Diffusion Tensor Imaging of the Normal and Pathologic Prostate at 3T

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Introduction Excellent quality data of the human prostate can now be routinely obtained using MR imaging. Due to the overlap of signal intensities between prostatic carcinoma and benign prostatic hyperplasia, diffusion weighted imaging has been utilised to aid tissue discrimination [1, 2]. Recently some initial exploratory work on the potential use of diffusion tensor imaging (DTI) has been performed [3, 4]. However, all previous work has been implemented at 1.5 T, wherein the inherently long echo-time required to perform appropriate diffusion weighting, the use of echo-planar imaging (EPI) and the absence of an endorectal coil result in poor SNR. To compensate for this an increased number of averages and thus extended imaging time (typically 15 mins) are often required. With the advent of whole-body imaging at 3T the use of DTI outwith the brain in a clinical environment has become increasingly viable. This work is concerned with establishing normative values of the diffusion tensor for asymptomatic volunteers and preliminary investigation into DTI of the pathologic prostate.

Methods All imaging was performed using a GE Signa EXCITE 3.0 T whole-body scanner with zoom gradients and an 8-channel torso phased-array coil. Nine asymptomatic volunteers (mean age 33 years range 19-49 years) and 13 patients (mean age 66 years, range 53-80 years) with proven prostatic carcinoma were scanned. High-resolution T2 weighted images were initially acquired for organ and lesion visualisation (field of view 20cm, matrix size 384×288, 3 mm slices). DTI was implemented using a spin-echo EPI sequence with diffusion gradients applied as a bipolar pair either side of the refocusing 180° pulse. Other acquisition parameters were as follows: TE/TR 64.8 ms (fractional echo) / 6.2 s, matrix size 128×128, ASSET factor 2, field of view 35 ×35 cm, slice thickness 2.7 mm, receiver bandwidth ±250 kHz. The total acquisition time was 4½ mins for 28 contiguous slices through the prostate and surrounding anatomy. Images were obtained with a *b*-factor = 0 s/mm^2 and 700 s/mm^2 with the diffusion gradients applied in six different directions resulting in 196 images per study. After acquisition regions of interest (ROIs) were then drawn, in patients, on areas of prostatic carcinoma and normal appearing peripheral zone where possible, using the T2 weighted images and radiologist's report as reference. Regions were selected from the well-differentiated normal peripheral zone and central gland in the healthy volunteers. The orientationally averaged diffusion coefficient, fractional anisotropy (FA), and trace elements (D_{xx}, D_{yy}, D_{zz}) were subsequently computed and recorded.

Results The accompanying table details the results obtained (all ADC values are given as ×10^{-3} mm^2/s). FA was found to be significantly higher in prostatic carcinoma compared to peripheral zone (p = 0.004) (see left-hand boxplot). Significant differences were

	Patients		Volunteers	
	Tumour (n=13)	Normal Peripheral Zone (n=9)	Normal Peripheral Zone (n=9)	Central Gland (n=9)
Avg ADC	1.26±0.28	1.62±0.21	1.51±0.31	1.27±0.13
FA	0.25±0.06	0.19±0.07	0.17±0.06	0.28±0.03
D_{xx}	1.30±0.31	1.64±0.26	1.50±0.28	1.19±0.12
D_{yy}	1.21±0.26	1.61±0.30	1.50±0.36	1.25±0.16
D_{zz}	1.26±0.21	1.60±0.17	1.52±0.33	1.37±0.17
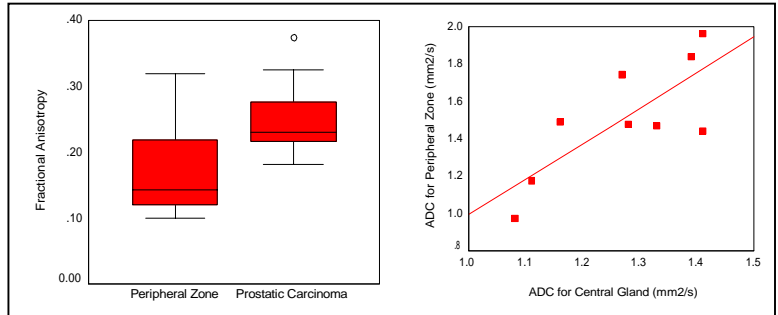
also demonstrated between prostatic carcinoma and peripheral zone for the average ADC and all trace elements (p < 0.019 in all cases). For the volunteers significant differences were noted between peripheral zone and central gland for all parameters (p <0.014) excepting D_{zz}. As previously reported [2] a significant correlation was also found between the average ADC values for the two tissue types (r=0.780, p=0.013) (see right-hand scatter plot). No significant correlations with age were noted.

Conclusions This work has demonstrated that DTI of the human prostate, in a clinically acceptable imaging time, is feasible at high field strength. FA offers some ability in the differentiation of healthy and diseased tissue. However, the range of values and degree of overlap obtained for prostatic tissues indicate that it is unlikely that diffusion weighted imaging will be used as a stand-alone discriminatory tool. It is more evident that the ability to calculate the diffusion tensor may aid patient management particularly in the areas of treatment monitoring and prediction [5].
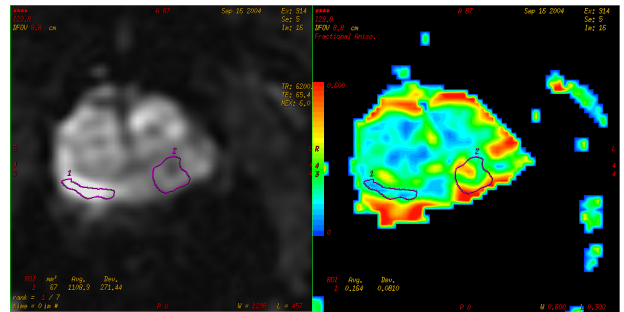
EPI image (b=0) and FA colour map with ROIs of peripheral zone (left) and prostatic carcinoma (right)

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