MERGING 4D ULTRASOUND AND MODIFIED VIRTUAL FIELDS METHOD TO REGIONALLY CHARACTERIZE ABDOMINAL AORTIC ANEURYSMS

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Introduction

Clinical management of abdominal aortic aneurysms (AAA) has been solely based on the maximum diameter threshold. Attempts to replace this generalized parameter with more patient-specific scientific indices have led to the discovery of biomechanical markers of AAA progression and rupture risk. However, to ensure that these markers are truly patient-specific, it is crucial to identify the individualized material parameter values of each AAA. In this study, we present a novel method to extract this information on patient-specific material behavior from AAA wall motion using a combination of 4D ultrasound (US), speckle tracking, and a virtual field method (VFM)-based inverse method [1].

Methodology

Patients with AAA underwent 4D US acquisition at a frequency of 4-8 Hz over multiple heartbeats. Image volumes were segmented at the diastolic phase, and the inner- and outer walls were tracked using an in-house speckle-tracking algorithm [2]. The point clouds at systole and diastole were fitted to B-spline grids, which were then co-registered to minimize the distance between adjacent knots, thus generating the displacement fields of the inner wall and outer wall. Displacement vectors in the bulk of the AAA wall were generated by interpolating corresponding displacement vectors on the neighboring nodes in the inner wall and outer wall. An unsupervised and discretized spline smoother was used to smooth the final displacement field, which was used as the full-field deformation field in a modified virtual fields (mVFM) approach.

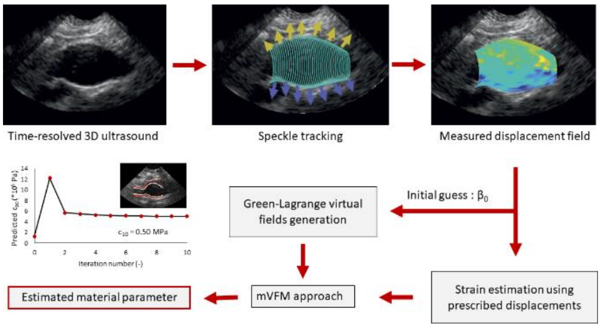

Figure 1: Overall schematic of the material parameter estimation method (mVFM).

mVFM (illustrated in Figure 1) uses a virtual work-based cost function based on traditional VFM, which leads to fast convergence. It also adopts an iterative nature similar to that of the finite element updating method. An appropriate test function is automatically chosen, and serves to tactfully eliminate parameters that are difficult to estimate.

Results

An initial guess of c_{10}=1.2·10^6 Pa was used in an uncoupled Neo-Hookean material model. The optimized global and local material parameter values were predicted within 3 and 10 iterations, respectively.

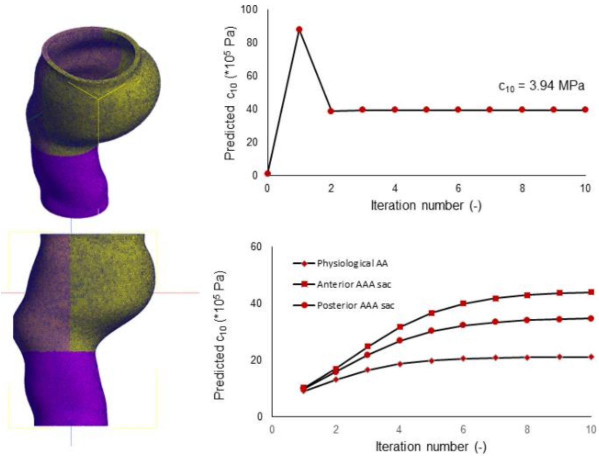

Figure 2a: AAA mesh showing physiological (purple), anterior AAA (yellow) and posterior AAA (orange) wall. Prediction of b: global and c: local values of material model parameters.

Discussion

mVFM was successfully implemented using AAA deformation fields obtained from routine US images. The anterior AAA sac and the healthy abdominal aorta had the highest and lowest shear modulus respectively [3]. As a next step, the use of more sophisticated material models using better input data[4] within the mVFM framework will be evaluated.

References

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Acknowledgements

The authors would like to thank the Dutch Research Council NWO (VIDI 17533) for financially supporting this project.