

Towards modelling thrombus formation in abdominal aortic aneurysms

Citation for published version (APA):

Gunther, T. W. M., Bovendeerd, P. H. M., & Vosse, van de, F. N. (2006). *Towards modelling thrombus formation in abdominal aortic aneurysms*. Poster session presented at Mate Poster Award 2006 : 11th Annual Poster Contest.

Document status and date:

Published: 01/01/2006

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.

Towards modelling thrombus formation in Abdominal Aortic Aneurysms

Tijmen Gunther, Peter Bovendeerd, Frans van de Vosse

Eindhoven University of Technology, Department of Biomedical Engineering

Introduction

In most cases intraluminal thrombus is found in Abdominal Aortic Aneurysms (AAAs), a pathological dilation of the infrarenal aorta (see fig. 1). These blood clots hinder blood-wall transport and alter the mechanical stimulation of endothelial cells, inducing arterial adaptation that can result in aneurysm growth.

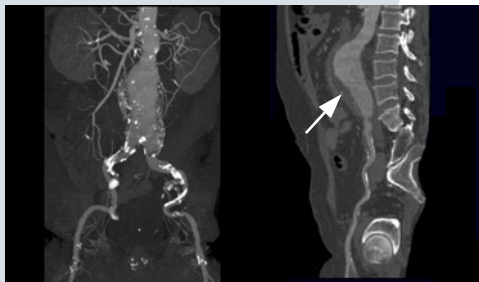


Figure 1 Frontal (left) and sagittal (right) view of an AAA with intraluminal thrombus (see arrow). [Courtesy of Leiden University Medical Center, NL]

Thrombus is formed by activation, adhesion and deposition of platelets under influence of various agonists (e.g. APD and Thromboxane III). Mathematically, these processes can be described by a set of coupled convection-diffusion equations (cf. [1]):

$$\frac{\partial c_i}{\partial t} + \mathbf{v} \cdot \nabla c_i = D_{iS} \nabla^2 c_i + S_i \quad (1)$$

with c_i the concentration of the species involved, \vec{v} the velocity, D_{iS} the diffusion coefficient and S_i the source term.

Methods

To obtain the necessary velocity field for eq. (1) we focus on solving the instationary Navier-Stokes equations:

$$\begin{cases} \rho \left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) - \eta \nabla^2 \mathbf{v} + \nabla p = \mathbf{0} \\ \nabla \cdot \mathbf{v} = 0 \end{cases} \quad (2)$$

with density ρ , dynamic viscosity η and pressure p . In SEPRAN [2] the validated (discontinuous pressure) 15-pts tetrahedra are used as benchmark to study the performances of the 10-pts tetrahedral in a continuous pressure formulation for an AAA geometry based on patient specific imaging data.

Results

In fig. 2 the 15-pts tetrahedron is validated by simulating a Womersley flow. The results of the AAA simulation (peak inlet flow of 6 [l/min], corresponding to $Re_R \approx 750$) are shown in fig. 3. Using the 10-pts tetrahedra the total number of nodal points is reduced by a factor 3. Total computing time /department of biomedical engineering

is reduced significantly (over 10 times) while the results are comparable.

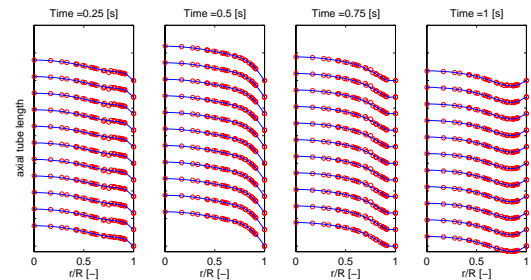


Figure 2 Validation of the 15-pts tetrahedron by comparing the numerical (circles) and analytical (line) results of oscillating flow in a rigid tube with $Q_{max}(t) = 4$ [l/min] at $t=0.5$ [s].

Discussion

The 10-pts tetrahedron provides a good alternative for the cost-inefficient 15-pts tetrahedral element. Moreover, they can also be used in a pressure-correction method (PCM) i.e. decoupling the continuity and momentum equation. Preliminary tests of oscillating flow in a tube show less CPU-time consumption per time step, but more time steps are needed.

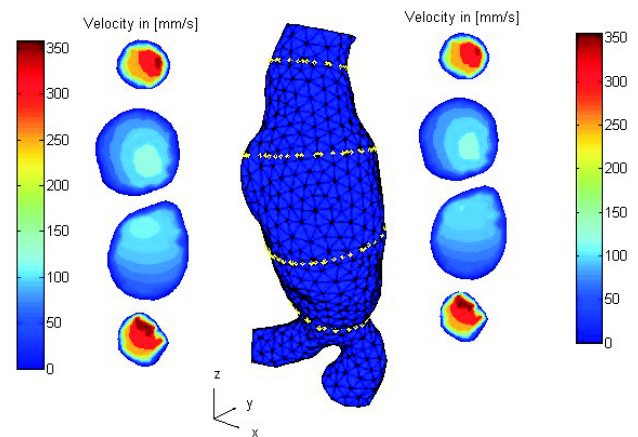


Figure 3 Cross sectional contour planes of the velocity in an AAA at time $t = 0.5$ [s] for the 15-pts (left) and the 10-pts (right) tetrahedra.

Future work

- Quantify the differences between 10-pts and 15-pts tetrahedron;
- Assessment of the PCM in physically and geometrically complex problems;
- Define model parameters for eq. (1).

References:

- [1] SORENSEN, E.N. *Ann. Biomedical Engng* vol. 27(4), pp. 449-458, 1999.
- [2] SEPRAN: User manual and standard problems, Ingenieursbureau SEPRAN, 2006.