High Resolution Diffusion Tensor Imaging in Prostate Cancer

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Introduction

With increasing incidence, prostate cancer is one of the most common forms of malignancy in men. Recently, magnetic resonance imaging (MRI) has been applied to the detection of prostate cancer [1]. It has been shown that the trace apparent diffusion coefficient (tADC) values were significantly lower in prostate tumor than in normal peripheral zone tissues. Although attempts of applying diffusion tensor imaging (DTI) technique to differentiating tumor tissues from normal ones has been sought after, the calculated fractional anisotropy (FA) index and fiber tracking results remain inconspicuous [2]. In this study, endorectal coils were used to acquire high resolution, high signal-to-noise (SNR) DTI images on twenty seven patients who had biopsy proven prostate cancer. FA and tADC values were calculated for the benign peripheral zone (PZ) and cancerous tissues. The aim of the study was to examine the correlations between tADC and FA values amongst benign and tumor tissues and to assess the feasibility of using high resolution DTI technique in identifying prostate cancer.

Materials and Methods

Twenty seven male patients (55-75 years; average, 64 years; median, 63 years) with intermediate PSA levels (mean: 9.7 ng/ml) were recruited in the study. For each patient diffusion tensor MRI (DTI) and subsequent TRUS biopsy were performed within two weeks. MR images were acquired on a 1.5T scanner (GE, Echo Speed, Milwaukee, WI, USA) with an endorectal coil. DTI was acquired using spin-echo echo planar imaging (EPI) with multiple transaxial slices of the prostate from base to apex. Imaging parameters: TR/TE=17000/79ms; slice thickness=1mm; in-plane resolution=1mm x 1mm; NEX=6; six diffusion-sensitive gradients at {±1,0,1}, {0,1,±1},{±1,1,0} with b=500 s mm^{-2}. Region of interest (ROI) was chosen at the locations with pathological proved cancerous tissues and paired benign tissues. Average tADC was determined by calculating the mean of the eigenvalues of the diffusion tensor and FA was determined as equation (1) at each ROI.

$$FA = \sqrt{\frac{3}{2}} \frac{\sqrt{(\lambda_1 - \langle D \rangle)^2 + (\lambda_2 - \langle D \rangle)^2 + (\lambda_3 - \langle D \rangle)^2}}{\sqrt{(\lambda_1 + \lambda_2 + \lambda_3)^2}} \qquad (1),$$

where λ1, λ2, and λ3 are the eigenvalues of the tensor and the symbol $\langle D \rangle$ is the mean. Correlation analysis was performed between tADC and FA on tumor and paired benign tissues, respectively. The statistical processing was carried out using the program for Graphpad PRISM, version 5.01. A P<0.001 was considered statistically significant.

Results

Among 27 patients, a total of 30 prostatic carcinomas and 30 paired benign tissues with pathologically proved localizations were analyzed. Figure 1 showed the tADC map and FA map of one patient. The tADC showed significantly lower values in tumors (0.89±0.18 μm^2/ms) than in benign peripheral zone (1.98±0.18μm^2/ms) ($p < 0.001$) and the FA showed significantly higher values in tumors (0.37±0.09) than in benign peripheral zone (0.16±0.04) ($p < 0.001$) (Figure 2). In Figure 3, tADC and FA in tumors showed a significant correlation with $r = -0.719$ ($p < 0.001$), but the correlation was not significant in benign tissues ($p = 0.082$).

Discussion and Conclusions

Our results showed both tADC and FA values were significantly different between tumor and benign tissues. Considering image qualities, the tADC maps offer better morphological judgments than FA maps. In addition, tADC and FA values exhibit a high negative correlation in cancerous tissues but not in normal peripheral zone tissues. These findings imply that the proliferation of adenocarcinoma hinders water molecule diffusion. Although our FA values in PZ (0.16± 0.04) was fairly close to that in previous reports (between 0.15 to 0.16) [2-4], none of the previous studies had reported the increased FA values in cancerous tissues. The formation of glandular configurations in cancerous tissues is expected to be the cause of the heightened FA values. In conclusion, this study shows the feasibility of identifying prostate cancers from normal tissues using high resolution DTI technique.

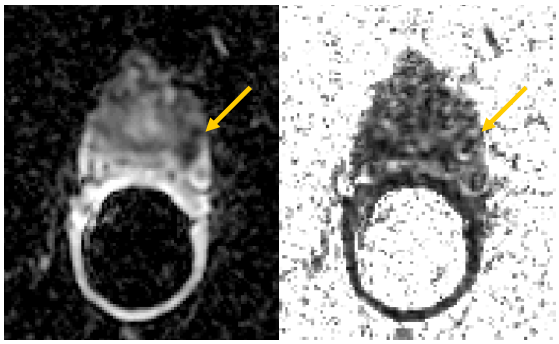

Figure 1. The left image shows the tADC maps in one patient with 1mm slice thickness. The right image shows the FA map at the same location. The yellow arrows show the tumor region confirmed by TRUS-biopsy.

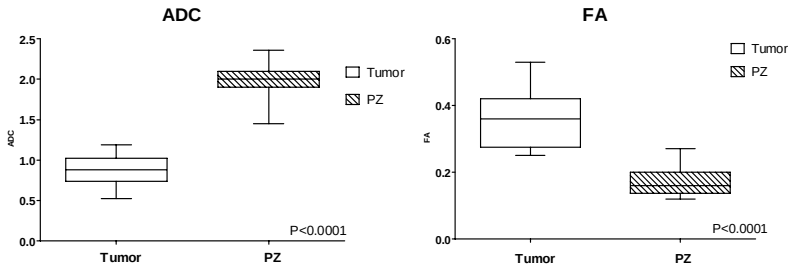

Figure 2. Statistical ADC and FA values in tumor tissues and benign PZ tissues.

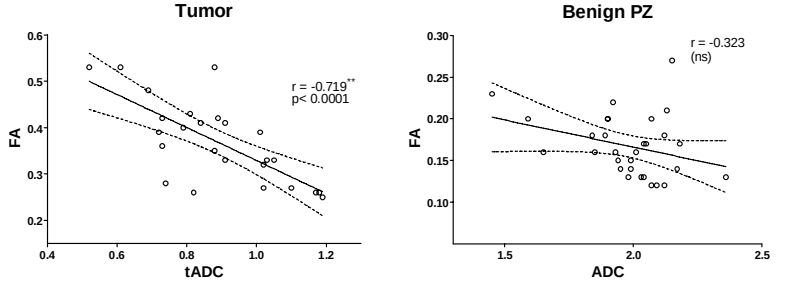

Figure 3. Correlation analysis between tADC and FA values in tumor tissues and benign PZ tissues.

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