

Improved Conspectuity and Delineation of High-Grade Prostate Tumors Using “Restriction Spectrum Imaging”: Quantitative Comparison with High B-Value ADC

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INTRODUCTION: Recently, enhanced diffusion techniques called restriction spectrum imaging (RSI) have been utilized to identify glioblastoma multiforme brain tumors (1). By optimizing the signal from the spherically restricted diffusion pool and attenuating the signal from all other diffusion pools, the signal from tightly packed tumor cells can be enriched. The output from these techniques has been termed the tumor ‘cellularity map’ (CM). By isolating the spherical restricted compartment from the cylindrically restricted and hindered compartments, RSI-CM provides significantly greater accuracy in distinguishing brain tumor from normal appearing white matter when compared with conventional imaging measures. Based on its prior ability to discriminate between brain tumors and adjacent normal tissue with high accuracy and high signal to noise, we hypothesize that RSI-CM will perform similarly in prostate tissue. Here, we evaluate RSI-CMs derived from the spherically-restricted water compartment for improved prostate tumor conspicuity and delineation from non-tumor tissue compared with high b-value ADC.

METHODS: RSI was performed in 5 pre-surgical patients with IRB approval: Gleason scores on final pathology specimens ranged from 3+4=7 to 4+5=9. Post prostatectomy whole mount sections were contoured for tumor by an experienced genitourinary pathologist. Conventional DWI data were collected at $b = 100, 400,$ and 800 s/mm². Multidirectional DWI data were collected at $b = 800, 1500,$ and 4000 s/mm² and corrected for spatial distortion as performed previously in the brain (1,2). All imaging was performed with an endorectal coil. Tumor conspicuity in RSI-CMs was qualitatively compared to conventional low b-value ADC maps, high b-value ADC maps and dynamic contrast enhancement K^{trans} maps generated through iCAD VersaVue software. Z-score maps were generated for purposes of quantification of tumor conspicuity from RSI-CM and high b-value ADC data and compared. Z-score maps were generated based on manually drawn ROIs of tumor and normal appearing prostate using the contoured whole mount sections as a guide. Receiver operating characteristic curves were used to evaluate the sensitivity and specificity of RSI-CM versus high b-value ADC for delineating tumor from normal-appearing prostate.

RESULTS: Significantly greater tumor conspicuity was seen with RSI-CMs compared with all other imaging maps. We have shown one representative case (Figure 1). Tumor is qualitatively more conspicuous on RSI-CMs when compared to K^{trans} maps, conventional ADC maps or high b-value ADC maps. In this example there was no visible increased perfusion on the K^{trans} map. The tumor is not conspicuous in the conventional low b-value ADC map, which shows severe spatial distortion (not uncommon in echo planar imaging without spatial distortion correction techniques). The tumor is not easily seen in the high b-value ADC maps but is readily apparent in the RSI-CMs. Quantitatively (Figure 2), Z-score plots show significantly greater mean Z-scores for RSI-CM (Z-score of ~3) versus high b-value ADC (less than 0.5). Greater sensitivity and specificity for delineating tumor from normal-appearing prostate were seen with RSI-CMs (AUC = 0.97) compared with high b-value ADC (AUC = 0.64).

CONCLUSION: These preliminary data suggest that RSI-CMs offer improved conspicuity and delineation of high-grade prostate tumors when compared with high-b-value ADC.

DISCUSSION: Distinguishing indolent disease from aggressive disease is a major concern in prostate cancer detection. Multiple studies have shown that DWI improves sensitivity and specificity in the diagnosis of prostate cancer by increasing tumor conspicuity on quantitative ADC maps. However, hemorrhage, inflammatory processes and benign nodules in the transitional zone can all exhibit lower ADC values leading to false positives (3). DWI can also suffer from severe spatial distortion limiting its co-registration to anatomic images, which is necessary for tumor localization. As previously shown in the brain and now preliminarily in prostate tissue, we show that by optimizing the signal from the spherically restricted diffusion pool and attenuating the signal from all other diffusion pools, the signal from tightly packed tumor cells can be enriched, leading to greater tumor conspicuity. These data support the feasibility of a fast 15 minute non-invasive imaging test (without IV contrast or an endorectal coil) that could accurately discriminate between aggressive tumors and benign tissue or indolent disease.

REFERENCES: (1) White et al., AJNR, epub Nov 8, 2012; (2) Holland et al., Neuroimage 50, 175-183, 2010; (3) Yoshimitsu et al., J Magn Reson Imaging 27, 132-139, 2008.

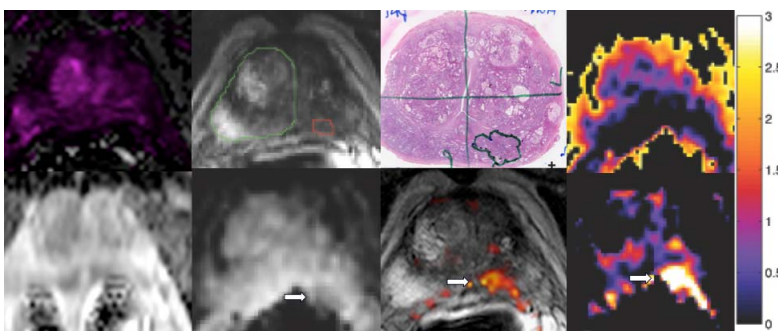


Figure 1: Clockwise from top left; K^{trans} , T2 with ROIs (green is normal appearing prostate and red is tumor), whole mount path, Z-score map high b-value ADC, Z-score map RSI-CM, RSI-CM thresholded and overlaid on T2, high b-value ADC map, conventional ADC map (note severe spatial distortion).

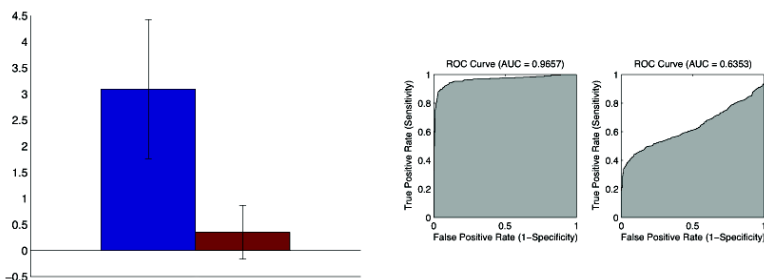


Figure 2: (left) Mean Z-score with standard deviation for 5 patients. Blue showing RSI-CM and red showing high b-value ADC. (right) ROC curves showing RSI-CMs on the left (AUC = 0.97) and high b-value ADC on the right (AUC = 0.64).