Q-space trajectory imaging (QTI) by multidimensional diffusion MRI (MD-dMRI) assessment of tissue microstructure as a novel imaging strategy to address prostate cancer; a pilot study

Langbein Björn¹, Fennessy Fiona¹, Szczepankiewicz Filip¹, Westin Carl-Fredrik¹, Kibel Adam², Tempany Clare¹
1 Brigham and Women’s Hospital, Department of Radiology
2 Brigham and Women’s Hospital, Division of Urology

Introduction
Prostate cancer (PCa) is the most common cancer in North American men¹. The international therapeutical approach is moving away from the treatment of the whole gland in a radical way towards a more individualized image guided approach, and as such new diagnostic imaging strategies are needed.

Specific aims
To determine the feasibility of using multidimensional diffusion MRI (MD-dMRI) to provide a novel way of detecting PCa, whole gland burden and tumor distribution of prostate as well as evaluation of normal prostate gland.

Rationale and background
PIRADS v2.1 assessment is known to be a reliable tool for detection of clinically significant PCAs.² However, mpMRI (T1, T2, DCE, DWI) is known to miss up to 26% of clinically important tumor lesions in a clinical setting.³ Information about the tumor on a microscopic scale could improve on current PIRADS methodology. Differences in fractional anisotropy between glioma, meningioma and normal tissue have been previously observed.⁴

Methods and material
We performed a prospective study of men presenting for PCa workup to the Urology clinic. Imaging was performed on a 3T scanner with a prototype spin-echo pulse sequence that facilitates multidimensional diffusion encoding⁵ (TE 75ms; TR 2400ms; b-value 1400s/mm² linear and 1100s/mm² spherical; resolution 2x2x4mm³) Using tensor-valued diffusion encoding, we obtained the following five parameters: 1) fractional anisotropy (FA), 2) mean diffusivity (MD), 3) microscopic anisotropy (Mka), 4) isotropic heterogeneity (Mki) and 5) total mean kurtosis (Mkt). We correlated all MRI data with the available pathology (H&E) of the biopsy samples and prostatectomy specimens.

Results
The study demonstrates the feasibility of performing MD-dMRI of the prostate at 3T in 38 patients. Current additional acquisition time is approximately 4 minutes. Pathology was correlated with prostate biopsy specimens in 26 patients and with prostatectomy specimens in 6 patients. To date no pathology is available for 6 patients. All parameters (FA, MD, Mka, Mki, Mkt) successfully showed a difference between focal prostate cancer lesion, normal peripheral zone and normal transitional zone. More specifically Mka, MD and FA differentiate cancer lesions from normal tissue in prostate. Parameter maps of Mka showed a higher value of 0.70 ± 0.33 for PCa and 0.3 ± 0.1 for normal prostate tissue, a lower MD of 1.1 ± 0.3μm²/ms and 1.5 ± 0.3μm²/ms and a higher FA of 0.3 ± 0.1 and 0.2 ± 0.1 respectively. In addition, we found a qualitative difference in FA, Mka, Mki and Mkt parameter maps of clinical insignificant cancer (Gleason Score 3+3=6) and clinically significant cancer (Gleason Score > 3+4=7), but further investigation is necessary.

Discussion and conclusion
In this pilot study, MD-dMRI and QTI analysis was feasible for evaluation of prostate in vivo. This non-invasive, in-depth analysis demonstrates significant differentiation between normal and tumor tissue in the prostate, reflective of microscopic tissue anisotropy. Our results support that regions with cancer generally show higher microscopic anisotropy than normal gland tissue, worthy of investigation in a larger study.

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Reference