Combining Rheometry and Elastography to Understand Large Deformation Soft Tissue Properties

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I. INTRODUCTION

Accurate mechanical properties of tissues are essential for inclusion in computational models of impact injury. High quality large deformation (i.e. nonlinearly viscoelastic) tissue properties at high strain rates relevant to injury are limited in literature and this is mostly due to the complexities characterizing nonlinear viscoelastic properties past the linear viscoelastic limit, and experimental challenges at high loading rates. We suggest a method of combining static compressive preload and high frequency shear strain to understand large deformation tissue properties *in vivo*. We investigated this method in stages, combining *ex vivo* rheometry and Magnetic Resonance Elastography (MRE) tests under static preload, and also demonstrated proof of principle in *in vivo* MRE data.

II. METHODS

Ex Vivo Rheometry Experiments

Bovine liver was obtained from a local abattoir and samples (20mm diameter and 3mm thickness) were excised from the liver avoiding the visceral peritoneum. Samples were preconditioned before testing and tested in shear with simultaneous compressive preloads of 1%, 10% and 20%, using a rotational rheometer (KNX 2100, Malvern, UK).

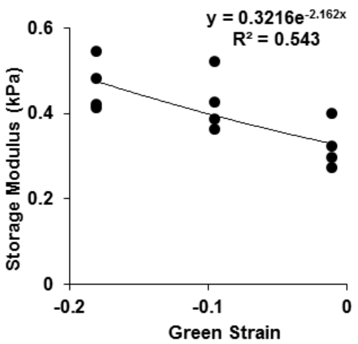
Ex Vivo MRE Experiments

Bovine liver was obtained from a local abattoir and samples dissected out (60mm X 60mm X 40mm) avoiding blood vessels. They were loaded into an MR-compatible device capable of applying simultaneous static compression and dynamic shear vibration, synchronized to the MRI scanner. MRE at steady-state 120Hz shear vibration was applied and MRE data (x,y,z(t) displacement maps) were collected at 0% - 30% compressive strain.

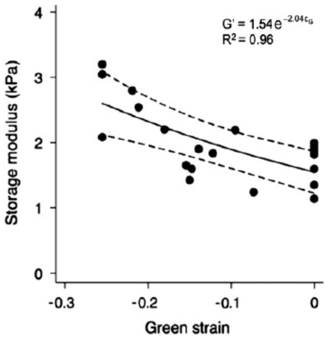
In Vivo MRE Experiments

MRE experiments have been conducted with human subjects acquiring images of the liver at the height of inspiration and expiration to obtain images at the maximum and minimum compressive strain exerted on the liver throughout the respiration cycle. MR-tagging (SPAMM) can be used to estimate liver deformation.

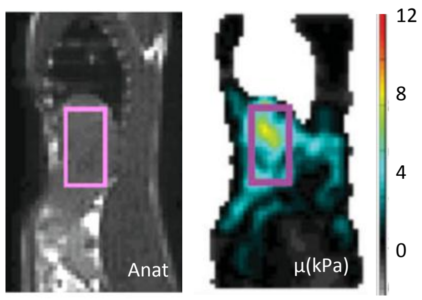
III. RESULTS



Ex Vivo Rheometry (F=1Hz)



Ex Vivo MRE (F=120Hz)



In Vivo MRE – Elasticity map (right) and matching anatomical image (left) of a sagittal slice through the abdomen. Rectangle is liver region of interest [1]

IV. Discussion and Conclusions

The slope of the modulus-strain line of best fit was in good agreement between the *ex vivo* methods. MRE is a promising method of quantifying large deformation properties *in vivo* under combined loading and at high frequency. A few limitations of this study include a slightly different mode of excitation across the three methodologies as well as postmortem tissue property changes in the *ex vivo* data. A promising method is presented for combining static preload with MRE to estimate large deformation tissue properties at high frequencies, where physiological or external preload can be applied to a tissue during MRE.

I. References

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