IMAGE-BASED IN VIVO ESTIMATION OF REGIONAL STRAIN AND STIFFNESS PROPERTIES OF THE WHOLE AORTIC VESSEL

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Introduction

The mechanical analysis of arterial tissues is a fundamental research topic in the field of cardiovascular pathologies [1]. It is well established that a plethora of cardiovascular diseases find their origin within the vessel biomechanics [2]. The current gold standard practice for tissue testing necessarily requires tissue harvesting. In order to avoid ex-vivo procedures, several image-based techniques for estimation of arterial mechanical properties were proposed [3]. The aim of the study is to present a workflow for semi-automatic estimation of strain and stiffness distributions on both ascending and descending aorta. The method is based on the segmentation and processing of ECG-gated CT datasets.

Methods

A total of 10 datasets of ECG-gated CT images was considered. All the datasets included the ascending and, where available, the descending portion of the aorta. The workflow included the following phases: segmentation (i), mapping (ii), strain (iii), stress (iv) and stiffness estimation (v). The automatic segmentation was carried out for each cardiac phase, according to an AI based algorithm (Figure 1 a). The aortic surface at baseline was then mapped with a structured mesh and then morphed to match the different cardiac phases with a morphing method. For strain estimation, the baseline centerline was calculated and the sectional length was evaluated for each point. The corresponding sectional length at each cardiac phase was recovered with the mapping from morphing. The circumferential strain (ε_θ) at each section was calculated according to the sectional length ratio. For stress estimation, circumferential stress was calculated according by assuming the aorta as a pressurized membrane. For stiffness estimation, the circumferential Young's modulus (E_θ) was evaluated as the stress – strain ratio, assuming a linearized material response under physiological conditions.

Results

The resulting strain and stiffness distributions were correctly evaluated for each case. An example of two cases of whole aorta with the resulting ε_θ distribution at systolic peak (Figure 1 b) and the corresponding E_θ (Figure 1 c) are reported. In both cases a high strain area (ε_θ > 20%) exists at aortic valve level in the outer curvature. This demonstrates the workflow potential to cope the valvular plane movement caused by left ventricular kinematics. The reported E_θ values were contained in the 1 – 3 MPa range, in line with literature [4].

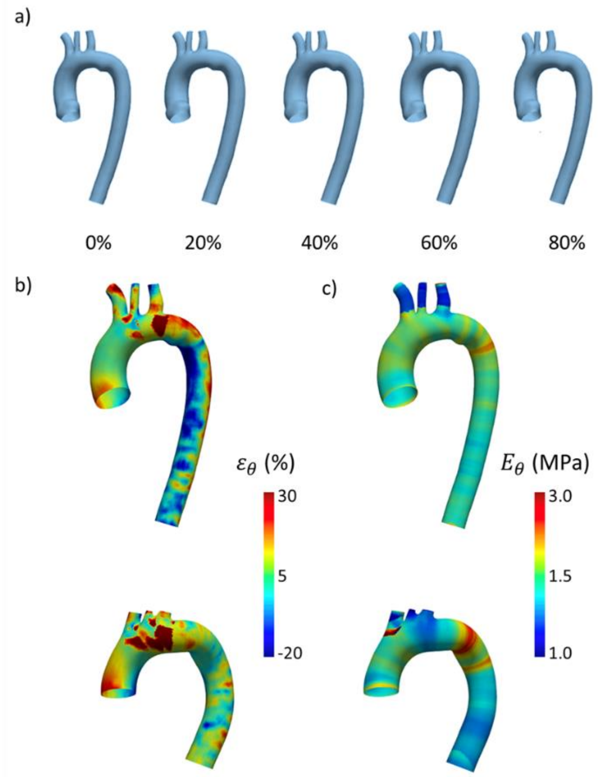

Figure 1: Segmentation at different phases (a), strain (b) and stiffness (c) distributions for two cases with whole aorta ECG-gated CT datasets.

Discussion and Conclusion

In general, the workflow was correctly implemented and applied to a patient population. The results demonstrated the successful obtainment of a regional in vivo characterization of whole aortas in terms of strains and stiffness.

References

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