Analyzing Acoustoelastic Effect of Shear Wave Elastography (AE-SWE) Data for Perfused and Hydrated Soft Tissues Using A Macromolecular Network Inspired Model

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Background, Motivation, and Objective

Shear wave elastography (SWE) has enhanced our ability to non-invasively make in vivo measurements of tissue elastic properties of animal and human tissues. Recently, researchers have taken advantages of acoustoelasticity in SWE to extract nonlinear elastic properties from soft biological tissues. However, most investigations of the acoustoelastic effects of SWE data (AE-SWE) rely on classic hyperelastic models for rubber-like (dry) materials. In this paper, we focus solely on understanding acoustoelasticity in soft hydrated tissues using SWE data and propose a macromolecular constitutive model to analyze how shear wave speed changes under the process of tissue hydration.

Statement of Contribution/Methods

Our approach incorporates two constitutive features relevant to biological tissues: static dilation of the medium associated with nonstructural components (*e.g.* tissue hydration and perfusion) and finite extensibility derived from an ideal network of biological filaments. In the presence of static dilation, the proposed method is able to model both AE-SWE measurements and shear wave speed (SWS) alterations associated with fluid transport. To our knowledge, this is the first analysis of this kind. Particularly, our approach treats AE in a strictly kinematic and energetic sense. Thus, relationships among the strain energy, deformation, and the internal stresses/pressure are not explicitly solved under certain boundary conditions.

Results/Discussion

A hydrogel swelling experiment was conducted. Basically, a tissue-mimicking phantom was fully submersed in a deionized water bath for approximately 18 days. SWS speed measurements were done before and after the swelling experiment following an established protocol (Rosen and Jiang, PMB, 2019). In order to investigate the applicability of the proposed theory to biological tissue, SWE and AE-SWE experiments reported in the literature for *ex vivo* and *in vivo* tissue experiments (Barr and Zhang, JUM, 2012; Jiang et al., Biomechanics and Modeling in Mechanobiology, 2015; Jiang et al., Medical Image Analysis, 2015, Vachutka et al., Ultrasonic Imaging, 2018, Helfenstein et al., J. of Biomechanics, 2015).

Our proposed model's predictions were in excellent agreement with all experimental results. The resulting curve fits produce very high R^2 values (0.970~0.998). The strong agreement found suggests that the proposed model is a viable approach to modeling AE in fluid permeated elastic media.