Synchrotron-based quasi-static pressure inflation of the mouse carotid artery

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Introduction

Recent synchrotron-based pre-clinical evidence has demonstrated that thoraco-abdominal aortic dissections initiate as micro-structural ruptures of the aortic lamellae in Ang II-infused mice [1]. Unfortunately, the contribution of micro-structural mechanics to cardiovascular disease initiation is still poorly understood. State-of-the-art 3D imaging techniques such as in vivo micro-CT and MRI cannot visualize these micro-structural components, while multiphoton imaging has a limited field of view [2]. Synchrotron-based imaging, on the other hand, would allow for more detailed 3D models but is typically based on scans of non-pressurized, ex vivo aortic samples. In order to overcome this limitation we developed a synchrotron-compatible pressure inflation device that allows for quasi-static imaging of the mouse carotid artery at different pressure levels.

Methods

Six wild type (WT) and six ApoE-/- mice, all male and on a C57Bl6/J background, were used for this study. After mounting the left carotid artery on the device, pressure was increased quasi-statically with a syringe pump, from 0 to 120 mmHg. Synchrotron-based phase-propagation imaging was performed at 25m source-to-sample distance, at 25 cm sample-to-detector distance and at 21 keV. A scientific CMOS detector (pco.Edge 5.5) was used in combination with a 4x magnifying visible-light optics and a 20 µm thick scintillator. The effective voxel size was 1.625 μm^3. During the scans the axial stretch was kept at the in vivo value. Images were segmented using an in-house developed automated segmentation algorithm. Aortic diameter, length, straightness and thickness were quantified at each pressure level.

Results

All three lamellar layers straightened and stretched simultaneously when aortic pressure was increased, confirming earlier reports [2]. The most important increase in lamellar straightness occurred between 0 and 30 mmHg. We did not find significant differences in straightness between the three different lamellar layers. The lamellar length increased quasi-linearly in all three lamellae and the decrease in thickness of the wall was equally distributed between lamellar and interlamellar layers. We did not find any statistically significant difference between WT and ApoE $^{-/-}$ mice. Segmented 3D models include both the medial lamellae and the tunica adventitia.

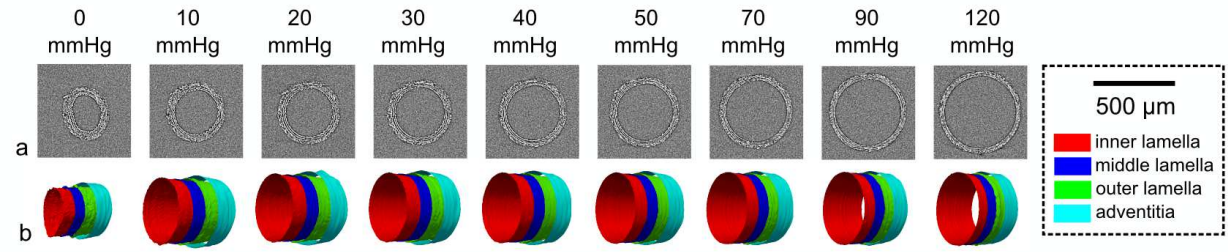

Figure 1. Synchrotron images (a) and corresponding 3D segmentations (b) of aortic lamellae and tunica adventitia in the mouse left carotid artery.

Conclusions

On the long term the results presented in this work might lead to a breakthrough in micro-structural computational biomechanics of the arterial wall. Ultimately, we hope that this will contribute to a better understanding of how the micro-structure affects the initiation and propagation of cardiovascular disease.

References

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