LOAD-INDUCED MICROSTRUCTURAL CHANGES OF COLLAGEN AND ELASTIN FIBERS IN THE HUMAN AORTIC WALL ARE LAYER-SPECIFIC

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Introduction

The mature human aortic wall evolved and developed into a three-layered structure, which on the one hand enables efficient blood flow and on the other hand provides strength to the aortic wall [1]. The health conditions in which the integrity of the aortic wall is at risk are therefore of great concern [2]. Effective treatment of such conditions could be strengthened by a predictive material model of the aortic wall, which could further support preoperative planning [3] and estimation of postoperative growth and remodeling [4]. A predictive material model of the aortic wall could only be developed based on experimental results that provide both the mechanical behavior and structural parameters of the aortic layers.

Methods

Medial and adventitial layers of human aortas were simultaneously subjected to equibiaxial loading and multi-photon microscopy (MPM). At several stretching steps, collagen and elastin were imaged based on their second-harmonic generation signal and two-photon excited fluorescence, respectively (Figure 1). The microstructural changes were quantified using the following parameters: number of fiber families, mean fiber direction, fiber orientation, fiber diameter, and fiber waviness, as in [5].

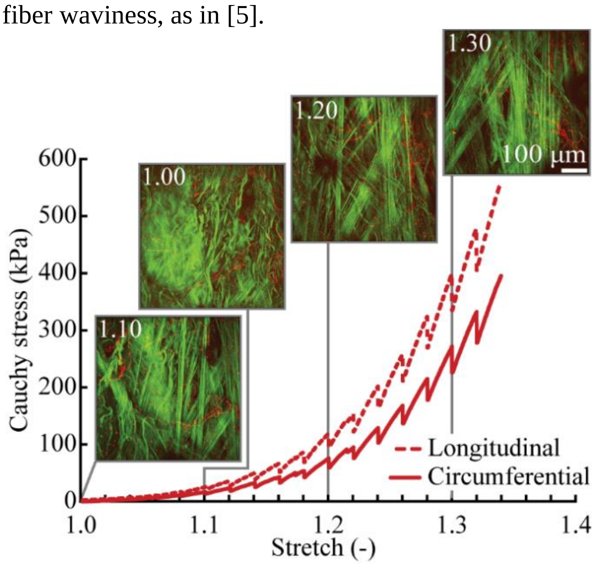

Figure 1: Representative mechanical response and MPM images showing structural changes of collagen fiber bundles (green) and elastin fibers (red) in the human aortic adventitia at exemplary stretching steps.

Results

The media and adventitia showed clearly distinct microstructural changes during equibiaxial loading (Table 1). In particular, the adventitial collagen, in contrast to the medial collagen, is divided into more fiber families. The medial elastin showed reduced waviness in contrast to the adventitial elastin. The medial collagen dispersion showed no change, while the adventitial collagen dispersion was substantially reduced. In addition, the waviness of elastin fibers showed a potential to serve as an indicator of tissue stiffness, while the waviness of collagen fibers served as an indicator of tissue strength.

Structural parameter	Media		Adventitia	
	Collagen	Elastin	Collagen	Elastin
FF	–	–	↑	–
α	–	–	–	–
κ	–	–	↓	–
D	–	–	–	–
W	↓	↓	↓	–

Table 1: Microstructural changes ('–' corresponds to no change, '↑' increase, and '↓' decrease) in the parameters of the number of fiber families (FF), mean fiber direction (α), fiber dispersion (κ), fiber diameter (D), and fiber waviness (W) observed for collagen and elastin in the human aortic media and adventitia subjected to equibiaxial loading.

Discussion

The results reflect the latest knowledge on the load-induced changes in the microstructure of the human aortic layers. The quantified structural parameters could provide a direct input for multiscale material models [6] and further support the development of the material models from reproductive to predictive capabilities.

References

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