High spatial resolution diffusion tensor and kurtosis analysis of formalin fixed whole prostate tissue

Roger Bourne[1], Dominic Pang[1], Andre Bongers[2], Carl Power[2], Paul Sved[1], and Geoffrey Watson[3]
[1]*University of Sydney, Sydney, NSW, Australia,* [2]*University of New South Wales, Sydney, NSW, Australia,* [3]*Royal Prince Alfred Hospital, Sydney, NSW, Australia*

Target audience Researchers and clinicians interested in diffusion-based interrogation of tissue structure.

Purpose To perform a high spatial resolution kurtosis analysis of diffusion signal decay in prostate tissue.

Methods Two radical prostatectomy specimens were formalin fixed 48 hr then imaged at 9.4T. Diffusion attenuation was measured with a 2D spin echo method[1]. FOV 61×61mm, matrix 256×256, δ=5ms, Δ= 20ms, 6-gradient directions, TE/TR = 28/2200 ms, *b*-values 0, 0.01, 1.6, 8 ms/μm^2, T=22°C. $SNR_{b=0}$ = 56. The *b*=0 and 1.6 ms/μm^2 data were used to calculate a monoexponential diffusion tensor (DTI_{mono}). A kurtosis function $S = S_o\exp(-D_K b + KD_K^2 b^2/6)$ was fitted to the signal acquired from each of the gradient directions using a NLLS approach. Two kurtosis tensors were then calculated from the kurtosis (*K*) and kurtosis-adjusted diffusivity (D_K) data.

Results Fig. 1 shows DTI_{mono}-derived mean diffusivity (MD) and fractional anisotropy (FA) maps of the mid gland. The organ has typical high FA in the capsule and bands of fibromuscular stroma separating the peripheral and central zones.

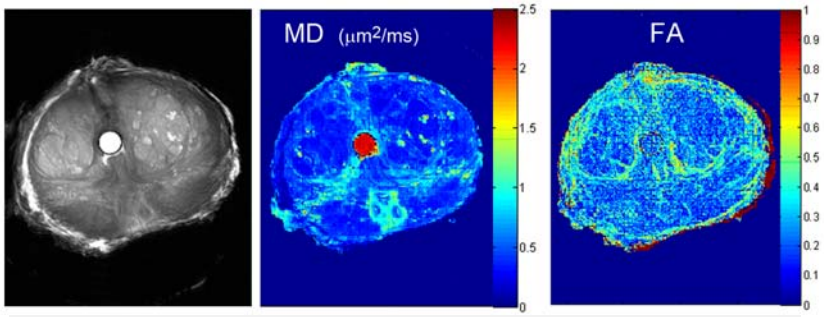

Fig. 1. Left: T_2-weighted. Centre and right: mean diffusivity (MD) and FA calculated from monoexponential tensor. The organ is suspended on a 5-mm saline-filled NMR tube inserted through the urethra.

Fig. 2 shows kurtosis analysis results from the same slice as Fig. 1. Kurtosis-adjusted diffusivity averaged over the six gradient directions (D_K-AV) is similar to DTI_{mono} MD but reveals slightly more structural detail. Average kurtosis (*K*-AV) is high in low diffusivity densely glandular regions of the prostate and relatively low in stromal tissue. Variance of the kurtosis (CV_K) is highest in stromal tissue and closely correlates with DTI_{mono} FA.

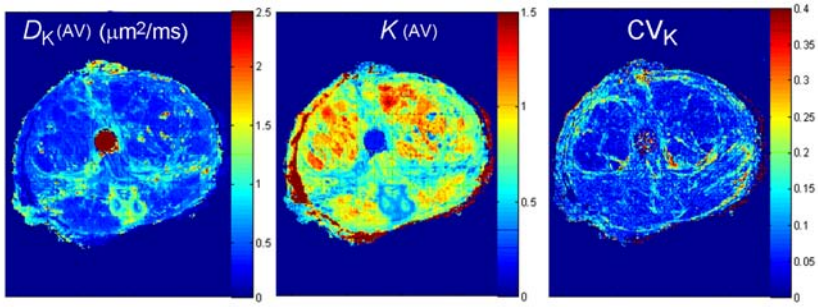

Fig. 2. Left: Kurtosis adjusted diffusivity (D_K) averaged over all gradient directions. Center: Kurtosis (*K*) averaged over all gradient directions. Right: Coefficient of variation of kurtosis through all gradient directions.

Fig. 3 shows data from two tensors calculated from *K* and D_K respectively. Mean diffusivity derived from D_K (MD-D_K) shows more stromal detail and a less variable diffusivity than MD, and also less variable diffusivity than D_K-AV. Similarly, mean kurtosis (MK-K) derived from the kurtosis tensor shows good anatomical detail but has less magnitude variation than the direction-averaged kurtosis (K-AV).

Similar results were obtained for the second organ.

Conclusion Kurtosis analysis of diffusion attenuation in the prostate returns parameters that appear to correlate strongly with variations in microscopic tissue structure and show less variability than tensor parameters derived from a monoexponential model of diffusion attenuation. The relative ease of acquisition of data for kurtosis analysis compared with the large number of *b*-values required for biexponential analysis may be advantageous for clinical applications.

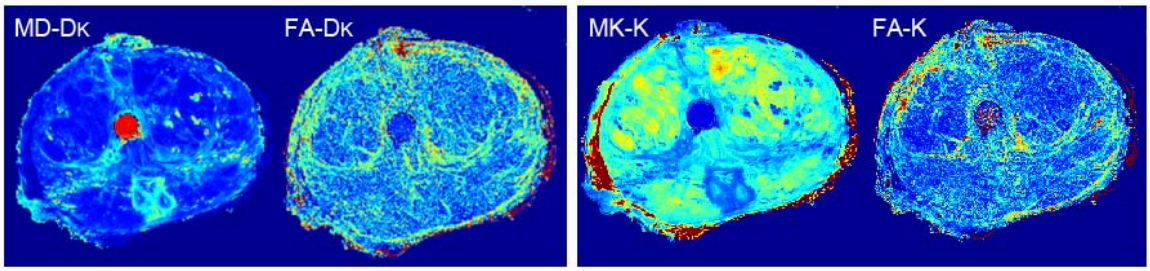

Fig. 3. Left: Mean kurtosis adjusted diffusivity and FA derived from a tensor calculated from D_K. Right: Mean kurtosis and FA of kurtosis derived from a tensor calculated from *K*.

References **1.** Bourne R, Bongers A, Charles N, Power C, Sved P, Watson G. Effect of formalin fixation on biexponential modeling of diffusion decay in prostate tissue. *Magnetic Resonance in Medicine.* 2012:In press. (Accepted 12-10-2012).