A numerical approach for the assessment of obesity-induced vascular changes in children

Asimina Kazakidi[1]

[1] Department of Biomedical Engineering, University of Strathclyde, G4 0NW

Introduction

Obesity in children and adolescents has taken epidemic proportions in recent years and has become one of the major challenges of the 21st century. Primarily a dietary disease, obesity is believed to accelerate the initiation and progression of endothelial dysfunction [1], one of the early biological markers for atherosclerotic lesions that underlie most cardiovascular diseases. Several markers have been proposed to help the clinical assessment of endothelial damage in high-risk paediatric patients. In obese children, arterial changes can painlessly be evaluated with measurements of the aortic and carotid intima-media thickness (IMT) and flow-mediated dilatation (FMD) of the brachial, radial and femoral arteries [2]. Pulse wave analysis is additionally utilised to assess arterial stiffness, distensibility and compliance. This study observes childhood obesity under the magnifying lens of blood flow mechanics associated with obesity-induced vascular changes. The scope is to develop a safe and high-fidelity multi-scale computational tool for prognostic markers and predictive personalised care of obesity-related cardiovascular diseases, and transfer it into the paediatric reality. The current presentation will discuss a computational model of an arterial conduit during FDM.

Methods

A simplified arterial conduit is modelled with flexible walls using physiological vessel dimensions and boundary conditions. Solutions to the time-dependent, incompressible Navier-Stokes equations are based on high-fidelity finite volume and hybrid Cartesian/immersed-boundary (HCIB) methods [3] that overcome several of the shortcomings of conventional computational fluid dynamic methods and provide increased spatial flow analysis. The codes have previously been validated and used extensively in various applications. Implementation of wall motion is particularly easy with HCIB methods, which are inherently capable of handling arbitrarily large body motions and allow for effective solutions of wall configuration.

Results and Discussion

The model approximates adequately the physical phenomenon and provides a haemodynamic characterization, including flow-induced shear stresses which are frequently used as indicators of pro-inflammatory manifestations of vascular disease. Future work will include multi-scale modelling that combines high-resolution 3D blood flow information, with macroscopic and microscopic features of the vascular environment. A comparison of various haemodynamic metrics, such as the time-averaged wall shear stress (TAWSS), the oscillatory shear index (OSI), and the transverse WSS will be performed for the assessment of vascular disease due to obesity, in association with medical data acquired from young obese patients.

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References

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