A wave propagation model of blood flow in large vessels based on boundary layer theory

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Introduction
1D wave propagation models of the cardiovascular system may be well suitable to provide clinically relevant information about the entire systemic circulation. The boundary layer theory introduced previously in 1D wave propagation already provided an improvement in estimating the wall shear stress [1]. The use of a viscoelastic material model is believed to yield even better results.

Methods

The arterial wall is modelled as a viscoelastic material using a standard linear solid model as depicted in figure 1. Here, \( \sigma_{\theta} \) represents the circumferential stress in the vessel wall. To validate the final model, experimental data as measured with the setup depicted in figure 3 is used.

Numerical Results

Introducing the standard linear solid model into the 1D wave equations yields a set of nonlinear differential equations that was solved using the spectral element method. Numerical and experimental results are shown below, when using linear elastic theory from [1] (figure 3) and when using the standard liner solid model.

In the total arterial tree coupling between arteries is provided by bifurcation elements. At the aortic root a flow pulse is prescribed and the truncated arteries are endowed with 3-element Windkessels to provide physiological peripheral resistance.

Discussion

- The proposed wave propagation model based on viscoelastic wall behaviour closely describes results from the experimental setup, in contrast to the model based on linear elastic theory.
- Pressure and flow data from the total arterial tree simulation are in the physiological range and are in agreement with literature data.
- Further refinements may be achieved by using a generalized Maxwell model to describe visco-elastic wall behaviour.

References


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