High b-value Diffusion Weighted MRI for Prostate Tumor Staging

Harsh K Agarwal[1,2], Kinzya Grant[2], Baris I Turkbey[2], Yuxi Pang[3], Marcelino Bernardo[2,4], Julien Sénégas[5], Dagane Daar[2,4], Junaita Weaver[2,4], Jochen Keupp[5], Maria J Merino[6], Bradford Wood[7], Peter A Pinto[8], and Peter L Choyke[2]

[1]Philips Research North America, Briarcliff Manor, NY, United States, [2]Molecular Imaging Program, NCI, National Institute of Health, Bethesda, MD, United States, [3]Philips Healthcare, Cleaveland, OH, United States, [4]SAIC Frederick Inc., Frederick, MD, United States, [5]Philips Research Laboratories, Hamburg, Germany, [6]5Laboratory of Pathology, NCI, National Institute of Health, Bethesda, MD, United States, [7]NIH Center for Interventional Oncology, National Institute of Health, Bethesda, MD, United States, [8]Urologic Oncology Branch, National Institute of Health, Bethesda, MD, United States

Purpose: Apparent Diffusion Coefficient (ADC) estimated from single compartment analysis of Diffusion weighted (DW) MRI has been successfully used in prostate oncology to identify and stage the tumor aggressiveness with its Gleason score and Clinical risk scores such as D'Amico [1,2]. Recent studies demonstrate the existence of multi-compartment diffusion nature of the tumor tissue which becomes more apparent in DW images at higher b values such as b=1000s/mm² providing good contrast between the tumor and the normal prostate tissue [3, 4, 5]. At higher b values DW-MRI image, the signal from fast decaying compartment of the normal tissue and even faster decaying compartment of the tumor tissue had disappeared and only the signal from slowly decaying compartment of the tumor tissue remain generating DW images with almost dark normal tissue and bright tumor tissue. In the absence of commonly agreed multi-compartment model for prostate tissue, we aim to qualitatively and quantitatively compare the high b value (b=1000 and 2000 s/mm²) DW-MRI images with ADC obtained from mono-exponential DW-MRI images with lower b values (b=0,188,350,563 and 750 s/mm²).

Methods: Multi-parametric MRI image with high b-value DW-MRI images were acquired for 55 consecutive patients with confirmed tumor in post MRI guided trans-rectal ultrasound (TURS) biopsy. 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. 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-element cardiac phased array surface coil and a single channel endorectal coil (BPH-30 Medrad, Pittsburgh PA). Multi-parametric MRI consist of two axial DW-MRI scans with 26 slices and FOV=140x140mm²,
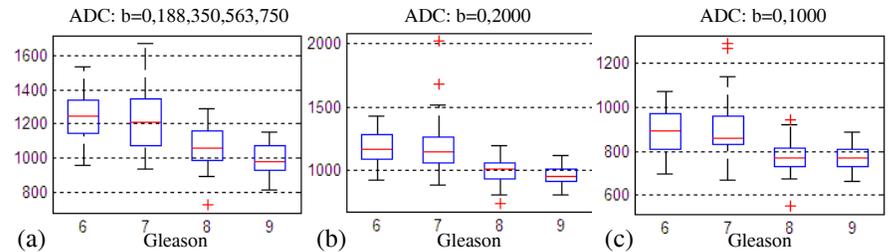

Figure 1: Box whisker plots of ADC values obtained using (a) regular DW-MRI (b)b=0 and 2000s/mm², and (c) b=0 and 2000s/mm² for Gleason grading of the tumor
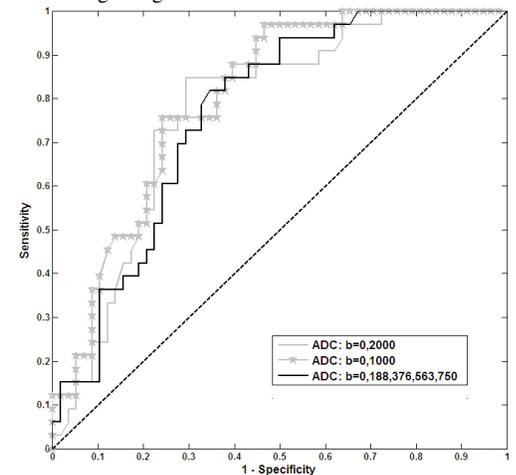
regular DW-MRI scan was obtained with b=0, 188 350, 563, 750 s/mm²(TE=51ms; TR=5010ms; spatial resolution 1.25×1.25×2.73mm3, slice gap = 0.27mm, NSA = 3,3,3,6,6) and high b value scan was obtained with b=0, 1000 and 2000 s/mm² (TE=51ms; TR=7036ms; spatial resolution 1.75×1.75×2.73mm², slice gap = 0.27mm, NSA = 1,5,5). Regions of interest (ROIs) were drawn on b=0s/mm² DW-MRI images by two readers. Two ROI's were drawn for each tumor, first ROI was drawn to contour entire perceived lesions on the central tumor axial slice and second ROI was drawn in the contralateral side of the same slice over the homogeneous normal appearing prostate tissue as an internal reference.

The mean ADC value of all ROI was obtained using regular DW-MRI scan, b=0 and 1000 s/mm², and b=0 and 2000 s/mm². Spearman correlation coefficients between the three ADC values and Gleason grading of tumor were also obtained. The receiver operating characteristics (ROC) was obtained for separating from low Gleason prostate tissue, i.e. Gleason 6 and 7, and high Gleason prostate tissue, i.e. Gleason 8 and 9, by varying the threshold to separate the two Gleason groups. The contrast to noise ratio (CNR) in two high b-value DW-MRI images and three ADC maps for each tumor was calculated by first subtracting the mean quantity from the contralateral normal ROI by that from the tumor ROI, then dividing it by the standard deviation of quantity in the contralateral normal ROI. Paired-wise student's t-test was used to compare the pair of CNR.

Results: 91 tumors (25 Gleason 6, 33 Gleason 7, 24 Gleason 8 and 9 Gleason 9 tumors) were identified in 55 patients by MRI guided TRUS biopsy. As seen in box-whisker plots in Figure 1, the ADC maps obtained from regular DW-MRI scan, b=0 and 1000 s/mm² and, b=0 and 1000 s/mm² are correlated with Gleason grading of the tumor with comparable spearman correlation coefficient of -0.4618, -0.5074 and -0.4571 respectively. As seen from the ROC curve in Figure 2, the ADC from b=0 and 1000 s/mm² is

Figure 2: ROC curve for separating low Gleason (6 and 7) from high Gleason (8 and 9) graded tumors.

better with comparable performance of ADC from regular DW-MRI and b=0 and 2000s/mm² DW-MRI. The CNR for the five quantities is shown in Table 1. The CNR in b=2000 s/mm2 is better than that in b=0,1000 s/mm² DW-MRI with p-value = 0.01 and no statistically significant difference was found between any pair of the CNR values (with sign correction for ADC values).

Discussion and Conclusion: In the absence of mutually agreed multi-compartment model of diffusion at high b value DW-MRI the simple quantities such as ADC from b=0 and 1000s/mm² and ADC from b=0 and 2000s/mm² is shown to have similar quantitative performance in terms of CNR and tumor Gleason staging as that of the ADC from regular DW-MRI scans.

Quantity	b=2000 s/mm² DW-MRI	B=1000 s/mm² DW-MRI	ADC: b=0,2000 s/mm²	ADC: b=0,1000 s/mm²	ADC: b=0, 188, 350, 562 and 750 s/mm²
CNR	5.5±7.1	3.0±6.3	-5.6±4.1	-6.0±5.9	-4.5±4.7

Table1: CNR between tumor and contralateral normal prostate tissue for different images estimated from DW-MRI.

However, qualitatively high b-value DW-MRI has an advantage complete background suppression which is helpful in identifying the tumors near the edge of the prostate tissue.

References:

[1] Turkbey B, et al. Radiology. 2011;258(2):488-495. [2] Vargas HA, et al. Radiology. 2011;259(3):775-784 [3] Katahira K, et al. Eur Radiology. 2011;21(1):188-196 [4] Kitajima K, et al. JMRI. 2012;36(1):198-205 [5] Metens T, et al. Eur Radiology. 2012;22(3):703-709