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Comparison of the Virtual Fields Method and the Optimization Method to Characterize Regional Variations in Material Properties of Soft Tissues

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Abstract: Characterizing regional variations of material properties in soft tissues is essential for biomedical engineering and clinical medicine, including but not limited to cancerous disease detection and patient-specific surgical planning of cardiovascular diseases. Identification of nonhomogeneous material property distribution usually requires solving inverse problems in nonlinear elasticity. Generally, inverse algorithms can be categorized into two groups: iterative inversion and direct inversion. In direct inversion, the material property distribution of soft tissues is estimated directly from the equilibrium equations, while the inverse problem is posed as an optimization problem in iterative inversion. In this presentation, we compare the performance of one direct solver, the virtual fields method, and one iterative solver, the gradient based optimization method, in reconstructing the spatial variation of anisotropic hyperelastic material properties of arteries. The virtual fields method is based on the principle of virtual work and capable of identifying material properties very fast. For the iterative method, to reduce the computational expenses for the gradient based optimization approach, we employ the adjoint method which efficiently computes the spatial derivatives of the cost function with respect to the material properties. The regional variations of material properties across the arteries will be reconstructed using the simulated data. We thoroughly compare the accuracy of the reconstruction results obtained by different methods. In addition, merits and disadvantages of the virtual fields method and the optimization method are discussed. This comparative study will further our understanding of solving nonlinear inverse problems in soft tissue mechanics using different approaches and provide us with useful information in selecting proper inversion approaches to characterize nonhomogeneous material property distribution of soft tissues.

Keywords: Inverse problem; the virtual fields method; the optimization-based inverse method; nonhomogeneous material property distribution characterization; biomechanics

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