EFFECT OF STRETCHING AND COMPRESSION ON THE DYNAMIC SHEAR MODULUS USING MRE

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Introduction: Magnetic Resonance Elastography (MRE) is a phase-contrast MRI based technique that can measure dynamic mechanical properties of soft tissues [1]. It is clinically employed for the assessment of hepatic fibrosis and is being investigated for use in many different organs, such as breast, brain, etc… [2]. While it is currently being used to measure the shear modulus of tissues in their resting state, there is evidence suggesting the use of MRE to investigate the strain-dependency of shear modulus [3]. We hypothesize that the knowledge and control of pre-strain applied to a tissue will improve the quality and type of information obtained with MRE. The goal of this study was to analyze the effect of controlled compression and tension on the dynamic shear modulus for the two directions of wave propagation orthogonal to the particle motion, both in a homogeneous medium and an ex vivo tissue sample.

Methods: This study was carried out using a 100% PolyVinyl Chloride (PVC) phantom and an ex vivo specimen of bovine liver. The experimental setup is shown schematically in figure 1, the phantom (or the tissue specimen) was strained along the A/P direction using a compression plate. A needle connected to a piezoelectric actuator sets motion to particles along the R/L axis. Data were acquired in a sagittal plane with 3 orthogonal directions of motion sensitization. We focussed on the properties of the wave propagation in the sagittal plane (S/I and A/P directions). The PVC phantom was excited with a 750Hz sinusoidal motion and was axially strained from -37% to +25%. The specimen of bovine liver was excited with a 200Hz sinusoidal motion and was axially strained from -34% to +19%. The field of view was 80x80mm for each acquisition. TR/TE were 817/121ms for PVC and 185/35ms for the liver specimen.

Results: Figure 2 shows typical results obtained from the PVC phantom. It is evident from the magnitude images that the phantom demonstrated expected lateral (S/I) strains. The change in the wave propagation pattern as we move from negative axial strain (compression) to positive axial strain is visible. For both the phantom and the specimen, the measured shear modulus increases with the absolute value of the axial strain under both compression and tension (Fig. 3 and Fig. 4). Under compression, the increase in the shear modulus was higher for wave propagation in the lateral direction and, for PVC, under tensile stress the increase in the shear modulus appeared higher for propagation in the axial direction. The difference between the shear moduli for the two directions of wave propagation was more significant under compression than under tension. These data suggest that shear waves propagate faster in the direction of particle stretching compared to the orthogonal direction with particle compression.

Conclusion: These preliminary results demonstrate that a medium's shear modulus depends on the applied pre-strain (compression or tension). These data provide motivation to further investigate the effects of pre-strain and their clinical utility to improve the information obtained from MRE, for instance, the potential to improve the shear modulus contrast of breast MRE under compression.

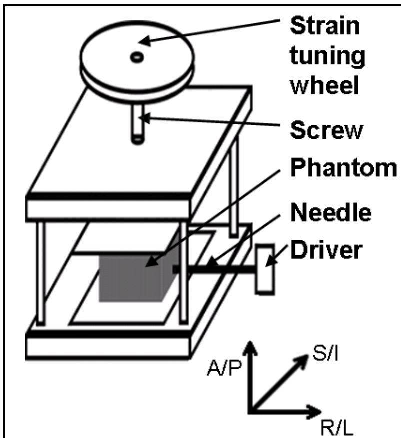

Figure 1: Medium compression/stretching setup

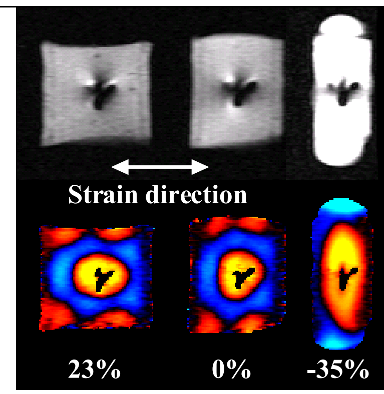

Figure 2: Example of magnitude (top) and wave (bottom) images at different strains for the PVC phantom.

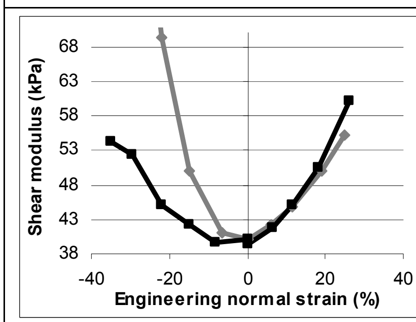

Figure 3: Shear modulus versus strain of the 100% PVC phantom (in grey the stiffness estimated along the S/I direction and in black the stiffness estimated along the A/P direction).

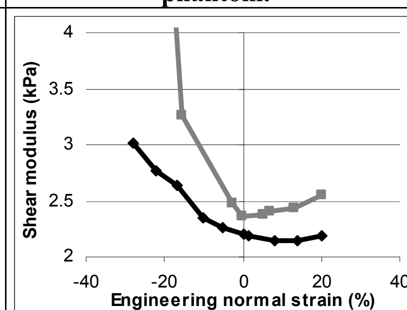

Figure 4: Shear modulus versus strain of the bovine liver (in grey the stiffness estimated along the S/I direction and in black the stiffness estimated along the A/P direction).

References:

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