Triexponential function analysis on diffusion-weighted MRI in diagnosing prostate cancer

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Introduction:
Intravoxel incoherent motion (IVIM) model has been reported to separate extravascular molecular diffusion and microcirculation of blood within the capillaries (perfusion) with a biexponential decay utilizing low b-values [1, 2]. At high b-values, on the other hands, a biexponential analysis differentiates between fast and slow diffusion component, which could represent extracellular free diffusion and intracellular restricted diffusion, respectively [3, 4]. Thus, using both low and high b-values, it is expected that triexponential function analysis would reveal three diffusion components in biological tissue. Tissue perfusion has been evaluated with dynamic contrast enhanced (DCE)-MRI applying pharmacokinetic analysis and intra- and extracellular components can be assessed only with histopathological specimens. The objective of our study is to evaluate the clinical usefulness of triexponential function analysis of diffusion-weighted MRI for the prostate cancer in the peripheral zone (PZ) with reference to the histopathological findings and pharmacokinetic parameters on DCE-MRI.

Materials and Methods:
This study was approved by the institutional review board (IRB) and was performed only after informed consent was obtained from each patient. 24 patients (mean age, 64.0±6.58 years) with biopsy-proven prostate PZ cancer underwent preoperative prostate MRI at 3.0-T unit including multiple b-values DWI with 8 steps of b-values of 0, 50, 100, 200, 500, 1000, 2000, and 3000s/mm². Regions of interest (ROIs) were placed to analyze triexponential function for cancerous and non-cancerous lesion by referencing histopathological results. A contralateral PZ in PZ cancer was served as normal. Triexponential function analysis was performed to derive perfusion-related, fast free, and slow restricted diffusion coefficients (Dp, Df, Ds), as well as fractions (Fp, Ff, Fs). Moreover, the results of triexponential function analysis were compared to those of bi- and monoexponential function analyses. Each diffusion parameter for normal PZ and cancerous lesions was compared by Wilcoxon signed-rank test. The ratio of extra- and intracellular component for cancerous lesions measured with the histopathological specimens and Ktrans and Ve calculated with DCE-MRI were compared to diffusion parameters using the Pearson correlation.

Results:
All diffusion parameters obtained are summarized on Table 1. Dp was significantly greater in cancerous lesions than normal PZ (P < 0.05), and Ds was significantly smaller in cancerous lesions (P < 0.01). There was no significant difference in Df between cancerous lesions and normal PZ (P = 0.35). Dp showed significant correlation to Ktrans (Fig. 1), while Ff was significantly correlated with Ve (Fig. 2). Fs was significantly correlated with intracellular space fraction evaluated with histopathological specimens (Fig. 3).

Conclusion:
Triexponential analysis can provide more detailed information on perfusion and diffusion of prostate cancer noninvasively, and makes it possible to assist in the diagnosis of prostate PZ cancer. Moreover, our findings suggested that the reduction of ADC in PZ cancer would be due to the decrease of Ds that reflects intracellular restricted diffusion.

Reference: