Breath Hold Phase Correction for Water-Fat Separated MR Thermometry Using B0 Field Changes

C. R. Wyatt[1], B. J. Soher[2], and J. R. MacFall[2]

[1]Department of Biomedical Engineering, Duke University, Durham, NC, United States, [2]Department of Radiology, Duke University Medical Center, Durham, NC, United States

Introduction

Proton resonance frequency shift (PRFS) thermometry of the breast is often confounded not only by the presence of fat in the tissue but also by respiration-induced B_0 changes even in the absence of detectable breast motion. We (and others) have measured B_0 changes of up to 0.16ppm due to respiration[1] leading to temperature errors on the order of 16°C (due to the 0.01ppm/°C PRFS sensitivity). This error must be reduced to less than 1°C for hyperthermia treatment. The B_0 changes can be reduced by performing breath-holds during the MR scans, but large differences between breath-holds (~0.03ppm) are often still present due to inconsistent volume of each breath hold. Since fat does not experience a thermally related PRFS effect, fat-water separation provides fat as a local reference material to estimate B_0 changes between breath-holds. However, since a tumor is not likely to contain significant amounts of fat reference material, surrounding fat-water voxels must be used to extrapolate B_0 changes into the tumor region. In this work, field fitting techniques used previously [2] are used to extrapolate fat referenced B_0 changes measured using fat-water separation methods to B_0 changes in a water-only simulated tumor in a fat-water breast phantom..

Materials and Methods

A fat-water gelatin phantom was developed to mimic a breast consisting of a 4.25"x5.875" container filled with 85:15 fat-water gelatin. A 2" cylinder was placed through the center of the phantom filled with 100% water gelatin (to mimic a tumor). The phantom was placed in a breast radiofrequency hyperthermia applicator equipped with MR imaging surface coils surrounded by a water bolus of room-temperature D_2O. The experiment was performed without heating to test just the B_0 correction. A healthy male subject (IRB approved protocol) was positioned in the prone position on top of the applicator, with the chest of the subject approximately 1.3cm from the top of the phantom. During breath holds, a multi-echo gradient-echo sequence using a 1.5T MRI system (Signa, GE Medical Systems) acquired images with TEs of 15.4, 21.8, and 28.2ms, FOV=28cm, 128x128, NEX=2, BW=15.62 kHz, TR=50ms, and slice thickness = 5mm. The acquisition time of the sequence and length of the breath hold was 16 seconds, with nine breath holds performed. Separate fat and water images were created using the single peak IDEAL fat-water separation algorithm[3], which also creates a B_0 map. Each B_0 map was subtracted from subsequent breath-hold map and the field difference was converted to phase differences at the time of the first echo. The converted phase differences at several points within the fat-water part of the phantom were extrapolated to form a predicted phase change at all pixels of the image, using a minimum curvature surface method [2]. The extrapolated phase changes were then used to correct each breath-hold image by subtracting the estimated phase error from the actual phase. The corrected phase difference was then converted into equivalent temperature difference using the PRFS method.

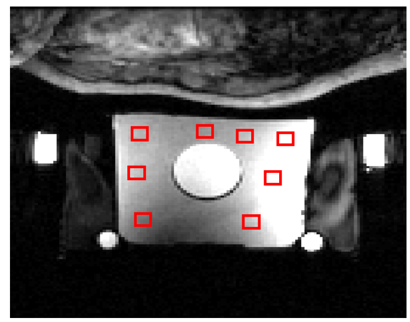

Figure 1: MR image of the phantom with male subject on top. Red rectangles indicate positions of 8 reference locations.

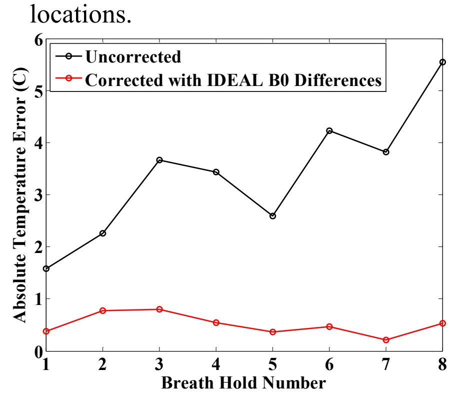

Figure 2: Plot comparing the uncorrected temperature with the corrected temperature inside the tumor

Results

A MR image of the phantom with the reference locations marked is shown in Figure 1. A plot comparing the uncorrected temperature change and corrected temperature change across the nine breath holds is shown in Figure 2.

Discussion:

As seen from Figure 2, the B_0 map extrapolation method reduces PRFS temperature errors between breath holds from a maximum of 5.55°C to less than 0.53°C. In addition, the fat-water separation method allows for temperature calculation in the fat using the water-fat frequency difference [4]. Therefore, this technique allows for a unique thermometry strategy in the breast, where fat-water separated images are acquired and used not only to calculate temperature in the fat but to correct conventional PRFS thermometry in the tumor for B_0 induced phase changes.

References:

[1] Peters, N., et al. JMRI 29 (3): 731-735 [2] Wyatt, C., et. al. International Journal of Hyperthermia, 25(6): 422-433 (2009) [3] Reeder, SB., et al. MRM. 51: 35-45 (2004) [4] Soher, BJ., et al. 16th ISMRM , Toronto, p3018 (2008)