Carbon Ion Radiation Therapy for Patients with Localized Prostate Cancer:

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Purpose:

During and after radiotherapy the prostate undergoes morphological changes visible in terms of a T2 signal loss and an altered diffusion behavior. Recent studies described T2- and diffusion-weighted imaging (DWI) of the irradiated gland for purposes of treatment monitoring[1,2]. Thereby, changes associated with radiotherapy, disease progress, and failure to respond to treatment all can be identified on a timely basis[3]. An innovative technique in the field of radiation oncology is carbon ion therapy (CIT)[4], which can be used for treatment of prostate cancer. As a result, treatment monitoring using multi-parametric MRI imaging, alongside biochemical laboratory surveillance is highly desirable for this emerging technique. Thus, the purpose of this study was to evaluate feasibility of T2-weighted (T2w) and DWI for CIT treatment monitoring of prostate cancer. An additional goal was to investigate the relationship between DWI and prostate-specific antigen (PSA).

Methods:

This study included 8 male patients with an average age of 69 years (range, 56 to 81 years) with histologically confirmed prostate cancer. All received multiparametric MRI imaging at 3 Tesla (Magnetom Tim Trio, Siemens Erlangen, Germany) using combined body-phased coils. Each patient received several MRI examinations at different time intervals; the first was conducted prior to CIT. All other examinations were conducted 10 days, 3 months and 6 months after CIT. Patients underwent CIT within an average 13 days (range, 7 to 20 days) after the first MRI. Data analysis included T2w images in 3 orthogonal planes (TR 2000 ms, TE 90 ms, FOV 140 cm, matrix 256x179, slice thickness 3 mm), as well as, DWI. For acquisition of DWI, a 2-D epi-sequence with the following imaging parameters was obtained: TR 3100 ms, TE: 52 ms, FOV: 280 x 210 mm^2, matrix128 x 96, slice thickness: 3 mm, b-values: 0 and 800 s/mm^2. PSA values were determined prior and after CIT.

In T2w images regions of interest (ROI) were drawn encompassing a focal T2w hypointensity. Focal areas were defined in accordance with histopathological findings of prostate cancer. ROI were drawn around diffusion restricted focal areas on ADC maps generated from a monoexponential fit of all b values using scanner software. As a control, ROI were drawn on the contralateral "healthy" prostate on the same plane in T2w and ADC. Differences between regions were statistically evaluated using a t-test ($p<0.05$).

Results:

T2w signal loss was most pronounced at the 6 months interval (figure 3), whereas ADC showed immediate and continuous improvement. The ADC control group, in contrast, presented with values that were essentially constant over time. Before treatment, a significant difference of ADC values between tumor and benign tissues was found ($p < 0.01$), whereas there was no significant difference of ADC values between them after treatment. PSA was measured at different time intervals: prior to CIT average PSA values were 8.26 ng/dl (range, 4.91 to 11.50), 3 months: 2.95 (range, 6.12 to 0.32) and 6 months: 1.48 ng/dl (range, 0.15 to 3.64).

Discussion:

Radiotherapy causes morphological changes in the prostate, which are visible in T2w and DWI MRI imaging. Besides PSA levels the desire to monitor treatment via MRI to spot a possible failed response or progress under treatment was the motivation for this study. Our results show that T2w images exhibit a signal loss relatively late at the 6 months interval whereas changes in DWI can be seen early and continuously following treatment. Analysis with PSA results proves an inverse correlation with DWI. T2w and DWI seem amenable to treatment monitoring along with PSA. Future research using T2w and DWI could show the potential benefit of CIT over conventional proton therapy.

Conclusion:

The results suggest that ADC values could serve as an imaging biomarker for assessing therapeutic response of prostate cancer to CIT.

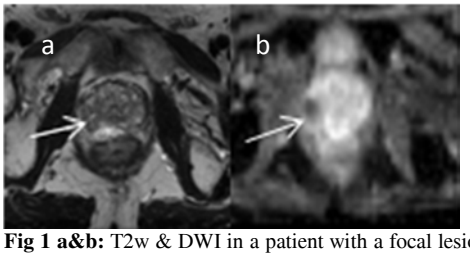

Fig 1 a&b: T2w & DWI in a patient with a focal lesion in the context of histologically confirmed prostate cancer **prior** to undergoing carbon ion therapy.

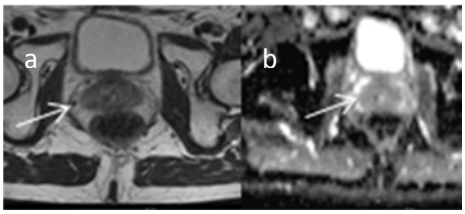

Fig. 2 a&b: same patient as Fig 1. Fig 2 shows T2w (a) & DWI (b) at the 6 months interval following CIT. The focal lesion is no longer delimitable.

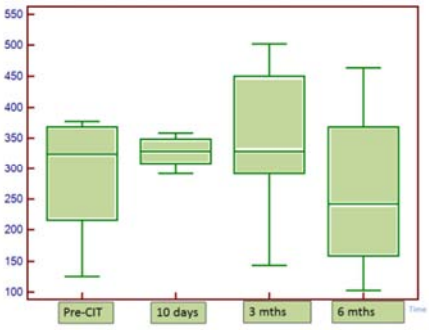

Fig3: T2w signal loss at different time intervals.

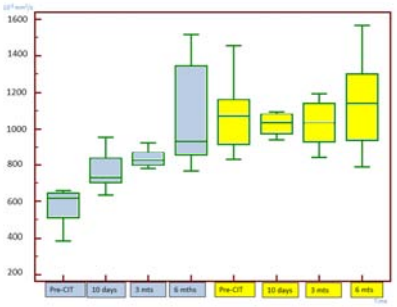

Fig 4: ROI data [10^{-3} mm^2/s]: derived from ADC of the focal (blue) and control areas (yellow) at different time intervals.

References:

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