Constitutive Modelling of Jugular Vein Tissue
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Introduction and Background

Motivations:
- Highly Non Linear Stress - Strain behavior
- Mechanical Anisotropy
- Large Deformations
- Viscoelastic nature of the material.
- Veins (ubiquitous throughout the body) affected by numerous diseases like CVI, Thrombosis; used in valve replacement, vein reconstruction etc., but without any proper study.
- Material Properties are not known.

Focus:
I. To determine suitable phenomenological strain energy based constitutive relation for JV valve and JV wall tissue.
II. Determination of material parameters required to implement the model numerically in FEM environment.

Methods and Results

Constant Invariant Testing and Strain Energy based Constitutive Relation:
- Constant α and Constant I₁ Tests for 16 wall samples and 8 valve samples were conducted to study the behavior of strain energy derivatives.
- Response curves (Fig. 3) were plotted based on the experimental data.
- Separate strain energy descriptor were selected based upon the behavior.
- Wall Tissue:
  
  \[ W = c_1(α - 1)^2 + c_2(α - 1)^3 + c_3(I_1 - 3) + c_4(I_1 - 3)(α - 1) + c_5(I_1 - 3)^2 \]
- Valve Tissue:
  
  \[ W = c_0(\exp[c_1(I_1 - 3)^2 + c_2(α - 1)^4] - 1) \]

Material Model Parameter estimation:
- Using Powell’s Method Algorithm to minimize the square of residuals between experimental and model predicted stress value.
  
  \[ \chi^2 = \sum_{i=1}^{N} (y_i - t_i)^2 \]
- Data from equibiaxial and off biaxial displacement controlled testing (with a maximum strain of 70%) was using for parameter estimation.
- 5 different protocols were used to collect data at 1Hz with 8 cycles of tissue preconditioning.

Discussions and Conclusion

- Material models presented for the wall & valve tissue were able to emulate the behavior of tissue under experimental testing, evident from high correlation coefficients.
- The study also provides investigators with representative material parameters to form a continuum model when such is required for numerical analyses and computational simulations.
- Additionally, it can be of great help during the primary stages of bio prosthetic designs, valve-replacement surgeries, and when investigating valvular diseases.