Quantitative Estimation of Prostate Cancer using Inner Product of Intervoxel Eigenvector (IPIE) Method

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INTRODUCTION

Prostate cancer is one of the most frequent cancers in a male malignant tumor. To confirm the diagnosis, an invasive needle biopsy is necessary. MR techniques provide the possibility of adding information for an accurate diagnosis before the needle biopsy. Diffusion tensor imaging (DTI) of the body can be used to detect malignant tumors, as it was reported that malignant tumors tend to show lower apparent diffusion coefficient (ADC) values than benign tumors [1]. However, significant differences cannot be seen with fractional anisotropy (FA) value in prostate cancer from DTI [2]. ADC and FA use only eigenvalues from DTI information. Eigenvectors have been used to neuroimage as MR tractography for investigating brain structures [3]. Similar to the brain, it might be applicable to the estimation of structures of the prostate. It is suspected that the structure will show deformities if prostate cancer exists. We propose the quantitative evaluation method, inner product of intervoxel eigenvector (IPIE) method, to assess changes of the structural tissue from eigenvectors of DTI, and evaluated the value of the prostate cancer before and after the carbon-ion radiotherapy (CIRT).

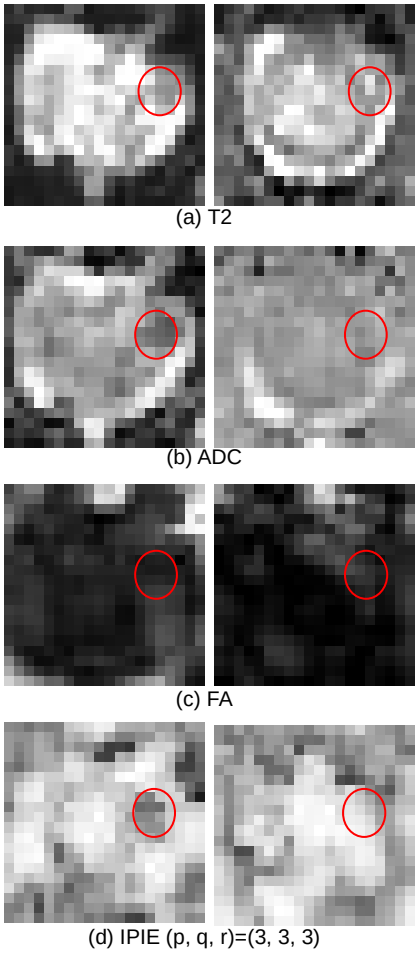
MATERIALS AND METHODS

Nine patients with prostate cancer were analyzed. Data is partially overlapped with the previous paper [2]. Diagnosis was confirmed by needle biopsy. All Patients underwent CIRT. All MR examinations were performed on a Philips Gyroscan Intera 1.5T or Intera Achieva 1.5T Nova Dual with an 8 channel phased-array receiver coil before CIRT. Follow-up studies were done for all patients from three to nine months after CIRT. MR diffusion weighted imaging protocols were as follows: single-shot EPI with SENSE, TR = 2761 ms, TE = 96 ms, SENSE factor = 2, slice thickness = 2.5 mm, slice gap = 0.5mm, field of view 35 x 35 cm, matrix size = 128 × 128, motion probing gradient (MPG) of 6 axes, b-factor = 0 and 700 s/mm2, Number of excitation = 4. The same sequences were also used for the follow-up studies.

The diffusion ellipsoid in prostate tissue was anisotropic and approximated a prolate model [4]. An organization of the normal prostate is symmetric and concentric circles structure, but the structure is deformed by prostate cancer. To evaluate local structural deformity, IPIE value was calculated by equation (1).

$$IPIE(x,y,z)=\sum_{i=-p/2}^{p/2}\sum_{j=-q/2}^{q/2}\sum_{k=-r/2}^{r/2}\{\mathbf{V}(x+i,y+j,z+k)\cdot\mathbf{V}(x,y,z)-1\}/\,pqr \qquad (1)$$

The coordinates x, y, and z direction represent read-out, phase-encoding, and slice direction, respectively. **V** (x, y, z) is the first eigenvector at (x, y, z), (p, q, r) is filter size. In this paper, (3, 3, 0), (5, 5, 0), (3, 3, 3), (5, 5, 5) are used for (p, q, r). Changes in ADC, FA, IPIE values on prostate cancer before and after CIRT were assessed. A paired t-test was used to analyze the changes in values after CIRT. The P value < 0.01 was considered significant to avoid type 1 errors in multiplicity.



(a) T2

(b) ADC

(c) FA

(d) IPIE (p, q, r)=(3, 3, 3)

Fig.1 T2, ADC, FA, and the inner product of intervoxel eigenvector (IPIE) images.
The region of interest (red lines) show prostate cancer. Left : before CIRT, right : after CIRT

RESULTS AND DISCUSSION

Images of T2, ADC, FA, and IPIE method, (p, q, r) = (3, 3, 3) are showed in Fig. 1. ADC values of prostate cancer increased significantly after CIRT (Fig. 2a, P<0.01, paired t-test) but there was no significant change in FA (Fig. 2b). In IPIE method values, (p, q, r) = (3, 3, 3) size is the most significantly increased after CIRT by paired t-test (Fig. 2c, P<0.01). It is able to show changes in the prostatic structure. This change could indicate structural improvement in the tumor.

CONCLUSION

In this research, to assess changes of the tissue structure due to prostate cancer, we propose the IPIE method using eigenvectors of DTI. The IPIE values are significantly changed in the prostate cancer region before and after CIRT. These results suggest the changes of the structural tissue, caused by prostate cancer, are quantitatively evaluated using the IPIE method.

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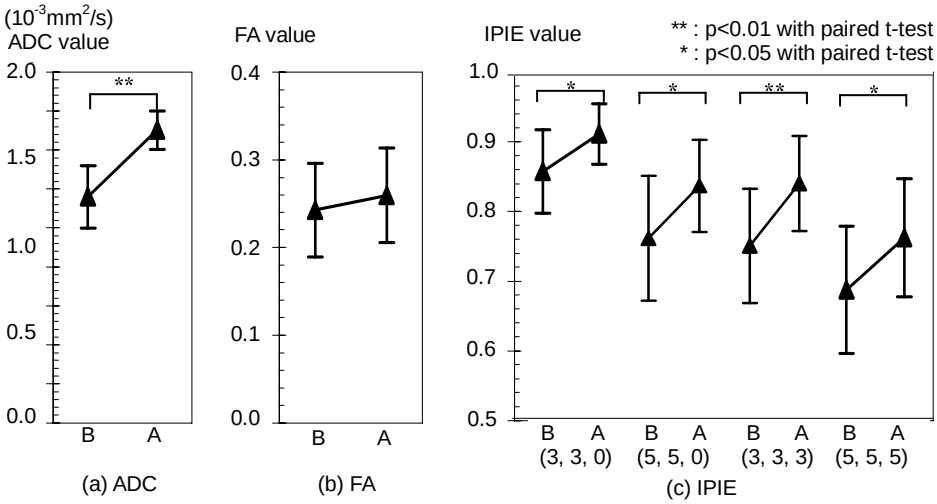

(a) ADC (b) FA (c) IPIE

Fig.2 ADC, FA, and the inner product of intervoxel eigenvector (IPIE) value on prostate cancer before and after CIRT.
B is before and A is after CIRT. In the IPIE method (c), four filter sizes are applied: (p, q, r) = (3, 3, 0), (5, 5, 0), (3, 3, 3), and (5, 5, 5).