Detection and Grading of Prostate Cancer using Diffusion Weighted Imaging: Kurtosis versus ADC

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Purpose

DWI is an essential functional modality in state-of-the-art multiparametric imaging of the prostate[1]. In clinical DWI, a low and a high b-value (e.g. 50; 800) are applied and the apparent diffusion coefficient (ADC) is obtained using a mono-exponential ADC fit[2]. Additional microstructural information may be derived from diffusion kurtosis imaging that describes the deviation of the diffusion propagator in tissue from a Gaussian function[3]. Kurtosis-based quantification may be depending on several pre-processing steps including noise correction and pixel- versus ROI-based fitting. Aim of the study was to comparatively investigate kurtosis-based quantification and standard DWI-derived ADC in the context of prostate cancer (PCa) and with respect to lesion detection and histological grading.

Methods

Fifty-five patients with biopsy proven peripheral PCa were included. All examinations were performed at 3.0 Tesla (Magnetom Tim Trio, Siemens Erlangen, Germany) with combined body-phased coils. Data was acquired using a 2-D EPI-sequence with a typical ADC- and a Kurtosis-optimized protocol. Parameters (Kurtosis): TE/TR 70/2700 ms, isotropic resolution 3.3 x 3.3 x 3.3 mm^3, 5 averages, three orthogonal diffusion gradient directions, b-values: 0, 50, 250,500, 750, 1000, 1250, 1500, and 2000 s/mm^2. Parameters (standard DWI): TE/TR 52/3100 ms, FOV: 280 x 210 mm^2, base resolution: 128 x 96, slice thickness: 3 mm, 5 averages, b-values: 0 and 800 s/mm^2.

D_{app} and K_{app} values were fitted with the following formula as proposed by Jensen et al. (with and without the background noise correction η): $S = \sqrt{\eta^2 + \left(S_0 \exp\left(-bD_{app} + \frac{1}{6}b^2 D_{app}^2 K_{app}\right)\right)^2}$.

Parametric maps of K_{app} and D_{app} were calculated for each patient using in house developed software. This fit was performed pixel-wise and region of interest (ROI)-wise and ROIs were placed on the diffusion weighted image according to the histologically reported area of PCa and into the corresponding area on the opposite site on the same plane (control). Differences between regions were statistically evaluated using a t-test ($p<0.05$). A receiver operating characteristics (ROC) analysis was performed for the calculated DWI parameters (K_{app}, D_{app} and ADC) to assess the ability for discrimination between tumor and benign tissue. Furthermore, using an ROC-analysis, we investigated these parameters considering the discrimination between low grade (Gleason ≤6, n=x) and high grade (Gleason ≥7, n=y) PCa.

Results

D_{app} was significantly lower and K_{app} was significantly higher in cancerous versus both benign areas (figure 2 and 3). For PCa a ROI-based D_{app} of 1.52 10^{-3} mm^2/s (±0.36) and ROI-based K_{app} of 0.87 (±0.22) and an ADC of 1.10 10^{-3} mm^2/s (±0.25) was determined. There were no statistically significant differences between ROI- and pixel-based fits nor between application of noise correction or not. The area-under-the-curve (AUC) considering tissue differentiation was best for ROI-based D_{app} with 0.86, followed by 0.87 for K_{app} and 0.83 for ADC. ROC-analysis yielded no statistically significant differences between K_{app}, D_{app} and ADC. In a subgroup analysis between low-grade (Gleason ≤6) and higher-grade PCa (Gleason ≥7) we found an AUC of 0.89, 0.88, and 0.85 for K_{app}, D_{app} and ADC, respectively. ROC-analysis showed no statistically significant difference in this sub-analysis.

Discussion and Conclusion

Our quantitative results are in good agreement with an initial study on kurtosis imaging of the prostate[4], which reported a D_{app} of 1.55 10^{-3} mm^2/s and a K_{app} of 0.96 for PCa tissue. However, unlike this previous study, we could not demonstrate a diagnostic benefit of kurtosis-derived D_{app}/K_{app} compared to standard ADC. This holds good for both lesion detection and lesion grading.

In conclusion, quantitative kurtosis derived parameters in our study did neither improve lesion detection nor grading compared to an ADC-based approach when the ADC is derived from an ADC-optimized protocol.

References

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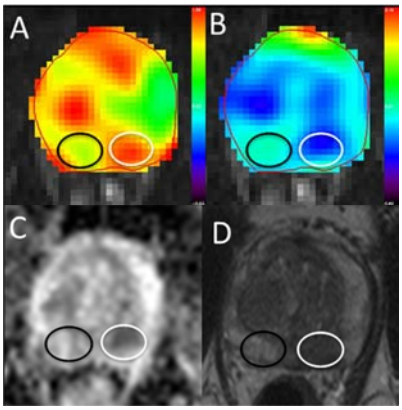

Fig. 1: K_{app} (A) and D_{app} (B) parametric maps of a 68-year-old patient with peripheral PCa (white ROI) and contralateral control (black ROI) with corresponding ADC map (C) and T2w image (D).

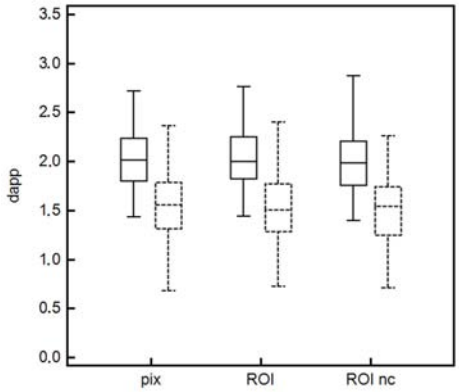

Fig. 2: D_{app} [10^{-3} mm^2/s]: boxplot diagram of PCa (dotted line) and contralateral (line) areas.

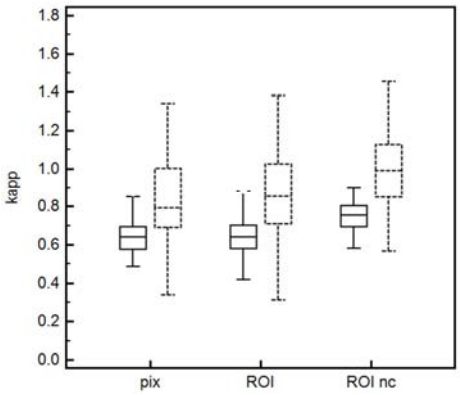

Fig. 3: K_{app}: boxplot diagram of PCa (dotted line) and contralateral (line) areas.