Diffusion Tensor Imaging and MR Spectroscopic Imaging of Prostate Cancer

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Introduction: Magnetic resonance spectroscopic imaging (MRSI) has been shown to provide important metabolic information which improves the MRI detection and characterization of prostate cancer (1,2). Prior to therapy, prostate cancer can be metabolically discriminated from healthy prostate tissues based on a significant reduction in citrate and polyamine levels and an increase in choline containing compounds (1,2). Specifically, a choline+creatine/citrate ratio ≥ three standard deviations of healthy values has demonstrated high specificity in detecting prostate cancer and the magnitude of this ratio has correlated with cancer aggressiveness (1,2). Recently, diffusion MRI has been shown to also detect significant differences between cancer and normal prostatic tissues (3-5). Prostate cancer has demonstrated a significant reduction in the directionally-averaged apparent diffusion coefficient (D_{av}) relative to healthy tissues (3). Non-distorted diffusion weighted prostate images can be acquired in three minutes using the DTI-SSFSE method (3), thereby allowing the addition of diffusion weighted MRI to clinical MRI/MRSI prostate cancer staging exams. The addition of higher spatial-resolution diffusion data to metabolic data should further increase the accuracy of prostate cancer detection and characterization. However to date, the relationship between abnormal metabolite levels and reduced D_{av} in regions of prostate cancer has not been determined. The goal of this study was to investigate this relationship in 26 prostate cancer patients using the concordance of biopsy and anatomic MRI results to identify regions of healthy and malignant prostate tissues.

Methods: All studies were performed on a 1.5 tesla scanner (Signa; GE Medical System) using the body coil for RF transmission and a disposable endorectal coil (Medrad, Pittsburgh, PA) in combination with a pelvic phased array coil for signal reception. The DTI-SSFSE sequence was previous described (3). The DT-SSFSE images were acquired in 3 minutes in oblique-axial plane with a FOV=18cm, 128x128 matrix, 1.4x1.4mm in-plane resolution, 4mm slices, rbw=62.5Khz, b-value=600, TE=67ms, with typically 7-9 slices covering the prostate. The DTI-SSFSE sequence was added to 26 MRI/MRSI exams of prostate cancer patients. The MR protocol consisted of FSE sagittal scouts, T1 axial SE images covering to the aortic bifurcation, fast spin echo T2 oblique-axial and coronal high resolution images, and 3D MRSI data acquired with a spatial resolution of 0.3cc (7mm per side).

All data was analyzed off-line using software developed at our institution. D_{av} maps were calculated and compared to MRI/MRSI data. Specifically, D_{av} values were correlated with the choline+creatine/citrate ratio for regions of healthy peripheral zone tissue and prostate cancer. Regions of prostate cancer were identified as regions having a positive biopsy (by sextant) and a clear-cut low T_2 signal intensity on MRI as assessed by an experienced radiologist, while regions of healthy peripheral zone tissue was identified as a region of high T_2 signal intensity and a negative biopsy. A total of 116 cancerous ROIs and 78 healthy ROIs from the 26 patients were included in the study. All ROIs chosen were completely within the prostate peripheral zone to avoid partial voluming with capsule and central gland. D_{av} maps were overlaid on the MRSI data and D_{av} values were calculated for both cancerous ROIs and healthy ROIs.

Results and Discussions: The (choline+creatine)/citrate ratio has been shown to be highly specific for detection of prostate cancer and provide insights into the aggressiveness of tumor (1,2). When D_{av} values from the cancerous ROI were compared with CC/C ratios, a significant negative correlation between them were found ($P<0.0001$). As the CC/C values increased, the D_{av} values decreased (Figure 1). Similar correlation was also found in the healthy ROIs ($P<0.0001$). In prostate cancer, the loss of citrate metabolism and increase in membrane synthesis and cell density (more choline metabolism) resulted in higher CC/C ratio. The densely packed tumor cells also lead to a decrease in D_{av}. In the healthy regions where prostate morphology is dominated by prostatic ducts, high citrate concentration in the ducts resulted in low CC/C ratios while the large extracellular space represented in this ductal tissue leads to higher D_{av}.

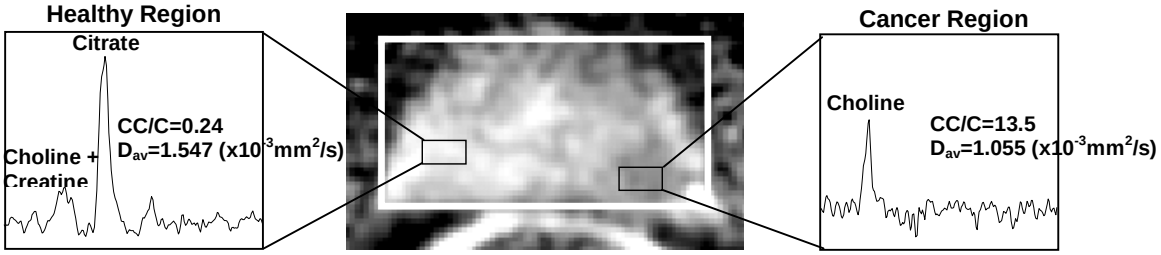

Figure 1. Non-distorted D_{av} map acquired with DTI-SSFSE allowed MRSI data to be correlated directly with DTI data. In the cancer region, lower D_{av} was associated with a high CC/C ratio; and in the healthy region, higher D_{av} was associated with a lower CC/C ratio. Notice the much higher spatial resolution offered by DTI compared to MRSI.

Conclusion: A significant correlation was observed between D_{av} measured by DTI-SSFSE and metabolite ratios measured by MRSI in both malignant and healthy prostatic tissues. Lower D_{av} was significantly ($p<0.0001$) associated with higher CC/C ratio and vice versa. These findings indicate that the two methods provide complementary information for the identification and characterization of prostate cancer with MRSI providing highly specific metabolic information and DTI providing high spatial resolution micro-structural assessments. Therefore, a combined MRSI/DTI-SSFSE approach may significantly improve the radiological assessment of this common and often deadly cancer.

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Reference:

[1] Kurhanewicz J, et al. Neoplasia. 2000; 2 (1-2):166-189
[2] Coakley FV, et al. J. of Urology. 2003; 170:S69-S76.
[3] Vigneron D, et al. ISMRM Abstracts, 2002; p457.
[4] Gibbs P. et al. Magn. Reson in Med. 2001; 46:1054-1058.
[5] Issa B, J of Magn. Reson. Imaging 2002; 16:196-200.