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PARAMETERIZATION OF MULTI-FREQUENCY NON-LINEAR INVERSION RECONSTRUCTION ON IN VIVO MOUSE LIVER MAGNETIC RESONANCE ELASTOGRAPHY DATA

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Background: Magnetic resonance elastography (MRE) enables non-invasive quantitative assessment of the mechanical properties of tissues and has been successfully applied on clinical MR scanners for liver fibrosis staging [1]. Its application on preclinical MR scanners is also of interest for researchers with the availability of different animal models where MRE parameters, such as higher mechanical frequencies, have to be adapted with the standout feature being the smaller imaging volume. Multifrequency MRE [2] has been proposed for tissue characterization as a valuable tool enabling detection of tissue alterations occurring below the MR image resolutions through the measurement of the dispersion relationship of the shear storage modulus [3]. However, tackling multifrequency MRE data reconstruction is still an open question; the simplest approach being to apply mono-frequency reconstruction and analyzing the subsequent summation of the individual results. More evolved algorithms considering simultaneously all the individual harmonic data, such as the Non Linear Inversion (NLI) reconstruction method [4], have demonstrated their ability to better characterize the mechanical properties through brain MRE [5].

Aims: In this work, we seek to demonstrate the ability of the NLI reconstruction method to characterize in vivo mouse liver viscoelastic parameters.

Methods: One healthy female mouse (mean weight 25g) was examined after receiving ethical approval and adhering to institutional animal care guidelines. Multifrequency MRE acquisitions were carried out on a Bruker Biospec 7T MR scanner using a Turbo Spin Echo MRE sequence (turbo factor=4) developed inhouse [6]. Single frequency acquisitions at 400 and 600 Hz were run and 4 equally distributed phase-steps were acquired for each frequency. 2

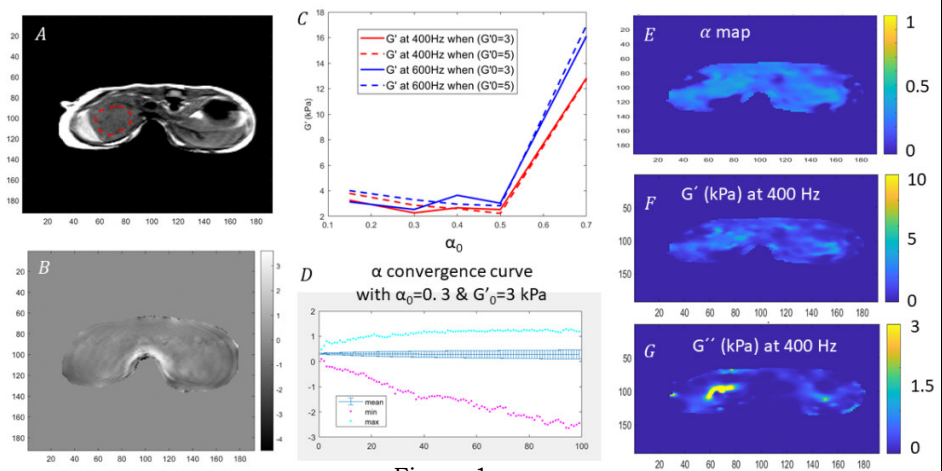


Figure 1

acquisitions with opposite motion encoding gradient (MEG) polarity were completed, 3 orthogonal MEGs were applied and 5 contiguous slices (1mm) were acquired to obtain 3D wave field images. Complex MR images were extracted and processed to obtain magnitude and unwrapped phase images. Power-law ($\sim \theta \cdot f^\alpha$) NLI reconstruction minimizes a multi-frequency objective function combining the uniformly weighted displacement error at each measurement frequency using gradient descent algorithms based on the adjoint field. The multi-frequency displacement fields were collectively processed using NLI inversion, yielding θ and α maps that allow the calculation of shear storage (G') and loss (G'') modulus across frequencies. Sensitivity to initialization parameters was evaluated via a convergence criteria so as to determine the optimal parameterization: $\alpha_0 = 0.15, 0.3, 0.4, 0.5, 0.7$, $(G'_0, G''_0) = (3, 1), (5, 2)$. Optimal NLI subzone size was found to be 5mm for the studied frequencies.

Results: MR magnitude (A) and phase (B) images are shown on Figure 1 with the ROI (red). Mean G' values (C) at 400 (red) and 600 Hz (blue) are given for varying $G'_0 = 3$ (solid line) or 5 kPa (dashed line) and $\alpha_0 = 0.15, 0.3, 0.4, 0.5, 0.7$. A good compromise between correct G' values and convergence of α (D) was found at $\alpha_0 = 0.3$ and $G'_0 = 3$ kPa. For this configuration, the obtained α (E), G' (F) and G'' (G) maps are shown.

Conclusions: This work presents the application of multi-frequency NLI inversion on preclinical mouse liver MRE data obtained in vivo. With the optimal initial parameters, NLI inversion is able to characterize the liver elasticity (G'), yielding to very good homogeneity, and the viscosity (G''). In future work, a cohort of several mice will be studied to evaluate the repeatability of the method.

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References: [1]Hoodeshenas et al. 2018 Top MRI; [2]Asbach et al. 2008 MRM; [3]Jugé et al. 2015 NMR Biomed; [4]Van Houten et al. 1999 MRM; [5]Smith et al. 2022 Brain Multiphysics; [6]Sango-Solanas et al. 2021 NMR Biomed.