Magnetic Resonance Imaging-guided Trans-urethral Ultrasound Therapy of the Prostate: A Preclinical Study with Radiologic and Histologic Correlation

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Introduction: Focal ablative therapy continues to be investigated as an alternative treatment option for organ-confined prostate cancer. Therapeutic ultrasound is an emerging treatment modality capable of achieving minimally invasive, precise, and conformal thermoablation in the prostate. Under magnetic resonance imaging (MRI) -guidance, a trans-urethral ultrasound applicator has the potential to accurately and reliably ablate cancer foci or cancerous regions, while minimizing the morbidities associated with conventional whole-gland resection or therapy. Herein we evaluate the feasibility and safety of a novel trans-urethral ultrasound therapy device combined with real-time multi-plane MRI-based temperature monitoring and temperature feedback control to enable spatiotemporally precise regional ablation of simulated prostate gland lesions in a preclinical canine model. Moreover, we report on ablation spatiotemporal accuracy and correlate ablation volumes measured with intra-procedural cumulative thermal damage estimates, post-procedural MRI, and histopathology.

Methods: Three canines were treated with three targeted ablations each, using a prototype MRI-guided trans-urethral ultrasound therapy system (Philips Healthcare, Vantaa, Finland). MRI provided images for treatment planning, guidance, real-time multi-planar thermometry, as well as post-treatment evaluation of efficacy. Post-treatment, specimens underwent histopathologic analysis to determine the extent of necrosis and cell viability. Statistical analyses (Pearson’s correlation, Student’s t-test) were performed to evaluate the correlation between ablation volumes measured with intra-procedural cumulative thermal damage estimates, post-procedural MRI, and histopathology.

Results: MRI combined with a trans-urethral ultrasound therapy device enabled multi-planar temperature monitoring at the target as well as in surrounding tissues, allowing for safe, targeted, and controlled ablations of prescribed lesions. Ablated volumes measured by cumulative thermal dose positively correlated with volumes determined by histopathologic analysis ($r^2=0.93$, p<0.001). Post-procedural contrast-enhanced and diffusion-weighted MRI demonstrated a positive correlation with non-viable areas on histopathologic analysis ($r^2=0.89$, p<0.001, and $r^2=0.91$, p=0.003, respectively). Additionally, a positive correlation was found between ablated volumes according to cumulative thermal dose and volumes identified on post-procedural contrast-enhanced MRI ($r^2=0.77$, p<0.01). No difference was found in mean ablation volumes assessed with the various analysis methods (p>0.05, Student’s t-test).

Conclusions: MRI-guided trans-urethral ultrasound therapy enabled safe and targeted ablations of prescribed lesions in a preclinical canine prostate animal model. Ablation volumes were reliably predicted by intra- and post-procedural imaging. Clinical studies are needed to confirm the feasibility, safety, oncologic control, and functional outcomes of this therapy in patients in whom focal therapy is indicated.