

A hybrid PRF/T1/T2* sequence for assessing tissue damage

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INTRODUCTION:

Real-time monitoring of MR-guided thermal therapies requires a method for assessing tissue damage. Currently, this is typically done using the metric of thermal dose¹, which in turn is based on PRF temperature measurements. The MR parameters T1 and T2* may also be useful indicators of the state of tissue and assist in tissue damage assessment. For this purpose, we have developed a hybrid PRF/T1/T2* sequence that allows simultaneous measurement of all three parameters. The sequence is used to analyze the behavior of T1 and T2* as a function of both temperature and thermal dose.

METHODS:

Hybrid PRF/T1/T2* Sequence. The sequence is a 2-D gradient echo sequence that acquires multiple echoes per excitation and alternates between two flip angles every other time frame. The variable flip angle approach is used to measure T1, T2* is calculated from the multiple echoes, and PRF temperature are obtained from the standard phase-based approach^{2,3,4}. For the T1 and PRF calculations, the multiple images acquired at varying TE's are optimally combined for both magnitude (weighted by $\exp(-2 \cdot TE/T2^*)$) and phase (weighted by $TE^2 \cdot \exp(-2 \cdot TE/T2^*)$). Sequence parameters were as follows: 0.75 x 0.75 x 5.0 mm resolution; TR = 50 ms; 12 echoes with TE's = 2.83, 6.27, ... 40.67 ms; 2 flip angle's = 30°, 70°; Bandwidth = 810 Hz/pixel; flyback gradient for monopolar echo read-out, 5.7 sec/scan.

Experimental Data. HIFU heating experiments were performed in an *ex vivo* turkey muscle sample in a Siemens 3T TIM Trio scanner. A fiber optic probe was inserted in the sample for baseline temperature measurement. Two HIFU heating runs were performed, each consisting of one central point and 6 surrounding points in a 2 mm radius circle with the beam repeatedly scanned at 100ms/point for a total of 210 seconds of heating. Run 1 was performed at 90 W and designed to induce heating below the damage level of 240 CEM. This data was used to calibrate the temperature dependencies of T1 and T2* (T1(T) and T2*(T)). Run 2 was performed at 120W and designed to exceed the damage threshold. Analysis of the data from Run 2 was performed by subtracting the calibrated T1(T) and T2*(T) from the measured T1 and T2* values. These temperature-corrected T1 and T2* values were analyzed as a function of thermal dose.

RESULTS & CONCLUSIONS:

Figure 1 shows maps of PRF temperature, T1 change, T2*, and thermal dose for Run 2. The time frames shown correspond to the peak of heating and after 5 minutes of cooling. It can be seen that while the temperature of the hotspot has mostly diffused after 5 minutes of cooling, regions in the center of the targeted area show depressed values for T1 and T2*. The calibration data from Run 1 is shown in **Figure 2**. T1(T) was fit with a linear function of slope 5.7 ms/°C and T2*(T) was fit with a linear function of slope -0.3 ms/°C. Temperature-corrected T1 and T2* values from a 15x15 voxel region about the targeted area are plotted as a function of log(dose) in **Figure 2**. The temperature-corrected T1 and T2* values remain near zero below the 240 CEM threshold and have a negative trend above this threshold.

The hybrid PRF/T1/T2* sequence provides additional information related to the state of the tissue that may be useful for assessing damage. Future work will examine these processes in the more complicated *in vivo* environment.

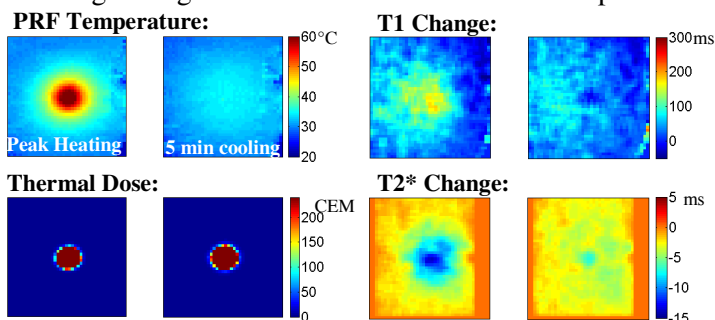


Figure 1: Maps of PRF temperature, thermal dose, T1 change, and T2* change for Run 2, show at the peak of heating and after 5 minutes of cooling for Run 2. T1 and T2* maps after cooling both show decreases in value at the center of heating where the thermal dose exceeded 240 CEM. The T1 changes were confirmed with inversion recovery imaging (not shown).

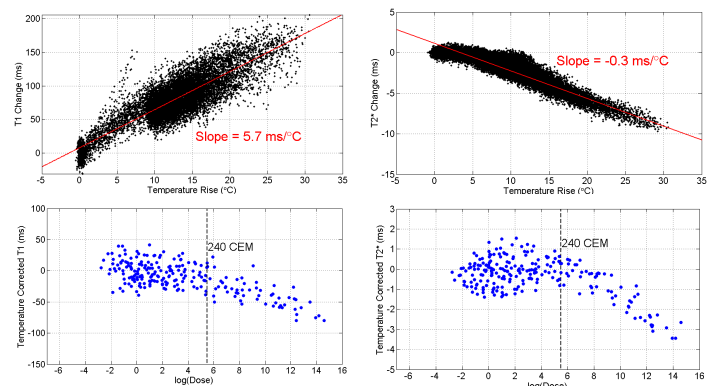


Figure 2: Top: Data from Run 1 showing T1 and T2* as functions of temperature, used to calibrate T1(T) and T2*(T) for sub-damage temperature changes. **Bottom:** Temperature-corrected plots of T1 and T2* as functions of log(dose).

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FUNDING: The Focused Ultrasound Surgery Foundation, The Margolis Foundation, Siemens Medical Solutions, NIH grants R01 CA87785, and R01 CA134599.