Validation of percutaneous MRI-guided laser ablation with real-time MR temperature monitoring in a canine prostate model

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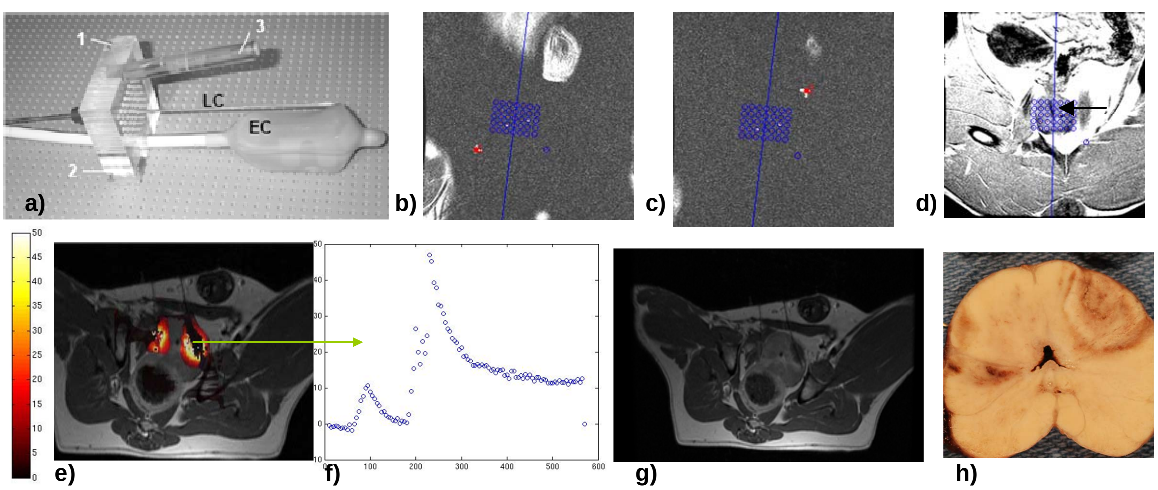
Introduction: Interstitial laser treatment for localized prostate cancer may overcome the morbidity associated with the current standard, radical prostatectomy [1]. The goal of our current study was to validate the efficacy of using a MR-registrable perineal template to percutaneously guide and execute multi-fiber laser treatment in a canine prostate model with real-time MR temperature monitoring.

Materials and Methods: Adult hound dogs (n=6) were used in this investigation with Institutional Animal Care and Use Committee approval. Each dog was sedated and placed in supine position; the template was then placed on the dog's perineum , and imaging was performed in a 1.5T MR scanner (Excite HD; General Electric Healthcare Technologies, Milwaukee, WI), using a 4-channel, receive-only phased-array body coil (MRI Devices Corp, Gainesville, FL). Coronal images (FOV, 20 cm, slice thickness, 1.5 mm) were acquired to cover the template and the prostate. These image sets were transferred to a workstation (Visualase; BioTex, Inc, Houston, TX) and input into the template planning program. The 3 fiducials on the template were identified and their trajectories projected through the prostate volume. A stainless steel stylet was used to insert the laser catheter (400-micron-core-diameter silica fiber in a water-cooled diffused-tip catheter) to reach the prostate (depth ~ 6 cm). The final catheter location was confirmed on another set of coronal images and verified by a low-power test pulse delivered under MRTI guidance. Real-time monitoring of the temperature changes was performed using a temperature-sensitive EPI sequence [2] (FOV, 24 cm; slice thickness, 4 mm) in conjunction with parallel imaging [3] to obtain 5 planes of temperature images every 6 seconds (laser power range was 4-10 W, and power-on times was 30-90 seconds). Temperature-sensitive images were processed and displayed on the workstation named above to provide real-time feedback during the procedure. Feedback included phase-difference images, an estimated region of coagulation based on an Arrhenius model of damage, and a magnitude image demonstrating anatomy. Control points specified by the user were used to monitor heating near the laser, the edges of the lesion, and critical structures, with an option for automated reduction of power if a specified threshold was reached. During treatment, applied power could be modulated manually (typically resulting in powers of 6-15 W) to obtain elliptical lesions with maximal dimensions of 2.0 cm along the fiber and 1.5 cm transverse to the fiber, using the Arrhenius damage estimate from the MRTI feedback as a guide. Damage was assessed with T1-weighted pre- and post-contrast imaging and T2-weighted imaging. Immediately after the procedure, the dog was euthanized by exsanguination and the prostate excised for pathologic analysis.

Results: The maximum discrepancy between the actual signal void from the laser catheter and the center of the predicted trajectory was less than 1 mm. Real-time monitoring detected a maximum temperature rise of ~ 50 ˚C. The necrotic lesion measured on gross pathology slices was 20 mm in length with minimal damage to the urethra and bladder. The damage measurements on the post-contrast T1 images was 159 mm^2, on pathology was 155 mm^2 and they matched well with Arrhenius damage estimation of 165 mm^2.

Conclusion: This minimally invasive approach to laser ablation of tissue in the prostate performed well, with a maximal positional error of less than 1 mm at an insertion depth of 6 cm. Large necrotic lesions (~ 2 cm) were created in the canine prostate, with minimal damage to important structures like urethra and bladder. The Arrhenius damage estimations, based on MR temperature history, compared well with pathology and post-treatment imaging. These results thus validate the potential efficacy of using a perineal implant as a tool to guide minimally invasive laser ablation of localized prostate cancer.



a) The perineal template with 3 fiducial markers (1,2,3); LC, laser catheter; EC, endorectal coil. b) & c) Markers 1 and 2 (red and blue dots) are evident on the coronal images. d) The signal void (black arrow) created by the catheter is within **1** mm from the center of the projected trajectory. e) Simultaneous laser ablation in both lobes of the prostate was monitored with the temperature-sensitive **EPI**. f) A temperature plot of one ablation is shown. Damage to the prostate tissue is evident on both g) the post-DCE T1-weighted images and h) the gross pathology section.

References : [1] Beerlage HP, Curr. Prostate Rep. (2003) [2] Stafford RJ, et al, JMRI **20**:706-14 (2004).; [3] Bankson JA, et al, ISMRM (2002).