AAA peak wall stress lacks reproducibility in rupture risk assessment

AAA Peak Wall Stress Lacks Reproducibility in Rupture Risk Assessment

L. Speelman[1], E.M.H. Bosboom[1], G.W.H. Schurink[2], M.J.H.M. Jacobs[2], F.N. van de Vosse[1]
[1] Eindhoven University of Technology, Department of Biomedical Engineering
[2] Maastricht University Medical Center, Department of General Surgery

Introduction

In the past, several research groups have focused on AAA wall stress in order to improve the rupture risk analysis [1-4]. In all studies, the reconstruction of the AAA from medical images required user-input, which may lead to uncertainties with respect to the real AAA geometry. However, the reproducibility of these analyses with respect to the peak stress has never been evaluated.
The purpose of this study is to assess the sensitivity of AAA wall stress analysis and to evaluate different stress parameters (peak stress and the 0.99 and 0.95 percentile of the stress) with regard to reproducibility and discriminatory power.

Materials and methods

Twelve patients with AAAs ranging from 44 to 57 mm in diameter were included. The CT scans were analyzed using the Hemodyn prototype software (PMS, Best, NL). After selecting the starting and end points, a fully automatic segmentation and meshing procedure was followed (fig 1). The resulting finite element wall meshes were used to compute stresses using Sepran (Sepralab, NL) as the finite element (FE) solver. The complete analysis procedure was repeated 5 times for each patient.

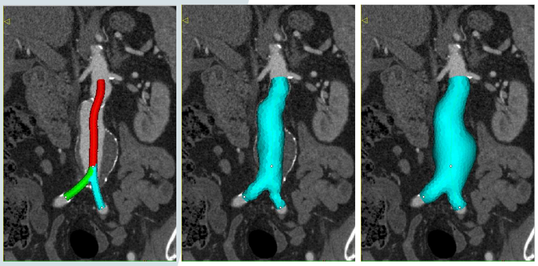

Figure 1 *Centerline tracking based on 3 user points (left). Segmentation of the lumen (middle) and wall (right) by automatic 3DAO deformation.*

In the FE simulations, the following settings are used:

- ☐ A peak systolic blood pressure of 18.7kPa
- ☐ A constant wall thickness of 2mm
- ☐ A realistic hyperelastic material model (G=0.9kPa)
- ☐ Total proximal and distal fixation of the wall

Results

When comparing the meshes for each AAA individually, only small and local differences can be seen. Figure 2 shows the mean and standard deviation (errorbars) for the peak, 0.99 and 0.95 percentiles stresses. The AAAs are ordered by maximum diameter.

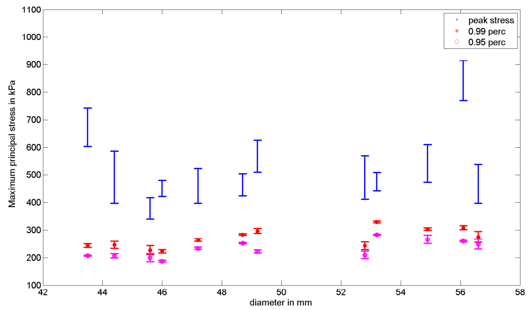

Figure 2 *Peak, 0.99 and 0.95 percentiles stress for all patients.*

The variation in peak stress is much larger than in 0.99 percentile stress. The outliers identified in the peak stresses are thus present in the top 1% of the stresses.
The wall stress distributions and stress maps of 3 analyses of one patient are displayed in figure 3. The stress maps comprise of the stress normalized to 0.99 percentile, plotted against AAA height. Correlation (ρ) between stress maps within one patient was much higher than correlation between stress maps of different patients ($\rho > 0.8$ versus $\rho < 0.6$).

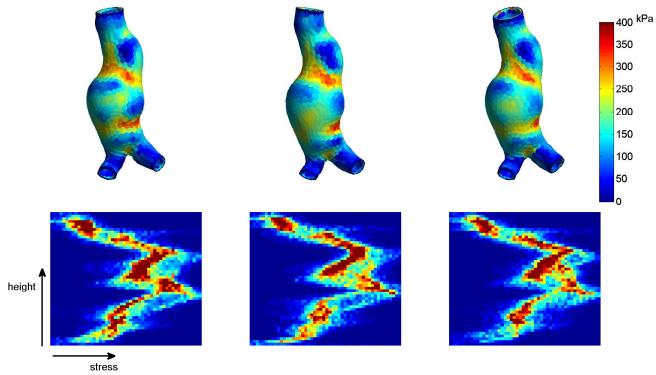

Figure 3 *Stress distributions and stress maps of 3 analyses for 1 patient.*

Conclusions

Variation in user-input resulted in small and local variations in the meshes, causing large variations in peak stress. The influence on stress distribution and the 0.99 percentiles, however, is much smaller. Further analyses should elucidate whether the 0.99 percentile stress is able to distinguish between low and high risk patients.

References:

[1] Fillinger et al: *J Vasc Surg* 2002 Sep; 36(3):589-97

[2] Venkatasubramaniam et al.: *Eur J Vasc Endovasc Surg* 2004 Aug; 28(2):168-76

[3] Raghavan et al: *J Biomech Eng* 2005 Oct; 127(5):868-71

[4] Truijers et al: *Eur J Vasc Endovasc Surg* 2007 Apr 33(4):401-7