Steady and unsteady blood flow simulations in the mouse aortic arch

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Transgenic mice have been used extensively for studying human atherosclerosis. This experimental model overcomes the limitations of human studies, e.g. invasive intervention, tissue sample and study time. The aim of this work is to demonstrate the feasibility of computational fluid dynamic (CFD) modelling of realistic blood flow in the mouse aortic arch, physiologically and geometrically. The aorta is the largest vessel in the body; it originates from the left ventricle of the heart and consists of the ascending aorta, aortic arch and descending aorta. The aortic arch is non-planar and has a complex three-dimensional geometry. The blood flow fraction in the major branches of the mouse aortic arch, namely inominate, left common carotid and left subclavian arteries, was measured by ultrasound biomicroscopy in normal CD1 mice. The geometry of the aortic arch was captured by plastic casting and micro CT imaging. Mouse blood viscosities were measured by rheometry. A well-validated, in-house finite element code which solves the three dimensional Navier-Stokes equations was used to compute the wall shear stress and velocity patterns in the ascending aorta and the aortic arch. The non- dimensionalisation scheme is based upon the following characteristic quantities: length R (inlet radius); time ω^{-1} (inverse unsteady frequency in radians); velocity U_0 (spatial and temporal mean inlet velocity); and pressure ρU_0^2. Using these characteristics, the dimensionless Navier-Stokes equations take the following form:

$$\alpha^2 \frac{\partial u}{\partial t} + \mathrm{Re}\, u \cdot \nabla u = -\mathrm{Re}\, \nabla p + \nabla^2 u$$

$$\nabla \cdot u = 0$$

where α, the Womersley parameter and Re, the Reynolds number, are defined as

$$\alpha = R\sqrt{\frac{\omega}{\nu}}$$

$$\mathrm{Re} = \frac{U_0 R}{\nu}$$

The calculated mean Reynolds number based on diameter was 165, and a Womersley parameter of 2.11 was used for unsteady flow. In this talk, we describe the steady and unsteady flow simulation results. We conclude that CFD modeling of hemodynamics in the mouse aortic arch is feasible.