypertension, and diabetes; disorders which themselves are thought to be accelerated by obesity. In this study, we utilised computational fluid dynamic (CFD) methods to examine various haemodynamic parameters, namely blood flow velocity, blood pressure, and wall shear stress (WSS), in the aortic arch and proximal branches. Two idealised three-dimensional geometries of the human aortic arch, based on anatomically-correct data from two different patient groups [3], were created using the ANSA pre-processor (BETA CAE Systems). A mesh independence study was completed to determine the optimum number of elements for the geometries. CFD simulations were performed in the open-source library OpenFOAM®, with the material properties of the working fluid, blood, in accordance with current literature [4]. Preliminary results considered both steady and time-dependent (pulsatile) flow for the solution of the incompressible Newtonian Navier-Stokes equations. The initial focus of the flow analysis was on the distribution of wall shear stress. Flow patterns observed for both models showed regions of considerable flow disturbance. The results demonstrate low shear stresses at locations on the aortic wall which are known to be susceptible to the development of atherosclerotic plaques. Blood flow parameters are significantly affected by the local anatomy of the aortic arch, highlighting important differences between the two models. The future direction of this work is to improve the accuracy of the simulations by implementing more complex boundary conditions. The investigation will then be extended to patient-specific aortic models to confirm the results of this work.

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