High Resolution MR Elastography Of The Human Brain: Technical Development And Applications In Aging And Alzheimer's Disease

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ABSTRACT (400 word limit):

Introduction: MR elastography (MRE) is a technique for determining the mechanical response of tissues using applied harmonic deformation and motion-sensitive MRI[1]. Performing MRE on human brain can provide information on different structures within brain tissue based on their mechanical properties, which can then be used to diagnose pathologies *e.g.*, Alzheimer's disease (AD) and dementias[2]. Aiming for higher resolution at 7T, MRE presents unique challenges of decreased octahedral shear strain-based signal-to-noise ratio (OSS-SNR)[3] and lower shear wave motion sensitivity. *Overall, this work seeks to investigate advanced reconstruction and denoising to improve accuracy of ultra-high field (7T) MRE in determining mechanical properties of small brain tissue structures, with applications in aging and early detection of dementias.*

Materials and Methods: Full brain coverage MRE, using our custom 2D multi-slice SE-EPI 7T MRE sequence[4] and custom pneumatic actuator[5], was performed on twenty healthy human subjects (young adults, Avg. Age 26.9±3.4 years), six subjects with cognitive deficits (CD, Avg. age 75.8±6.5 years), and nine age-matched ($p>0.10$) cognitively normal subjects (CN, Avg. age 69.0±8.0 years) at 1.1mm^3 isotropic resolution and 50Hz, using a 32-channel head coil (Nova Medical) on a 7T Siemens Magnetom MRI Scanner (TR/slice=140ms, TE=65ms, GRAPPA=3, Partial Fourier=7/8). To improve image reconstruction, we used Gadgetron[6], an open-source MRI image reconstruction software, on the raw data to generate magnitude and phase images before employing MP-PCA denoising[7] and Algebraic Inversion (AIDE) to calculate the magnitude of the complex shear modulus ($|G^*|$)[4]. Segmentation of brain regions was performed on MP2RAGE T1scans (0.7mm^3) using Freesurfer and were co-registered using SPM12.

Results: We observed a whole-brain average 127% increase in OSS-SNR using denoising and a 375% increase using advanced reconstruction and denoising concurrently. Advanced reconstruction also removed artifacts in phase images observed in low SNR areas (Figure 2a). We observe a significant decrease in average $|G^*|$ between CN and CD groups in each brain region except EC (Figure 2b). Additionally, we observe a significant decrease in $|G^*|$ between young adult and CN groups in WB, GM, WM, TL, and HC because of normal aging (Figure 2b).

Conclusions: Overall, we successfully developed and implemented high resolution MRE at 7T to determine mechanical properties of small brain tissue structures, showing regional differences in brain stiffness in subjects with cognitive deficits.

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References: [1]Muthupillai, 1996 [2]Murphy, 2011 [3]McGarry, 2011 [4]Triolo, 2022 [5]Triolo, 2022 [6]Hansen, 2013 [7]Veraart, 2016

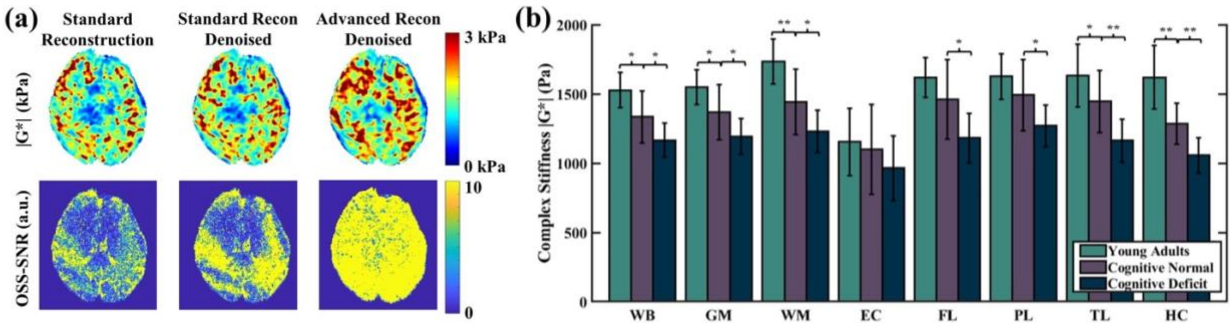

Figure 2: (a) High resolution Elastograms and OSS-SNR maps with MP-PCA Denoising and Advanced Reconstruction methods using Gadgetron in One Young, Healthy Subject. (b) Average |G*| for Young Adults, CN, and CD individuals in all Segmented Brain Regions of Whole Brain (WB), all Gray Matter (GM), all White Matter (WM), the Entorhinal Cortex (EC), Frontal Lobe (FL), Parietal Lobe (PL), Temporal Lobe (TL), and Hippocampus (HC) (one-tailed, unequal variance, t-tests * $p<0.05$, ** $p<0.01$)