High spatial resolution diffusion tensor and kurtosis analysis of formalin fixed whole prostate tissue
Roger Bourne1, Dominic Pang1, Andre Bongers2, Carl Power2, Paul Sved1, and Geoffrey Watson3

1University of Sydney, Sydney, NSW, Australia, 2University of New South Wales, Sydney, NSW, Australia, 3Royal 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 method1. 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/µm², T=22 oC. SNR = 56. The b=0 and 1.6 ms/µm² data were used to calculate a monoexponential diffusion tensor (DTI mono). A kurtosis function $S = S_0 \exp(-D_K b + K D_K b^2/6)$ 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. 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. 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.