# Fat-Referenced MR Thermometry during Canine Prostate Ablation

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**Introduction:** MR thermometry is increasingly required to monitor and guide focused ultrasound (FUS) ablation procedures, such as in the prostate [1,2]. During the FUS ablation, temperature mapping is used to ensure adequate thermal dose delivery to the treatment region and to avoid unnecessary heating of the rectum and neurovascular bundles [2]. However, the conventional proton resonance frequency shift (PRFS) thermometry technique [3] is sensitive to time-varying $B_0$ field disturbances. It has been shown that fat signal can be used to measure and correct for these field disturbances [4-6]. In this work we test a 3-echo fat-referenced thermometry technique [7,8] during a canine prostate ablation procedure. For comparison purposes, conventional and corrected PRFS measurements are also computed.

**Methods:** This study was done in compliance with Animal Studies Ethical Committee approved protocols. Canine prostate ablation was performed using a 1000-element transrectal FUS transducer (InSightec, Tirat Carmel, Israel). MR imaging was performed on a 1.5T GE scanner (GEHC, Waukesha, WI) with an 8-channel torso array coil. A multi-echo multi-slice spoiled-gradient-recalled acquisition (SPGR) with flyback gradients was used for each thermometry measurement. Imaging over 3 axial slices was achieved in under 7 seconds using the following imaging parameters: TE {10.3ms, 12.7ms, 15.1ms}, TR = 52ms, flip = $20^0$, FOV = 36cm, matrix 128×128, 4mm slice, bandwidth 100 kHz. After initial positioning of the FUS transducer, the balloon surrounding the transducer was filled with cold ($14^0$C) de-gassed water to provide rectal wall cooling during the procedure. After anatomy temperature equilibrated, a baseline thermometry acquisition was acquired. Ablation of the left prostate lobe was achieved with six separate sonication sets. Following completion of the final set, (83 minutes after the baseline acquisition) a second fat-referenced thermometry acquisition was performed.

Fat phase ($\phi_f$) and water phase ($\phi_w$) images were computed for each 3-echo measurement using the phase-based separation method described in Ref. [8]. The difference between measurement and baseline fat phase images ($\Delta\phi_f$) was interpolated using a 2D second-order spatially-varying polynomial to generate a phase disturbance correction map ($\Delta\phi_b$). The fat referenced temperature change ($\Delta T$) is computed according to:

$$\Delta T = \frac{\Delta\emptyset_w - \Delta\emptyset_b}{\gamma\alpha B_0 TE} \qquad (1)$$

where TE = 12.7ms was used in the equation denominator. The conventional PRFS thermometry measurement was computed using a subset of the multi-echo SPGR dataset (images acquired with TE = 12.7ms). A drift-corrected PRFS measurement was also computed by measuring the DC component of the $B_0$ field drift in an unheated region of muscle tissue (green ROI in Fig. 1b) and subtracting this measured value from the conventional PRFS temperature map.

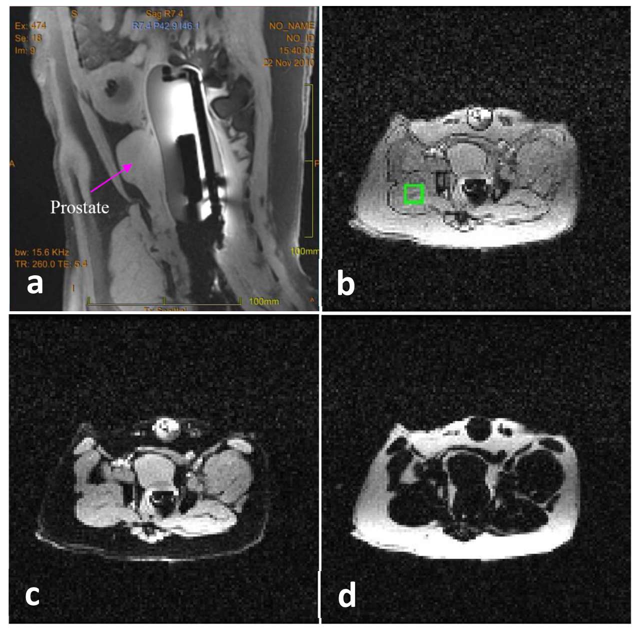


**Fig 1.** FUS experiment with (a) experimental setup (b) axial SPGR image, (c) reconstructed water, (d) and reconstructed fat image. Green ROI in (b) denotes region used to measure field drift for the corrected PRFS measurement.

**Results:** The experiment setup and transducer positioning are shown in Fig. 1a. Reconstructed water and fat magnitude images are shown in Fig. 1c and Fig. 1d, respectively. The conventional, drift-corrected, and fat-referenced temperature maps are depicted in Fig. 2. Phase drift is readily apparent in the conventional PRFS measurement as denoted by the large (~$20^0$C) negative temperature change values in the unheated muscle regions. A thermocouple in the mouth confirmed that a core body temperature of 35°C was maintained for the experiment duration. The negative temperature values encountered in the conventional PRFS were not seen in the fat-referenced approach. The fat-referenced and drift-corrected PRFS techniques corrected for this time-varying $B_0$ field disturbance.

**Conclusion:** We have demonstrated using a 3-echo fat-referenced thermometry technique during a canine prostate ablation procedure to correct for measurement errors caused by time-varying $B_0$ field perturbations. Although these perturbations were also corrected in the drift-corrected PRFS measurement, this method required that the reference region temperature was constant for the experiment duration. To ensure this, a region far from the treatment zone was selected. The fat-referenced technique is not limited by this constraint, and all regions of fat (even in the heated area) were used to provide a more complete spatial sampling of the time-varying $B_0$ field perturbations.

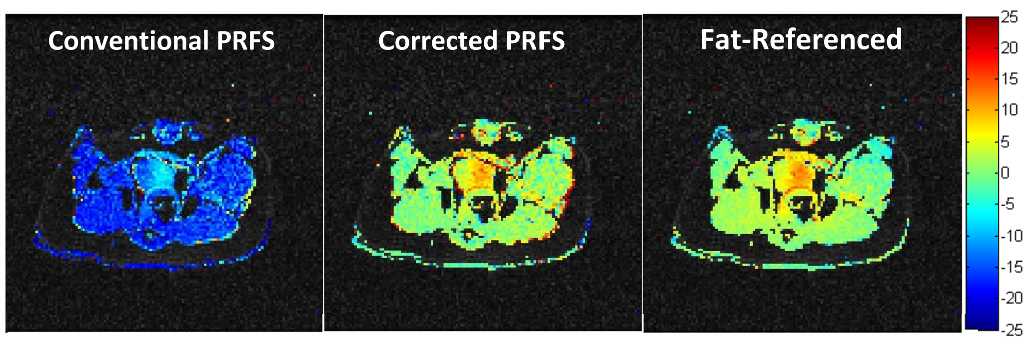


**Fig 2.** Temperature change maps (°C) for three methods measured 83 minutes after baseline acquisition. Temperature map was displayed in pixels where the SNR of the reconstructed water image is greater than 3. Residual heat from the sonication of the left prostate lobe is apparent in the temperature maps.

**References:** [1] R Chopra et al. Phys Med Biol 54:2615-2633 2009. [2] A Ross et al. Phys Med Biol 49:189-204, 2004. [3] Y Ishihara et al. MRM 34:814-823 1995. [4] K Kuroda et al. MRM 38:845-851, 1997. [5] A Shmatukha et al. JMRI 25:579-587, 2007. [6] B Soher et al. MRM 63:1238-1246, 2010. [7] L Hofstetter et al. Proc. ISMRM, p245, 2010. [8] L Hofstetter et al. Proc. ISMRM, p1770, 2011.