Clinical Evaluation of Transurethral MR-HIFU for the Treatment of Localized Prostate Cancer

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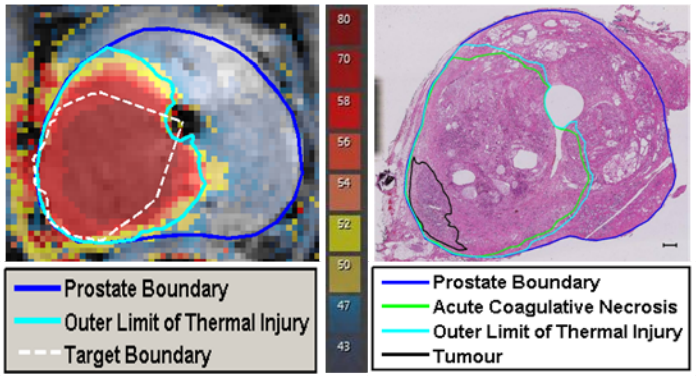
Introduction: Minimally invasive image guided treatment of localized prostate cancer using high intensity ultrasound (US) energy offers the potential for targeting tumours identified through MR imaging, while at the same time sparing surrounding sensitive structures[1,2]. Transurethral approaches have the advantage of delivering ultrasound (US) energy directly to the prostate gland without passing through intervening tissues[3]. We report initial results of transurethral US treatment of localized prostate cancer, using MR thermometry at 3T to monitor temperature and provide real-time temperature feedback in up to ten slices simultaneously.

Methods: Five men (ages 57-76, weights 64-95 kg, prostate volumes 31-71 cc) underwent transurethral ultrasound prostate therapy at Sunnybrook Health Sciences Centre between Nov 2012 and July 2013. All participants had biopsy-proven MRI-visible prostate cancer with Gleason scores of 7 or less. After transurethral US treatment, radical prostatectomy was performed and whole mount pathology on the excised gland was used to determine areas of thermal damage, with the ultimate goal of correlating this with both treatment planning and MR imaging.

The 8-element US applicator and associated hardware were built in-house. Treatment planning and temperature feedback control at the target boundary were implemented using Sonalleve software (Philips Healthcare, Helsinki, Finland), in combination with PRF thermal maps obtained using a Philips Achieva 3T MRI scanner. Initial MRI scans were performed to confirm the positioning of the applicator within the prostate and to obtain images needed for treatment planning and device alignment. A single tumour-containing treatment volume covering arcs of 62º-226º and 2-6 slices was then defined by a radiologist. During treatment, the applicator rotated through the treatment volume while feedback control kept the temperature at the outer (control) boundary constant by varying the rotation speed, power and frequency of the individual transducer elements. A segmented EPI thermometry sequence[4] provided thermal maps with a spatial resolution of 1.1 x 1.1 x 5.0 mm^3 and a temporal resolution of 6.3 s for 10 slices. Post-treatment 3D THRIVE images were obtained before and after injection of Gd contrast agent (Gadovist, 0.1mmol/kg).

Results: To the right are a thermal map and equivalent histology image for one slice of 71 cc prostate. The prostate boundary and outer limit of thermal injury are shown on both images. Thermal damage reaches to the prostate boundary within the treated segment in this case, and includes the entire tumour. The table below summarizes some experimental parameters and analysis results. The range of values for the target volume and treatment times are shown, while the accuracy values have been averaged over all patients. Two parameters are used to evaluate the accuracy of temperature control at the control boundary. The targeting accuracy is defined as the distance between the control boundary and the isotherm of the desired temperature, while the temperature accuracy is the difference between actual and desired temperatures at the control boundary. The treatment accuracy is defined as the distance between the planned treatment boundary and the outer boundary of thermal damage from histology.



Target Volume Range (cc)	US Treatment Times (min)	Total MRI Times (min)	Mean Targeting Accuracy (mm)	Mean Temperature Accuracy (ºC)	Mean Treatment Accuracy (mm)
4.0 - 19.5	9 - 35	88 - 157	-1.38 ± 2.20	-1.3 ± 3.8	-1.95 ± 2.14

Discussion: Planned treatment volumes ranged from 4.0 to 19.5 cc, while the US treatment times ranged from 9 to 35 minutes, scaling approximately with the treatment volumes. The total MRI time includes pre- and post-treatment scans as well as the treatment itself, and is the amount of magnet time that would need to be booked for the procedure. The mean targeting and treatment accuracy values are less than 2 mm; the targeting accuracy is only slightly larger than the thermometry spatial resolution (1.1 mm) All three mean accuracy values show a small degree of under-treatment, reflecting the conservative approach that was taken in the initial procedures. However the above images indicate that it is possible to treat consistently to the prostate boundary in a very large prostate using this transurethral method.

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3. Chopra R et al. Radiology 2012; 265(1): 303-313. 4: Ramsay et al, JMRI 2013 [Epub ahead of print].