Repeatability of Diffusion Imaging of the Prostate at 3T

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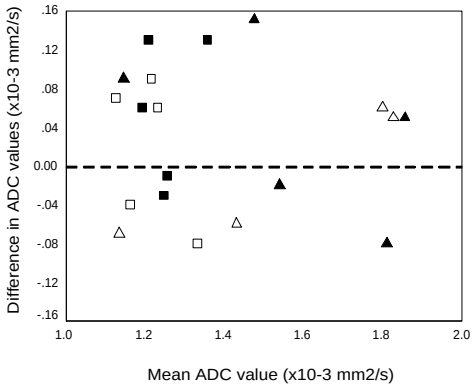
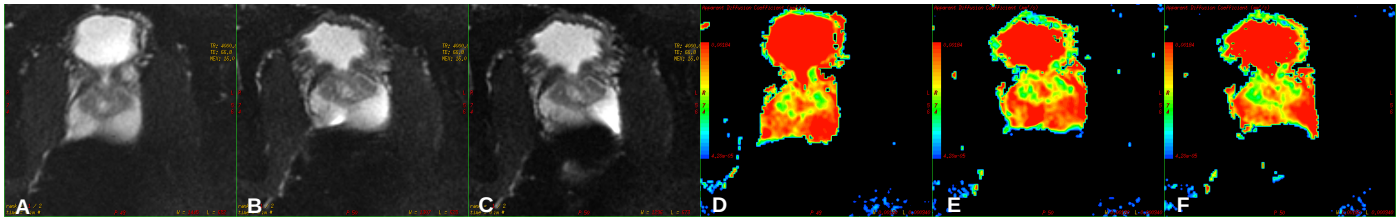
Introduction Recent work has demonstrated the feasibility of diffusion weighted imaging (DWI) of the human prostate in symptomatic patients [1] and normative values have also been established [2,3]. Many authors have suggested that apparent diffusion coefficients (ADCs) may be useful in monitoring the response of tumours to treatments such as radiotherapy and/or neoadjuvant chemotherapy [4,5]. However, for this to be a viable proposition it is evident that the reproducibility and repeatability of calculated ADC values needs to be assessed. This is of particular importance bearing in mind the poor SNR nature of whole-body diffusion imaging. To date, there appears to be only limited data assessing this issue in diffusion imaging in the brain [6], and no published work addressing the subject in the prostate. This study aims to partially redress the balance by exploring both medium and short-term repeatability in DWI and diffusion tensor imaging (DTI) of the 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. Five asymptomatic volunteers (mean age 36 years range 29-49 years) were scanned on two occasions approximately 1 month apart. High-resolution T2-weighted images were initially acquired for organ visualisation. DW images (with *b*-factor = 0 s/mm^2 and 500 s/mm^2) were acquired using a spin-echo EPI sequence (field of view 26 cm, matrix size 224×224, ASSET factor 2, slice thickness 5 mm). Diffusion tensor imaging (with *b*-factor = 0 s/mm^2 and 700 s/mm^2) was implemented using a similar sequence with the diffusion gradients applied in six different directions (field of view 35 cm, matrix size 128×128, ASSET factor 2, slice thickness 2.7 mm). DWI and DTI were both performed twice at the 2nd visit to assess short-term repeatability. Regions of interest were selected in the normal peripheral zone (PZ) and central gland (CG), and care was taken to ensure region correspondence between scans. From the DW images the ADC values were calculated and from the DT images the orientationally averaged diffusion coefficient (oADC), fractional anisotropy (FA), and trace elements (D_{xx}, D_{yy}, D_{zz}) were computed. Plots of the difference between the measurements of a parameter vs. the mean of the parameter were then produced to assess experimental bias. Finally, repeatability was calculated using the previously described method of Bland and Altman [7].

Results No evidence of experimental bias was noted from both a short-term and medium-term perspective for all calculated parameters, with the mean differences close to zero in all situations. An example Bland-Altman plot is shown for the diffusion weighted imaging results (■=CG short-term, □=CG medium-term, ▲=PZ short-term, △=PZ medium-term). The results of the repeatability assessments are shown in the accompanying table (all values are given as $\times 10^{-3}$ mm^2/s). From this table it is clear that diffusion weighted imaging has excellent repeatability in both the short and medium-term. The size of change required for significance is between 11 and 14%. Changes less than this during treatment monitoring must be treated with caution. The orientationally averaged ADC calculated from DTI data appears to have excellent short-term repeatability (8-10%) but rather poorer medium-term repeatability (17-31%). The results for fractional anisotropy demonstrate that relatively large changes must occur to be regarded as significant. Example DW images from one volunteer are shown below highlighting the excellent repeatability (A is the initial scan, B and C are the scans taken a few minutes apart one month later, and D, E, and F are the corresponding ADC maps).



Parameter	*Medium-Term*			*Short-Term*		
	Mean	*Mean Diff.*	*Repeatability*	*Mean*	*Mean Diff.*	*Repeatability*
ADC (PZ)	1.57	0.04	0.17 (11%)	1.53	0.03	0.17 (11%)
ADC (CG)	1.25	0.06	0.17 (14%)	1.21	0.02	0.14 (12%)
oADC (PZ)	1.65	0.02	0.28 (17%)	1.66	-0.04	0.16 (10%)
oADC (CG)	1.22	0.04	0.38 (31%)	1.21	-0.02	0.10 (8%)
FA (PZ)	0.15	-0.10	0.14 (93%)	0.14	0.01	0.05 (36%)
FA (CG)	0.29	0.09	0.20 (69%)	0.25	-0.02	0.05 (20%)



Discussion This work has demonstrated that DWI of the prostate appears to be highly repeatable and as such has the potential to monitor relatively small treatment induced changes. However, some care must be taken over the interpretation of these results due to the small sample size involved. DTI appears to be less repeatable over the longer term. It was noted that at least one subject had an excessively air filled rectum, leading to increased susceptibility effects, and that in another subject the PZ and CG were not well differentiated. Both of these factors may have adversely affected the results.

[1] K Hosseinzadeh and SD Schwarz (2004) *J. Magn. Reson. Imaging* 20:654-661. [2] S Sinha and U Sinha (2004) *Magn. Reson. Med.* 52:530-537. [3] P Gibbs *et al* (2001) *Magn. Reson. Med.* 46:1054-1058. [4] NJF Dodd and S Zhao (1997*) Phys. Medica* 13:56-60. [5] D Jennings *et al* (2002) *Neoplasia* 4:255-262. [6] A Pfefferbaum *et al* (2003) *J. Magn. Reson. Imaging* 18:427-433. [7] JM Bland and DG Altman (1996) *Br. Med. J.* 313:744