Fat Temperature Imaging with T1 of Fatty Acid Species using Multiple Flip Angle Multipoint Dixon Acquisitions

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INTRODUCTION
Noninvasive temperature imaging for breast is desired for thermal therapies such as high intensity focused ultrasound (HIFU) surgery to ensure the heat deposition to the target tumor and to protect the surrounding normal tissues. The key issue for breast temperature imaging is to develop a reliable thermometry technique for adipose tissues. In vitro spectroscopic measurements of the temperature dependences of the MR parameters of the fatty acid components have shown that the relationship between $T_1$ of methylene (CH$_2$) and methyl (CH$_3$) protons and temperature is linear and reproducible(1). Since these two components have different temperature coefficients, extraction of a particular fatty acid component and quantification of the $T_1$ of a particular component is necessary to image fat temperature quantitatively. In the present study, fat temperature imaging technique based on a multiple flip angle, multipoint Dixon acquisition and a least square estimation scheme is proposed.

METHODS
A sequence of spoiled gradient recalled acquisition in steady state (SPGR) was designed to evaluate $T_1$ of CH$_2$ and CH$_3$ as depicted in Fig. 1(2). In the first shot, echoes with different TE's were acquired at a certain flip angle ($\alpha_0$) to obtain real and imaginary parts of water, CH$_2$ and CH$_3$ signals based on the multipoint Dixon scheme proposed by Reeder et al(3). In the following shots, similar echo sets were obtained with different flip angles. Each set of echoes was reconstructed separately to have the complex CH$_2$ and CH$_3$ images with different flip angles. Then the CH$_2$ and CH$_3$ image sets were used to derive $T_1$ maps of these proton components based on a $T_1$ calculation technique previously introduced(4). The $T_1$ maps were then converted to temperature maps. In our first implementation, the following parameters were used: TR, 36 ms, TE, from 1.33 to 18.4 with 1.14 ms steps; number of echoes, 16; flip angles, 20, 50 and 70 degrees; spatial matrix, 128 x 128; SENSE factor, 2. A phantom with olive oil and water bottles was constructed as shown in Fig. 2. The olive bottle on the top left was heated up to around 65 degree, while the other bottles were kept at room temperature (27oC). The acquisitions were repeated in the cooling period of the oil sample.

RESULTS
Total acquisition time for 16 echoes and 3 flip angles were 6 seconds. Based on the selection of the number of echoes and number of flip angles, successful separation of the chemical species and calculation of $T_1$'s for CH$_3$ and CH$_2$ were performed by using first 5 echoes and 3 flip angles. The results are shown in Fig. 2 with the original axial view of the phantom for a flip angle of 20 degrees. Two flip angle acquisitions in 4 second yielded similar results with the 3 angle cases. Temperature images were obtained as shown in Figure 3 based on the temperature coefficients (1.52 [%/oC] and 2.36 [%/oC]) for CH2 and CH3 protons obtained previously(1).

CONCLUSION
The basic function of the proposed technique with multipoint Dixon and multiple flip angle scheme was demonstrated. The technique can image temperature based on $T_1$ of CH$_2$ in 4 second, which seemed to be practical enough for monitoring temperature in breast under HIFU.

REFERENCES

Fig. 1 Schematic diagram of the fat temperature imaging technique based on $T_1$ of CH$_2$ and/or CH$_3$ obtained by multipoint Dixon and multiple flip angle acquisitions.

Fig. 2 Axial view of the phantom consists of olive oil and water bottles (a), and the water (b), CH$_2$ (c) and CH$_3$ (d) images separated by the multipoint Dixon scheme.

Fig. 3 Temperature maps based on $T_1$'s of CH$_2$ (upper row) and CH$_3$ (lower).