Section: **E-Learning und Simulation**

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Abstract-Title:

WALL SHEAR STRESS SIMULATIONS IN A CT BASED HUMAN ABDOMINAL AORTIC MODEL

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Abstract-Text:

Purpose

A Dilatation of the aorta, or aneurysm, is mainly due to a highly fatigued vessel wall. If left untreated, it will enlarge and may rupture. Ruptures occur when the mechanical stress acting on the inner wall exceeds the failure strength of the diseased aortic tissue. Abnormal wall shear stress (WSS) distributions may therefore be a predictor for the risk of rupture and a tool to control the efficiency of the therapy. In this work, we present a method for the computation of WSS based on finite element simulations. In order to show the distributions of WSS in a normal subject, the workflow is applied to a healthy model of abdominal aorta.

Method

For realistic simulations, the aortic model was reconstructed from high-contrast CT images. A total of 210 slices were acquired with a thickness of 1mm, covering the aorta from the renal arteries to the aortic bifurcation. An essential prerequisite for the simulations is a precise description of the geometry. The CT data were therefore accurately segmented, extracting the region of interest that is the inner wall of the aorta. A 3D surface mesh was then created from the geometric model using our medical framework “MediFrame”. The surface mesh representing the boundaries of the aortic wall was then smoothed and cleaned for further processing. For the blood simulations, a mesh model of 3D finite volumes -finite blood elements- was generated using the mesh generator Gambit. The fluid domain, consisting of tetrahedral and some pyramidal cells obtained from applying boundary layers, was then exported as a mesh file suitable for the FVM simulations.
WSS simulations were computed using the CFD program Fluent. Fluent solves the equations governing the blood flow to compute velocity and pressure distributions and derive shear stresses along the wall from the gradient of the velocity profiles. Realistic boundary conditions at the inlet were considered in terms of a mean unsteady velocity profile obtained from previous MR flow measurements. As at the outlets, the zero-pressure boundary condition was considered. The wall was assumed to be rigid with the no-slip condition at its boundaries. Blood was considered as a Newtonian fluid with a constant viscosity of 0.003 Nsm-2 and the flow as laminar. Blood density was taken as 1005kgm-3. And finally, equally spaced time steps were used to simulate two cardiac cycles.

Results

The simulation results show realistic mean WSS distributions and provide quantitative description of the stress conditions in the aortic model. The mean range of the computed values is compatible compared to the range obtained by other in vivo and in vitro methods (between 0dyn/cm2 and 10.4dyn/cm2) as reported in [1] and [2]. Indeed, regions of relatively low wall shear stresses were observed in the infrarenal aorta, which explains why these regions are subject to aneurysms, formation of thrombus and ruptures.

Conclusion

The presented workflow allows a numerical method for the computation of shear stresses along the aortic wall, which are not obtainable with experiments. They are important in evaluating the efficiency of the treatment but also allow predicting risk of rupture and making decision about whether a surgery is necessary or not. However, further development and validation should be investigated in order to reach much more realistic computations that can be implemented clinically.

References[1] Taylor et al., "In vivo quantification of wall blood flow and wall shear stress in the human abdominal aorta during lower limb exercise", Annals of Biomedical Engineering, Vol.30,pp.402-408,2002.

[2] Oshinski et al., "Determination of wall shear stress in the aorta with the use of MR phase velocity mapping", J Magn Reson Imaging, 1995;5(6):640-7.