Title: Blood Flow Analysis of the Aortic Arch using Computational Fluid Dynamics in a Coupled 3D-0D Framework

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Regions of the aortic arch affected by an aneurysm or dissection may require surgical intervention using vascular grafts, which includes a means of re-perfusing the supra-aortic branch vessels, comprised of the left subclavian artery (LSA), left common carotid artery (LCCA) and brachiocephalic artery. Open surgical grafts are widely used in arch reconstruction yet the graft configuration which ensures optimal post-surgical perfusion is currently poorly understood. For example, peripheral organ ischaemia and post-operative malperfusion remain a concern. It is clear, therefore, that enhanced understanding of perfusion in patient-specific cases is critical to improving clinical practice an patient outcomes.

In this work, a representative computational model of the aortic arch was investigated via computational fluid dynamics on ANSYS Fluent® to analyse the haemodynamics of a human aortic arch using a coupled 3D-0D numerical framework. The outlet boundary conditions were created by discretisation of the 3-element Windkessel (3EWM) model, which enabled simulation a range of physiologically realistic downstream conditions, both healthy and pathological. The 3EWM is computationally efficient, does not require any specification of pressure or flow rate at the outle, and describes the pressure-flow relation due to the distal vasculature downstream of the 3D domain. Furthermore, the parameters of the 3EWM were tailored to match clinical pressure data and the resultant pressure waveform was verified on MATLAB®.

The haemodynamic parameters under investigation include flow rate as a measure of perfusion, time averaged wall shear stress (TAWSS), oscillatory shear index (OSI), and pressure distribution. These are clinically significant in the case of open surgical vascular grafts as an abnormal distrubtion can increase the risk of graft failure through platelet activation and thrombosis, and focal development of post-surgical intimal hyperplasia at regions of anastomosis.