# Quantitative Evaluation of Treatment Related Changes on Multi-Parametric MRI after Laser Interstitial Thermal Therapy of Prostate Cancer

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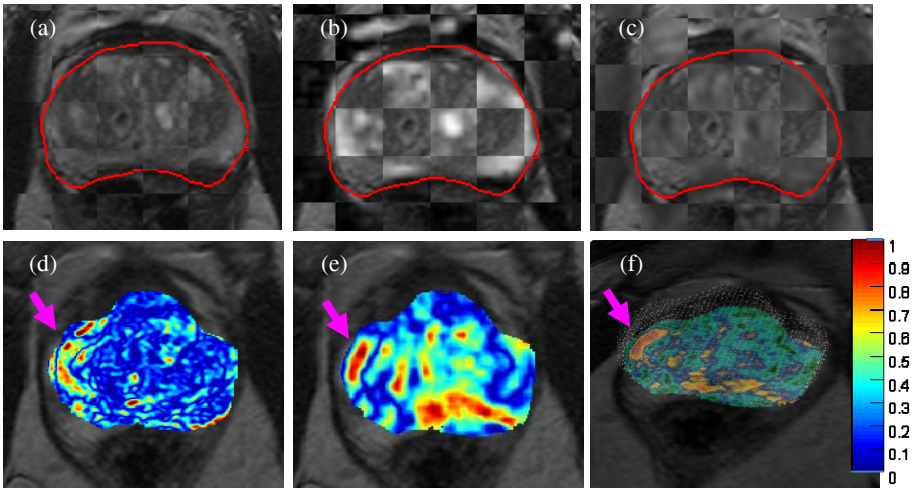
**PURPOSE:** We present a quantitative image analysis framework to enable evaluation of treatment-related changes *in vivo* at high-resolution for patients undergoing laser interstitial thermal therapy (LITT), where we bring multi-parametric (MP)-MRI protocols into alignment and then construct a weighted MP-MRI signature. LITT is a promising new treatment for low-grade, organ-confined prostate cancer (CaP) [1]. Studying *in vivo* imaging characteristics of LITT-induced changes in the prostate will enable (a) building of prognostic imaging indicators of focal treatment response, and (b) rigorous comparisons between radical and focal therapies for CaP.

**METHODS:** All patients in this study were confirmed to have organ localized CaP with Gleason scores between 6 and 7. Between 1 and 4 months after initial MP-MRI acquisition (see Table), each patient underwent MRI-guided LITT using the Visualase Thermal Therapy System (Visualase Inc, Houston, TX). During LITT, laser applicator placement was performed using the Invivo DynaTRIM transrectal biopsy guidance system (Invivo, Pewaukee, WI). Follow-up MP-MRI (see Table) was acquired between 3 and 4 months post-LITT. MP-MRI acquisitions comprised T2-weighted (T2w), Dynamic Contrast Enhanced (DCE), and Diffusion weighted (DWI) protocols, and were acquired using a Siemens Symphony 1.5 T MRI machine using a whole-body coil. ADC maps were calculated based on DWI MRI. The 4 steps within our framework were: (i) Volumetric affine registration of pre-, post-LITT MRI while optimizing spatially constrained normalized mutual information (NMI) between images. (ii) Volumetric affine registration to bring DCE and ADC into alignment with corresponding T2w MRI (pre-, post-LITT) using spatially constrained NMI. Note that all MRI data is transformed to the pre-LITT T2w MRI frame of reference by combining transformations as needed, which enables per-voxel comparisons between pre- and post-LITT MP-MRI imagery. (iii) After correcting intensity acquisition artifacts, automated prostate capsule segmentation was done on pre-LITT T2w MRI via a previously presented algorithm [2]. Quantitative MP-MRI features considered were T2w ($f_{T2}$) and ADC ($f_{ADC}$) intensity values, with Tofts' modeling of DCE-MRI to yield $f_{V_e}$ and $f_{K_{ep}}$. (iv) Per-voxel difference maps for each MP-MRI parameter were calculated as $\delta_\beta = |f_\beta^{pre} - f_\beta^{post}|, \beta \in \{T2, ADC, K_{ep}, V_e\}$ to yield a weighted difference map $\widetilde{\delta} = \sum \alpha_\beta \times \delta_\beta$. A grid search strategy was used to determine weights ($\alpha_\beta$) which optimized efficacy of each difference map ($\delta_\beta$) in quantifying treatment related change.

| Parameters | T2w | DCE | DWI |
|---|---|---|---|
| Matrix size | 256 x 192 | 128 x 96 | 128 x 128 |
| Slice thickness (mm) | 3 | 5 | 3 |
| Acquisition parameters | TR/TE = 5250/91 | TR/TE = 7.9/3.68 | b-values = 0,50,800 |

**RESULTS AND DISCUSSION:** Patient outcome was determined via repeat biopsy, post-LITT. Treatment change was evaluated within the ablation zone (location of Visualase applicator during treatment). 5 studies were not utilized due to lack of outcome. For the 2 successfully treated patients considered (see Figure): (1) Registered MP-MRI images (pre-/post-LITT T2w, T2/ADC) showed contiguous structures (zonal boundaries, nodules, prostate capsule), implying successful alignment (though DCE/T2 registrations were relatively poor), (2) T2w ($\delta_{T2}$) and ADC ($\delta_{ADC}$) were assigned the highest weights in $\widetilde{\delta}$ (ranging 0.39-0.5 each), while DCE was assigned a much lower weight (ranging 0.05-0.1), possibly because of poor Tofts' model convergence, (3) the weighted MP-MRI difference map was highly specific to the successfully treated CaP region (ablation zone) compared to the individual protocols.




**Top row (Patient 1)**: Checkerboard overlays showing registration results for (a) pre-LITT DCE/T2, (b) pre-LITT ADC/T2, (c) post/pre-LITT T2. Red outline on each image corresponds to the automated prostate capsule delineation. (note contiguous structures in checkerboards). **Bottom row (Patient 2)**: (d), (e) normalized T2w and ADC difference maps respectively (DCE was non-specific). (f) 3D integrated MP-MRI difference map showing significant change within the ablation zone. In (d), (e), (f) location of focal LITT ablation is denoted by purple arrow.

**CONCLUDING REMARKS**: We have presented a computerized decision support framework for quantitatively analyzing focal therapy changes within the prostate which brings different MP-MRI parameters into alignment and differentially weights their contributions for treatment evaluation. On a small preliminary cohort, our framework accurately quantified changes in MP-MRI imaging markers. The integrated MP-MRI difference map demonstrated excellent utility in quantifying the extent and types of focal treatment-related changes, *in vivo*.

**REFERENCES:** [1] P. Colin et al, *Adv Urol*, 2012, v 589160, [2] Anon.