Measurement of the T1 and T2 temperature dependence of human breast adipose tissue

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INTRODUCTION

For MRI-guided High Intensity Focused Ultrasound (MRgHIFU) ablation of breast tumors MR thermometry of adipose tissue surrounding the tumor is important for treatment monitoring in tumor margins and for safety reasons. The thermal dose in the area around the primary tumor mass, which may contain adipose tissue, should exceed the level that is required to kill cancer cells in the margins of the tumor [1]. Furthermore temperature monitoring of tissue in the near and far field of the ultrasound beam is necessary to prevent unwanted damage to healthy tissue. However, the commonly used thermometry method based upon the Proton Resonance Frequency Shift (PRFS) only works well in tissue with high water content and with the use of fat suppression. Other thermometry methods based on the change in the relaxation times have been proposed for monitoring temperature in adipose tissue [2]. T1 or T2 temperature dependence was reported for bovine [2], porcine [3],and ovine fat [4], but to the best of our knowledge, the T1 or T2 temperature dependence of human breast adipose tissue has not yet been investigated. In preparation of MRgHIFU ablation in the breast, our aim was to assess the T1 and T2 temperature dependence of human adipose breast tissue and to compare these with the T1 and T2 temperature dependence of sunflower oil and pig fat, which are commonly used phantom materials to mimic human fat.

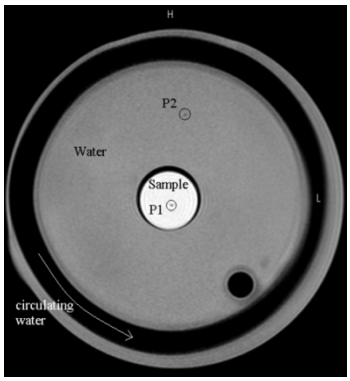

Fig. 1 Water bath. P1: Probe 1, P2: Probe

METHODS

Samples: Breast fat (from unembalmed female human cadavers, N=2), subcutaneous pig fat (from the abattoir, N=3), and sunflower oil (N=3). Each sample was put in a 50-ml Falcon tube and placed inside a water bath which was positioned in the bore of a 1.5-T MRI scanner (Achieva, Philips Healthcare, Best, The Netherlands). The temperature of the sample was increased, by heating the water from 26.5°C to 72°C in increments of about 5°C and then allowed to cool back to 26.5°C with the same temperature intervals. The temperature was measured with fiber optic probes (Luxtron Corp.Santa Clara, USA) at two positions. Probe 1 (fig.1) was placed in the center of the sample and probe 2 in the surrounding water bath. The T1 and T2 mapping was started when the temperature difference between probe 1 and 2 was less than 0.5°C and temporal fluctuations of both probes had stabilized to less than 0.5°C per 10 minutes.

Acquisition: To map both T1 and T2, a 2D mixed sequence,with combined multiple inversion recovery and multi spin echo [5] was used: TR-IR=2290ms, TR-SE=760ms, TE=4x50ms, IR_delay=370ms, FOV=142x142mm, slice thickness=10 mm, acquired matrix =71x71, NSA=2, water suppression SPIR.

Post processing: T1 and T2 maps were calculated from monoexponential fits and the average value of a ROI (12 voxels) was obtained.

RESULTS

T1 mapping: Figure 2a shows the T1 temperature dependence of the three samples (sun flower oil, pig fat and breast fat). For all samples T1 changed non-linearly and reversibly with temperature. For all samples the dT1/dT slope for adjacent temperature intervals increased from 4.4±0.6 (average±stdev) ms/°C at 29.1°C to 8.8±0.7 ms/°C at 68.9°C (body temperature: 5.2 ms/°C). Oil had an average T1 offset compared to breast of +23.8±1.8 ms.

*T2 mapping:*Figure 2b shows the T2 temperature dependence. Irreversible T2 changes were found for breast and pig fat at about 37°C and 45°C. During cooling, T2 decreased linearly with temperature (R^2>0.993) with temperature coefficients 0.77 ms/°C, 1.1 ms/°C and 1.3 for oil, breast and pig fat respectively.

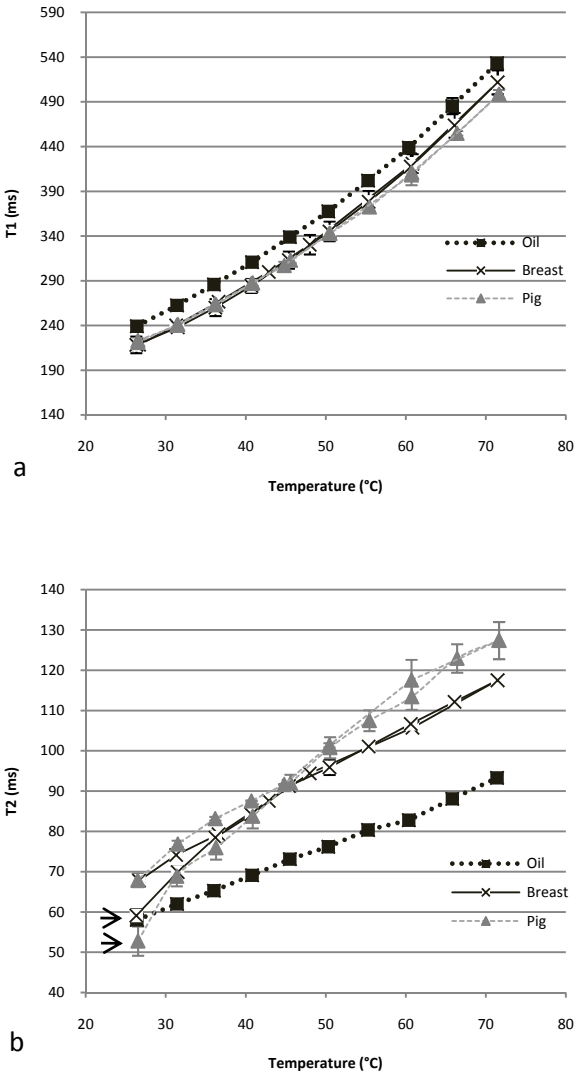

Fig. 2a) T1 and b) T2 versus temperature for sunflower oil, breast and pig fat. (error bars represent standard deviation over samples; arrows indicate start of heating curve)

DISCUSSION

Reversible T1 changes but irreversible T2 changes were found for breast and pig fat. This is consistent with the results of [6] in bovine fat. The T1 temperature dependence was similar for all three samples. T2 had a larger temperature dependence for pig than for breast fat. The nonlinear T1 temperature dependence was expected in adipose tissue which contain a mixture of different fatty acid components. In imaging, however, mono-exponential relaxation of adipose tissue is often assumed. If the T1 temperature curve is well calibrated it could be used in imaging strategies that combine T1 thermometry of fat with PRFS thermometry of water [7]. Future work will investigate intra- and inter-subject T1 and T2 temperature dependence variation of breast adipose tissue.

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