Respiration Artifact Correction in PRF MR Thermometry using Phase Navigators

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Purpose

Temperature measurements using the PRF shift method are susceptible to errors introduced from motion-induced B0 variations. In temperature imaging in the breast, this artifact is not due to the motion of the breast itself, but is due to the B0 variations caused by susceptibility changes in the chest and abdomen[1]. Respiratory motion outside of the imaging region leads to B0 variations from excitation to excitation which produce frequency offsets. Each offset results in an added linear phase and apparent position shift that changes between excitations, causing ghosting artifacts. If not corrected, these variations cause artifacts in both the magnitude and phase images leading to errors in temperature measurements. For gradient recalled (GRE) images, the phase offset evolves linearly with echo time (TE). This artifact becomes more apparent when collecting more than one phase encode line per excitation, such as in a segmented echo-planar imaging (seg-EPI) sequence because of the longer TE, the phase change while reading multiple lines, and the low sampling bandwidth in the phase encode direction[2].

Methods

A 3D seg-EPI sequence was modified to include flyback readout and two FID (no gradient) within-sequence phase correction navigators, one before the EPI readout and one after (Figure 1). With no gradients, these navigators provide an estimate of the average phase over the sensitive volume of each channel in the receiver array. The phase difference between the two FID's consists of a constant phase difference due to the offset of the image and a variable phase due to the signal frequency variation due to respiration. After removing the average phase difference, the remaining phase variation is primarily due to B0 variation. Measurement error is reduced by taking the average phase difference of corresponding samples in each FID (Figures 2 & 3). The phase variation about the mean is then divided by the time difference between the navigators to give a slope of the phase offset (in radians/ms) due to respiration for each excitation. The phase of the lines acquired each excitation is adjusted by the slope during that excitation multiplied by the individual TE, incorporating echo-shifting. The slope of the phase change is calculated and used for correction for each coil separately. Experiments were performed both in *in vivo* human breast and gelatin phantom. 3D *in vivo* human breast images were collected on a Siemens Trio 3T scanner to assess the effectiveness of the correction method (2x2x3 mm, Coronal, Flip Angle = 20, TR/TE = 47/15 ms, EPI Factor = 7, 8 slices with 25% oversampling, BW = 751 Hz/Px, 10 acquisitions). A focused ultrasound heating experiment was performed using a gelatin phantom with a male volunteer above to create the respiration while imaging and heating with focused ultrasound (1x1x3 mm, Coronal, Flip Angle = 20, TR/TE = 32/15 ms, EPI Factor = 7, 8 slices with 25% oversampling, Bandwidth = 744 Hz/Px, 20 acquisitions, ultrasound: 25W, 60 second).

Results, Discussion, and Conclusions

Figure 3 shows the phase difference between the two navigators for the first acquisition in the breast. The dashed black line shows the mean phase variation after removing the average phase difference. Figure 4 shows the slope of the phase change induced by respiration for 10 acquired data sets in the breast. Figure 5 shows the PRF temperature change of an aqueous tissue voxel near the center of the breast for both corrected and uncorrected using the first acquisition as the reference phase. The standard deviation of the uncorrected and corrected are 2.57 °C and 1.12 °C, respectively. Figure 6 shows the PRF temperature map for the peak temperature measurement for uncorrected (top) and corrected (bottom). The phase change due to respiration causes measured temperature change artifacts where no heating has occurred. The method presented here provides promising results for respiration correction in breast imaging and its use in interventional methods.

References 1. Nicky *et al* JMRI 2009;29:731-5. 2. Moortele *et al* MRM 2002;47:888-95.

Funding Sources: NIH R01 EB013433, CA 172787

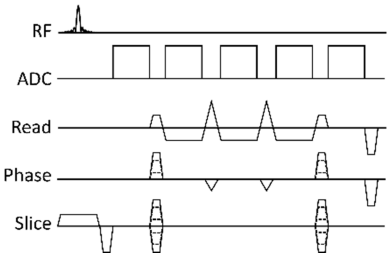

Figure 1. Sequence Design

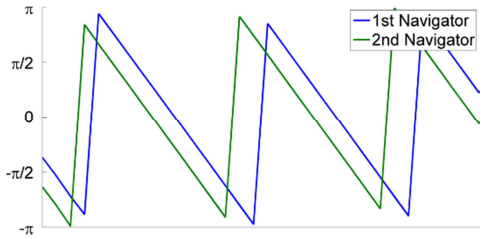

Figure 2. Example of phase during navigator readout

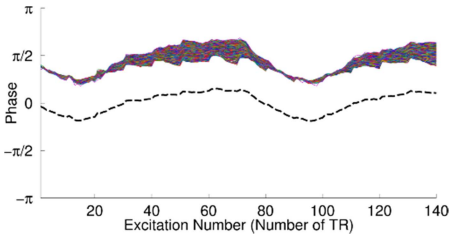

Figure 3. Phase Difference between first and second navigator for the first image acquisition of *in vivo* breast. The dashed black line is the mean phase variation after removing the average phase difference.

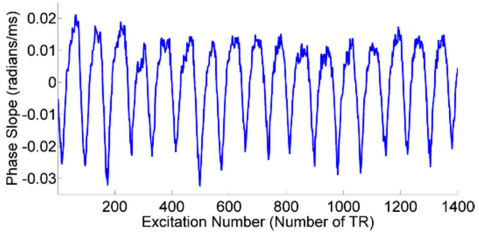

Figure 4. Slope of phase change due to respiration over 10 image acquisitions of *in vivo* breast.

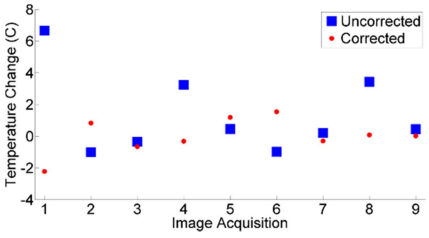

Figure 5. PRF Temperature change of single voxel of aqueous tissue near the center of the breast.

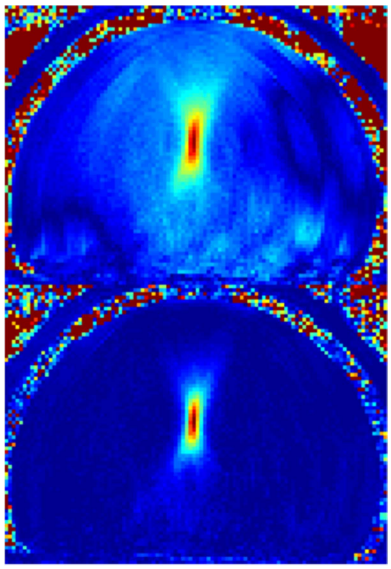

Figure 6. Gelatin PRF temperature for uncorrected (top) and corrected (bottom)