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CENTRELINE ANALYSIS OF THE ROLE OF GEOMETRY ON FLOW IN CURVED BLOOD VESSELS

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ABSTRACT

Atherosclerosis is associated with the curvatures of large arteries, such as the aorta and coronaries, and it has been shown to correlate well with haemodynamic mechanisms, such as low oscillatory wall shear stress values [3]. Blood flow simulations in patient-specific geometries offer valuable data to investigate the genesis, development and distribution of arterial disease. However, these types of simulations lead to vast amount of data which ideally need to be simplified in order to classify and elucidate the main flow-related mechanisms that govern the evolution of arterial disease.

The formation of secondary flow patterns in cardiovascular vessels and their association with quantities such as wall shear stress under physiological conditions is not completely understood. Although many individual studies have been performed to analyse flow in isolated environments, such as flow round bends of fixed curvature [1,2] or helical pipes of fixed curvature and torsion [1,4], the coupling between a series of bends of varying curvature and torsion is less well understood [7]. This type of flow environment is important to understand how different arterial regions might be fluid dynamically coupled, for example in selecting an appropriate inflow length of vessel to allow the flow to become fully developed in an anatomically correct computational flow model.

This presentation will analyse the flow patterns generated in idealised geometries to give insight into the generation and coupling of secondary flows in the more complex geometries that arise in the human vasculature. Figure 1 shows the non-planar double bend geometries that will be studied, which approximate a curved artery or a peripheral artery graft model with the proximal branch of the host vessel occluded. The unsteady Navier-Stokes equations for incompressible, Newtonian and laminar flow are solved in these fixed geometries using a Galerkin spectral/*hp* element method [5], which combines the geometric flexibility of standard finite element methods with the favourable convergence properties of high order spectral methods.

The three-dimensional flow sets generated are then reduced to the cross sectionally averaged Navier-Stokes equations about the centreline of the vessel, using the three-dimensional coordinate system along

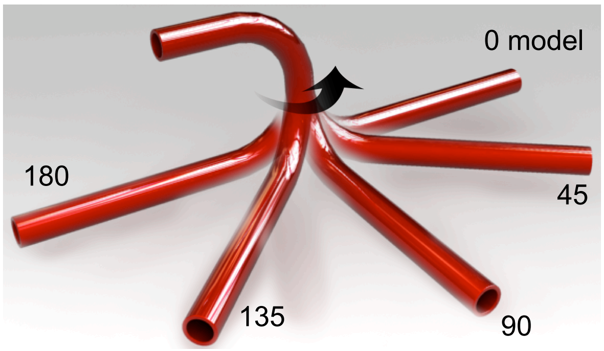

Figure 1: Non-planar double bend idealised geometries in which the secondary flow patterns will be studied. Numbers indicate the azimuthal angles between the plane of curvature of each bend. (Taken from [6].)

a generic spatial curve proposed by Germano [4]. This data reduction allows us to identify the individual roles of centripetal and pressure forces, viscous contributions and convective acceleration. Quantification of the interactions between the pressure and the inertial fields provides a valuable insight into the generation and evolution of secondary flow patterns and their association with quantities such as wall shear stress. We also express the vorticity transport equations in the Germano's coordinate system [4] to identify the terms governing the generation, transport and accentuation of vortical structures.

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