Dynamic MR Elastography at 3T: Comparison of Spin Echo- and Gradient Echo-based Techniques

T. C. Dunn[1], S. Majumdar[1]

[1]Musculoskeletal and Quantitative Imaging Research Group, Department of Radiology, University of California, San Francisco, San Francisco, CA, United States

Introduction: Dynamic Magnetic Resonance Elastography (MRE) has been demonstrated to be able to determine mechanical properties of soft tissues using both Gradient Recalled Echo (GRE) (1) and Spin Echo (SE) techniques (2). The purpose of this study was to directly compare phase to noise characteristics of these MRE techniques at 3 Tesla.

Methods: All scanning was performed on a GE Signa 3 Tesla system with a standard head coil. A bi-layer, 0.5% and 1.0% agar phantom of 8 cm height and 16 cm^2 square cross-sectional area was used. The layers were aligned horizontally, side-by-side, both in contact with the external actuator contact plate. For the dynamic MRE experiment, a trigger signal was sent from the scanner to a digital waveform generator (Model 33250A, Agilent) at the beginning of each TR (175 ms). The wave generator output the "motion signal" of a burst of N cycles of 500 Hz sinusoidal voltage to an amplifier (A-303, A.A. Lab Systems), connected to a piezoelectric bending element (EPA-104, Piezo Systems) energized with $\pm$140 V, similar to a previous technique (3). The bending element created shear waves in and out of the slice selection plane. After 5 cycles of motion, M balanced, bipolar motion encoding gradients (MEGs) were played in the slice selection direction. For these experiments, M was set to 5, 10, and 15, and N was set to be M+5 for the GRE and 2M+8 for the SE techniques. For the GRE technique, M motion encoding gradients (amplitude = 3.5 G/cm) were played for each TR, with alternate TR's being played at the same phase step but with motion encoding of opposite polarity. Therefore, two pairs of magnitude and phase images are produced, and the difference of the phase images produces the "wave image". The TE's were 20, 30, and 40 ms for the GRE method for N = 5, 10, and 15, respectively. For the SE technique, 2M motion encoding gradients are played for each TR, with M MEG's before the refocusing pulse, and M MEG's of the opposite polarity after the refocusing pulse. Therefore, a single pair of magnitude and phase images is produced. The "wave image" is produced by subtracting the phase image with no motion applied (Figure 1). The TE's were 40, 60, and 80 ms for the SE method for N = 5, 10, and 15, respectively. For each condition, eight offsets between the phase of mechanical motion and MEG's were acquired. Each offset had a scan time of 30 s for the SE method, and 60 s for the GRE method.

The relative performance of each technique was determined by phase-to-noise ratio (PNR) efficiency maps. To calculate PNR, an absolute maximum intensity projection was performed across the eight wave images. This was divided by the arctangent of the inverse of the magnitude signal to noise, found by dividing the magnitude images by the standard deviation of the signal in a region of air and averaging across the magnitude images for the eight offsets. The PNR was divided by the square root of the scan time to calculate PNR efficiency. Finally, a single region of interest (ROI) was chosen in the 1.0% agar region to compare the techniques. Phase wrap artifacts were removed by thresholding for the GRE technique. The mean PNR efficiency in the ROI for the 6 experimental conditions was analyzed by a two-way ANOVA and Student's t-tests for posttests.

Results and Discussion: Unlike a prior demonstration that found no artifact with the piezoelectric bending element (3), it was found to produce image artifacts for the GRE technique to a depth of approximately 1 cm. In addition, standard phase unwrapping was unsuccessful due to the relatively large noise in the wrap transition regions, and therefore artifact remained along the phase wrap locations. These two issues need to be addressed to make the GRE technique useful in practice, and are not necessary with the SE method. The ROI was chosen to be approximately 3 cm from the surface, beyond the region of signal loss for the GRE method. The comparison of PNR efficiency in the ROI for the different methods found significant differences (Figure 2), with the "GRE, M=10" and "SE, M = 5" having the highest, equivalent PNR efficiency. These results show that the same PNR efficiency can be achieved with one half the number of motion encoding gradients and a longer TE by the SE technique compared to the GRE technique.

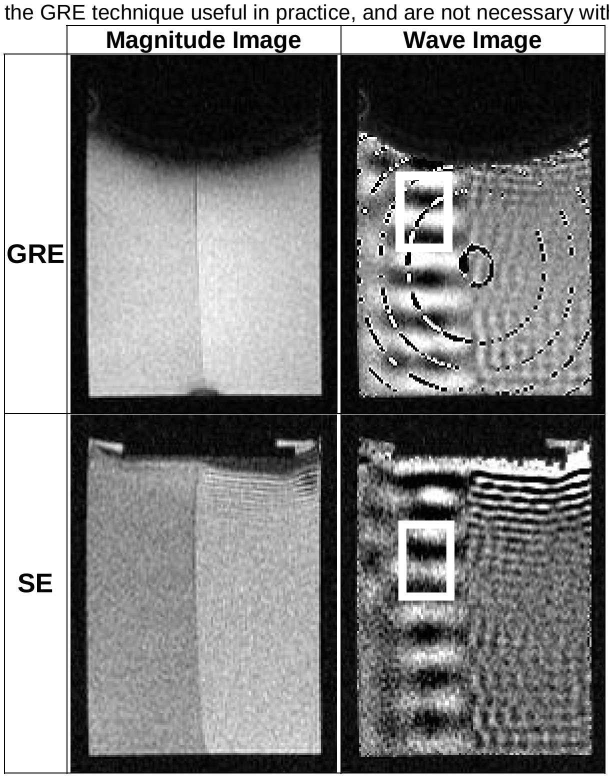

Figure 2. Representative magnitude and wave images and ROI location. M, number of MEG's = 10.

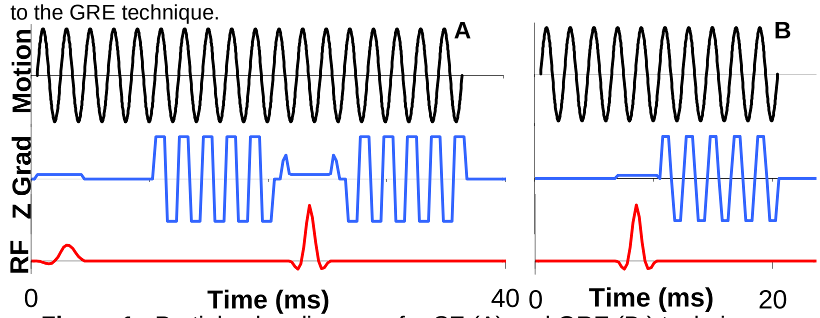

Figure 1. Partial pulse diagrams for SE (A) and GRE (B) techniques.

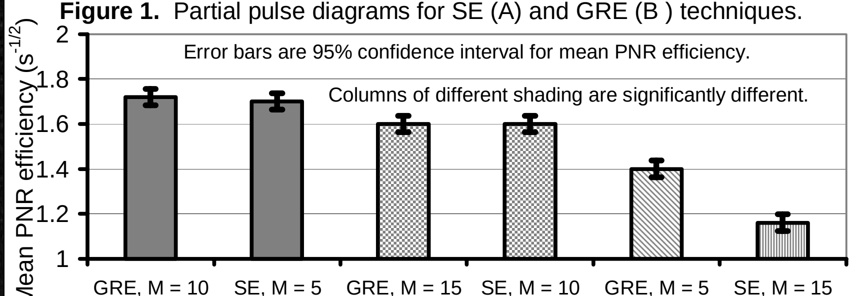

Figure 3. Mean Phase-to-Noise Ratio Efficiency results.

References: [1] Muthupillai R, et al., Science, 296, 1854, 1995.
[2] Hamhaber U, et al., MRM, 49:71-77, 2003.
[3] Rossman P, et al., Proc. ISMRM, 1075, 2003.

Acknowledgements: This work is supported by NIH grant R01 AR46905.