In vivo evaluation of hybrid PRF/T1 approach for temperature monitoring during breast MRgHIFU treatments

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INTRODUCTION:

Our group has developed a breast-specific MR-guided high intensity focused ultrasound (MRgHIFU) system[1] with the goal of being able to safely and effectively treat localized breast tumors. A major component of the project is to implement an MR sequence that can simultaneously and accurately monitor temperature changes in both fat-based and water-based tissue types throughout an MRgHIFU breast tumor ablation treatment. To this end we have developed a multi-echo hybrid PRF/T1 sequence. This abstract presents precision results for T1 measurements in breast adipose tissue and PRF measurements in breast glandular tissue for four healthy volunteers.

METHODS:

Hybrid PRF/T1 Sequence. The sequence uses a variable flip angle approach to measure T1 and the standard phase-based approach to measure PRF[2]. To improve data acquisition efficiency, we have added a high bandwidth multi-echo read-out with a flyback gradient. The multiple images acquired at varying TE's are optimally combined for both magnitude (weighted by exp(-2·TE/T2*)) and phase (weighted by TE^2·exp(-2·TE/T2*)). Sequence parameters were as follows: 160 x 160 mm FOV; 1.25 x 1.25 x 3.5 mm resolution; TR = 20 ms; 6 echoes with TE's = 2.5, 5.25, … 16.25 ms; 2 flip angle's = 20°, 45°; Bandwidth = 810 Hz/pixel; 6/8 partial Fourier; 1.9 sec/scan.

Experimental Data. Volunteers were imaged in the breast MRgHIFU system without any heating. The set up is shown in **Figure 1**. 3-pt Dixon images were acquired for fat/water segmentation. A total of 100 time frames were acquired with the hybrid PRF/T1 sequence. The first 50 time frames were used for an atlas-based approach to correct phase errors due to breathing[3]. The second 50 frames were used to analyze the precision of the T1 and PRF measurements. A 3x3 mean filter was applied to the calculated T1 maps. To obtain an estimate of precision, a pixel-by-pixel standard deviation over time was calculated for both measurements. The results reported in **Table 1** are the mean and standard deviation of these values over a 6 x 6 ROI placed in fat and glandular tissue, respectively.

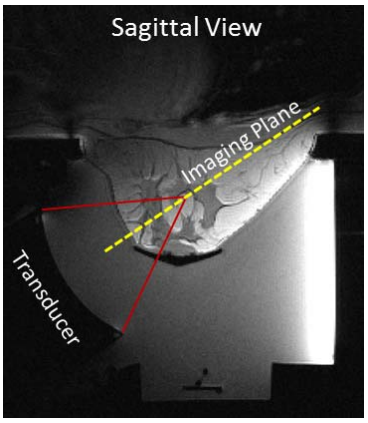

Figure 1. Sagittal view of the breast in the MRgHIFU system. The PRF/T1 imaging plane is oriented parallel to the beam path.

RESULTS & CONCLUSIONS:

Figures 2 and **3** show example images from Volunteer # 1. Fat-only and water-only Dixon images are shown in **Figure 2**. A magnitude image from the hybrid PRF/T1 sequence is shown in **Figure 3A**, along with T1 and PRF precision maps in **Figure 3B** and **3C**. The white boxes indicate the 6x6 ROI used for calculation of the values presented in Table 1. The precision values for T1 and PRF measurements in all volunteers are summarized in **Table 1**. Reported values for the temperature dependence of T1 in fat range from 1 – 2 %/°C[4], indicating that the hybrid PRF/T1 sequence used in conjunction with the developed breast MRgHIFU system is capable of measurement precision of ~2-6°C in breast adipose tissue (at 3.75 x 3.75 mm resolution) and ~1°C in breast glandular tissue (at 1.25 x 1.25 mm resolution) with 1.9 second temporal resolution.

	T1 Precision (%)	PRF Precision (°C)
Volunteer #1	3.8 +/- 0.4	1.2 +/- 0.2
Volunteer #2	3.7 +/- 0.4	1.0 +/- 0.2
Volunteer #3	6.1 +/- 2.1	1.2 +/- 0.2
Volunteer #4	7.4 +/- 1.0	0.8 +/- 0.2

Table 1. T1 and PRF precision values.

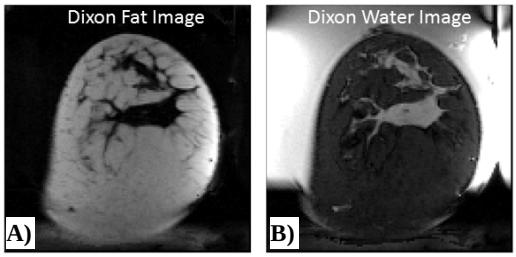

Figure 2. 3-pt Dixon fat-only and water-only images from Volunteer #1. This information is used for segmentation: T1 measurements are made in fat and PRF measurements in water.

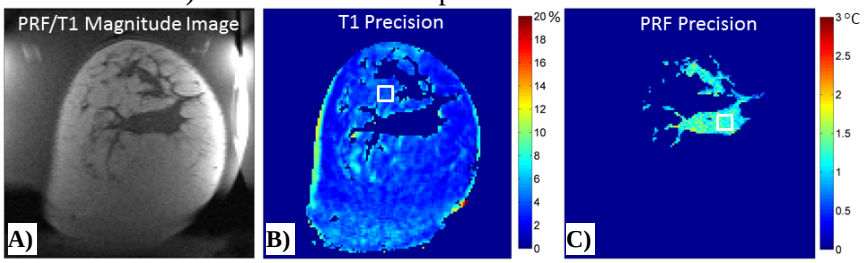

Figure 3. Example images from Volunteer #1. A) Magnitude image from the 1st echo of the PRF/T1 sequence. B) Map of T1 precision throughout the fatty tissue, shown as percent error. C) Map of PRF precision throughout the water-based tissue, shown as error in °C.

REFERENCES: 1. Payne et al. Med Phys, 39(3): 1552-1560, 2012. 2. Todd et al. MRM, 2012. DOI: 10.1002/mrm.24228. 3. Vigen et al. MRM 2003;50(5):1003-1010. 4. Rieke et al. JMRI 27:376-309, 2008. **FUNDING**: The Focused Ultrasound Surgery Foundation, The Margolis Foundation, Siemens Medical Solutions, NIH grants R01 CA87785, and R01 CA134599.