Robustness of normalized ADC values of prostate cancer against different imaging conditions and calculation methods

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Introduction and Purpose

Diffusion-weighted MR imaging (DWI) has potential roles in the management of prostate cancer (PCa), for example, in active surveillance, evaluating treatment efficacy, and predicting disease recurrence [1]. The apparent diffusion coefficient (ADC), in particular, is currently emerging as parameter to distinguish aggressive from indolent PCa. Future success of such concepts will also rely on methods for reproducible ADC assessment and on work devoted to define reliable thresholds. Absolute ADC values, however, have been reported to strongly vary with imaging equipment or calculation method, for example, with magnetic field strength (1.5 vs 3.0 T) or with the choice of DWI data (b-values) used for ADC calculation [2]. The purpose of this work was to determine whether normalized ADC values, provide a robust quantitative MRI measure of molecular water diffusion under various conditions.

Materials and Methods

After obtaining IRB approval, 22 patients who were scheduled for radical prostatectomy underwent 3-T MRI (Magnetom Tim Trio, Siemens, Erlangen, Germany) with three different DWI protocols: *SC-3* involved imaging with surface coils (SC) only and ADC calculation with 3 b-values [50, 500, 800 s/mm^2], *ERC-3* applied an additional endorectal coil (ERC) for imaging and the same 3 b-values stated above, while *ERC-6* was also performed with an additional ERC but used a total of 6 b-values [0, 500, 1000, 1500, 2000, 2500 s/mm^2] for ADC calculation. DWI relied on a single-shot echo planar imaging sequence in (nearly) transverse planes perpendicular to the posterior prostate surface (in-plane resolution: 1.0 × 1.0 mm^2, TR/TE: 3000/85 ms, slice thickness: 3 mm, FOV: 250 × 250 mm^2). The surface coils consisted of a 6-channel body matrix coil (ventral) and selected channels of a 24-channel spine matrix coil integrated in the patient table. All ADC values were computed by nonlinear least-squares fitting of the signal intensity vs. b-value plots.

Whole-mount histopathological work-up was performed for all 22 patients. A senior histopathologist accurately marked all cancerous tissue regions and labelled them with the corresponding Gleason score (GS, Fig. 1a). Further analysis involved all prostate cancers of the peripheral zone with GS=6 (3+3) only. These regions of proven cancer were then matched to apparent image findings on the nearest MRI slice by inspecting the prostate morphology and landmarks on T2-weighted images (Fig. 1b) and DWI/ADC images (Fig. 1c). Mean ADC values were determined over corresponding tumor ROIs. Normalized ADC (nADC) values were computed as the simple ratio between mean ADC in the tumor ROI and that in a mirror ROI of healthy tissue (Fig. 1c). Differences between tissue regions and calculation methods were analyzed with paired t-tests. Statistical analyses were performed with SPSS 18 (IBM SPSS) using a significance level of 0.05.

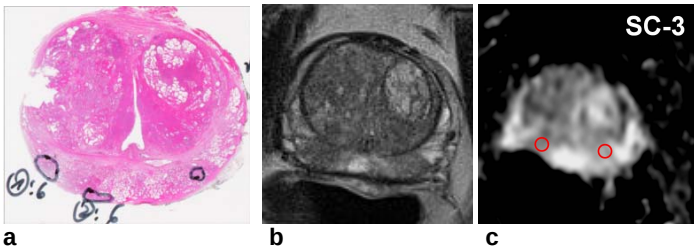

Figure 1: Example of a 67 y.o. patient with a preoperative PSA level of 12.2 ng/mL. **(a)** Tumor regions were marked and labelled with the Gleason score 6 (3+3) in the whole mount step section by a senior histopathologist and matched to the corresponding T2-weighted image finding **(b)**. Regions of interest of the tumor ADC (patient right) and of the mirror location (patient left) in the corresponding ADC map **(c)** were used to calculate the normalized ADC.

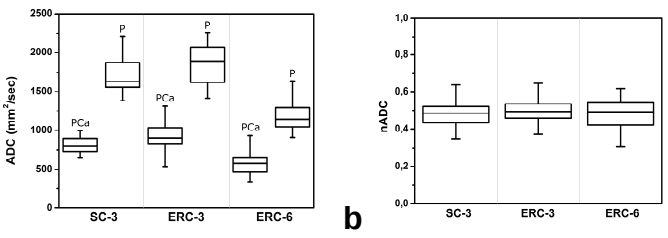

Figure 2: The box plots show absolute ADC values averaged over both PCa and healthy mirror ROIs (P) **(a)** as well the normalized ADC values **(b)** as a function of imaging and calculation methods (SC-3: imaging with surface coils only and ADC calculation with 3 b-values, ERC-3: with supplemental endorectal coil and 3 b-values, ERC-6: with ERC and 6 b-values).

Results

A total of 43 GS 6 (3+3) tumors in 20 patients were included. Absolute ADC values were significantly different ($p<0.001$) between tumor and healthy mirror regions for all protocols (SC-3, ERC-3, ERC-6). Significant differences ($p<0.001$) were observed in the absolute ADC values with just the use of an ERC (between SC-3 and ERC-3) or just a different choice of b-values (between ERC-3 and ERC-6). After normalization, the differences in nADC between these protocols were not significant ($p=0.117$ and $p=0.330$, respectively). Mean and standard deviations of the resulting nADC differences were -0.015 ± 0.062 (SC-3 vs. ERC-3) and 0.011 ± 0.077 (ERC-3 vs. ERC-6).

Discussion and Conclusion

Non-use and use of an additional endorectal coil under otherwise identical examination conditions and in the same patient generated highly significant differences in the calculated absolute ADC values for both tumor as well as healthy tissue ROIs. The same phenomenon was observed when different sets of b-values were applied for ADC calculation, which confirms the findings of other studies in the literature. Differences in the normalized ADC values, in contrast, were no longer significant with differences in imaging conditions (additional ERC) or calculation methods (b-value set). In conclusion, normalized ADC values appear to be a more robust parameter for the quantification of diffusion abnormalities in the prostate.

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References [1] Lawrence EM, et al., Nature Rev Urol 2012, [2] Thörmer G, et al., Eur Radiol 2012