MR Phase Shift Behavior in Frozen ex vivo Tissue

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Introduction MR-guided cryoablation is a promising method for the minimally invasive therapy of prostate, liver, and kidney tumors. It is also being developed for eliminating the most common cardiac arrythmias in both children and adults. Most often, ultrasound is used to guide cryoablation, but this approach suffers from poor visualization of the frozen tissue. MRI, on the other hand, provides good visualization of iceball formation and growth as tissue freezes and signal intensity of the frozen region decreases. The purpose of this work was to study the phase behavior of the MR signal of *ex vivo* frozen tissue of three different types: heart muscle, liver and prostate.

Methods Freshly excised *ex vivo* tissue samples were used. Three porcine cardiac muscle, two porcine liver and one canine prostate tissue samples were imaged in an interventional MRI scanner (0.5T GE Signa SP). A receive only endorectal coil was placed adjacent to the tissue samples of dimensions 10x10x25mm which were placed on a plexi-glass plate between two 12x12x65mm copper blocks 25mm apart. A cryo probe (Oncura Medical Ltd.) was inserted into each copper block. Four fiber-optic temperature sensors (Luxtron, Santa Clara, CA) were placed into the tissue sample 5mm apart.

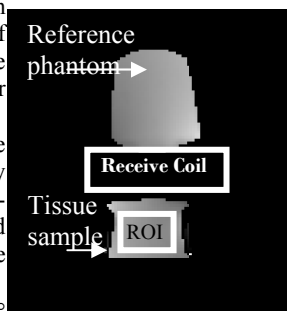

Figure 1. Phase Image for heart 1 experiment.

A non slice-selective pulse sequence was used for imaging (TR = 200ms, FOV = 200mm, flip angle = 60° and BW of 31.25 kHz). Images were acquired at echo times of 250us, 310us, and 610us. Imaging was repeated as the tissue was cooled from room temperature to -40°C in 5°C increments. No images were acquired for temperature between room temperature and near zero temperature. A reference phantom was placed on the other side from the receive coil as shown in Figure 1.

For each temperature the phase difference images were found by subtracting a room temperature phase image from the phase images at other temperatures. The phase drift was measured with the reference phantom (plastic surgical tape) that was assumed to stay at a constant temperature. Mean phase drift of the reference phantom was subtracted from the phase difference images. The data for each experiment was fit to an exponential curve.

Results The results of our experiments showed that there is a consistent phase shift in frozen *ex vivo* tissue of three different types as shown in Figure 2. Below –10 °C, the exponential function describes the phase shift behavior with temperature quite accurately. Between -10 °C and zero, the phase shift has a minimum.

Using the phase shift at different echo times, frequency shift was calculated as a function of temperature. At -30°C the frequency shift was on average 150 Hz. The offset frequency was then used to find the phase shift values for different echo times. The predicted values of the phase shift due to PRF effect appeared to be a small portion of the overall observed phase shift in tissue with temperature. Both observed and predicted phase shifts for TE=150μs and TE = 210μs are shown in Figure 3.

Discussion This study has shown that there is a measurable phase shift in the frozen tissue. As expected at ultra short echo times imaging only a small fraction of the phase shift is due to PRF effect. The phase shift due to non-PRF effect is consistent in all the studied tissue types, it changes exponentially with decreasing temperature. For several data sets near zero region exhibited deviation from exponential behavior. This phase behavior in this region will be studied in the future experiments.

The results of this study indicate a consistent change of phase in all three types of frozen tissue. The magnitude of the phase shift in one liver experiment was much less than the other data. It is possible that inadequate temperature isolation of the phase drift correction phantom may have resulted in a small unknown underestimation of the phase shift. Future work will include an investigation of the temperature response of the phase drift correction phantom itself.

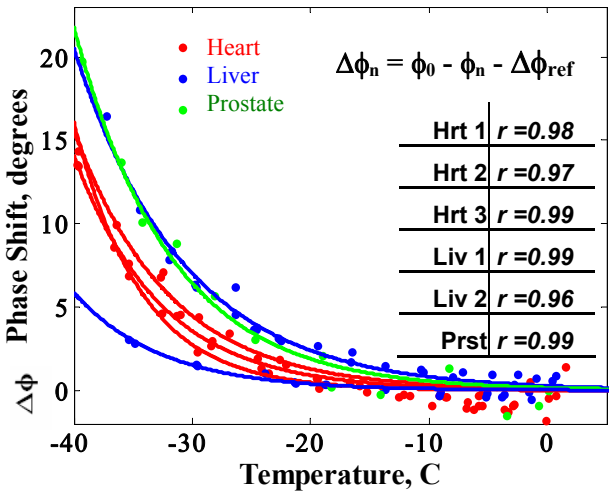

Figure 2. Phase shift data and data fits for heart muscle, liver and prostate tissue. TE = 250 μs.

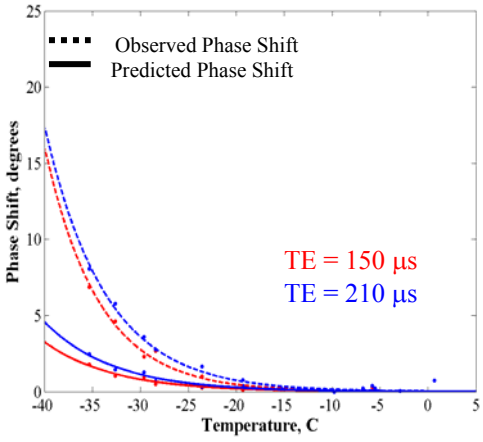

Figure 3. Phase shift data for heart 2 experiment.

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[2] Butts K, Sinclair J, Daniel BL, Wasanpura J, and Pauly JM, Temperature Quantitation and Mapping of Frozen Tissue. J Magn Reson Imaging 2001;13(1):99-104

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