PRF Shift in Frozen Tissue at 3T.

E. Kaye[1,2], A. Lu[3], M. Alley[2], and K. Butts Pauly[2]

[1]Electrical Engineering, Stanford University, Palo Alto, California, United States, [2]Radiology, Stanford University, Palo Alto, California, United States, [3]University of Chicago

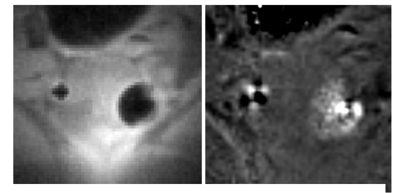
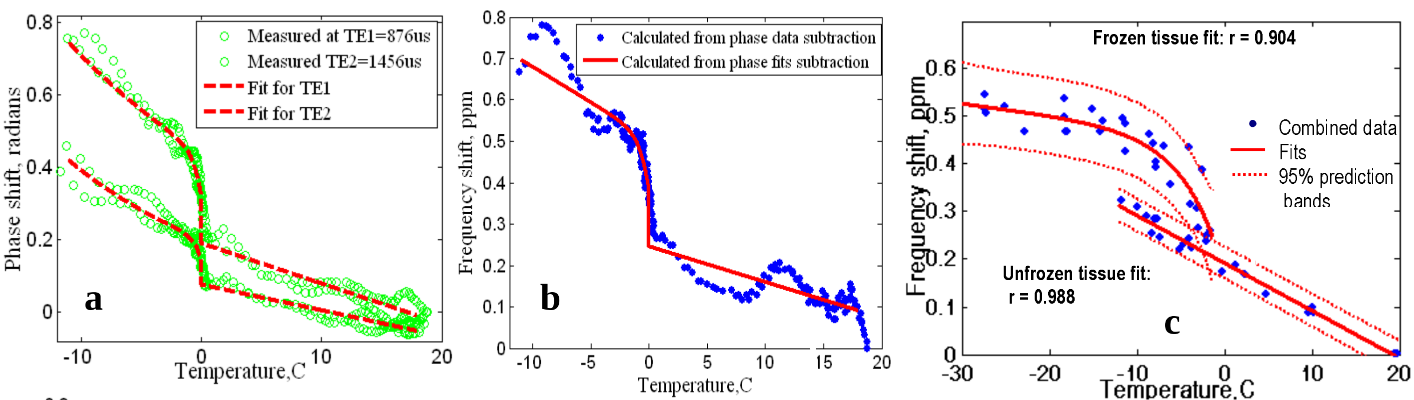


Figure 1. Cryoablation of canine prostate. Left: magnitude, right: phase shift. [3]

Introduction Conventional therapies for prostate cancer have significant morbidity and risks. In a substantial fraction of cases, only a portion of the gland is affected. In these cases, MR-guided cryoablation presents a minimally invasive treatment option. In clinical cryoablation temperature monitoring is typically done with temperature sensors built into cryoprobes or inserted in addition to cryoprobes. Placement of temperature sensors is invasive, time consuming, and doesn't provide continuous temperature feedback throughout the region of treatment. The following MRI parameters have been shown to be sensitive to temperature: signal intensity, R2*, and phase shift [1,2,3]. The phase shift is a parameter that is usually used for MRI-based thermometry in tissue at T>0°C. In frozen tissue, there is still little known about the phase and proton resonance frequency (PRF) shift dependence on temperature. In [3] measurable phase shift was reported during 0.5T prostate cryoablation in canine model in vivo (Fig.1). In a previous 7T spectroscopy study [4], PRF shift as a function of temperature was found to go from a linear temperature dependence at T>0°C to an exponential dependence at T<0°C, as shown in Fig.1c. In this work, for the first time, we measure frequency shift in frozen tissue on a clinical 3T MRI scanner.

Methods Porcine muscle (n=2), sliced to 4x1x1 cm^3 slabs, were frozen to -15°C and passively thawed inside an 8-channel RF head coil. Fiber optic temperature sensors (Luxtron, Santa Clara, CA) were placed in the center of each sample. As a reference, another slab of room temperature tissue was imaged in the same FOV. Imaging was performed on a 3T GE Signa MRI scanner, using a Cartesian 3D SPGR sequence, with the following parameters: BW=125Hz,



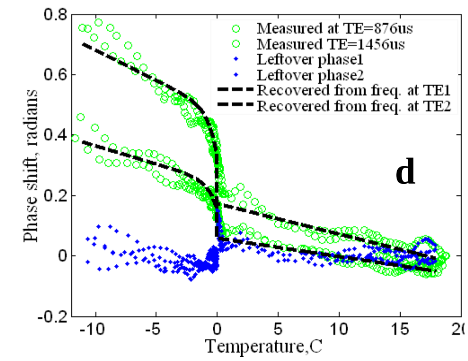


***Figure 2. a.** Phase Shifts (o) and fits (-- -) at two TEs. **b.** PRF shift calculated from phase shift data point by point (dots) and from the fits (line). **c.** PRF shift in frozen tissue at 7T spectrometer [4]. **d.** Comparison between measured phase shifts at the two TEs (circles), the phase shifts calculated from estimated PRF shift of Figure 1b (dashed lines), and the leftover phase. There is little non-echo time dependent phase.*

flip angle = 30°, TE1/TE2 = 0.8ms/1.4ms, TR=20ms, slice thickness = 5mm, FOV = 26x7cm, matrix size 256x64. One image was acquired for each TE, and the imaging was performed continuously as the temperature increased in the frozen tissue.

The phase shift due to the temperature was calculated by subtracting from every phase image the phase at room temperature, similarly to that done in PRF thermometry. Mean phase shift of the room temperature sample was subtracted to account for phase drift. The phase shift was then calculated in an ROI surrounding the temperature sensor. For each TE, phase shift data was fit to a line for T>0°C and to an exponential for T<0°C. Then the frequency shift was found as a difference in phase shifts between TE1 and TE2, divided by the difference in echo times.

Results The phase shifts are shown in Figure 1a, indicating a significant echo time dependent component. The calculated frequency shift is shown in Figure 1b. Between room temperature and T=0°C, PRF and temperature are linearly related. The slope of the frequency shift was estimated as –0.09ppm/°C. At T=0°C, the proton frequency shift starts to grow exponentially rather than linearly, with the greatest gain occurring in [-2°C; 0°C] interval. Figure 1c. shows the PRF temperature dependence measured in frozen kidney tissue at 7T spectrometer [3]. It can be seen that the PRF shift measured at 3T scanner are comparable with previously reported results. In addition, from the estimated PRF shift values, phase shift values were calculated for the corresponding TE1 and TE2. The measured phase shift at TE1 and TE2, and the phase shift recovered from measured frequency shift are shown in Figure 1d. From the plot, it is apparent that all the measured phase shift in frozen tissue can be attributed a frequency shift, and the non echo time dependent phase shift is near zero.

Discussion The results of this study supported previously obtained measurements of proton resonant frequency shift in frozen tissue on a 7T NMR spectrometer. Today PRF shift based temperature mapping techniques are successfully being used to monitor thermal therapies, however, so far it has been always limited to the temperatures greater than 0°C. In this study we demonstrated that phase shifts can be measured in frozen tissue on a 3T clinical scanner using a short echo time pulse sequence. The temperature dependence of the PRF shift in frozen tissue is not the same as in unfrozen tissue, but it appears to be quite similar between different tissue types and magnetic field strength types (kidney tissue at 7T and muscle at 3T). In order to study PRF shift in frozen tissue as a potential temperature mapping technique, further experiments will be performed. It will be necessary to quantify accurately the PRF shift at different temperatures and in different types of tissue.

References: [1] Wansapura JP, Acad Radiol, 2005, [2] Kaye E, IMSRM 06,07, [3] Lu A. ISMRM07, [4] Kaye E, ISMRM 08. Acknowledgements:, NIH RR009784, NIH CA092061