Performance of High b-Value DWI in identifying high risk prostate cancer patients

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Target audience: Radiologist and Researchers working on diffusion MRI and prostate cancer MRI.

Purpose: Multi-parametric MRI (MPMRI) plays an integral role in the detection and localization of prostate cancer [1]. ADC maps obtained from mono-exponential modeling of diffusion weighted imaging (DWI) have been shown to detect prostate cancer [2] and also correlate with tumor aggressiveness [3]. However, at high b-value (b>800mm/s^2), signal from tumor tissue does not follow the mono-exponential diffusion decay thereby affecting the repeatability and reproducibility of ADC obtained from high b-value DWI. The underlying histopathology suggests that at high b-value DWI only high grade tumors will retain its signal due to restricted diffusion. Therefore, radiologic consensus meeting for prostate cancer such as PI-RADS, recommend evaluation of not only the ADC values from DWI with b-values up to 800s/mm^2, but also high b-value (b>800s/mm^2) DWI for PCa detection [4,5]. Few studies have tested the diagnostic accuracy of a specific or a pair of high b-values in DWI for the detection of PCa [6,7,8]. However, to date, there has been no study on the predictive power of the high b-value DWI in stratification of patients with high risk prostate cancers. Therefore, we aim to determine the performance of high b value DWI for distinguishing high risk patients in with prostate cancer lesions in the PZ and to test how the performance of this approach changes at higher SNR.

Methods: This study was approved by the institutional review board (IRB) and was compliant with the Health Insurance Portability and Accountability Act (HIPAA). Informed consent was obtained from each patient. MPMRI with multi-b-value DW-MR images were acquired in 17 patients with suspected lesions identified from standard MPMRI and these lesions were biopsied using TRUS/MRI fusion guidedance. MRI images were obtained using a 3T clinical MR scanner (Achieva 3.0T-TX, Philips Healthcare, Best, NL) with the anterior half of a 32-channel SENSE cardiac coil (Invivo; Gainesville, FL, USA) and an endorectal coil (BPX-30, Medrad, Pittsburgh, PA, USA). Multi-b-value DWI along with MPMRI consisted of tri-planar T2 weighted MRI, regular axial DWI, regular high b-value DWI and axial DCE-MRI were acquired. Regular DW-MRI scan was obtained with b=0, 188 350, 563 and 750 s/mm^2 (TE=52ms; TR=4873ms; spatial resolution 1.25×1.25×2.73mm^3 5 min total data acquisition time), regular high b-value DW-MRI scan was obtained with b=0, 1000 and 2000 s/mm^2 (TE=52ms; TR=7184ms; acquisition time = 102sec for b>0) and multi b-value scan was obtained with 16 b-values even spaced between 0-2000 s/mm^2 (TE=58ms; TR=3990ms; acquisition time = 24 sec for b>0).

Region of interests (ROIs) identified on MPMRI were retrospectively drawn on a single slice of b=0 DWI of regular high b-value DWI, multi-b-value DWI using T2*contrast and on standard ADC maps. Whole PZ over the same slice was also marked using MIPAV (Medical Image Processing, Analysis, and Visualization; National Institutes of Health, Bethesda MD, USA). MATLAB (The MathWorks, Inc., Natick, MA) was used to perform image and statistical analysis. Mean ADC values over the tumor ROI were computed. ADC and multiple DWI images in regular high b-value DWI and multi-b-value DWI dataset were also analyzed by computing the contrast between tumor and whole PZ. Contrast over images was calculated from the following equation: $C = (I_{tumor} - I_{PZ}) / I_{PZ}$. I_{tumor} is the mean intensity of the tumor ROI and I_{PZ} is the mean intensity of the PZ ROI without tumor ROI.

The tumors were classified as high and low grade cancer by CAPRA scoring system which is commonly used to determine eligibility of prostate cancer patients for active surveillance [9].

The receiver operating characteristic curves (ROCs) were obtained for separating high from low grade prostate cancer within the PZ for each b-value by varying the threshold. Area under the curves (AUCs) were obtained from ROCs using the trapezoidal method.

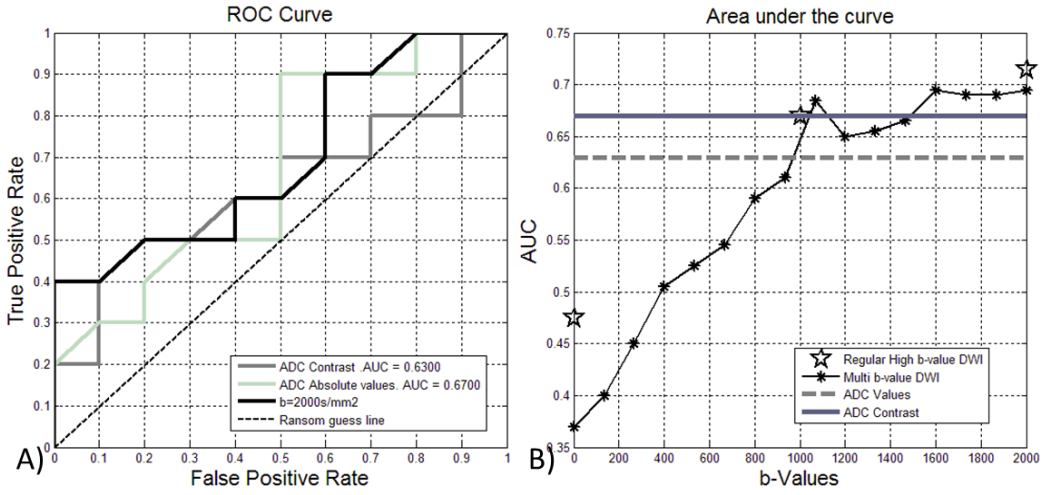

***Figure1**: Receiver operating characteristic (ROC) analysis (A) and area under the curve (AUC) (B) of PZ for high versus low grade PCa. ROC curve shown at b = 1333.33 s/mm^2 for the PZ (A). AUC is shown in the black starred line for the 16 different b-values in PZ (B). AUCs for ADC absolute values and contrast (dark and light grey lines) are also shown for the purpose of comparison.*

Results: 20 tumors (n=7 Gleason 6(3+3), n=8 Gleason 7(3+4), n=1 Gleason 7(4+3), n=1 Gleason 8(4+4), and n=3 Gleason 9(4+5) tumors) were identified by TRUS/MRI fusion guided biopsy in 17 patients. The ROC for the ADC maps obtained from standard DWI when absolute ADC values were used to identify high grade tumors (ADC absolute) and when contrast in ADC values (ADC contrast) from the background PZ is used are shown in Figure 1a). Higher AUC from the ADC absolute value (dark grey line) was observed with a value of 0.6700 than from the ADC contrast (light grey line) that had a value of 0.6300. A sample ROC curve is also shown at b = 2000s/mm^2 in Figure A (black solid line) as well as the random guess line (black dashed line). AUC improved to 0.6700 and 0.7150 for b=1000 and 2000 s/mm2 DWI, respectively at higher SNR. Figure 1b) shows the AUC for the regular high b-value DWI (stars) and multi-b-value DWI (dark line) in addition to the AUCs for the ADC absolute values (dark grey line) and ADC contrast (light grey line).

Discussion and Conclusion: High b-value DWI has been used to identify high grade cancer in prostate MRI. The performance of high b-value DWI was measured as AUC for separating high grade tumors from low grade tumors using the contrast between the tumor and background tissue in peripheral zone of the prostate. In this preliminary study (17 patients and 20 biopsy identified tumors), it is found that the performance of high b-value DWI increases with the increase in b-value. However, after b=800s/mm^2, there was marginal improvement in the performance with the increase of b-values. The performance of high b-value DWI did not increased significantly with the increase in SNR. Further study with a larger number of patients is warranted.

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