# Diagnostic value of ADC in patients with prostate cancer: influence of the choice of b-values

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## Introduction/Purpose

Diffusion-weighted images (DWI) and maps of the apparent diffusion coefficient (ADC) are useful to identify prostate regions suspicious of cancer (PCa) [1]. The differentiation between high (Gleason Score GS≥7) and low (GS≤6) grade tumors can support therapeutic decision making [2]. However, there is a substantial variability in the threshold ADC values [3] used to separate malignant from benign lesions, which is probably due to the choice of b-values. DWI scans at low b-values are contaminated by perfusion effects while higher b-values are associated with an increased background noise. In this work, the influence of the choice of b-values on the calculated ADC maps was investigated for 40 patients with known prostate cancer. The diagnostic power to distinguish between tumor and healthy prostate tissue as well as between high and low risk malignancy was compared for different quantitative ADCs. The diagnostic value of the corresponding ADC maps was also rated by three different operators.

## Materials and Methods

Forty consecutive patients with histologically confirmed PCa underwent multiparametric, endorectal MR diagnostics at 3T (Magnetom Tim Trio, Siemens), 13 of which had a low grade (GS=6) carcinoma. ADC maps were calculated retrospectively (Matlab, Mathworks) using standard (std: 0, 800), mainly diffusion weighted (mdw: 50, 800), strongly diffusion weighted (sdw: 400, 800), and all (all: 0, 50, 400, 800) b-values [s/mm$^2$]. Index lesion and corresponding mean $ADC_{PCa}$ were determined for each patient by reviewing all the information available (DWI, T2w and dynamic contrast-enhanced imaging, 3D spectroscopy, histology data). In addition, the ratios of $ADC_{PCa}$ to the ADCs of both peripheral zone (PZ) and central gland (CG) were calculated. Respective differences were analyzed with a one-way ANOVA with factor *method* (significance level 5%). An ROC analysis was performed to evaluate the value of fixed ADC thresholds to distinguish between low and high risk cancers. Three operators were asked to define an index lesion using T2w and DWI data, and then to rate the diagnostic value of the ADC maps (Fig. 1) as good (2), fair (1), or poor (0).

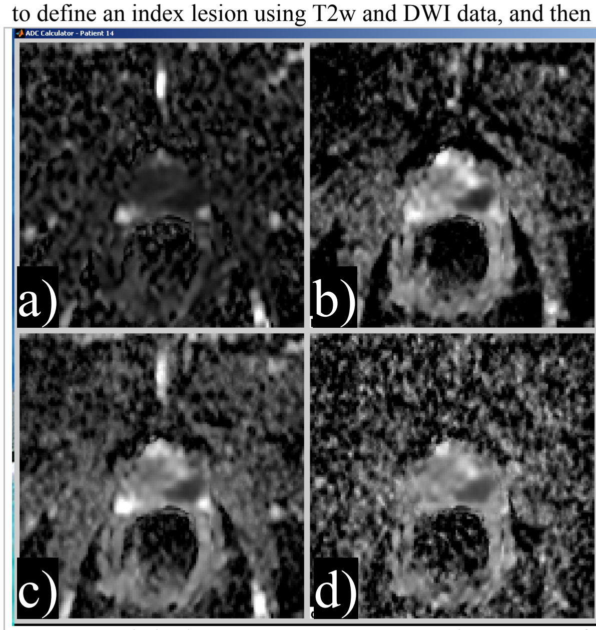


**Fig. 1.** Calculated maps $ADC_{all}$, $ADC_{mdw}$, $ADC_{std}$, and $ADC_{sdw}$ **(a-d)** of a 61 year old patient (PSA 8.6 ng/ml) with a PCa in the left peripheral zone near the apex. Histopathological analysis after R0 resection of the prostate revealed a high grade tumor (GS 4+4=8).

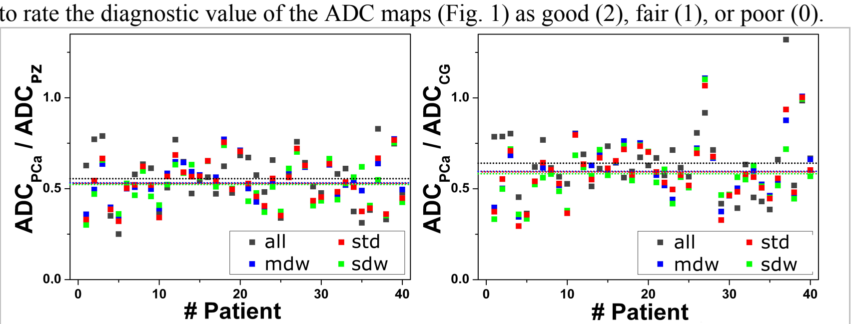


**Fig. 2.** Individual (squares) and mean (dotted lines) ADC ratios between cancerous (PCa) and healthy tissue (PZ: peripheral zone, CG: central gland).

| | Apparent Diffusion Coefficient [mm/s$^2$] | | | |
|---|---|---|---|---|
| | std | mdw | stw | all |
| PCa | 0.95±0.22 | 0.91±0.21 | 0.80±0.20 | 1.26±0.28 |
| PZ | 1.81±0.23 | 1.72±0.21 | 1.53±0.22 | 2.35±0.51 |
| CG | 1.63±0.22 | 1.55±0.16 | 1.38±0.14 | 2.02±0.36 |

**Tab. 1.** Rounded ADC values (mean ±SD) averaged over small ROIs in respective regions. Differences between methods are highly significant (p<0.001).

| | ADC Ratios | | | |
|---|---|---|---|---|
| | std | mdw | stw | all |
| PCa/PZ | 0.53±0.12 | 0.53±0.12 | 0.52±0.12 | 0.55±0.15 |
| PCa/CG | 0.59±0.16 | 0.60±0.16 | 0.58±0.16 | 0.64±0.18 |

**Tab. 2.** Rounded average ADC ratios. Differences between methods are not significant (PZ: p=0.680, CG: p=0.412).

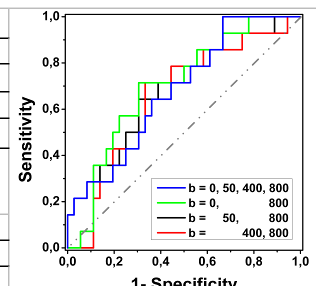


**Fig. 3.** The ROC analysis resulted in AUCs of 0.65, 0.66, 0.68 and 0.70 for $ADC_{sdw}$, $ADC_{mdw}$, $ADC_{all}$, and $ADC_{std}$.

## Results

The choice of b-values had a highly significant (p<0.001) influence on the absolute ADC values for all tissue types (Tab. 1) but not on the ADC ratios between cancer and healthy (PZ, CG) tissue (Fig.2, Tab. 2). The AUC for the differentiation between high and low grade cancers ranged from 0.65 ($ADC_{sdw}$) to 0.70 ($ADC_{std}$) (Fig. 3). On average, 85% of the index lesions were correctly identified by the operators. $ADC_{mdw}$ (1.6±0.3) was rated best, followed by $ADC_{std}$ (1.1±0.3), while $ADC_{all}$ maps received poor (0.3±0.2) rating (Fig. 1). In the case of low grade carcinomas, only $ADC_{mdw}$ maps were rated better than fair (1.4±0.3), all others scores were <0.8.

## Discussion and Conclusion

Even though the absolute ADC values varied significantly, the numerical ADC ratios (contrasts) were largely independent of the combination of b-values. The predictive value for the grade of malignancy, however, was only moderate. All operators preferred $ADC_{mdw}$ (b=50, 800) maps for diagnostic purposes, especially with low grade tumors. The slightly better rating of $ADC_{mdw}$ vs. $ADC_{std}$ is most likely explained by the clearer appearance of the healthy tissue, which could be due to a reduced influence of perfusion effects. The rather poor rating of $ADC_{all}$ is attributed to the low contrast between prostate and surrounding tissue. In conclusion, we have found the combination of one high and one low b-value (b≠0) in the calculation of the ADC maps to be the most suitable for diagnostic evaluation.

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**References** [1] M.Haider et al., AJR 2007;189:323. [2] N. deSouza et al., Clin Radiol 2008;63:774. [3] J. Kim et al., Korean J Radiol 2009;10:535.