8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

Mitral valve finite element analysis using human uniaxial tensile data

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Key Words: *Mitral valve, human tissue, finite element.*

ABSTRACT

Anterior and posterior leaflets and chordae tendinae from post-mortem human mitral valves were mechanically tested by means of a uniaxial tensile testing machine. The use of autopsy material from human subjects was approved by the Ethics Committee of the Medical University Graz. After preconditioning the specimens were tested under cycling uniaxial loading at a strain rate of 5mm/min. Two healthy valves and one diseased valve (HOCM) were tested in the circumferential (parallel to the annulus) and the radial (perpendicular to the annulus) directions. They exhibited nonlinear elastic anisotropic behavior, see Figures 1 and 2. The posterior leaflet was found to be more extensible than the anterior leaflet (Figure 2) and the diseased valve more extensible than the healthy valve.

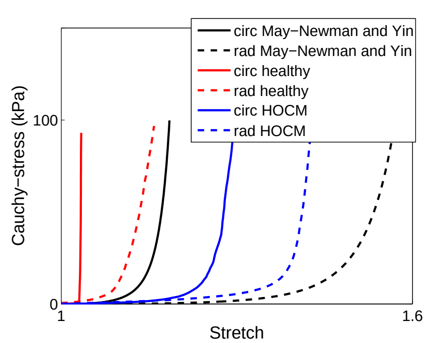

Figure 1: Uniaxial tensile tests for one healthy and one diseased (HOCM) anterior leaflet compared to May-Newman and Yin porcine data. circ=circumferential, rad= radial, HOCM= hypertrophic obstructive cardiomyopathy.

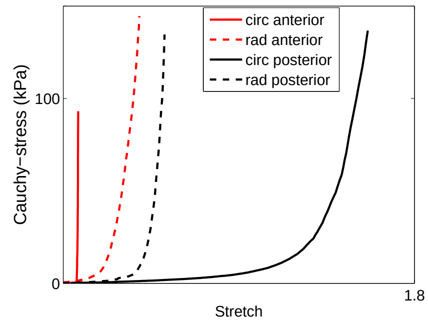

Figure 2: Uniaxial tensile tests for anterior and posterior healthy specimens.

The results on porcine mitral valve leaflets from May-Newman and Yin [1] show that the porcine tissue is softer than the human tissue tested in this study. The extensibility of soft tissue decreases with age. The healthy individuals from whom the healthy valves were excised were 59 and 88 years old, whereas the porcine data may correspond better to children. Hence, this may explain the differences observed between porcine and our human stress-stretch relationships.
We found that for the healthy individuals the chordae experienced between 3 and 5% of strain at a load of 2N depending on their size and type. For the diseased case, the chordae were more extensible (more than 15% strain for the thickest chordae at a load of 2N).
These experimental data were used in a three-dimensional finite element model based on [3] using a transversely isotropic hyperelastic material model for the leaflets described in [2]. Figure 3 illustrates the principal stretches computed with the human data (healthy and diseased) and the porcine data in the center part of the anterior leaflet. For all cases, the anterior leaflet experienced anisotropic large deformations. However, in the healthy human case the anterior leaflet showed a much stiffer behavior than in the diseased and porcine case.

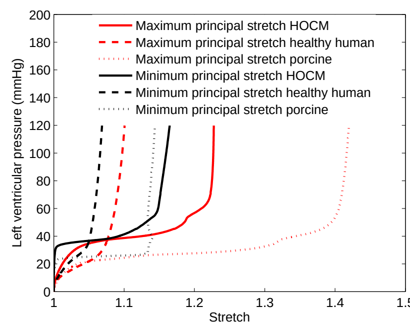

Figure 3: Principal stretches computed in the center part of the anterior leaflet.

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