Real-Time Interleaved Temperature and ADC Measurements For Early Assessment of Tissue Viability during Prostate Thermal Therapies
Juan Camilo Plata1, Andrew Holbrook1, Punit Prakash2, Vasant Salgaonkar2, Peter Jones2, Chris Diedrich2, Graham Sommer1, and Kim Butts Pauly1
1Stanford University, Stanford, CA, United States, 2University of California, San Francisco, San Francisco, CA, United States

Introduction: The safety and efficacy of MR-guided thermal therapies is greatly dependent on the ability to predict tissue’s response to treatment. Most prediction strategies rely on indirect measures such as temperature and estimated thermal dose to infer expected tissue viability [1]. Using more physiologically relevant metrics would provide a direct measure of tissue response to treatment. Diffusion weighted MRI (DWI) has demonstrated a 36% reduction in apparent diffusion coefficient (ADC) following HIU induced tissue damage of the prostate [2]. However, using the temperature sensitivity of ADC as either a thermometry tool or to obtain an immediate map of tissue damage has been more complicated. Increasing temperature leads to an increment in ADC, but physiological effects simultaneously cause ADC to decrease. We obtained interleaved temperature and ADC measurements in order to explore the origins of the 36% reduction in ADC and whether its onset can be used for an early detection of tissue necrosis.

Methods: Interleaved ADC and temperature measurements were obtained during heating of ex vivo bovine muscle tissue initially at room temperature (Fig. 1). Heating was performed on a 3T GE MRI scanner equipped with an InSightec ExAblate 2000 HIFU system (1MHz). Temperature images were obtained using proton resonant frequency (PRF) shift measurements from a GRE sequence (TR=70ms, TE=8ms, FOV=15cm, resolution=1.17mm). ADC measurements were computed using diffusion images from three orthogonal directions using a diffusion weighted spin echo sequence (b=1000 s/mm²) with a non-flyback ssEPI readout sequence (TR=1250ms, effective TE=80ms). These measurements were also obtained in vivo during a high intensity ultrasound treatment of the canine prostate (baseline temperature 34°C) using a customized transurethral transducer (8.73 acoustic Watts/cm², 6.8MHz (Fig. 2). Hot spot tracking was implemented to compensate for temperature dependent translations in our EPI images. Tracking was achieved by selecting the maximum value within the ROI following convolution with a Gaussian kernel. Temperature measurements were obtained by computing the mean from an ROI centered on the temperature hot spot.

Results: During the ex vivo experiment ADC values varied directly with temperature (2.1%/°C) regardless of thermal dose delivered to the tissue (Fig. 3a). During the in vivo experiment however, ADC initially increases with temperature (2.7%/°C) but stalls once the thermal dose delivered to the tissue was greater than t10=240 min, even though the temperature was still increasing (Fig 3b). ADC temperature sensitivity for both in vivo and ex vivo experiments generally agree with previously reported values of 2.4%/°C [3].

Discussion: Variations in ADC temperature sensitivity from expected values can be attributed to differences in baseline temperatures as well as relatively large changes in temperature during the heating procedure leading to differences in the activation energy for translational molecular diffusion [3]. Future studies will terminate treatment once ADC values stop increasing with temperature to assess whether this trend can be used as an early marker for tissue viability.


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