Relationship between Temperature and T2 in Subcutaneous Fat and Bone Marrow at 3T

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Target Audience: Researchers and clinicians interested in MRgHIFU.

Purpose: MR-guided high-intensity focused ultrasound (HIFU) uses the proton resonant frequency shift (PRF) for temperature monitoring in water-based tissues, but is difficult to use in tissues with high lipid content, such as abdominal fat and bone marrow. Previous studies have shown a change in T2 of subcutaneous fat, red and yellow bone marrow during treatments with focused ultrasound [1]. The lack of calibration data for 3T acquisitions, however, makes it difficult to convert T2 values into maps of tissue temperature. In this study we investigated the dependence of T2 on temperature in porcine adipose tissue and bovine yellow bone marrow at 3T, and evaluated the influence of pulse sequence parameters on the regression.

Methods: Two petri dishes were filled with porcine adipose tissue and bovine yellow bone marrow (fig.1 a,b) and placed in a thermally insulated water bath held at a constant temperature. Temperature in the water and within the samples was monitored with fiber optic sensors.

T2 was quantified in a 3T MRI scanner with a double-echo fast spin-echo sequence with and without water suppression (TE = 35/182 ms and 28/147 ms, TR = 1500 ms, ETL = 40, FOV = 12 cm, 128 x 128 matrix size, 8 mm slice thickness). Images were acquired during heating (25°, 35°, 45°, 55°, 65° and 70° C) and subsequent cooling (55°, 35° and 25° C) after reaching thermal equilibrium.

Results and Conclusions: Figure 1 (c-f) shows examples of T2 maps of fat and marrow at 25° and 70°C. The T2 values within a 10x10 pixel ROI (black square on fig. 1) versus temperature are plotted in Figure 2. The T2 values in the fat sample (fig. 2a) increased linearly with heating, but followed a different slope during cooling due to irreversible tissue changes. The bone marrow sample exhibited a non-linear relationship between T2 and temperature during heating below 45°C (fig. 2b). As in the fat sample, the T2 values were higher and followed a different slope during cooling.

Table 1 shows the linear regression coefficients of T2 versus temperature for the different acquisition parameters. There was ~25% difference between measurements with and without water suppression (WS). This could be due to the contribution of water spins in the non WS acquisitions and/or suppression of a portion of the fat spins in the WS acquisition. The difference in the T2 vs. temperature coefficients between the two sets of echo-times was smaller. These results suggest that calibration and treatment should be done with the same imaging parameters.

In conclusion, we have calibrated the temperature dependence of T2 in subcutaneous fat and yellow bone marrow for temperatures between 25° and 70°C at 3T. This will allow for reliable and accurate monitoring of temperature in fatty tissues during treatment of patients with MR-guided HIFU.

	Fat		Marrow	
	Heating	**Cooling**	**Heating**	**Cooling**
Water Suppr. TE = 28/147	6.41	5.74	7.05	5.39
Water Suppr. TE = 35/182	6.16	5.37	7.00	5.39
No Water Suppr. TE = 35/182	4.64	4.10	5.48	4.47

Table 1. Relationship between T2 and temperature (ms/°C) for porcine adipose tissue (fat) and bovine yellow bone marrow (marrow).

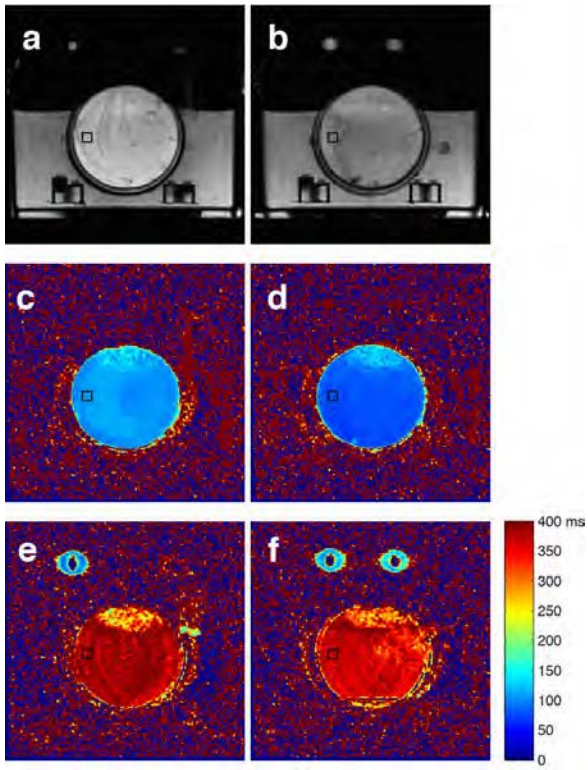

Figure 1. FSE images of petri dishes (no water suppression), containing porcine adipose tissue (a) and bovine yellow bone marrow (b); T2 maps of the tissues at 25°C (c,d); and at 70°C (e, f), acquired with water suppression.

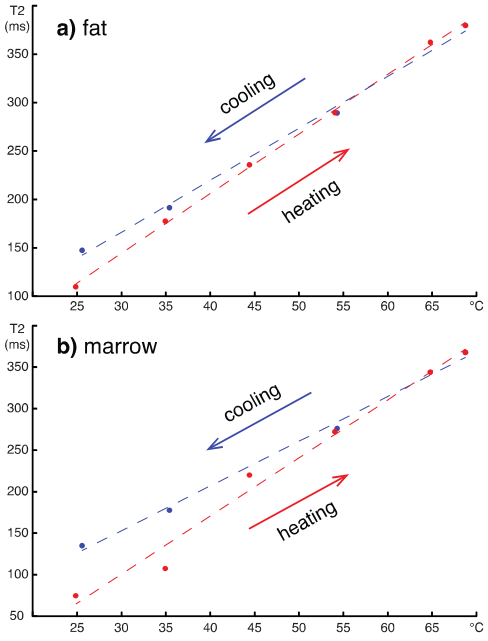

Figure 2. Plot of T2 vs temperature for fat (a) and marrow (b) during heating (red) and cooling (blue), acquired with TE = 35/182 and water suppression. Linear regression lines added.

References and Acknowledgements: [1] Baron P, et al. Magn Reson Med 2013

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