Patient-specific development of Abdominal Aorta Aneurysms

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Introduction

The arterial wall is known to be subject to significant remodelling processes induced by local hemodynamics. This remodelling is believed to be important for the development of vascular properties in time. Computational methods can be employed to get a qualitative insight in velocity fields and stress configurations in patient-specific anatomies of abdominal aortic aneurysms.

Objective

Develop an efficient finite element algorithm that can predict the remodelling (development) of the arterial wall in Abdominal Aortic Aneurysms (AAA) in time.

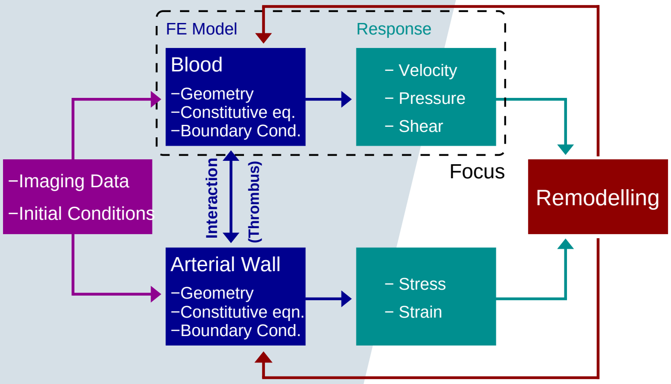

Figure 1: *Overview of the followed procedure.*

Methods

The procedure depicted in figure 1 is followed to derive proper input parameters for the remodelling proces. Solution of the equations governing fluid motion yields fluid pressure and wall shear stress (WSS). Pressure induces stresses and strains in the arterial wall. Both WSS and the stress/strain configuration are considered important initiators of the remodelling process and determine a new configuration with adapted geometrical and material properties.

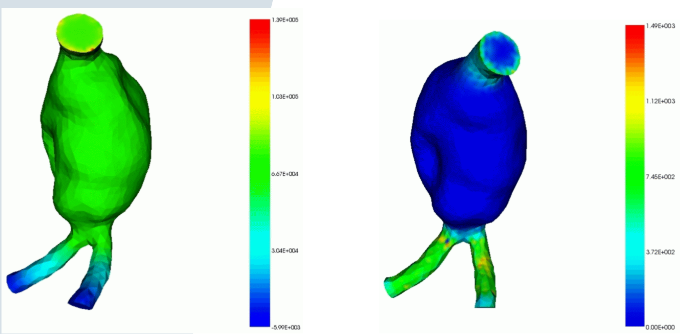

Figure 3: *Typical pressure distribution (left) in $[N/m^2]$ and Wall shear distribution (right) on the arterial wall at low Re.*

Results

Complex anatomies can be segmented from medical imaging data and are meshed with 15-noded tetrahedral elements. Infrarenal flow signals found in literature [1] are used to prescribe a plugflow inlet velocity profile during a heartcycle. An example of a resulting velocity field at low Reynolds number is shown in figure 2. In figure 3 a typical pressure and wall shear distribution is projected on the outer wall. The pressure on the wall as a result of fluid flow is neglectible compared to the pressure induced by the propagating wave.

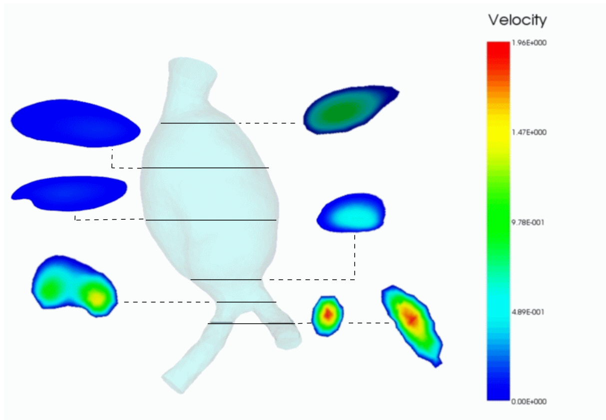

Figure 2: *Crossectional velocity profiles at different locations in the AAA.*

Discussion & Conclusions

- Within practical limits (~ 13.000 elements) no convergence is reached above $Re_R = 300$, while a physiological Re_R of about 1000 is desired.
- WSS computations are influenced by the coarseness of the wall description.

Future work

- Explore other solution procedures to solve the Navier-Stokes equations more efficiently.
- Patient-specific measurements of flow and pressure instead of assumed boundary conditions are necessary.
- Generate realistic meshes of the arterial wall together with suitable constitutive equations to perform stress computations.
- Formulation and implementation of adaptation laws for more realistic vascular behaviour possibly taking thrombus formation into account.

Literature

1 In vivo Quantification of Blood Flow and Wall Shear Stress in the Human Abdominal Aorta During Lower Limb Exercise, C.A. Taylor, C.P. Cheng et al., Ann. of Biomechanical Engineering, Vol. 30:402-404 (2002)

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