

# The Effect of Varying Diffusion-Encoding Gradient Strength and Separation on Measured Apparent Diffusion Coefficient and T2 of Prostate

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**Target audience:** Researchers who focus on advanced Diffusion Weighted MRI (DWI) techniques, radiologists who are using DWI for prostate cancer diagnosis.

**Introduction:** A previously reported hybrid imaging method<sup>[1]</sup> treats apparent diffusion coefficient (ADC) and T2 as coupled parameters, and measures ADC and T2 as functions of echo time (TE) and diffusion weighting factor (*b*-value), respectively. Results showed that both ADC and T2 calculated from the hybrid imaging data can help differentiate normal tissue regions and cancer foci. The results are consistent with studies of neurological model systems which demonstrated that ADC and T2 are frequently coupled<sup>[2]</sup>. In this study, we examined the effect of the diffusion gradient separation time ' $\Delta$ ' on T2 and ADC values, in normal prostatic tissue and prostate cancer. Changes in ADC with  $\Delta$  would suggest effects of restricted diffusion or motion. Here we report the effects of varying  $\Delta$  on prostate cancer contrast.

**Methods:** This IRB-approved study included twelve patients with biopsy proven prostate cancer. The average age of the patients was 56.1 years; range 41-67 years; median serum prostate-specific antigen level 7.06 ng/ml; range 3.53-20.34 ng/ml. Thirteen cancer and twelve normal regions of interest (ROIs) were outlined on ADC images by an experienced radiologist (AO) after reviewing both ADC and T2-weighted images and the biopsy histology reports. DWIs were acquired in the axial plane with free breathing, using a standard pulse gradient spin echo (PGSE) sequence with EPI readout, on a Philips 3T Achieva scanner. Five DWIs were acquired for each subject, each with three *b*-values: 0, 750, and 1500 s/mm<sup>2</sup>. TE's in the five DWI acquisitions were 47, 75, 100, 75 and 100 ms, and the corresponding separation between the two diffusion gradients ( $\Delta$ ) was 24.5, 24.5, 24.5, 52.5, and 77.5, respectively. In the first TE=75, 100 ms acquisition pair,  $\Delta$  was kept fixed. In the second TE=75, 100 ms acquisition pair,  $\Delta$  was optimized by scanner console to minimize the diffusion gradient strength *g*. The diffusion gradient duration  $\delta=11.8$  ms was kept constant for all DWI acquisitions. All

data were acquired using 2.5x2.5mm<sup>2</sup> in-plane resolution, with 3 mm thickness, TR=3000 ms, and NA=4; total scan time was 13.1-14.5 minutes for the five DWI acquisitions. ADC and T2 were calculated at each TE and *b*-value, respectively, using least squares fitting to a mono-exponential decay model. The average ADC and R2 (R2=1/T2) results for prostate cancer and normal prostate tissue ROIs were compared between acquisitions with fixed and non-fixed  $\Delta$ 's using two-sided paired t-test.

**Results:** Figure 1 compares ADC and R2 values averaged over the ROIs, between acquisitions with fixed and non-fixed  $\Delta$ 's. Standard deviation of voxel values in each ROI was used as error bars. Values calculated from cancer tissue ROIs are shown in red, those from normal tissue ROIs are shown in green. There was no significant difference in ADC and R2 values calculated from acquisitions obtained with non-fixed  $\Delta$  (x-axis) vs. fixed  $\Delta$  (y-axis), from both cancer and normal prostatic ROIs.

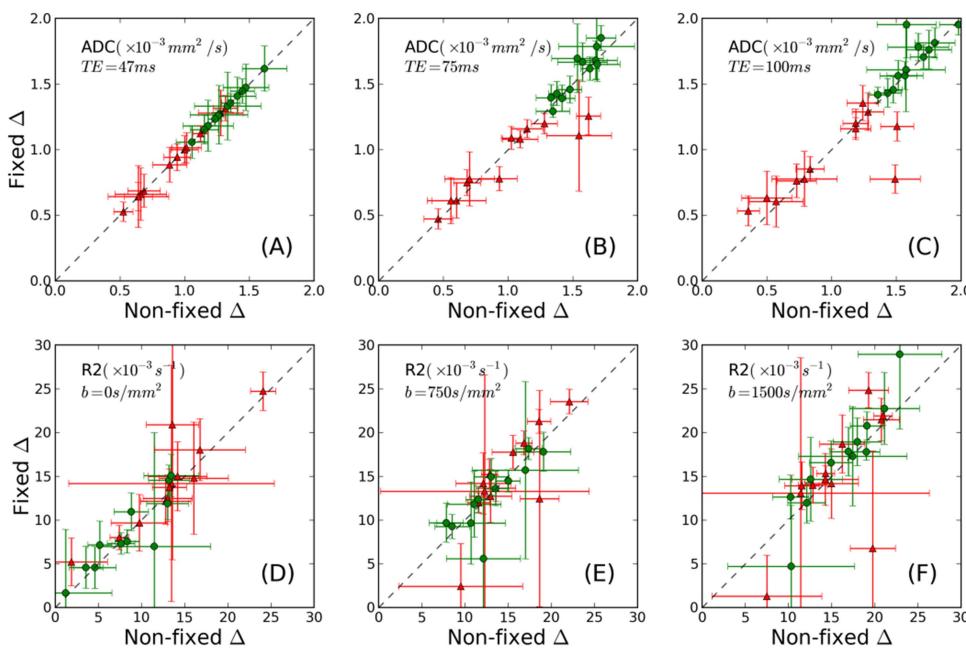


Figure 1. (A)-(C) ADC comparisons between fixed and non-fixed  $\Delta$ s at TE=47,75,100ms. (D)-(F): R2 comparisons between fixed and non-fixed  $\Delta$ s at *b*=0,750, 1500 s/mm<sup>2</sup>. (Red—cancer tissue ROIs, green—normal tissue ROIs)

**Conclusion and Discussion:** No significant differences were observed between ADC and T2 values calculated from acquisitions with fixed and non-fixed  $\Delta$ , in both normal prostatic tissue and cancer. Potentially, this may indicate that the  $\Delta$ 's applied in this study are not long enough for values to be affected by restricted diffusion caused by the cell boundaries. The observed variations between results obtained with non-fixed and fixed  $\Delta$ 's may be caused by patient motion, but may also reflect increased sensitivity to the micro-environment with fixed  $\Delta$ 's.

**References:** [1] Wang S. et al., J. Magn. Reson. 2013; [2] Burdette JH. et al., Radiology. 1999.