High-Speed Reduced-FOV MR Elastography

K. Glaser[1], J. Felmlee[2], R. Ehman[3]

[1]Mayo Graduate School, Mayo Clinic College of Medicine, Rochester, MN, United States, [2]Radiologic Physics, Mayo Clinic College of Medicine, Rochester, MN, United States, [3]Radiology, Mayo Clinic College of Medicine, Rochester, MN, United States

Introduction: MR elastography (MRE) [1] measures the viscoelastic properties of an object by imaging shear wave propagation. The shear waves are measured as phase in MR images which are then processed to give quantitative information about the properties of the object [2]. Accurately determining these properties may require at least 7-D data (3-D, 3 polarizations of motion, and time) and require long acquisition times (T_{acq}) for patient studies. In situations such as breast cancer, the properties of a specific region of interest (ROI), defined using *a priori* information such as from CE-MRI, may be of more interest than the properties of the whole object. Since many MRE processing algorithms are localized or window-based techniques, displacement data are only needed in a small region centered about the ROI. Certain 1-D methods [3] can significantly reduce the T_{acq} at the expense of some spatial information. Using a similar selective excitation and reducing the imaging field of view (FOV) to the size of the beam [4] allows for the measurement of 2-D/3-D wave fields in a fraction of the normal time. The displacement data measured using this reduced FOV technique (rFOV MRE) will be valid everywhere in the FOV, and the viscoelastic properties will be valid for the central part of the FOV in a region determined by the size of the excitation and the window size and/or PSF of the processing algorithm(s).

Methods: MRE data were acquired using an agar gel phantom and a preserved post-mortem breast tissue specimen in a 1.5 T GE Signa scanner (GE Medical Systems, Waukesha, WI). The phantom (Fig. 1D) contained three cylindrical plugs (arrows in Fig. 1D) 4-times stiffer than the surrounding medium that were 25-, 8-, and 3-mm in diameter. A full 20-cm FOV, 256×64 SE MRE acquisition was performed using 400-Hz shear waves, 8 time offsets, and through-plane shear motion (Fig. 1A). The rFOV MRE data were acquired using a one-eighth FOV and a SE beam selective excitation that was approximately 5-mm thick along the original slice selection direction and 20-mm wide in the phase encoding direction. Horizontal and vertical rFOV data were collected around each plug (Figs. 1B and 1C, respectively). Shear stiffness estimates (elastograms) were obtained using eight directional filters [5] and a direct inversion of the wave equation [2] in a 7×7 window (Fig. 2). The breast specimen (Fig. 3B) had no pathology and a 15-mm diameter region (arrow in Fig. 3B) was ablated in it with focused ultrasound (FUS) [6] to form a stiff lesion in the tissue. The same MRE and rFOV MRE protocols were used centered on the FUS lesion with 200-Hz shear waves, a one-quarter FOV, and a 15×15 inversion window.

Results:

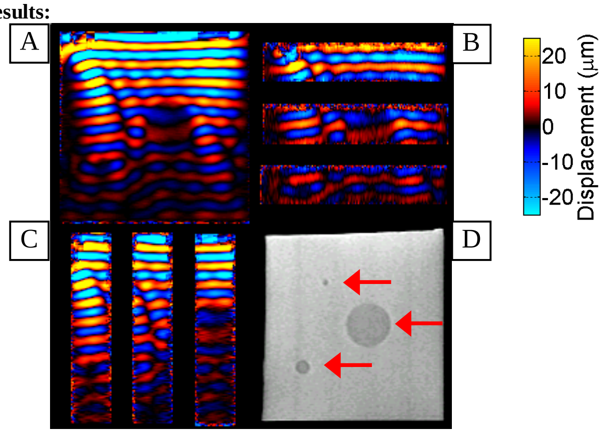

Figure 1: (A) Full-FOV MRE wave image. (B, C) Horizontal and vertical rFOV wave images for each plug. (D) Proton density weighted FSE reference image.

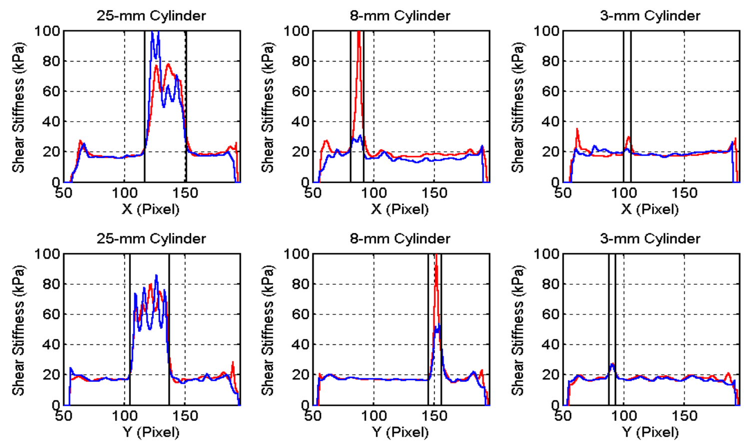

Figure 2: (Blue lines) Horizontal and vertical line profiles through the elastograms from the horizontal and vertical rFOV data, respectively. (Red lines) Matching profiles from the full-FOV elastogram. (Black lines) Boundaries of plugs from Figure 1D.

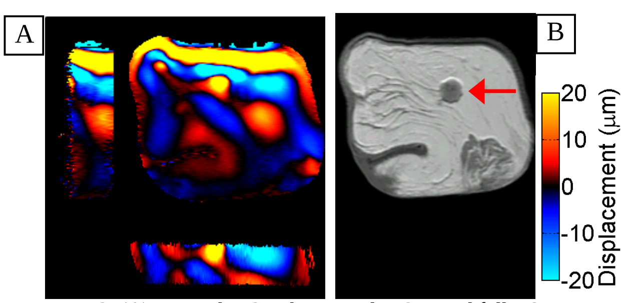

Figure 3: (A) Vertical rFOV, horizontal rFOV, and full-FOV wave images of the FUS lesion. (B) Proton density weighted FSE image.

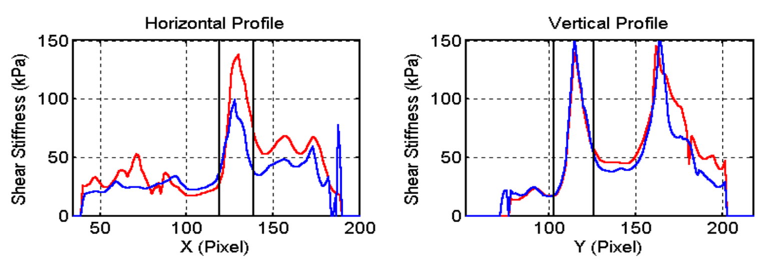

Figure 4: Horizontal and vertical line profiles through the elastograms from the full-FOV and rFOV data in Figure 3 using the same convention as in Figure 2.

Discussion: The results demonstrate that a 2-D rFOV MRE technique using a SE beam excitation can produce stiffness estimates comparable to those obtained from full-FOV 2-D MRE. The primary benefit of this technique is a reduction in the acquisition time, by as much as a factor of eight shown here, while still maintaining 2-D spatial information for analysis. The technique should be easily extendible to other sequences, including GRE, FSE, EPI, and 3-D acquisitions for even more efficient MRE acquisitions.

References:

[1] Muthupillai R., et al., *Science*, 269:1854-1857, 1995.

[2] Manduca A., et al., *Med. Image Anal.*, 5(4):237-254, 2001.

[3] Glaser K., et al., 10th ISMRM, #39, 2002.

[4] Haacke E., et al., "Magnetic Resonance Imaging: Physical Principles and Sequence Design", New York: John Wiley and Sons, 1999.

[5] Manduca A., et al., *Med. Image Anal.*, 7:465-473, 2003.

[6] Wu T., et al., *Magn. Reson. Med.*, 45(1):80-87, 2001.