Preliminary Experience with Liver MRI and 1H MRS at 7 Tesla

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Introduction: Magnetic resonance imaging and spectroscopy are useful in cancer diagnosis and treatment-response monitoring in many cancers, including those of the liver (1). Ultra-high magnetic fields have the potential to improve the quality of MRI by giving increased SNR and better image contrast. The increased SNR and spectral dispersion of ultra-high field can improve the precision of quantitative MRS and allow detection of metabolites not visible or poorly resolved at lower field strengths (2). Body imaging at 7 Tesla is feasible (3) but challenging due to B_0 inhomogeneity, B_1 inhomogenetiy, and SAR limitations. Here we present the first data showing the feasibility of *in vivo* liver MRI and MRS at 7 T.

Methods: MRI and MRS of the liver were collected on a research system with a 7 T magnet (Magnex Scientific, Oxfordshire, UK), with a Siemens Sonata gradient system and TIM console (Siemens, Erlangen, Germany). The transmit signal from an 8-kW RF amplifier (CPC, Brentwood, NY) was split with an 8-way power divider and phase-modulated using variable cable lengths and high-power phase shifters (ATM, Patchogue, NY) for each transmit element. A novel, 8-channel flexible body surface array with TEM/stripline elements was used to both transmit and receive (4). The transmit phase for each of the eight channels was optimized *in vivo* using a B_1 shimming algorithm described previously (5). Four healthy volunteers were studied under a protocol approved by our institution's IRB.

Prior to imaging, the B_0 inhomogeneity was minimized using the manufacturer's 3D phase map algorithm, and the transmit B_1 was maximized over a ~5x5cm region in the anterior of the right lobe of the liver. For each subject, multi-slice gradient recalled echo (GRE) images and GRE images with variable flip angles (GRE-VFL) were acquired during brief breath-holds. Figure 1 shows a representative image from a multi-slice GRE acquisition (eight 5 mm slices, TR/TE=150/4 ms, FOV = 26 cm, 256x256 matrix, 66 kHz readout bandwidth) acquired over two 20s breath-holds and Figure 2 shows a GRE-VFL image (one 5 mm slice, TR/TE=100/10 ms, FOV = 26 cm, 256x256 matrix) acquired in one breath-hold.

After imaging, MRS was performed using a 30x30x30 mm voxel placed in the anterior right lobe of the liver. Spectra were acquired using a PRESS sequence with WET water suppression, TR/TE=3000/50ms. The B_0 field was shimmed using the manufacturer's 3D phase map tool performed during a breath-hold. In one of the studies, to maximize B_1 homogeneity in the area of interest only 4 channels were used to transmit and while still using 8 channels to receive. Spectral acquisition was performed during consecutive sets of 20s breath-holds (6) or by triggering with respiratory bellows. For both imaging and spectroscopy, the eight receive channels were combined using the manufacturer's sum-of-squares algorithm.

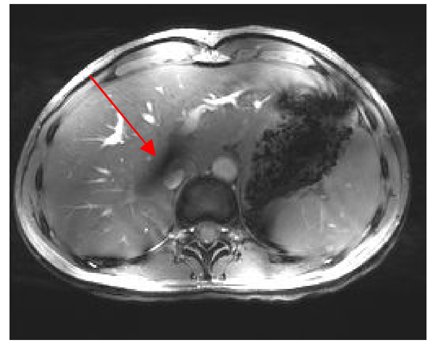

Figure 1 – Axial image from a multi-slice gradient recalled echo image acquired over two 20 s breath-holds. The arrow indicates a remaining area of interference.

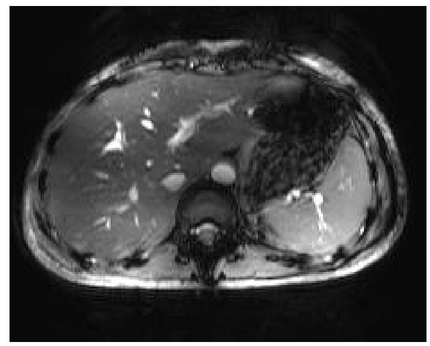

Figure 2 – Axial image using a gradient recalled echo, variable flip angle sequence in one breath-hold.

Results and Discussion: The gradient-echo images generally have good SNR but show strong signal inhomogeneity. Intensity correction would be required to make the images of diagnostic quality. The B_1 shimming algorithm greatly improved the homogeneity of the images, removing a majority of the destructive interference in the region of interest. A few areas of interference remain in the images as the algorithm was developed primarily for smaller regions (Figure 2). Future algorithms for homogenous excitation over large regions are under development.

Both imaging and spectroscopy were successfully acquired during breath-holds. Triggering using the respiratory bellows was less effective for MRS. Spectroscopy was not successful in 2 of 4 subjects due to inability to shim B_0. The spectrum shown in Figure 3 has a broad linewidth, and better B_0 shimming methods are needed to improve the spectral quality. Nevertheless, some metabolite resonances are visible in the 3-4ppm range, with a probable choline resonance at 3.2ppm.

These results demonstrate the feasibility of liver imaging and spectroscopy at 7 Tesla. The primary areas that need further development are optimization methods for producing homogeneous B_1 fields for uniform excitation over the liver, and methods for localized B_0 shimming to improve spectroscopy linewidth.

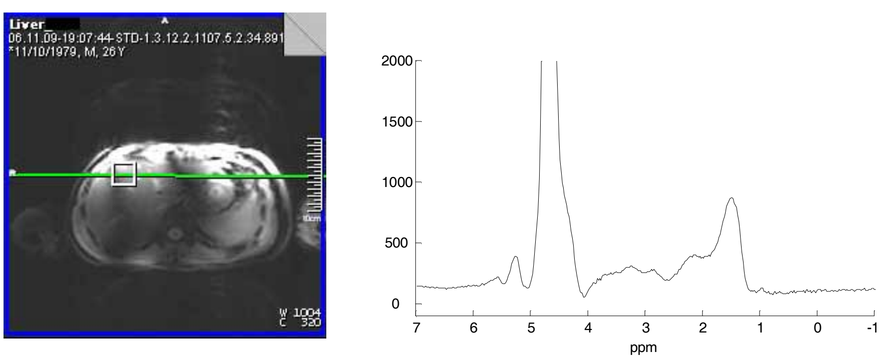

Figure 3 – Water-suppressed liver spectrum acquired over six 20s breath-holds, with 8 spectra acquired during each breath-hold. The spectrum shows residual water, lipids at 5.4, 2.2, and 1.3 ppm, and a group of unidentified broad resonances between 2.9-3.8 ppm. The water linewidth is ~100Hz. The location of the voxel is shown on the left in a low-resolution axial GRE image. This image was collected using 4 channels in transmit and 8 in receive to minimize interference in the area of interest for spectroscopy.

References: 1) Li C-W, et al., MRM 2005; 2) Gruetter R, et al., JMR 1998; 3) Vaughan JT, et al., MRM 2004; 4) Snyder CJ, abstract submitted to ISMRM 2007; 5) Van de Moortele P-F, et al., MRM 2005; 6) Katz-Brull R, et al., MRM 2003

Acknowledgements: Supported by NIH-123 4567890, NIH-098 7654321, and the MIND Institute