Visualization of prostate fibromuscular stromal matrix using *ex-vivo* high-resolution DTI tractography

Nyoman D. Kurniawan[1], Gary Cowin[1], Paul Sved[2], Geoffery Watson[3], and Roger Bourne[4]

[1]*Centre for Advanced Imaging, University of Queensland, Brisbane, Queensland, Australia,* [2]*Department of Urology, Royal Prince Alfred Hospital, The University of Sydney, Sydney, New South Wales, Australia,* [3]*Department of Anatomical Pathology, Royal Prince Alfred Hospital, University of Sydney, Sydney, New South Wales, Australia,* [4]*Discipline of Medical Radiation Sciences, Faculty of Health Sciences, The University of Sydney, Sydney, New South Wales, Australia*

Introduction: 16.4T high-resolution diffusion weighted imaging (DWI) of formalin-fixed prostate tissue has revealed distinct microscopic diffusion environments and tissue architecture consistent with that seen on light microscopy [1]. The epithelial cell layer has highly restricted diffusion with the voxel bulk mean diffusivity, D = 0.54 ± 0.05 x 10^{-3} mm^2/sec. The diffusion in the fibromuscular stromal matrix is relatively less restricted, D = 0.91 ± 0.17 x 10^{-3} mm^2/sec. It was suggested that the negative correlation between measured apparent diffusion coefficient (ADC) and cancer Gleason grade observed *in vivo* may be the result of an increase of partial volume of epithelial tissue and associated decrease of stromal tissue and ductal space [2].

Our preliminary data show that the fibromuscular stromal tissue exhibits microscopic diffusion anisotropy with the mean fractional anisotropy (FA) range of 0.47-0.66, which is higher compared to the epithelium-containing voxels with mean FA range 0.31-0.54. We hypothesize that a combination of high-spatial resolution and tissue intrinsic anisotropy will permit reliable 3D reconstruction of the fibromuscular stromal structures. ***This study aims to optimize the methodology for the visualization of fibromuscular stromal matrix using the fiber tracks calculated from DTI-tractography.***

Materials & Methods: A 3 mm diameter normal prostate tissue sample was collected from a formalin fixed radical prostatectomy specimen and immersed in 0.2% Magnevist. MRI was performed on a 16.4T Bruker Microimaging (5 mm solenoid RF coil, Micro2.5 gradient set: 2.5 G/cm/A) using 3D spin-echo DTI sequence at 80µm isotropic resolution with δ/Δ = 2/12 ms, b=120, 250, 500, 1000 2000, 5000 and 10000 s/mm^2, 6 non-collinear directions and 2 *b* = 0 images.

Prior to processing the whole dataset, a tissue mask was applied to remove the buffer signals from outside the tissue while keeping the sample ductal spaces. Diffusion parametric images were calculated using DiffusionToolkit 0.5 using the conventional fiber propagation algorithm FACT. Additional reconstructions were also performed using non-conventional algorithms: 2nd order Runge Kutta (RK), which propagates the fiber tracks using tensor deflection, and streamline interpolation (IS) [3].

Results DTI tractography produces streamlines that correlate with the orientation of fibromuscular stromal anisotropy shown by the directional color-encoded FA images. The longest and most dense fibertracks were derived from data acquired using 1000 ≤ *b* ≤ 2000 s/mm^2. At *b* ≥ 5000 s/mm^2, the FA values started to increase from a stable value, which is probably due to an increase of the noise level.

At *b* = 2000 s/mm^2, FACT algorithm produced 4200 ± 100 fibertracks with an average of 0.6 ± 0.5 mm long. The RK and IS algorithms produced longer fibertracks (1.0 ± 0.7 and 1.6 ± 0.9 mm, respectively) and high number of fibertracks (9650 ± 250 and 13952 ± 468, respectively). The RK and IS methods appeared useful to recover the fibertracks at high *b*-value (*b* ≥ 5000 s/mm^2), however they also produced more false streamlines into non-stromal tissues.

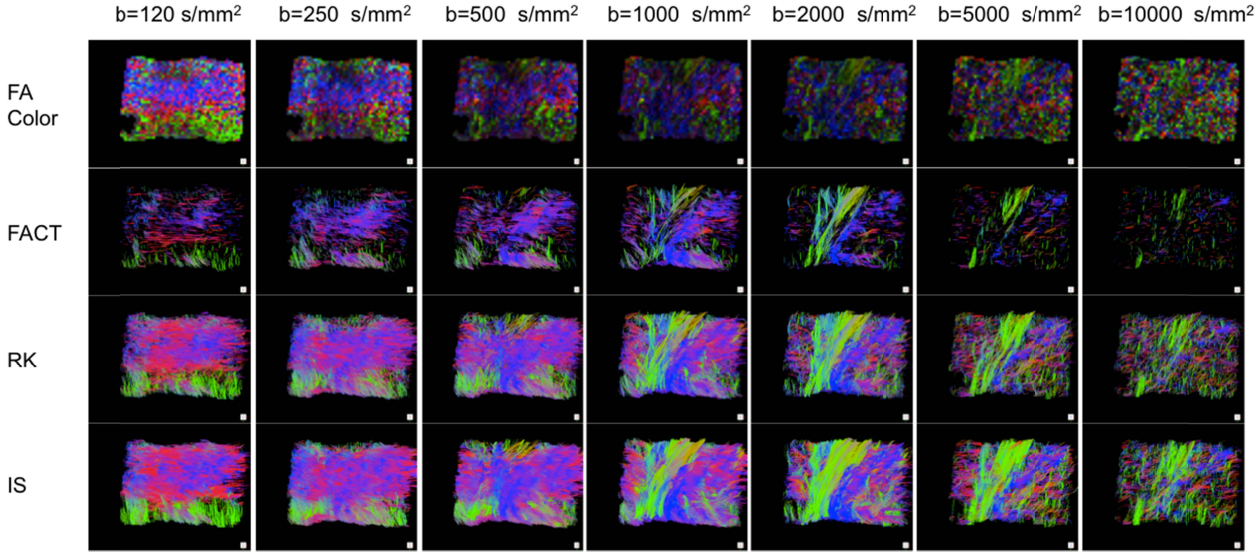

Figure 1: DTI tractography reconstruction of a normal prostate tissue sample acquired at multiple b values. (Row 1) Directional color-encoded FA map. (Row 2,3,4) Fibertracks reconstructed with FACT, 2nd order Runge-Kutta and Interpolated Streamlines algorithms, respectively. To aid visualization, only the streamlines that intersect the displayed slice are shown.

Conclusion: In formalin-fixed prostate tissue, the most dense and longest stromal tissue fiber tracks are generated from DTI data with *b*-values in the range 1000-2000 s/mm^2. The 2nd order Runge-Kutta and Interpolated Streamline propagation algorithms produced more number and longer tracks than the FACT algorithm. Correlation with serial section histopathology will be required to confirm that the generated fiber tracks accurately reflect stromal muscle fiber orientation. These high-resolution *ex-vivo* studies will inform attempts to measure fractional anisotropy of prostate tissue at low spatial resolution *in vivo*.

References: (1) Bourne R, et al. 16 T diffusion microimaging of fixed prostate tissue: preliminary findings. Magn Reson Med. 2011 doi: 10.1002/mrm.22778. (2) Bourne R et al. Microscopic Diffusivity Compartmentation in Formalin-Fixed Prostate Tissue. Magn Reson Med. Accepted 24 September 2011. (3) Ruopeng W & Wedeen VJ, TrackVis.org, Proceedings of ISMRM 15, 2007; 3720.