Fast EPI Based 3D MR Elastography of the Brain

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Introduction

Many diffuse brain diseases are not well evaluated by conventional techniques. This provides motivation for developing techniques for imaging other independent tissue characterization parameters. For instance it has been hypothesized that neurodegenerative processes such as Alzheimer's disease may be associated with early changes in the mechanical properties of brain tissue. Magnetic Resonance Elastography (MRE) is a noninvasive imaging technique that quantifies mechanical tissue properties by measuring and analyzing displacements due to shear wave propagation. In order to understand the wave motion and the underlying mechanical properties the complete wave field must be sampled and analyzed. A single MRE image acquisition is sensitized to motion in a single direction, and three acquisitions are necessary to capture all three orthogonal components of displacement. These acquisitions are usually repeated to capture displacements at several equally spaced time points in the wave cycle, and each acquisition is also repeated with the motion sensitizing gradients reversed to remove systematic phase errors. Thus, a full measurement of the wave field with four temporal samples per cycle requires 24 image acquisitions for each slice. In the past, a 3D Gradient Echo (GRE) sequence was used to image the brain [1]. The 30 plus minute imaging time of 3D-GRE was prohibitive for use with cognitively impaired patients. Spin Echo-Echo Planar Imaging (SE-EPI) has become a common tool in applications requiring fast image acquisition, such as functional imaging and diffusion weighted imaging. SE-EPI has also been previously investigated in MRE [3]. The goal of this work is to implement 2D multiple slice SE-EPI for MRE that allows for full wave field capture in a clinically acceptable amount of time, 10 minutes or less.

Materials and Methods

Wave motion is transmitted into the brain by an actuator consisting of 2 passive Pressure Activated Driver (PAD) drums [2] arranged in a "V" shape. The volunteer lies supine with the back of his/her head resting in the "V". The drums were driven at 60 Hz, 180° out-of-phase with each other.

Two scenarios were studied: (1) used an acquisition matrix of 128x128 and 4 shots, while (2) used an acquisition matrix of 64x64 and 1 shot. The common imaging parameters were: 2200ms TR, 24 – 4 mm slices, 24 cm FOV, 2 passes to allow for contiguous slices, and 24 acquisitions for each slice as above. All studies were performed on a 1.5T GE scanner with the pulse sequence shown in Figure 1.

Both data sets were reconstructed to a 128x128 matrix. The images were processed using a 3-dimensional extension of the spatio-directional filters [4]. Twenty different directions, in an icosahedral pattern, were used to achieve near-isotropic directional coverage. Next, the data was processed using a local frequency estimator (LFE) algorithm to extract the mechanical properties [5].

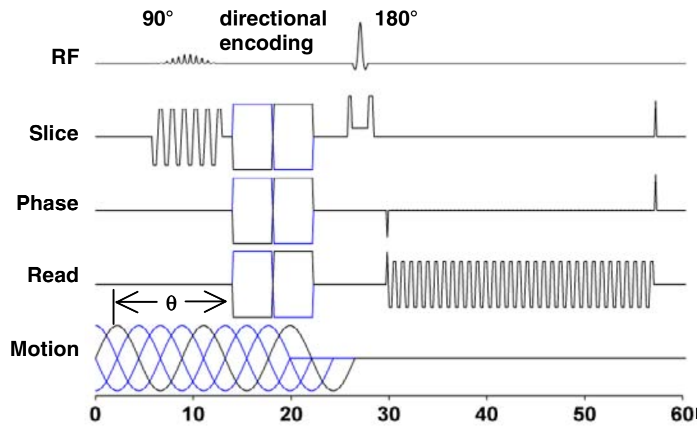

Figure 1: Spin echo EPI pulse sequence depicting a single shot 64x64 acquisition.

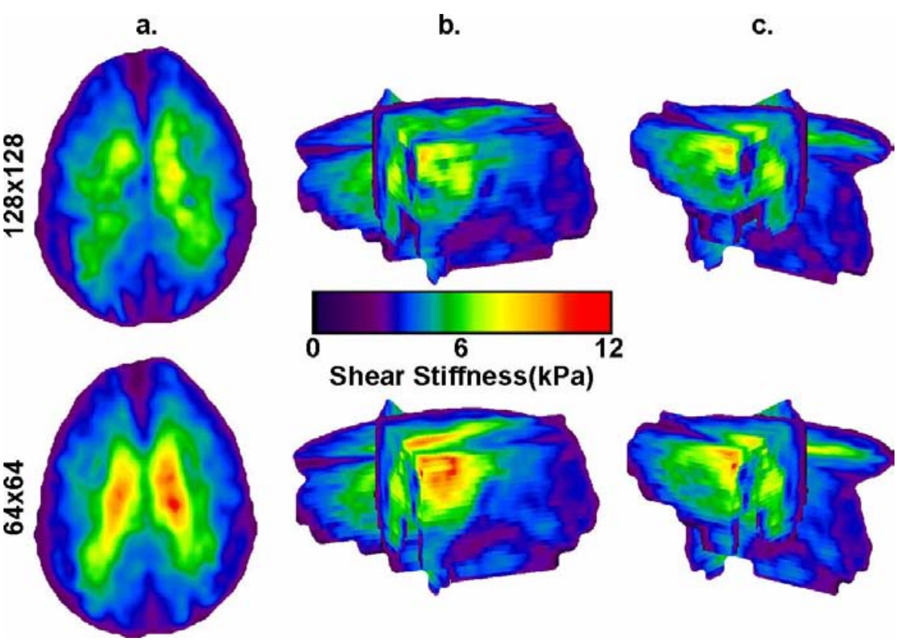

Figure 2: Shear Stiffness Maps for 128x128 & 64x64 matrix sizes, a. A superior axial slice b. & c. Renderings of coronal and sagittal planes intersecting the axial slice from column a.

Results

The scenario 1 and 2 data sets were acquired in 10 minutes and 3 minutes respectively. Figure 2 shows shear stiffness maps with renderings in the 3 imaging planes. The mean shear stiffness for gray matter was 3.2 $\pm$ 0.58 kPa and deep white matter was higher at 7.6 $\pm$ 1.7 kPa. These findings are lower than previous values [6].

Discussion

SE-EPI was successfully implemented to collect MRE data. The scan times of the scenarios tested were within the clinically acceptable range for cognitively impaired patients. The scan time can be further reduced by decreasing the number of slices acquired. The lower shear stiffness values found may be a result of the full 3D inversion. Previous published results were of a single 2D slice with a single motion sensitization direction.

References

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