

MRI Guided HIFU of Visceral Fat: Effect of Heating on T2 Relaxation of Fat

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Target Audience: Basic researchers interested in thermal ablation of fat using MRI-Guided HIFU.

Purpose: MRI-guided high intensity ultrasound (MR-HIFU) allows non-invasive ablation of deep tissues without heating surrounding areas. MR-HIFU uses MRI to precisely target the HIFU beam and to monitor the temperature of the target and the surrounding regions. A novel application of MR-HIFU is ablating fat tissue to reduce the metabolic activity of fat deposits and reverse the development of obesity, diabetes and metabolic syndrome. Visceral fat may play a central role in fatty liver disease because of its proximity to the hepatic portal vein, allowing liver cells to be directly exposed to the metabolites and signaling molecules from visceral adipocytes [1, 2]. Animal studies have shown that surgical reduction of visceral fat volume can reduce liver fat accumulation and improve glucose tolerance. [3-5]. Unfortunately, accurate monitoring of HIFU-induced temperature changes in fat is difficult with the Proton Resonance Frequency Shift (PRFS) method used for most MR-HIFU procedures [6]. To overcome this limitation, we used T2 mapping to evaluate the effects of HIFU on fat while using PRFS to monitor the temperature of surrounding tissues in real time.

Methods: MR-HIFU was performed on a 1.5 Tesla whole body scanner (Philips IngeniaTM) equipped with a Philips SonalleveTM HIFU system. The HIFU transducer is integrated into the MRI table and can be translated and rotated to aim the HIFU beam at specific targets within the body. The 256-element focusing transducer produces a focal spot approximately 2 mm in diameter and 10 mm in length. MR-HIFU was used to ablate perinephric visceral fat (70 watts of acoustic power applied for 16 seconds) under MRI guidance in an obese male Sprague-Dawley rat weighing 650 g. Real time MRI thermometry (2.5 second temporal resolution) via PRFS was used during the HIFU ablation to monitor temperature in nearby tissues, such as in the kidneys, muscle, skin, etc. Thermometry was performed in two orthogonal planes, one along the HIFU beam path and the other perpendicular to the beam. Fat tissue does not display an adequate PRFS dependency on temperature, so heating in the fat was assessed by measuring the T2 before and after HIFU ablation. T2 maps were acquired with a multi-echo sequence (scan time of 1 minute and 22 seconds) with 8 echo times ranging from 21 to 266 ms.

Results: At 1.5 T, the T2 of fat was 125 ms before ablation. During the HIFU ablation (FIGURE 1), some heating of the surrounding tissue was observed, reaching a maximum temperature of approximately 55° C. As expected, no temperature change was detected in the fat with the PRFS-based sequence. After ablation, the T2 of the targeted fat increased by 31% to 165 ms (FIGURE 2). Other areas of fat outside the target region showed no change in T2 after ablation.

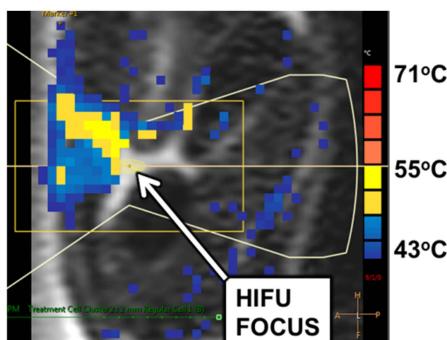


Figure 1: MRI thermometry acquired during HIFU ablation. No heating is observed in the fat region due to the lack of a temperature sensitive PRFS signal. The surrounding tissues show very little heating.

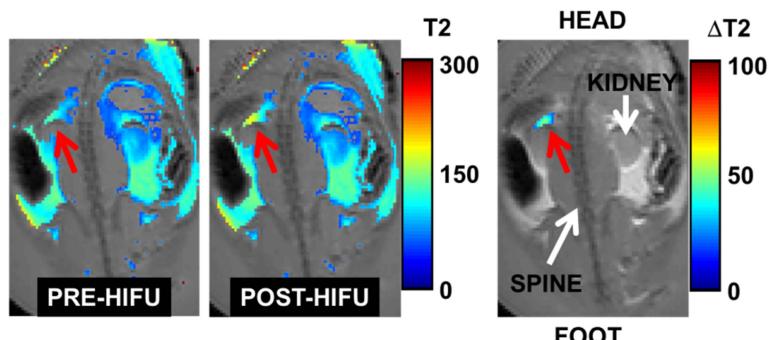


Figure 2: T2 map (color) overlaid onto T2-w images (grayscale) before (left) and after (middle) application of MRI-HIFU to fat (red arrows). The T2 value at the treatment site increased by 39 ms, while other areas showed no change in T2 on the subtraction map (right).

Discussion: We have demonstrated that T2 mapping can be used to monitor the ablation of fat tissue after the application of focused acoustic energy. The approach can be used together with PRFS methods to monitor temperature changes in surrounding tissue to ensure procedure safety. These methods will be further developed to correlate the fat T2 values to the *in-vivo* temperature, and assess the therapeutic effect of visceral fat ablation in animal models of obesity and diabetes.

References:

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