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

K. Kuroda[1,2], T. Iwabuchi[3], M. K. Lam[3,4], M. Obara[5], M. Honda[6], K. Saito[3], M. V. Cauteren[5], and Y. Imai[6]

[1]Graduate School of Engineering, Tokai University, Hiratsuka, Kanagawa, Japan, [2]Medical Device Development Center, Foundation for Biomedical Research and Innovation, Kobe, Hyogo, Japan, [3]School of Engineering, Tokai University, Hiratsuka, Kanagawa, Japan, [4]Image Sciences Institute, University Medical Center Utrecht, Utrecht, Netherlands, [5]MR Marketing, Philips Electronics Japan Medical Systems, Shinagawa, Tokyo, Japan, [6]Department of Radiology, Tokai University, Isehara, Kanagawa, Japan

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 (α_1) 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 T1's for CH_2 and CH_3 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 [%/°C] and 2.36 [%/°C]) for CH2 and CH3 protons obtained previously(1).

DISCUSSIONS

Separation of chemical species and T_1 calculation for them were achieved by the multipoint Dixon, multiple flip angle acquisitions. The resultant temperature images demonstrated the feasibility of the proposed technique for quantitative imaging of fat temperature. As was anticipated from the content ratios, the resultant temperature images obtained by CH_3 were with higher noise figure than those by CH_2, regardless to the higher temperature sensitivity of CH_3. The frequency separation between water and the fatty acid components had to be optimized according to the thermal shift of the water proton resonance frequency. Combination with temperature measurement using the water resonance shift determined by the complex water images for high-water-content tissues like mammary gland is under our consideration.

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

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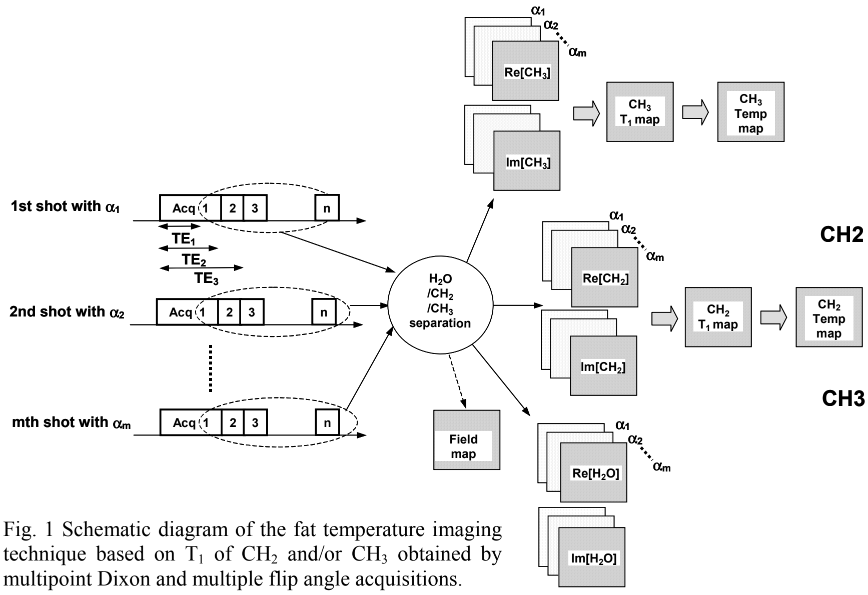

Fig. 1 Schematic diagram of the fat temperature imaging technique based on T_1 of CH_2 and/or CH_3 obtained by multipoint Dixon and multiple flip angle acquisitions.

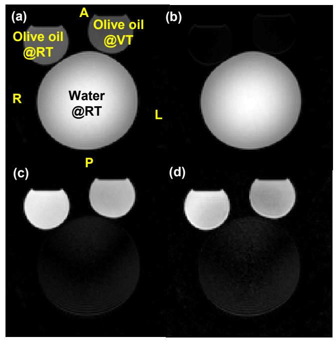

Fig. 2 Axial view of the phantom consists of olive oil and water bottles (a), and the water (b), CH_2 (c) and CH_3 (d) images separated by the multipoint Dixon scheme.

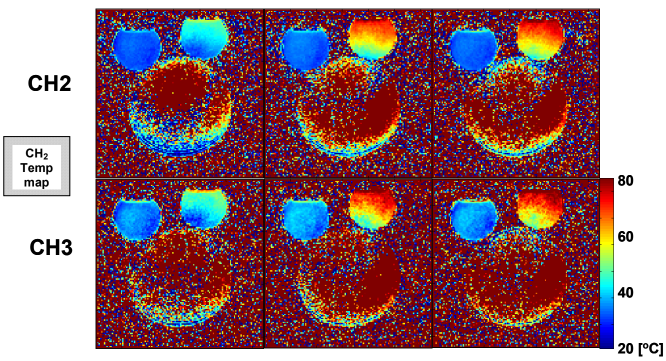

Fig. 3 Temperature maps based on T_1's of CH_2 (upper row) and CH_3 (lower).