MR Elastography of in vivo Human Liver

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Introduction: Previous studies of ex vivo specimens have established that fibrosis is associated with increased liver stiffness (1). MR Elastography (MRE), an emerging technique for quantitating tissue mechanical properties, is applied to in vivo human liver to determine the feasibility of measuring liver stiffness in vivo. MRE experiments commonly experience signal loss artifacts near electromechanical drivers, which have limited adequate data acquisition for some applications, motivating consideration of novel vibration sources. To provide the necessary control over the relative phase between vibration and motion sensitization, pulse sequence triggers of wave generation have been used, but these enforce longer scan TRs for low-frequency acquisitions. The challenges of this work were to accomplish liver MRE within a breathold utilizing a novel displacement source in order to limit motion and driver artifacts.

Methods: MR Elastography techniques described previously (2-3) were adapted for this study to assess an organ that requires breathold scans and is protected from direct shear by the ribcage. MRE experiments were performed in five healthy volunteers (age 23-45, three males, two females) after obtaining informed consent. Shear displacements were generated by the top surface of a passive speaker connected by plastic tubing to a 30 cm diameter audio speaker generating 50-100 Hz acoustic vibrations. The active speaker, located 3 meters from the magnet bore, was enclosed in stiff plastic to channel the pressure variations into the tube. The passive speaker was placed on a ramp which aims the vibrations at the liver while allowing the speaker to be positioned below the ribcage (Figure 1a) for greater volunteer comfort. While triggered-wave experiments allowing adequate wave travel time to reach the liver would have required a TR of 100 msec or more, the TR can be set to an integer multiple of the wave period if the speaker operates continuously for the duration of each image acquisition. This continuous mode of operation was used with TRs of 40 and 25 msec for frequencies of 50 and 80 Hz, respectively, for breathold times of 7-10 seconds per offset. A fixed gap of five seconds between offset acquisitions was implemented for the volunteer to reestablish end-inspiration breathold. Eight phase offsets were acquired for each volunteer using 1 period of motion-sensitizing gradient and a matrix size of 256 x 64, an FOV of 24-32 cm and 10 mm thick sagittal sections. T2-weighted FSE images were collected at the same section locations to provide anatomy information to complement the elastograms. The wave images were processed with the Local Frequency Estimator and also by manual estimation of wavelength from image profiles. The LFE shear stiffness estimates were thresholded on the basis of displacement SNR so that only areas of adequate wave penetration are visible.

Results: No artifacts were detected in the vicinity of the displacement source using a gradient echo acquisition. Images acquired during 8-10 second breatholds were acceptably free of motion artifacts. Displacement images at 80 Hz showed only 1-2 cm of penetration into the liver before attenuation to noise levels in the livers of 5 healthy volunteers. Anatomical and 50 Hz displacement images are displayed in Figure 1 for a 45 year old healthy male volunteer. The stiffness estimates were performed manually from line profiles in the direction of wave propagation, although good agreement was observed with SNR-thresholded LFE estimates. The average over the volunteers was 1.93 $\pm$ 0.23 kPa at 50 Hz; 80 Hz stiffness estimates averaged 1.80 $\pm$ 0.98 kPa. The displacement amplitude in the image in Figure 1 has a maximum value of 90 microns; no discomfort was reported by the volunteers.

Discussion/Conclusions: The feasibility of in vivo liver MRE has been established. Methodological improvements in displacement generation allowed placement of the wave source immediately adjacent to the tissue of interest, and improved scan timing has reduced subject motion related to long breathold scans. Our results are comparable to previously published liver specimen studies (4-5). MR Elastography has potential for imaging human liver stiffness in vivo.

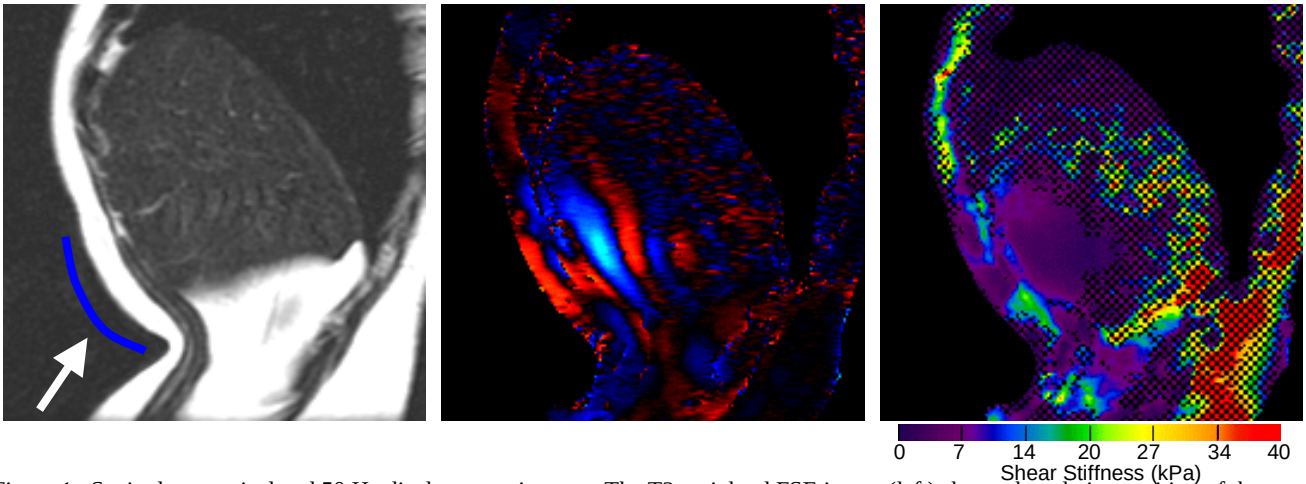

Figure 1. Sagittal anatomical and 50 Hz displacement images. The T2-weighted FSE image (left) shows the relative position of the passive speaker (arrow) to the liver. The wave image (center) shows the displacements propagating well into the liver. The checked areas on the LFE-derived stiffness map (right) represent regions with insufficient displacement SNR for stiffness characterization.

References: 1) Yeh et al., Ultr.Med.Biol., 2002 2) Dresner et al., JMRI, 2001. 3) Muthupillai et al. Science, 1995. 4) Shi et al., Ultr. Imaging, 1999. 5) Kruse et al. Phys. Med. Biol., 2000.