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ONE-DIMENSIONAL MODELS FOR BLOOD FLOW APPLICATIONS

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One-dimensional (1D) modelling has been used extensively to simulate arterial hæmodynamics, with applications ranging from pulse wave propagation and wave intensity analysis to the development of diagnostic tools. Predictions from 1D blood flow models exhibit many of the features of the systemic arteries of both normal and diseased physiologic and geometric data, and can provide useful information at a reasonable computational cost. In the last decade only, several models have been developed, with different formulations and numerical schemes. More recently, there has been an interest in comparing and validating these approaches against measured data. A major aspect that still needs to be considered is how these models can be used for practical applications, and if they are likely to be useful in the clinical decision-making process.

In this talk, we will cover two of these aspects: numerical comparison against experimental data, and discuss how we can apply 1D models to aneurysm detection and evaluation of coronary blood flow.

Aneurysm Detection An abdominal aortic aneurysm (AAA) is a blood-filled balloon-like bulge of the abdominal aorta, usually exceeding the normal diameter by more than 50%. It is the most common form of aortic aneurysm, although they are often asymptomatic. As it increases in size, an AAA is more likely to rupture and becomes a life-threatening condition.

Preliminary results show that it is possible to detect a pulse alteration at the extremities for large aneurysms. To determine the pressure and flow waveform at any location in the vascular system, we use a model arterial network, decomposed into segments connected to each others. We use a transfer function to calculate the aortic pressure from the measured data, and impose the resulting waveform at the inlet of the network as a boundary condition. Manifestations of changes in pulse wave velocities and waveforms will be investigated and quantified against the measured data, and the practical value of the proposed method will be assessed.

Coronary Modelling Fractional flow reserve is a clinical index used to determine if a coronary stenosis (reduction in diameter due to coronary artery disease) can affect blood flow to the heart. It is performed invasively in the catheterization laboratory and represents the fraction of the normal maximal coronary blood flow that is achieved in the presence of a stenotic artery. Under hyperæmic conditions, coronary resistance will be minimal, and flow can be assumed to be proportional to pressure.

Recently, non-invasive methods have been proposed to estimate this index, relying on computed tomography images and computational fluid dynamics. 1D modelling has also been used, but to a lesser extent due to evident limitations in model complexity (mostly due to the difficulty of representing patient-specific geometries). From the practical point of view, this might not be so important, if we can achieve a certain degree of accuracy and reproducibility. We will present preliminary results obtained with model data, and discuss how, with 1D models, we can investigate important mechanisms of coronary blood flow.

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