Optimum Spatial Resolution and Number of Averages of Diffusion Tensor Imaging in Prostate Cancer Detection

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Abstract

This study aimed to investigate the diagnostic performance of trace apparent diffusion coefficient (tADC) maps in prostate cancer (PCA) detection at different spatial resolutions and number of averages (NAV), and to determine a practical protocol that could provide satisfactory diagnostic performance for PCA detection. The tADC maps were reconstructed into three different isotropic resolutions, i.e. 1 mm, 2 mm and 3 mm. For each resolution there were three different NAVs, i.e. 2, 4, and 6 averages. The diagnostic performance of tADC maps for each data set was determined by comparing with the TRUS biopsy results core by core. We found that the voxel size of $(2\ mm)^3$ with two number of averages showed satisfactory diagnostic performance. Acquisition time for this protocol was around 4 to 5 minutes and could be a practical tool for PCA detection.

Introduction

Magnetic resonance (MR) diffusion imaging has been applied to the detection of prostate cancer [1]. Recently we have shown that trace apparent diffusion coefficient (tADC) value was significantly lower in prostate cancer (PCA) than that in normal peripheral zone tissue, and that 1-mm isotropic tADC maps were feasible for PCA detection [2]. To obtain tADC maps at 1-mm isotropic resolution, however, requires multiple averages to attain sufficient SNR, inevitably prolonging the scanning time. In this study, nine combinations of image resolution and number of averages of diffusion-weighted images (DWI) were investigated. By comparing with transrectal ultrasound guided (TRUS) biopsy results, we aimed to determine a practical protocol that could provide satisfactory diagnostic performance for PCA detection.

Materials and Methods

Fifteen male patients (57-74 years; average, 63 years; median, 63 years) with elevated prostate specific antigen (PSA, mean: 9.7 ng/ml) were recruited. They received endorectal MRI study followed by TRUS biopsy within one month. MR images were acquired on a 1.5T scanner (GE, Echo Speed, Milwaukee, WI, USA). Diffusion tensor imaging (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 = 17000/79 ms; slice thickness = 1mm; slice gap = 0, in-plane resolution = 1mm x 1mm; six diffusion-sensitive gradients at {±1,0,1}, {0,1,±1},{±1,1,0} with b = 500 s mm^{-2}; number of averages (NAV) = 6. The acquired DWI images were reconstructed into three different isotropic resolutions, i.e. 1 mm, 2 mm and 3 mm. For each resolution there were three different NAVs, i.e. 2, 4, and 6 averages. The DWI data sets were entitled as D_{12}, D_{14}, D_{16}, D_{22} D_{24}, D_{26}, D_{32}, D_{34}, and D_{36}, where D_{ij} represented the data set with isotropic resolution = i mm and NAV = j. TRUS biopsy was performed by sampling 12 cores systemically in the prostate gland, from right lateral, right medial, left medial to left lateral aspects at three levels at base, mid and apex. For image analysis, the peripheral zone of the prostate was identified and categorized into 12 regions as those in the TRUS biopsy. Trace ADC was determined by calculating the mean of the eigenvalues of the diffusion tensor. According to our previous work, a tADC value of 1.0 $\mu m^2/ms$ was used as a threshold for PCA detection [2]. The diagnostic performance of tADC maps for each data set was determined by comparing with the TRUS biopsy results core by core.

Results

In a total of 180 cores, 39 cores in 7 patients were found to contain PCA in pathological results. Figure 1 shows tADC maps of one patient derived from 9 DWI data sets. The positive nodules (indicated by arrows) are those detected based on tADC < 1.0 $\mu m^2/ms$. One can see that as the resolution decreased, the number of positive nodules also decreased. Table 1 shows the diagnostic performance of nine data sets with nine different combinations of image quality. The best diagnostic accuracy was found in the data sets at 2-mm resolution, with little improvement as NAV increased.

Discussion and Conclusions

In this study, we have compared diagnostic performance of PCA detection among nine DWI data sets with different combinations of image quality, three spatial resolutions and three NAVs. From Fig. 1, the tADC positive nodules decrease with the voxel sizes. This can be explained by the partial volume effect. Increased NAV could reduce the number of positive nodules on tADC maps especially at 1-mm resolution. High NAV used at 1-mm resolution, however, would prolong the acquisition time and lead to higher failure rate and more motion artifacts. Comparing with the TRUS biopsy results (Table 1), we can see that as NAV increases, false positive nodules decrease but false negative nodules increase. Although the data set at 3-mm resolution has better signal-to-noise ratio, it does not help in increasing the sensitivity under the condition of inadequate spatial resolution. To conclude, higher NAV yields higher specificity whereas smaller voxel sizes yield higher sensitivity. In this study, the voxel size of $(2\ mm)^3$ with two number of averages showed satisfactory diagnostic performance. This protocol only requires 4~5 minutes acquisition time and could serve as a practical tool for PCA detection.

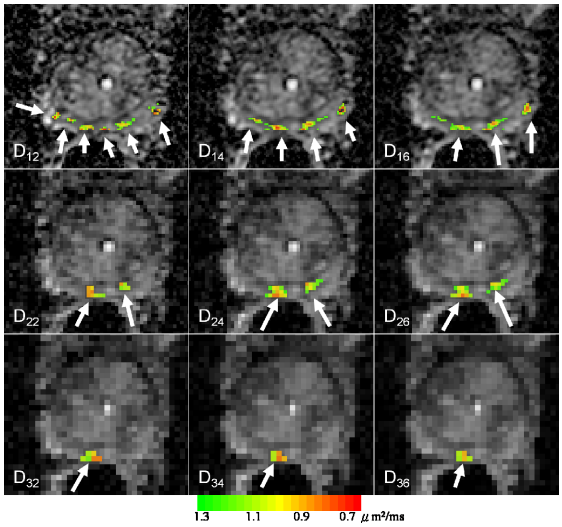

Fig.1 Positive nodules (yellow arrows) with quantitative tADC value of less than 1.0 $\mu m^2/ms$ rendered from 9 data sets of DWI with different combinations of spatial resolution and number of averages.

	True positive	False positive	False negative	True negative	Sensitivity	Specificity	PPV	NPV	Accuracy
D_{12}	39	55	0	86	100%	61%	41%	100%	69%
D_{14}	38	40	1	101	97%	72%	49%	99%	77%
D_{16}	38	27	1	114	97%	81%	58%	99%	84%
D_{22}	36	24	3	117	92%	83%	60%	98%	85%
D_{24}	36	24	3	117	92%	83%	60%	98%	85%
D_{26}	36	23	3	118	92%	84%	61%	98%	86%
D_{32}	29	20	10	121	74%	86%	59%	92%	83%
D_{34}	29	20	10	121	74%	86%	59%	92%	83%
D_{36}	28	19	11	122	72%	87%	60%	92%	83%

Table 1 The results of 9 imaging resolution levels using tADC value of 1.0 $\mu m^2/ms$.

References

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