MR-guided focal laser ablation for prostate cancer followed by radical prostatectomy: Validation of ablation volume

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Purpose: Focal therapy is an emerging targeted therapeutic approach, treating only the tumor fraction of the prostate, leaving the remainder of the prostate gland untreated. It is a promising treatment option for low- and intermediate grade prostate cancer (PCa). The aim is to achieve cancer control without the morbidity associated with radical treatment, preserving the quality of life. Laser-induced interstitial thermal therapy, also known as focal laser ablation (FLA) is a relatively new technique. During this therapy a laser fiber is positioned into the tumor under image guidance and the targeted tissue is irreversibly damaged and destroyed. The total ablation process takes only a few minutes. Magnetic resonance (MR) image guidance appears essential in FLA and might prove to be the only imaging modality for correct targeting of the index lesion, facilitating accurate fiber placement, real-time monitoring of the ablation process with the help of temperature mapping, and to verify complete tumor ablation (1). To date, only a few studies have been performed on MR guided FLA in prostate cancer patients (2-5).
The goal of our study was to validate MR-guided FLA: Before radical prostatectomy, patients with PCa were treated with transrectal MR-guided FLA. Hereafter, laser software, MR images and histopathologic specimens were used to assess the expected and actual size of a single ablated region.

Materials and Methods: The study was approved by the Institutional Review Board (IRB) and 3 patients with newly diagnosed and histopathologically proven low or intermediate grade prostate cancer, no previous treatment for PCa and a MRI visible lesion on the diagnostic multiparametric (mp) MR images were included. For all patients MR-guided FLA was intended as extra treatment and for this reason only one ablation per patient was performed. Their main treatment was radical prostatectomy. All MR-guided FLA procedures were performed on a 3 Tesla MR scanner (TrioTIM, Siemens, Erlangen, Germany) under local anaesthesia. A needle guide was inserted in the rectum, directed to the lesion and after correct alignment the laser fiber (Visualase Inc. Houston, Texas, USA) was inserted. The ablation procedure was continuously monitored with real-time MR temperature images (TMAP: TR 65 ms, TE 20 ms, flip angle 30°, resolution 2.0x1.0 mm, slice thickness 5 mm), acquired in a single plane through the laser fibre with a temporal resolution of 4.95s. Based on the temperature maps, a damage estimation map (figure 1A) of the final ablation zone was computed by the Visualase software using the Arrhenius model. Directly after the ablation T1-weighted fat-saturated contrast enhanced images (figure 1B) were acquired (T1 TSE axial: TR 700 ms, TE 11 ms, flip angle 150°, resolution 1.0x0.8 mm, slice thickness 3 mm). Three weeks after the MR guided FLA, patients underwent an open radical prostatectomy. The resected prostate specimens were fixed overnight in 10% neutral buffered formaldehyde. Transverse whole mount step sections were created at 4-mm intervals in a plane parallel to the axial plane used to perform the T1-weighted sequence and stained with hematoxylin-eosin (H&E). An experienced uropathologist contoured and measured the extent of necrotic tissue, transition zone and vital tumor on the histopathologic specimens (figure 1C). Two experienced radiologists contoured in consensus the ablation zone on the T1-weighted contrast enhanced images and volumes were calculated. The size of the ablation zones calculated by the Visualase software was measured and with the ellipsoid formula a ablation volume was calculated and compared with the ablation volumes on the histopathology and MR images.

Results: MR-guided FLA was feasible in all patients. All patients were dismissed 1 hour after treatment. An overview of the measured volumes is given in table 1. The transition zone between necrotic and viable tissue ranged from 0 – 5 mm, based on the histopathologic measurements. The damage estimation maps clearly overestimate the final necrotic volume. The ablation volumes seen in the T1-weighted images slightly underestimate the necrotic volume.

Table 1: Overview of the ablation volumes

Patient	Ablation volume on damage estimation map (cm^3)	Ablation volume on T1-weighted contrast-enhanced images (cm^3)	Necrotic volume on histopathology H&E (cm^3)
1	3.30	1.00	1.13
2	3.65	0.17	0.16
3	2.32	1.10	1.84

Discussion and Conclusions: In our study, a wider transition zone between necrotic and viable tissue was found than in a previous study by Stafford et al. (0.5 - 2.5 mm) in which the ablation effect of the same laser system was studied in canine prostates (6). In addition, they found a strong correlation (r^2=0.94) between damage estimation maps and post ablation T1-weighted MR images. Our results show that the damage estimation maps overestimated the final necrotic area. Although only 3 patients were treated in this study, the damage estimation maps appear not reliable to assess the ablation zone during MR-guided FLA therapy. The non enhancing area on the T1-weighted images gave a better indication of the final necrotic zone and should therefore be used in the assessment of MR-guided FLA therapy.

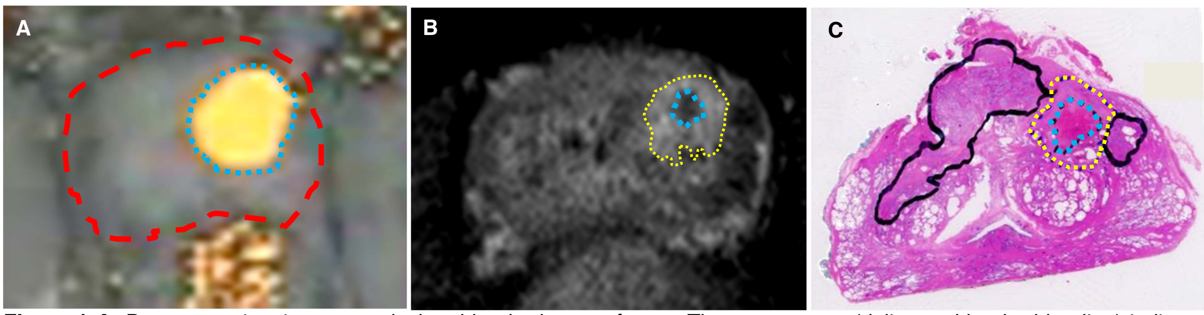

Figure 1 A: Damage estimation map calculated by the laser software. The orange spot (delineated by the blue line) indicates the ablation zone as calculated by the software. **B.** Axial T1-weighted contrast enhanced image of the prostate directly after MR-guided FLA. The blue line indicates the non enhancing ablation zone. The yellow represents the enhancing part, indicating tissue reaction **C.** H&E staining of the resected prostate. The blue line indicates the necrotic zone and the area between the blue and yellow line indicates the transition zone between necrotic and viable tissue.

References: [1] Lindner et al, EurUrol 2010;57(6):1111-1114. **[2]** Oto et al, Radiology 2013;268(2):451-460. **[3]** Raz et al, EurUrol 2010;58(1);173-177. **[4]** Woodrum et al, Urology 2010;75(6):1514-1516. **[5]** Woodrum et al,JVIR 2011;22(7):929-934. **[6]** Stafford et al, JUrol 2010;184(4)1514-1520