BIOMECHANICS OF ASCENDING AORTIC DISSECTIONS

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Introduction

Changes in arterial wall constituents results in pathological conditions like atherosclerosis, aneurysms, and dissection which may be fatal if left untreated. In this study we investigate the structure-function relationships in ascending thoracic aortic dissections (TAD) and aortic aneurysms (TAA) using biaxial mechanical testing in combination with immunohistochemical (IHC) methods. Together, such studies are important to assess the contributions of individual arterial components in tissue growth and remodelling.

Methods

TAA (n=3) and TAD (n=7) tissue explants were obtained from consenting patients undergoing open surgical repair at Narayana Hrudayalaya hospital through approved protocols by the Institute ethics committee board. Mechanical experiments were performed using a planar biaxial instrument (BiSS (P) Ltd, India), details of which are published elsewhere [Agrawal, 2013]. Briefly, square samples oriented along circumferential (C) and longitudinal (L) directions in the stretcher were tested using equibiaxial (E) and non-equibiaxial (NE) force controlled protocols. Experimental data during tissue unloading, obtained following tissue preconditioning, were fit to a strain energy function [Holzapfel, 2000] given as:

$$\psi_{hz} = \frac{c}{2}(I_1 - 3) + \frac{k_1}{2k_2}\sum_{i=4,6}\left\{e^{k_2(I_i-1)^2} - 1\right\} \quad (1)$$

Unknown parameters in the equation include c (kPa), k_1 (kPa) and k_2. Strain invariants I_4 and I_6 are defined as the square of stretches in two orthogonal directions and depend on an unknown collagen angle (**θ**). Four parameters in Eq. 1 were determined using a Levenberg-Marquardt optimization in MATLAB (Table 1). Tissue constituents were visualized using IHC to delineate the presence of various tissue constituents.

Results

The Holzapfel model, shown for a representative sample (AD4), fits the experimentally data (r^2= 0.9847). Parameters to the model show large variation in material responses with L direction stiffer than C for most samples. Histological images show highly fragmented elastin fibers with some lipid deposits in some of the specimens.

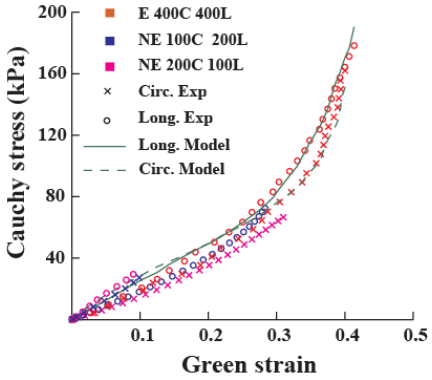

Figure 1: Biaxial experimental data from a TAD sample and corresponding model fit.

	TAD (n=7)	TAA (n=3)
c (kPa)	33.43± 13.35	32.75± 12.76
k_1 (kPa)	0.22± 0.28	1.03± 0.85
k_2	8.89± 7.96	2.75±1.6
θ(°)	30.57± 7.68	34.00± 4.60

Table 1: Model parameters (mean± stdev) for TAD and TAA samples.

Discussion

Few studies currently report the mechanical characterisation of human thoracic aorta [Iliopoulos, 2009, Ferruzzi, 2012]. Our data show no significant difference in parameters for TAA and TAD samples except for k_2. Ongoing investigations are aimed at analysing about 7 additional samples to delineate age and gender dependent responses in samples. Our studies also use layer specific response to separate effects of individual constituents on tissue mechanics.

References

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