Initial Evaluation of a Fast Chemical Shift Thermometry Technique in the Breast

H. Ai[1], B. A. Taylor[1], A. M. Elliott[1], H. LePetross[2], J. D. Hazle[1], and R. J. Stafford[1]

[1]Imaging Physics, The University of Texas MD Anderson Cancer Center, Houston, Texas, United States, [2]Diagnostic Imaging, The University of Texas MD Anderson Cancer Center, Houston, Texas, United States

Introduction:

Thermal therapy delivery in the breast is of growing interest because of the minimally-invasive, cosmetically appealing and repeatable nature of this therapy [1]. However, recent efforts to establish efficacy have failed, primarily because there is no method by which to evaluate the extent to the damage created. MRI is a powerful modality for imaging the breast and advances continue in dynamic imaging, diffusion, perfusion and spectroscopic imaging of the breast making MRI an ideal modality for targeting, monitoring and potentially verifying treatment. Furthermore, with respect to treatment guidance, techniques such as the temperature dependent proton resonance frequency (PRF) shift of water can be employed for monitoring and controlling therapy delivery in the breast [2,3]. The disadvantage of this method in breast is that the technique is susceptible to motion artifacts which cause large variances in the local field as well as the fact that lipid resonance is not temperature sensitive and therefore must be separated from the water signal or suppressed. In this work, we investigate a potential fast chemical shift imaging method for real-time temperature imaging in the breast. Similar to previous work using LSEPI for CSI [3], we evaluate the potential use of the sequence in patients without heating using a multi-echo gradient echo technique with 16-echoes and peak parameter identification using the Steiglitz-McBride algorithm [4].

Methods:

All measurements were performed in a 3T clinical MRI scanner (Excite HD®, General Electric, Milwaukee, WI) running TRM gradients.and an 8-channel receive only phased-array breast coil. MR imaging was performed using a 2D multiecho fast GRE sequence with parameters: flip angle 30°, FOV= 30x30cm, slice thickness 4.0mm, encoding matrix of 160 x 128, TR=75ms and BW=250 kHz. A total of 16 echoes were collected with an echo spacing of 1.82ms between them. A total of 20 seconds of imaging data was collected. All patient data gathered during the study was collected in compliance rules set forth by our institutional review board and federal HIPPA regulations. Data was analyzed using MATLAB® (MathWorks, Natick, MA, U.S.A) based on the Steiglitz-McBride algorithm [4]. The uncertainty in the temperature was evaluated by measuring the spectral ppm shift between lipid and water at various pixels across the breast. For lipid peak chemical shifts we calculated averaged voxels of varying sizes (3x3 to 15x15) in order to compensate for low lipid SNR in fibroglandular tissue. Since the background field should be slowly varying in the tissue, using this background lipid signal as an internal reference could be useful for correcting error in the temperature estimations in glandular tissue when there are errors from motion or susceptibility.

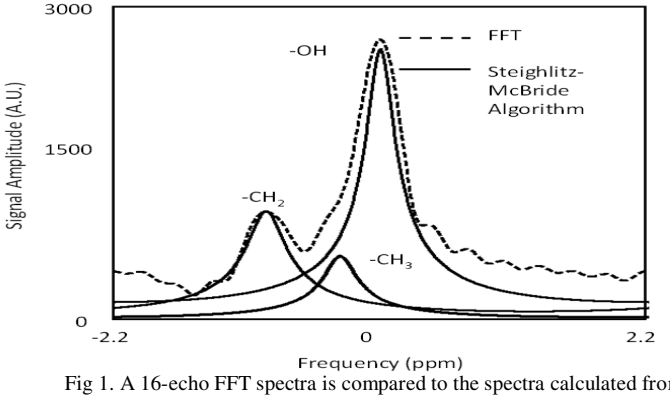

Fig 1. A 16-echo FFT spectra is compared to the spectra calculated from the Steighlitz-McBride (SM) algorithm. The SM algorithm is capable of distinguishing peaks such as the methyl peak ($-CH_3$) where the FFT is limited due to low spectral resolution. Note that the methylene ($-CH_2$) and methyl ($-CH_3$) peaks are aliased to allow low receiver bandwidths to boost SNR.

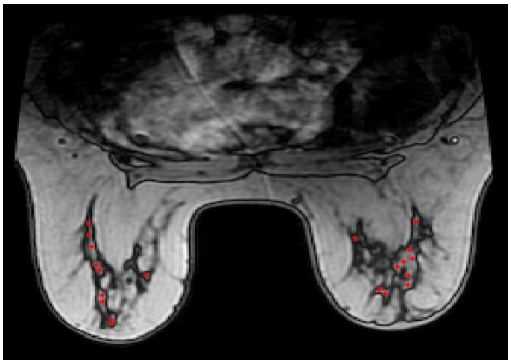

Fig 2. Pixels were selected across the breast fibroglandular tissue.

Results:

Using water chemical shifts alone, temporal uncertainty over 20 seconds is (0.87±0.92)°C averaged over multiple points in one breast and was (2.53±1.28)°C in the contralateral breast. Using chemical shifts between water and background lipid, in one breast the temporal uncertainty for temperature over 20s is (3.01±1.35)°C and (3.60±1.34)°C in the contralateral breast. Using background voxels from 5 x 5 to 15 x 15, the uncertainty in the difference between the water and lipid frequency was on average 13.8% lower than the expected quadrature sum of the uncertainties from the two frequencies indicating correlation between the peak motion. The average spatial uncertainty (i.e., "noise") measured in the fibroglandular tissue were (0.32±0.07) °C (0.0031 ± 0.0007 ppm), 2.1 ± 1.0 ms, and 1.56 ± 0.95 % for the temperature (chemical shift), T2* and amplitude, respectively. The noise measurements encompassed theoretical lower limit of uncertainty (Cramer-Rao Lower Bound) at the 95% confidence level which were calculated as 0.0037 ppm (PRF), 1.2 ms (T2*), and 2.4% (amplitude).

Conclusions:

It is possible that the difference between breasts is due to motion. Moderate compression of breast is needed to minimize motion, and hence temporal uncertainty in temperature estimates. The spatial uncertainty in the proton resonance image was 0.0031 ± 0.0007 ppm, which agrees to the theoretical lower bound of the uncertainty, but over time it could be as high as 0.0166 ppm, indicating motion instability. The temperature uncertainty was consistently reduced by subtraction of lipid peak while the improvement was largely limited by its low SNR. The optimal method to determine background lipid peak thus is still an area of research for this technique.

References:

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