

Diffusion Kurtosis Imaging in Prostate Cancer

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Introduction:

Diffusion weighted imaging (DWI) and the calculated apparent diffusion coefficient (ADC) is showing potential for improving detection of prostate cancer (PCa), as the increased cellularity of many tumors is associated with restricted water diffusion and thus with a decreased ADC [1,2]. The ADC assumes Gaussian water diffusion and is calculated by monoexponential fitting. However, the water diffusion is non Gaussian if restrictions are present. Diffusion kurtosis imaging (DKI), which is an extension of conventional DWI, is a promising tool to visualize non Gaussian water diffusion and thus can provide a specific measure of tissue structure, such as cellular compartments and membranes [3,4]. To the best of our knowledge, DKI has not been performed in the prostate yet. Therefore the aim of this study was to investigate the influence of restricted diffusion in PCa using diffusion kurtosis imaging.

Materials and Methods:

Six patients (mean age=65.4±8.5) that were suspected to suffer from prostate cancer due to an elevated PSA level (mean PSA=9.15±3.0 ng/ml, range=6.2-15 ng/ml) were investigated and underwent TRUS-guided biopsy after MRI. Imaging was performed on a 3 Tesla Scanner (Magnetom Tim Trio, Siemens Medical Solutions, Erlangen, Germany) using an endorectal coil (MedRad Inc., Pittsburgh, USA) in conjunction with a standard 6 channel pelvic phased array coil. Transverse DW images were acquired using a single-shot spin-echo echo-planar imaging (SS-EPI) sequence and the following parameters: Three orthogonal gradient directions and six b-values (b=0, 100, 500, 1000, 1500, 2000) were used along each direction, TR/TE=3300/75 ms, FOV=20x20 cm², matrix size=92x92, 17 slices with a slice thickness/spacing of 3/0.5 mm, bandwidth=1430 Hz, NEX=6, and a total acquisition time of 5 min 30 s. Additionally, anatomical imaging was performed with a transversal T₂-weighted sequence (TR/TE=4560/104 ms, matrix size=384x384) covering the same volume as the diffusion sequence. The diffusion coefficient D and the kurtosis K were obtained by fitting the signal S(b) as a function of the b-value using the Levenberg-Marquardt algorithm and the following equation: $\ln[S(b)/S(0)] = -b \cdot D + 1/6 \cdot b^2 \cdot D^2 \cdot K$. In addition, the ADC was calculated by a linear fit: $\ln[S(b)/S(0)] = -b \cdot \text{ADC}$. Regions of interests (ROIs) were placed in cancerous tissue and in contralateral healthy tissue on the basis of biopsy findings, T₂-weighted images, and ADC-maps, by an experienced radiologist.

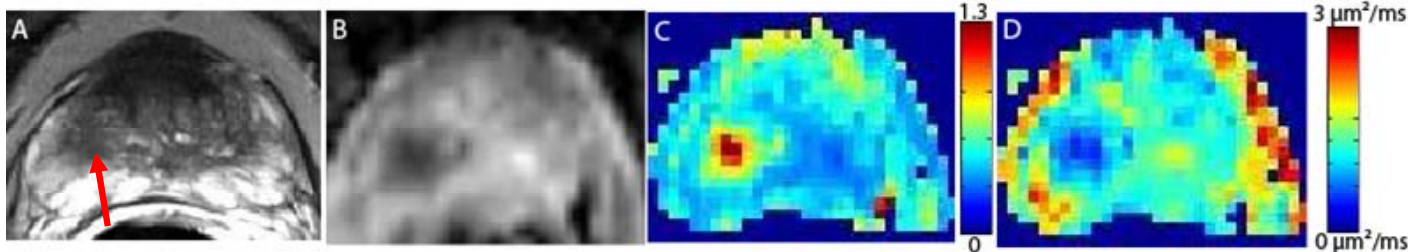


Fig. 1: Images of an exemplary patient with prostate cancer, indicated by the red arrow. A: T₂-weighted image; B: ADC-map; C: K-map; D: D-map. The PCa can be clearly delineated on the K-map.

Results and Discussion:

Fig. 1 shows one transversal slice of patient #2 with biopsy proven PCa (PSA=11 ng/ml). The tumor is indicated on the T₂-weighted image by a red arrow and can clearly be delineated by the increased kurtosis compared to the healthy tissue, whereas ADC- and D-values are decreased in the PCa. The findings in this patient are exemplarily for all patients as can be seen in the parameters calculated for each patient (Fig. 2). All patients showed an increased value of the kurtosis in the tumor compared to healthy tissue and five of the patients a decreased ADC- and D-value. The mean parameter values in the tumor and the contralateral healthy tissue were: $K=1.02 \pm 0.25$ vs. 0.65 ± 0.06 , $D=1.33 \pm 0.29 \mu\text{m}^2/\text{ms}$ vs. $1.78 \pm 0.17 \mu\text{m}^2/\text{ms}$, $\text{ADC}=0.82 \pm 0.2 \mu\text{m}^2/\text{ms}$ vs. $1.15 \pm 0.08 \mu\text{m}^2/\text{ms}$. The average ROI size in PCa and healthy tissue was $108 \pm 32 \text{ mm}^2$ and $97 \pm 33 \text{ mm}^2$, respectively. These preliminary results demonstrate an increased deviation from Gaussian diffusion in PCa compared to healthy prostate tissue, indicating increased restriction due to higher cell density or decreased permeability. The kurtosis holds promise to distinguish prostate cancer and healthy tissue but more patients have to be included in the future to evaluate the diagnostic performance in detail.

References:

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- [3] JH Jensen et al., MRM: 2005; 53; 1432-40
- [4] J Lätt et al., MRI: 2008; 26(1); 77-87

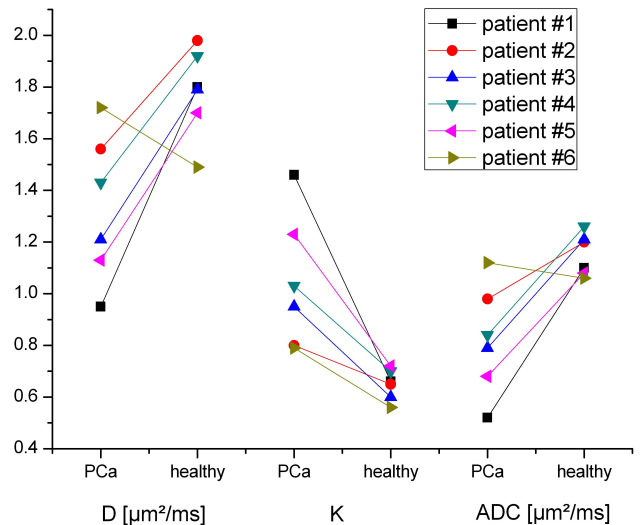


Fig. 2: Plots of the diffusion parameters in the tumor and the healthy region for each patient.