Comparison of Magnetic Resonance Temperature Imaging for Magnetic Resonance Guided Focused Ultrasound Treatments at 3 and 1.5 T Field Strengths.

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TARGET AUDIENCE AND PURPOSE: This work compares a 7-channel Magnetic Resonance guided Focused Ultrasound (MRgFUS) breast system at both 3T and 1.5T field strengths. MRgFUS systems that operate at 3T have the advantage of increased SNR, which is vital for MR temperature imaging (MRTI). However, 1.5T systems have the advantages of reduced sensitivity to susceptibility and motion artifacts, shorter T1, longer T2, and greater accessibility. Currently, there are more 1.5T scanners at medical facilities and 1.5T is often preferred due to well-established protocols, imaging sequences, and vender RF coils. If an MRgFUS system is shown to be effective and safe at 1.5T strength, nearly all hospitals could have access to MRgFUS treatments. Using 1.5T magnet strength would allow more common and cost effective treatments.

METHODS: Design: The MRgFUS system includes a small coupling tank (14 cm diameter, 12 cm high); a 940 kHz, laterally shooting 256-element phased array ultrasound transducer (IGT, Inc.) coupled to the breast system with 5 degrees of manual mechanical steering, 3 degrees of electronic steering; a receive-only 7-ch phased array RF coil consisting of 6 channels in a ladder geometry[2] wrapped around the cylinder; each element was 5 cm wide by 9 cm high; and a 17 cm diameter chest loop. (**Fig 1**) Experiments were performed in a TIM Trio 3T and an Espree 1.5T MRI scanner (Siemens, Erlangen, Germany). The breast systems were identical, except for the 7-ch MRgFUS coil, which was properly tuned and matched at the two different field strengths[3]. **SNR:** Relative SNR (rSNR) maps were obtained in a homogeneous $CuSO_4$ phantom using a 2D GRE pulse sequence (TR/TE 500/10ms, 1x1x5 mm^3 spatial resolution, 90° flip angle). Both the SNR and the noise correlation were measured (**Fig 2**). **Human Imaging:** With IRB approved informed consent the same female volunteer was imaged at the two different field strengths with the 7-ch MRgFUS coil using a 3D 2-point Dixon VIBE sequence (TR 20ms, $1x1x1mm^3$ spatial resolution, 25° flip angle, TEs@1.5T=2.38 and 4.76ms, TEs@3T=2.45 and 3.68ms (**Fig 3**). **MRTI:** Relative temperature maps were obtained while performing a trajectory heating at 10 W for 30 s in a homogenous gelatin phantom at the two field strengths (GRE-EPI, TR/TE 40/23 ms, $2x2x3mm^3$ resolution, EPI factor = 9, 3.2 sec/acquisition, 10 slices 25% oversampling, flip angle@1.5T=30°, flip angle@3T=15°. Flip angles were optimized for the field strength (**Fig 4**).

RESULTS: Design: The RF coil design was successfully integrated into the MRgFUS system for both field strengths providing the SNR required for both temperature and anatomical imaging over the entire volume of the breast. **SNR**: Comparison of SNR showed the 3T coil had an increase of 2.8 times the 1.5T coil in the center of the breast phantom. **Human Imaging**: The anatomy images look very similar at both field strengths for the fat contrast. However, the water contrast is better at 1.5T due to the reduced water ghosting. **MRTI**: The standard deviation in temperature through time in a 5x5x2 cm^3 unheated volume is 0.09°C at 3T and 0.31°C at 1.5T. The FWHM of the peak temperature rise was 4 x 16 mm for both field strengths (top row, **Fig 4**). The difference in temperature accuracy between 1.5 and 3T is apparent in the trajectory temperature images (bottom row, **Fig 4**) with the 1.5T image much noisier with a more diffuse temperature pattern.

DISCUSSION AND CONCLUSION There are advantages and disadvantages of performing MRgFUS at both field strengths. While the temperature accuracy was better with the 3T coil, the anatomy images at 1.5T were less susceptible to motion artifacts. We believe that, using this system, breast MRgFUS treatments could successfully be performed at either field strength.

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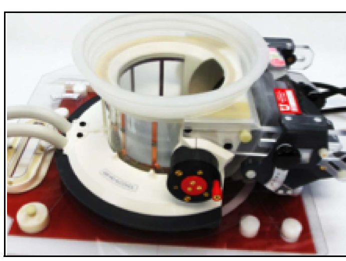

Figure 1. The MRgFUS breast system with coil support, 7-ch MRgFUS coil, US transducer and mechanics.

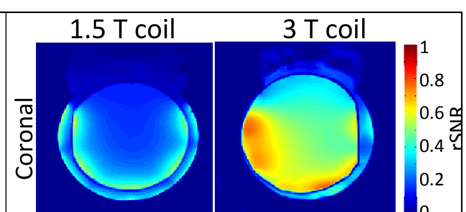

Figure 2. SNR scans. Coronal slices.

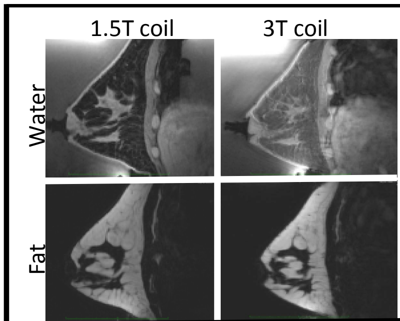

Figure 3. Vibe fat/water images. The US transducer is at the bottom of the image. Top: water contrast. Bottom: fat contrast. Left Column: 1.5 T coil. Right Column: 3 T coil.

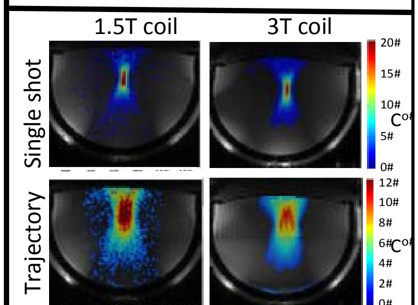

Figure 4. US heating in a homogenous phantom. Top row: Single shot. Bottom row: Trajectory heating. Transducer is shooting from the top of the image.

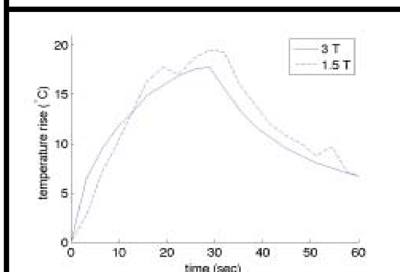

Figure 5. Line plot of temperature of hottest voxel through time.

References:[1.] Minalga E. et al. Magn Reson Med. 2013 Jan;69(1):295-302. [2.] A EW et al. Journal of Magnetic Resonance; 1986. p 156-161.[3.] Roemer et al. Magn Reson Med 1990;16(2):192-225.