Flow assessment in curved vessels by means of ultrasound

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Introduction

The most common arterial disease is atherosclerosis. The spatial distribution of artherosclerosis is correlated with the distribution of the arterial wall shear stress (WSS) [1]. Atherosclerotic plaques (figure 1) tend to form on those locations where oscillating or low shear stresses occur [2].

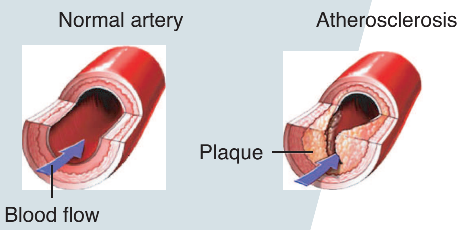

Figure 1: Atherosclerotic plaque in a vessel [3]

Doppler ultrasound can be used as a non-invasive method to obtain the WSS and flow. Because it is difficult to perform velocity measurements close to the vessel wall, the WSS and flow must be estimated from the centreline or core blood velocity.
In practice, vessels can be slightly curved and tapered causing an asymmetry in the flow, which results in an inaccurate assessment of both flow and WSS.

Aim

Estimate the 3d curvature and tapering of a vessel from the shape of the core velocity profiles over time. Apply this knowledge to derive flow properties and assess flow and WSS as a function of time.

Research approach

Velocity estimation by means of ultrasound

Currently the WSS is derived from the centreline or core velocity, determined by Doppler ultrasound. To enable simultaneous assessment of flow and wall motion a 2d cross correlation algorithm will be developed to determine the blood flow velocity from the raw ultrasound data (figure 2).

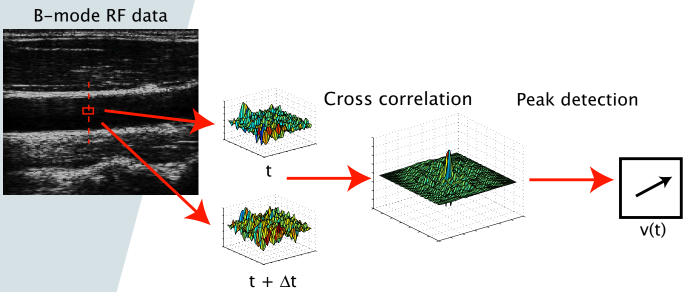

Figure 2: Schematic overview of the crosscorrelation algorithm

This algorithm will be applied at a few positions across the vessel lumen to accurately reconstruct the velocity profile in the core.

Influence of geometrical parameters

The influence of the 3d shape of the vessel on the flow will be investigated with experiments in a phantom setup and computational modelling. To gain fundamental knowledge of the influence of the geometrical parameters, experiments will primarily be performed on perfect geometries.

Experiments in a phantom setup enable the application of an arbitrary flow to an arbitrary tube (e.g. curved and/or tapered). Flow measurements can be performed using ultrasound but also by additional techniques such as LDA or PIV.

The computational model solves the instationary Navier Stokes equations for a specific input geometry using a finite element method. Figure 3 e.g., shows a pulsatile flow through a 3d rigid curved tube.

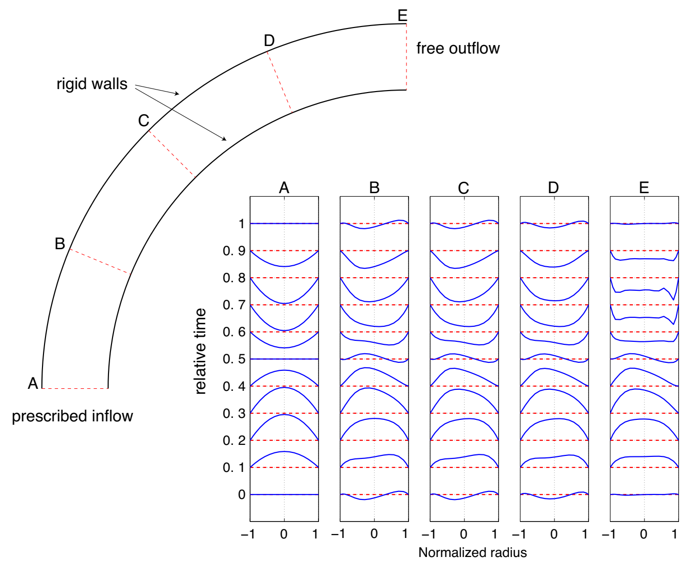

Figure 3: Computational model showing the asymmetric velocity profiles in a curved tube. (Re≈200, De≈60)

Results and future work

Preliminary results using the cross correlation algorithm look promising but have to be evaluated in the phantom setup. The 3D rigid tube computations show good results. The computational model will be upgraded with flexible walls.

References:

[1] Davies, P.F., *Physiological Reviews, 75:519-560, 1995*

[2] Caro, C.G. et al., *Proceedings of the Royal Society London, B, 177:109-159, 1971*

[3] *Mount Auburn Hospital, www.mountauburn.caregroup.org*