Anisotropic Diffusion in Prostate Cancer: Fact or Artefact?

S. A. Reinsberg[1], J. M. Brewster[1], G. S. Payne[1], M. O. Leach[1], N. M. deSouza[1]

[1]Cancer Research UK Clinical MR Research Group, Institute of Cancer Research & Royal Marsden NHS Trust, Sutton, Surrey, United Kingdom

Introduction: Previous MR diffusion studies have reported that prostate tumour exhibits elevated fractional anisotropy as compared with healthy prostatic tissue [1-3]. These findings are unexpected in view of prostatic tissue structure on histology and the possible use of anisotropy data as a diagnostic tool in prostate cancer has not been established. We have analysed data from diffusion-weighted imaging (DWI) as well as from Monte-Carlo simulations in order to determine whether noise may lead to the appearance of anisotropy in genuinely isotropic diffusion.

Methods: Eleven men (mean age 71±4 years) with biopsy-confirmed prostate cancer were studied. Imaging was done on a 1.5 T Intera (Philips Medical Systems, Netherlands) using an endo-rectal balloon receiver coil inflated with 50ml of air. In addition to a clinical diagnostic scan (T_2-weighted TSE T_r/T_e=2000/90 ms, 20 slices, thickness 3mm, FoV 140mm,), data using echo-planar DWI with diffusion gradients applied in three orthogonal directions at b-values of 0, 300, 500, 800 s/mm^2 were acquired. ADC maps were calculated using the manufacturer's software. Measures of anisotropy such as fractional anisotropy (FA) as well as the volume ratio (VR) were calculated off-line by in-house software according to established conventions [4]: Regions of interest (ROIs) of peripheral zone (PZ) defined as non-malignant (3-4 negative unilateral biopsies), whole central gland (CG) and tumour (low signal intensity within the PZ with corresponding biopsy positive for tumour) were drawn on T2-weighted images on three consecutive slices by an experienced radiologist. ROIs were transferred to co-registered ADC maps for calculation of mean anisotropy. Monte-Carlo simulations were performed to evaluate the effect of noise on calculation of mean FA and VR at a given noise level.

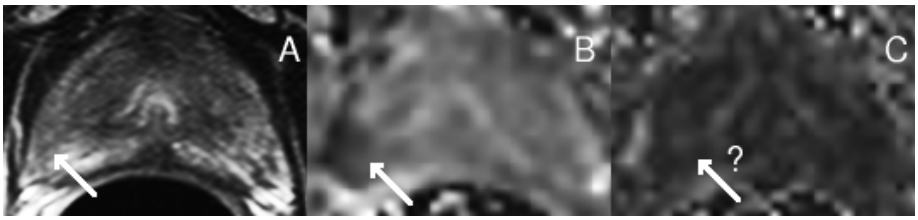

Fig.1 T_2-weighted image (A), fractional anisotropy (B), and apparent diffusion coefficient map (C). Tumour is seen in the right peripheral zone (arrow).

Results: A typical T_2-weighted study shows a poorly defined low signal-intensity region on T2-W (Fig. 1A), which was biopsy positive for tumour seen as a focus of restricted diffusion (Fig. 1B). However, FA maps (Fig. 1C), though generally slightly heterogeneous, do not highlight this region. A one-tailed t-test for eleven patients shows that the difference of mean FA between non-malignant PZ (FA=0.09±0.05) and tumour (FA=0.11±0.06) is not significant (p=0.07>0.05). Fig.2 shows the spread and distribution of FAs in the three types of ROIs. Malignant lesions have a wider spread of the 25%-75% quartiles for these data which indicates that noise is the likely cause for previously observed anisotropy as suspected by Chen *et al*.[3]. Fig. 3 demonstrates the influence of increased noise on the calculated anisotropy. We simulated various noise levels of the eigenvalues of an isotropic diffusion tensor and plotted means of the subsequently calculated anisotropy parameter (FA and VR) vs the noise. Both anisotropy measures show a continuous increase with increasing standard deviation (i.e. decreasing signal-to-noise).

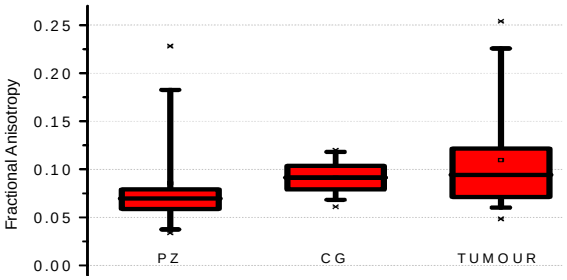

Fig.2 Box chart of fractional anisotropy for peripheral zone (PZ), whole central gland (CG) malignant peripheral zone (TUMOUR)

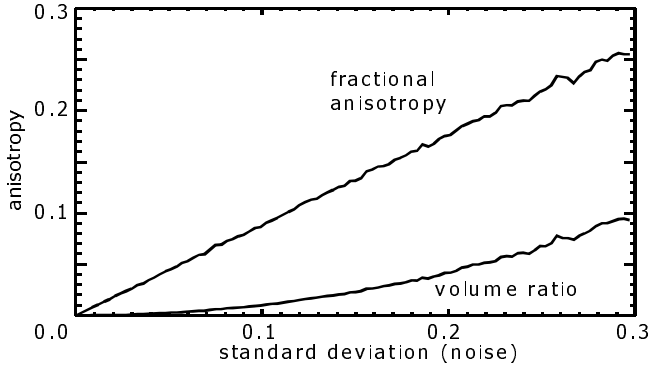

Fig.3 Monte-Carlo simulation of increased anisotropy as a result of noise. Two popular measures (fractional anisotropy and volume ratio) are displayed. Noise is expressed in terms of standard deviation.

Discussion and Conclusion: The applied diffusion-weighted imaging protocol allowed high signal-to-noise acquisition of diffusion maps. The derived anisotropy measures in the prostate suggest that there is no detectable increase in FA or VR in malignant regions. This is in contradiction to previous findings which we believe were based on noisy data.[1,2] We have identified how noise leads to an appearance of anisotropy in genuinely isotropic diffusion.

References: [1] D.Tozer *et al.*, In Proc. 11th ISMRM #460; 2003.
[2] X. Wang *et al.*, In Proc. 12th ISMRM #939; 2004.
[3] A.P. Chen *et al.*, In Proc. 11th ISMRM #579; 2003.
[4] C. Pierpaoli *et al.* Radiology 201, pp.637, 1996

Acknowledgement: This work is supported by CRUK (C1060/A808/G7643) and NEAT (DoH).