Title: Fluid-Structure Interaction simulation of multiple bifurcations in arm under transient boundary conditions due to Flow mediated dilation

George Hyde-Linaker[1], Richard Black[1], Asimina Kazakidi[1]

1: Department of Biomedical Engineering, University of Strathclyde

Abstract body:

Flow mediated dilation (FMD), a non-invasive clinical assessment of endothelial function, is a valuable indication of atherosclerosis. The haemodynamics associated with FMD are strongly influenced by the fluid-structure interaction (FSI) of the blood flow and arterial wall. In FMD, the diameter of the brachial artery is ultrasonically measured before, during and after a cuff being applied to the lower arm of the subject. The cuff is distal to the ultrasound probe to capture predominantly endothelium-dependent vasodilation. This cuff is inflated rapidly after establishing a baseline brachial artery diameter, the cuff remains inflated for 5 minutes and is then rapidly deflated. This process induces a period of reactive hyperaemia, resulting in the brachial artery to vasodilate due to the increased shear stress causing nitric oxide (NO) to be released. NO is a vasodilator. By assessing the peak diameter of the brachial artery, an FMD percentage can be calculated, this value reflects the subject's endothelial function. FMD is calculated as a percentage between the peak arterial diameter and the baseline diameter of the brachial artery.

The clinical application of the FMD test for establishing a subject's endothelial function is very useful for paediatric patients that are predisposed to high cardiovascular (cv) risk. There are several risk factors that affect these patients, insulin resistance, sleep apnea, lack of physical exercise etc. Early detection of high cv risk using FMD will permit behavioural and or drug countermeasures to be incorporated in the patient's lifestyle to prevent the accelerated development of atherosclerosis a high cv risk patient is likely to experience. Furthermore, patient specific modelling of the FMD test will remove the ethical issues of applying an inflated cuff to the lower arm of a paediatric patient. Additionally, computational modelling permits a wide and robust investigation into haemodynamic parameters that are not easily measurable in-vivo. These parameters, such as pulse wave velocity (PWV), oscillatory shear index (OSI) and wall shear stress (WSS) are valuable for assessing the development of atherosclerosis.

Therefore, a numerical model using computational fluid dynamics (CFD) in STAR CCM+ has been generated for modelling the haemodynamics in the bifurcation of the brachial artery to the radial and ulnar arteries. Thus far, an idealised geometry has been utilised using geometry characteristics from a virtual database. The model has fluid-structure coupling due to the mapping between the CFD modelled fluid domain and the solid domain which is modelled using a finite volume solid stress model. The model employs transient boundary conditions in accordance with the cuff application under FMD. PWV and WSS in addition to wall displacement, velocity and pressure are presented.