

## MR-Guided Prostate Hyperthermia with a Commercial Endorectal HIFU Ablation Array

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**Target Audience:** Researchers and clinicians, interested in thermal therapy.

**Purpose:** Hyperthermia (40-45°C, 15-60 min) has been combined successfully with several cancer treatment modalities, such as radiation and chemotherapy [1]. Clinical studies have demonstrated feasibility of safe application of prostate hyperthermia with endorectal ultrasound applicators [2]. ExAblate 2100 (InSightec, Haifa, Israel) with the endorectal array is a commercially available MR-guided High-Intensity Focused Ultrasound (HIFU) system for prostate ablation. In contrast to HIFU, hyperthermia requires a more diffused energy deposition sustained over longer durations to establish uniform temperature distribution and sufficient thermal dose within the entire targeted volume. The goal of this project was to identify operational modifications, and assess the feasibility of delivering protracted MR-guided prostate hyperthermia with the ExAblate 2100 prostate applicator.

**Methods:** Hyperthermia-specific sonications, such as planar and diverging beam patterns, curvilinear and multi-point focusing were implemented on the ExAblate 2100 prostate phased array ablation system with calculated phase delay tables, input power and exposure times as determined from simulations (fig.1). These sonications were performed on a tissue-mimicking phantom, with applied power set at surface acoustic intensity  $\sim 0.86 \text{ W/cm}^2$ , total heating time at 15 min, and cooling water flow at 22°C. The sonication parameters were within the limits of the device, designed for ablation delivery. PRF thermometry was performed on a 3T MRI scanner (General Electric, Waukesha, WI) using a spoiled gradient echo sequence: TE = 16 ms, TR = 29 ms, BW =  $\pm 31.2 \text{ kHz}$ , FOV = 14 cm, slice thickness = 5 mm, flip angle = 30, and 256x128 matrix. The complex images were transferred to a workstation in real-time and temperature images were reconstructed with custom software.

**Results:** Continuous wave sonications generated therapeutic temperature rises during phantom experiments over large contiguous regions. Temperature profiles showed diffuse therapeutic hyperthermia temperature elevations after 5 min, and up to 12°C temperature rises after 15 min heating with a power setting of  $0.86 \text{ W/cm}^2$  (well below system maximum). Planar sonication using iso-phase excitation of the transducer array elements resulted in heating volumes determined by the width of the array. Sonication with a diverging pattern caused heating in a cylindrically defused volume with its extent greater than the array width (fig. 2a). Sonication with curvilinear pattern resulted in wedge shaped heating volumes caused by cylindrical focusing (fig 2b). Simultaneous multipoint focusing using 6-point focusing created an irregular heating pattern.

**Discussion:** This initial study demonstrates the feasibility of delivering protracted mild hyperthermia 40-45°C for >15 min to target regions of the prostate with the ExAblate 2100 prostate ablation system. Array beamforming can be utilized effectively to tailor energy deposition based upon the size and location of target volumes such as small targets for focal therapy or larger hemi-gland targets. These experiments illustrate the ability to successfully employ hyperthermia specific beamforming to control the shape of energy deposition, to deliver long duration power output with the ExAblate 2100 prostate system, and to monitor the resulting heat generation with MR thermometry.

**References and Acknowledgements:** [1] Wust et al. The lancet oncology 2002;3(8):487-497 [2] Hutchinson et al. Int. J. of Hyperthermia 1998;14(1):39-56. This study was supported by grants from Focused Ultrasound (FUS) foundation and National Institutes of Health (NIH) (R01CA122276, R01CA111981, R00HL097030).

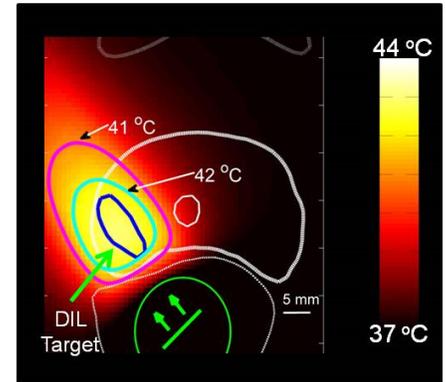


Fig.1. Simulation of hyperthermia with an iso-phase "planar" beam pattern to a dominant intraprostatic lesion (DIL) or small focal tumor in right quadrant of the prostate ( $I = 0.88 \text{ W/cm}^2$ ,  $T_{\text{max}} = 44.7^\circ\text{C}$ , perfusion =  $2.5 \text{ kg/m}^3/\text{s}$ )

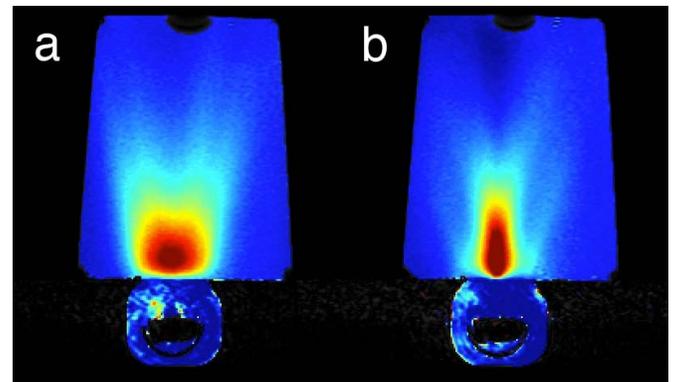


Fig. 2. MR temperature images captured during CW sonications in tissue mimicking phantoms with ExAblate 2100 prostate array are shown here ( $0.86 \text{ W/cm}^2$ , 15 min.) Heating from (a) diverging and (b) curvilinear in axial plane are shown.