

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

Citation for published version (APA):

Bessems, D., Rutten, M. C. M., & Vosse, van de, F. N. (2004). *A wave propagation model of blood flow in large vessels based on boundary layer theory*. Poster session presented at Mate Poster Award 2004 : 9th Annual Poster Contest.

Document status and date:

Published: 01/01/2004

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

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

David Bessems, Marcel Rutten, Frans van de Vosse
Eindhoven University of Technology, Department of Biomedical Engineering

Introduction

In cardiovascular surgery patient specific data are needed for pre-operative decision making. When making proper assumptions on the local velocity profiles, 1D wave-propagation models may be well suitable to provide clinically relevant information (e.g. wall shear stress). Existing 1D wave-propagation models use rough estimates for velocity profile functions, resulting in poor estimates for the wall shear stresses. Velocity profiles based on boundary layer theory are believed to result in better friction estimates.

Objectives

- Revisit the 1D wave-propagation theory by Hughes and Lubliner[1] and modify it using a velocity profile function based on the boundary layer theory (BLT).
- Compare resulting profiles and wall shear stresses to Womersley's theory.
- Determine the influence of the friction term in comparison to Poiseuille friction.

Methods

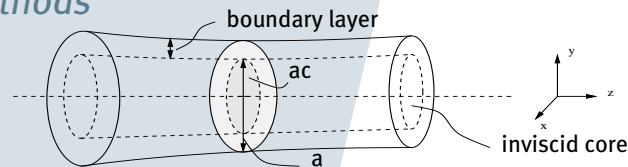


Figure 1: Part of a vessel (radius a) divided into a core (radius a_c) and a boundary layer (thickness δ_v).

By dividing the flow in a vessel in an inertia dominated core and a friction dominated boundary layer (see Figure 1) and by assuming equilibrium between inertia and viscous forces at $r = a_c$, a velocity profile v is derived as a function of the flow q and the pressure gradient $\frac{\partial p}{\partial z}$.

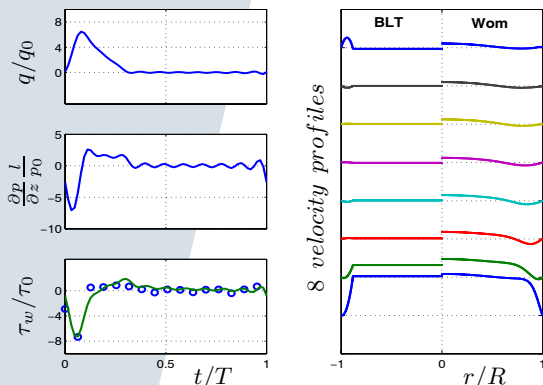


Figure 2: (left) Typical aortic flow q , pressure gradient $\frac{\partial p}{\partial z}$ and wall shear stresses (τ_w) derived by the BLT (\circ) and the Womersley theory (Wom) (-). (right) The resulting velocity profiles at 8 time steps.

A comparison between BLT and the exact solution of the Navier-Stokes equations by Womersley is presented in Figure 2. The derived velocity profile function is used in the 1D wave propagation model to obtain an equation for mass conservation and momentum balance.

/department of biomedical engineering

Numerical Results

An aorta-like vessel as well as an A.tibialis posterior-like vessel are modelled using 1D spectral elements. Physiological flow pulses are imposed at both inlets whereas resistances are prescribed at the outlets. Numerical results of the wave-equation using BLT and friction according to Poiseuille flow are shown below.

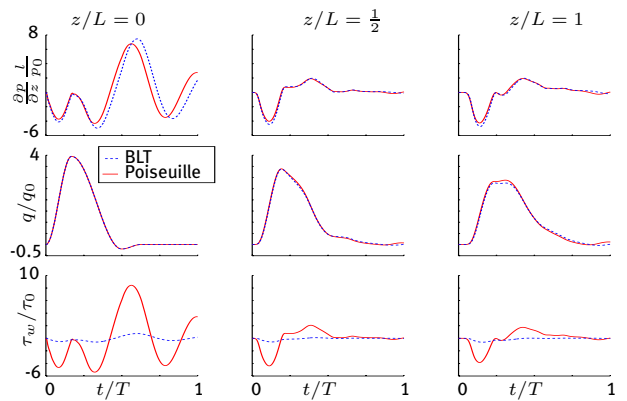


Figure 3: Normalized pressure gradient (top), flow (middle) and wall shear stress (bottom) as a function of time at 3 axial positions in an aorta-like tapered vessel using friction according to BLT (dashed) and Poiseuille theory (solid).

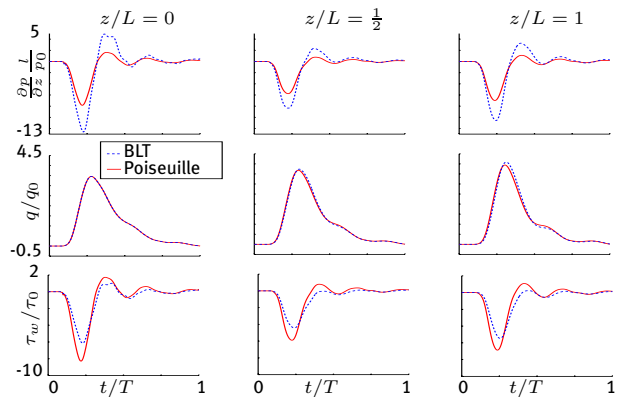


Figure 4: Normalized pressure gradient (top), flow (middle) and wall shear stress (bottom) as a function of time at 3 axial positions in an A.tibialis posterior-like tapered vessel using friction according to BLT (dashed) and Poiseuille theory (solid).

Discussion

Velocity profiles obtained by BLT provide good approximations for wall shear stress when compared to Womersley's theory. Results of wave propagation simulations show that the choice of a proper velocity profile function is not only crucial in predicting the wall shear stress, but also in monitoring the pressure and flow wave characteristics.

References

- Hughes, T. J. R. and Lubliner, J. (1973). On the one-dimensional theory of blood flow in large arteries. *Math. Biosciences*, 18, 161-170.