Multifrequency Magnetic Resonance Elastography (MRE) at 7T

Authors & Affiliations
E.R. Triolo[1], A. Alipour[2], O. Khegai[2], P. Balchandani[2], M. Kurt[1,2]
1. Department of Mechanical Engineering, University of Washington
2. BioMedical Engineering and Imaging Institute, Icahn School of Medicine at Mount Sinai

Abstract: (should not exceed 400 words)
Introduction: Magnetic resonance elastography (MRE) is a technique for determining the mechanical response of tissues using applied harmonic deformation and motion-sensitive MRI[1]. Studies using MRE to investigate the mechanical properties of the human brain are most commonly performed at conventional field strength (3 Tesla (T) or 1.5T), although there have been a few attempts at the ultra-high field strength, 7T[2]. Additionally, most biological tissues, including the human brain, exhibit a frequency-dependent mechanical response[3] which has yet to be explored at 7T. In this study, we investigat the frequency dependence of the mechanical properties of the brain, first validating our methods using a linearly elastic phantom.
Materials and Methods: For validation of the sequence, MRE was performed on a custom MRE phantom (CIRS 049) at 30-80Hz in 10 Hz increments, using a 32-channel head coil (Nova Medical) on a 7T Siemens Magnetom MRI Scanner (see Table 1 for parameters). Full brain coverage MRE was then performed on one healthy human subject at 1.1mm isotropic resolution at 40, 60, and 80Hz. The MRE sequence was a modified single-shot multi-slice spin-echo 2D-EPI sequence with trapezoidal flow-compensated motion encoding gradients (MEGs), synchronized with the acoustic actuator[4] by TTL triggering at the beginning of every TR. Images were masked, denoised using a MP-PCA algorithm[5], and unwrapped[6]. We performed post-processing[4] before using Algebraic Inversion to calculate $|G^*|$[7]
Results: MRE was successfully performed on the phantom at all frequencies, the wavefield images of which are shown in Figure 1 for each frequency. This data was also used to determine the filter window necessary for quartic smoothing kernel at each frequency, as this must be scaled for wavelength to prevent over-smoothening of short wavelength waves. MRE was also successfully performed on the healthy human subject at the representative frequencies. Elastograms of a representative slice for each frequency are shown in Figure 2.
Conclusions: In the future, this multifrequency MRE protocol can be used to determine region specific frequency-dependent mechanical properties as it has in the past at 3T[3], but at the ultra-high resolution possible at 7T.
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References: [1]Braun, *et al., Neuroimage*, 2014, [2]Murphy, *et al., PloS one*, 2013, [3] Kurt, *et al. NeuroImage*, 2019, [4]Triolo*, et al. Proc. BMES*, 2021, [5]Veraart, *et al. Neuroimage*, 2016, [6]Herraez*, et al., Applied Optics*, 2002, [7]Oliphant, *et al., Magn. Reson. Med.*, 2001
Presentation category, please mark all that apply: [ ] AI [ ] Body/Cancer Imaging [ ] Cardiac Imaging [x] Neuro Imaging [ ] Nanomedicine [x] Imaging methods and medical devices

Figures and tables (should not exceed the space of this page).

Table 1: *MRE Parameters for Each Frequency*

Frequency (Hz)	Echo Time (TE, ms)	Repetition Time (TR, ms)	Vibration Cycles/TR
30	90	6667	5
40	74	6000	6
50	65	5600	7
60	65	6000	9
70	65	5715	10
80	65	5500	11

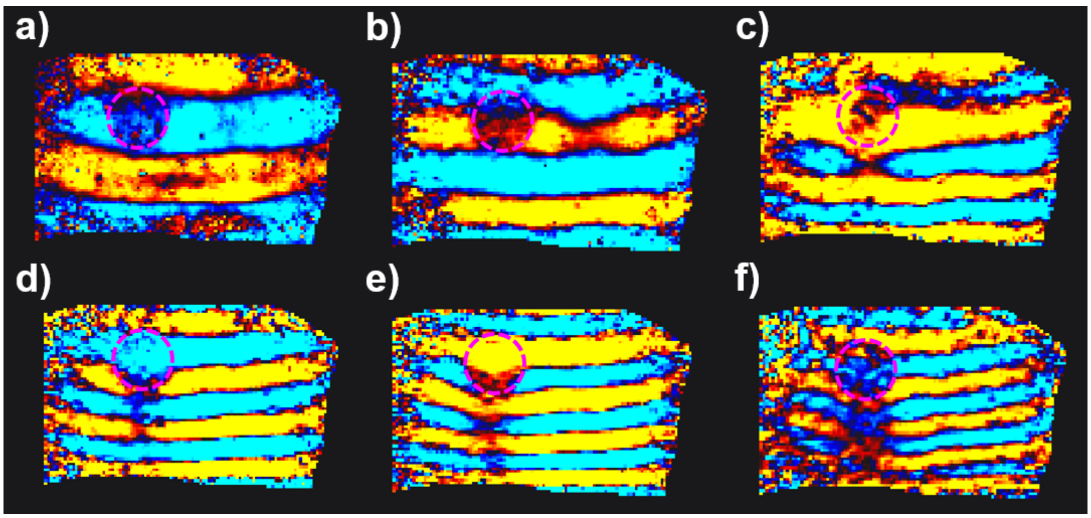

Figure 1: *Wavefield in the x-Direction in a Central Slice of the Phantom at Each Frequency a)30Hz, b)40Hz, c)50Hz, d)60Hz, e)70Hz, and f)80Hz, Where the Pink Outline is the Location of a Stiff Inclusion*

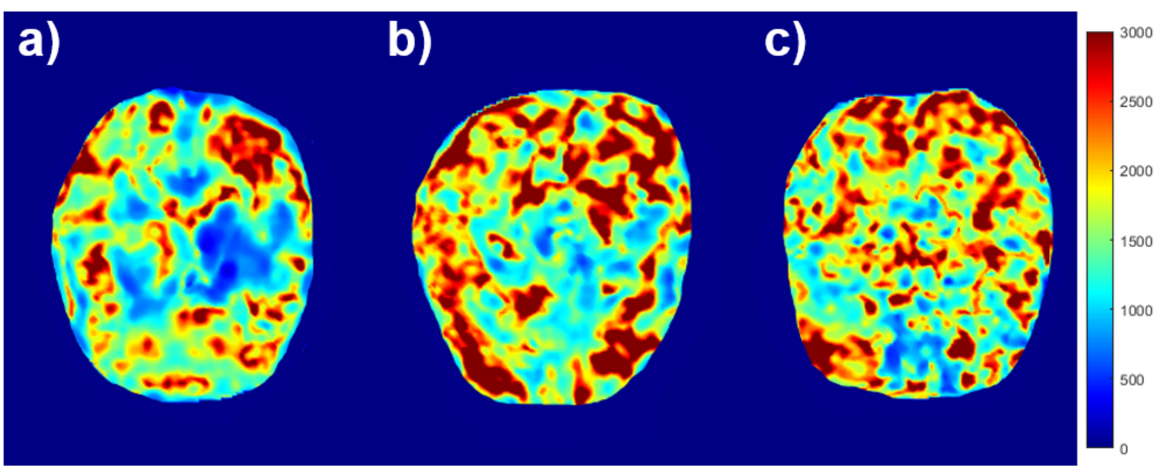

Figure 2: *The Magnitude of the Complex Shear Modulus Estimate, |G*|, (in Pa) at a Representative Slice for Each Frequency (a) 40Hz, (b) 60Hz, (c) 80Hz*