Temperature Mapping Considerations in the Breast with Spectroscopic Imaging: Internal Referencing Significantly Improves Temperature Change Stability in Vivo

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Introduction: Breast cancer treatment with thermal therapies such as focused ultrasound may profit from MR guided thermometry (1). The presence of substantial lipid signal in addition to water in many breast voxels makes rapid spectroscopic imaging a natural choice for MR thermometry in this organ. Here, we assess the extent of artifactual apparent temperature change measurements made in unheated human breasts in vivo with a rapid spectroscopic imaging method and demonstrate how utilizing the water-methylene frequency difference significantly improves the stability associated with temperature change measurements as compared to using the temperature sensitive water frequency alone.

Methods: Nine healthy women, median age 51 years, provided informed consent according to the local institutional review board. A line scan echo planar spectroscopic imaging (LSEPSI) sequence (2) implemented at 1.5 T was used to gather spectra with a TR/TE of 3200/10 ms/ms and a 10 Hz spectral resolution from 4,096, 0.025 ml voxels every 6.4 s for 5.3 minutes from one breast and then the other using a 14 cm diameter receive only surface coil. The axial slices selected for serial spectroscopic interrogation were chosen from axial T2-weighted FSE sequences. Spectra were fit with a double Gaussian function to provide frequency measurements of water and methylene resonances from voxels with sufficient signal from each species. The root mean square (RMS) of the fluctuations of the water frequency and the water-methylene frequency difference, referenced to baseline values, were evaluated from all available breast voxels over the 5.3 minute course of each study and converted to apparent temperature changes using Hindman's relation of 0.01 ppm/°C (3).

Results: Figures 1 a and b show the fluctuations of the baseline referenced apparent temperatures as measured from the water frequency and from the water-methylene frequency difference in the breast of a volunteer, demonstrating considerably more stability in the latter. Figure 2 shows the mean RMS values of the apparent temperature changes as measured with both methods for all 9 subjects. In 8 of the 9 subjects the RMS values were significantly smaller when using the frequency difference vs. the water frequency alone ($p < 0.01$, students unpaired t-test) with mean values of approximately 0.6 and 2°C, respectively.

Discussion: In the breast, standard phase mapping techniques for temperature change monitoring suffer from lipid signal contamination and motion, both in and outside of the imaging plane (1). Bolan et al have shown that relatively large frequency fluctuations occur due to magnetic field changes in the breast due to the motion and susceptibility variations in surrounding organs like lung and heart (4). The fairly significant amount of apparent temperature changes occurring when using the water frequency alone in the breast are most probably a consequence of these effects caused by nearby organs. Using the water-methylene frequency difference in voxels where significant signal from water and methylene is available significantly reduces this problem and makes fast spectroscopic imaging advantageous for MR guidance of thermal therapies in the breast.

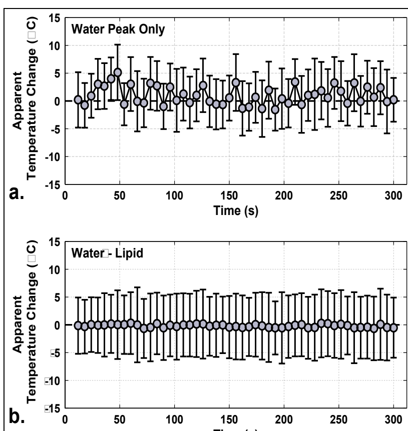

Figure 1: Plots of the apparent temperature change as a function of time for the water peak alone (a.) and for the water-methylene peak frequency difference (b.) in a volunteer. Substantial variation was observed in the breast when the temperature variation was measured with the water peak alone in the breast but not in the phantom. This variation was considerably reduced when temperature variation was measured with the water-methylene frequency difference.

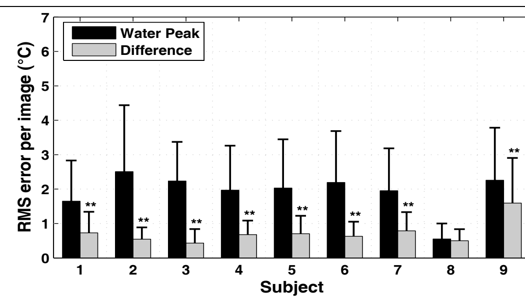

Figure 2: Root mean square (RMS) (mean ± S.D.) of the apparent temperature variations for the nine volunteers as found from using the water peak alone and with the water-methylene frequency difference. In eight of nine volunteers, the RMS was significantly less ($P<0.01$) when measured with the water-methylene frequency difference than with the water peak alone.

References:

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