Intravoxel Incoherent Motion MR Imaging on Prostate Cancer

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Introduction

Intravoxel incoherent motion (IVIM) MR imaging[1], developed more than 20 years ago mainly for neurological applications, has attracted renewed attention in body MR imaging in recent years[2-3]. The IVIM method has the potential to separate perfusion from pure diffusion in DWI studies without use of any contrast agents. DWI-derived perfusion (active blood microcirculation) information is intrinsically linked with angiogenesis in aggressive tumor growth, thus, it is not unrealistic to expect that different perfusion patterns would be found in prostate tumors in comparison to normal tissues. In this retrospective study, we have analyzed 22 DWI data sets from patients with prostate cancers, and found significant increases in IVIM-related perfusion in tumors.

Methods & Materials

All measurements were performed on a 3T Philips MRI scanner (Philips Healthcare**,** Best, NL) with a combined SENSE cardiac and an endorectal coil (Medrad, Indianola, PA). After three orthogonal (axial/coronal/sagital) high-resolution T2-weighted scans, an axial diffusion-weighted imaging (DWI) scan was acquired using a single-shot spin-echo EPI sequence. Five b-values (b = 0, 188, 375, 563,750 s/mm^2) of diffusion-sensitive gradients were applied during data acquisitions and high b-values images (b = 563 and 750 s/mm^2) were acquired twice to increase S/N. To avoid fold-over artifacts, a SENSE factor of 2 (plus an over-sampling factor of 2) was employed along phase encoding (RL) direction. The other relevant acquisition parameters were TR/TE of 4243/57 (ms), FOV (AP/RL/FH) of 160,180 and 60 mm and the corresponding acquired voxel size of 1.25*1.25*3.0 mm^3, EPI factor of 73, half scan factor of 0.73, number of scan average (NSA) of 4 and the total scan duration of 5.5 min. All patients (N=22) had transrectal ultrasound (TRUS) guided biopsy-proven prostate cancers characterized by their Gleason scores (GS), and lesion malignancy was further classified as either high grade (GS > 4+3, N=10) or low grade (GS < 3+4, N=12). On the semi-log plot of pixel signal intensity (s) vs. b-values ($\log(s/s_0) = -b*ADC + \log(1-f)$), the apparent diffusion coefficient (ADC) was fitted (by nonlinear least-squares method) as the slope on four b-values images (without b = 0 s/mm^2), the fitted data was then extrapolated to obtain the intercept ($\log(1-f)$), which gave the value of perfusion fraction (f). On each patient DWI, two ROIs were carefully drawn (by one experienced radiologist) on the tumor and non-tumor region, respectively, and the corresponding average and standard deviation (SD) values of ADC and f within the ROI were recorded for further statistical analysis. The visualization and analysis of DWI data was carried out in in-house written IDL software (ITT Visual Information Solutions, Boulder, CO).

Results & Discussion

Figure (a) shows the T2W image from one patient (ID#20) where the lesion was located in the right peripheral zone (PZ) as indicated by a yellow arrow, and the same region was highlighted with a green dashed line in the corresponding histopathology image. Two ROIs were drawn as shown in Figure (b) in the tumor and contra-lateral normal tissue region, and the signal decay due to different diffusion-sensitive gradients was modeled as a linear equation on the semi-log plot (see insets), with the fitted slope and intercept representing ADC and perfusion fraction (f), respectively. The tumor perfusion fraction (f) was higher than from the normal tissue region in 20 of 22 patients, see figure (c), suggesting that active growing tumor had higher microvasculature density and possible high blood flow. The statistical analysis for all patients showed that the mean of perfusion fraction (f) in tumor regions was significantly ($P < 0.01$) higher than that from normal tissues (7.9% +/- 3.2% vs. 4.7% +/- 2.2%). There was no significant difference for perfusion fraction (f) between high-grade (N=10) and low-grade (N=12) tumors (data not shown). Figure (d) shows the distribution of ADC and perfusion fraction (f) from both tumor and normal tissue regions in all patients. It is indisputable that the mean of ADC in tumor regions was significantly ($P < 0.01$) lower compared with that from normal regions (0.933 +/- 0.258 vs. 1.732 +/-0.355 10^{-3} mm^2/s), which is consistent with the published results on prostate tumors[4]. In summary, we have shown that perfusion fraction (f) obtained from DWI study was significantly higher in tumors than in normal tissues, making it a possible surrogate biomarker and a potential additional MRI parameter for accurate diagnosis of prostate cancer.

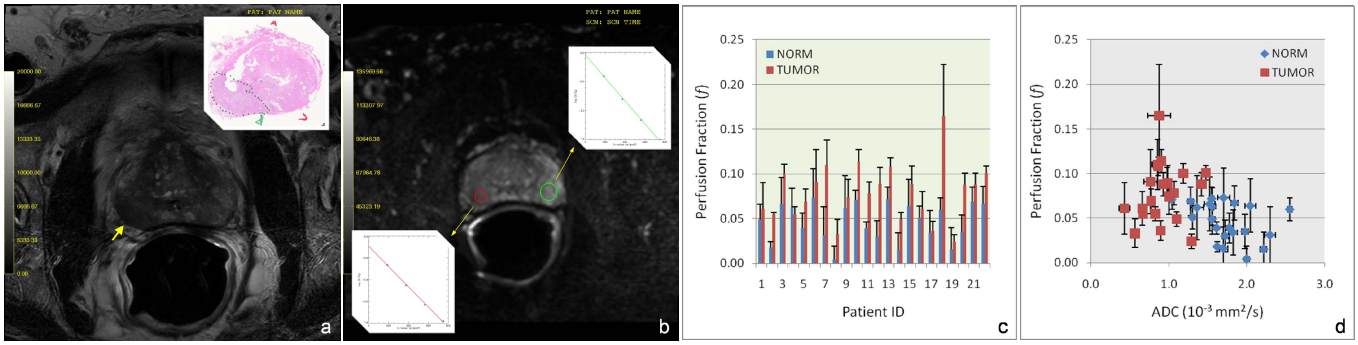

Figure (a-d): (a) T2W image with histopathology image inset, the lesion in right peripheral zone is indicated by yellow arrow (T2W) and dashed green line (inset); (b) DWI image (b = 0 s/mm^2), where red and green circles indicating representative ROIs in tumor and normal tissue regions and insets showing the corresponding curve fittings in semi-log plot; (c) Comparison of perfusion fraction (f) in tumor and normal tissue regions in each patient ; and (d) Scatter plot of ADC and perfusion fraction (f) within ROIs in tumor and normal tissues for all patients.

References

(1). Le Bihan D, et al. Radiology 1988; 168: 497-505. (2). Luciani A, et al. Radiology 2008; 249 (3): 891-899. (3). Riches SF, et al. NMR in Biomedicine 2009; 22(3): 318-325. (4). Xu J, et al. MRM 2009; 61: 842-850.