Computed High b-value DWI for Detection of Prostatic Cancer at 3-Tesla MRI

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Introduction: Diffusion weighted MR imaging (DWI) with high b-values over 1000 s/mm^2 is reported to be useful for prostate cancer (PCa) detection, because it provides better contrast between cancerous and background tissue than DWI with a standard b-values (1,2). However, increase of b-values causes several problems; such as poor signal-to-noise ratio (SNR), and severe eddy current distortions from the large diffusion-sensitizing gradients used, which compromise the image quality of DWI. Computed DWI (cDWI) is a recently proposed computational technique that produces any b-value images from DWI acquired with at least two different b-values (3,4). As high b-value images could be mathematically calculated from acquired DWI with lower b-values, disadvantages associated with direct high-b-value measurements may be avoided. Under the above-mentioned situation, we hypothesized that the cDWI with a high b-value has equal to or better potential for PCa detection than the original DWI with direct measurement of high b-values. The aim of our study was therefore to evaluate the ability of cDWI at b=2000 s/mm^2 ($cDWI_{2000}$) calculated from directly measured DWI (mDWI) with b=0 and 1000 s/mm^2 for PCa detection as compared with mDWI at b=1000 ($mDWI_{1000}$) and b=2000 s/mm^2 ($mDWI_{2000}$) on a 3T MR system.

Materials and Methods: 80 patients (age ranged from 50 to 77 years old) with biopsy-proven PCa underwent preoperative T2-weighted imaging (T2WI) and DWI (b=0, 1000, 2000 s/mm^2) on a 3T MR system. Computed DWI at b=2000 s/mm^2 ($cDWI_{2000}$) were calculated from mDWI with b=0 and 1000 s/mm^2 using the mono-exponential model. Contrast ratio (CR) between cancerous and non-cancerous lesions was evaluated on each DWI by means of ROI measurements with referencing results of pathological examination using following formula: $CR = (SI_{ca} - SI_{non\text{-}ca})/(SI_{ca} + SI_{non\text{-}ca})$, where the SI_{ca} and $SI_{non\text{-}ca}$ are the averages of the signal intensity in the cancerous or non-cancerous lesions. CR of $cDWI_{2000}$, $mDWI_{1000}$, and $mDWI_{2000}$ were compared by means of the Tukey-Kramer's test. To assess diagnostic performance of each DWI, two radiologists independently evaluated the following four sets of images: T2WI alone, T2WI+$mDWI_{1000}$, T2WI+$mDWI_{2000}$, and T2WI+$cDWI_{2000}$ to assign a likelihood of the presence of cancer in eight regions of the prostate using a five-point scale (1=definitely not cancerous, to 5=definitely cancerous). Receiver operating characteristic (ROC) analyses were performed for comparison of diagnostic performance and determination of feasible threshold values. Sensitivities, specificities and accuracies of all four protocols were compared with each other by means of McNemar's tests. P-values less than 0.05 were considered significant for all statistical analyses.

Results: The representative case is shown in Figure 1. The CR of $cDWI_{2000}$ (0.29±0.16) was significantly higher than that of $mDWI_{2000}$ (0.21±0.11, $p<0.05$) and $mDWI_{1000}$ (0.12±0.07, $p<0.01$). The Results of ROC analysis is shown in Figure 2. Area under the curves (Azs) of the combined T2WI and $cDWI_{2000}$ and the combined T2WI and $mDWI_{2000}$ were significantly greater than those of the T2WI alone and the combined T2WI and $mDWI_{1000}$ ($p<0.05$). The sensitivity of the combined T2WI and $cDWI_{2000}$ was significantly better than that of the T2WI alone ($p<0.05$). The specificity and accuracy of the combined T2WI and $cDWI_{2000}$ were significantly better than those of the T2WI alone and the combined T2WI and $mDWI_{1000}$ ($p<0.05$). However, when compared to the combined T2WI and $mDWI_{2000}$, the differences were not significant.

Conclusion: $cDWI_{2000}$ has better potential for detection of PCa than $mDWI_{1000}$, and considered at least as valuable as $mDWI_{2000}$ in this setting.

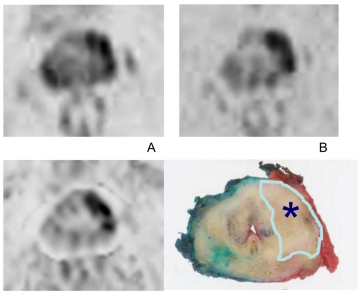

Figure 1. 66-year-old PCa patient with Gleason score of 4+3=7 PCa, pT3a, initial PSA of 10.5ng/ml
Measured DWI with b=1000 (A) shows diffuse abnormal signal intensity in the bilateral PZ. Both measured DWI with b=2000 (B) and computed DWI with b=2000 (C) demonstrate abnormal signal in the left PZ and TZ, whereas the right PZ shows normal signal intensity. Pathological specimen (D) confirms PCa only in the left lobe of PZ and TZ (asterisk area).

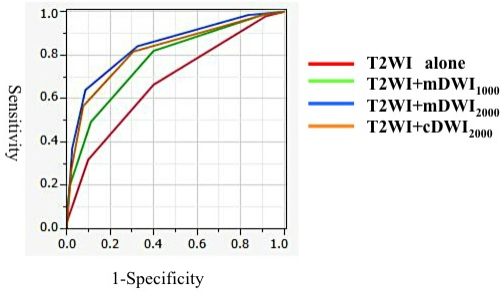

Figure 2. ROC curves of four protocols for PCa diagnosis
Azs of the combined T2WI and $mDWI_{1000}$ (Az=0.77), the combined T2WI and $mDWI_{2000}$ (Az=0.84) and the combined T2WI and $cDWI_{2000}$ (Az=0.81) were signiifcantly higher than that of T2WI (Az=0.67, $p<0.05$).

Table 1. Diagnostic performances of each protocol

	Sensitivity(%)	Specificity(%)	Accuracy(%)	PPV(%)	NPV (%)
T2WI alone	69	61.5	65.1	63.1	67.4
	(216/313)	(201/327)	(417/640)	(216/341)	(201/298)
T2WI+mDWI$_{1000}$	85.3*	63.0	73.7*	67.9	82.9
	(267/313)	(205/327)	(472/640)	(267/393)	(205/247)
T2WI+mDW$_{I2000}$	87.5*	68.5 *.**	77.8 *.**	72.7	85.1
	(274/313)	(224/327)	(498/640)	(274/377)	(224/263)
T2WI+cDWI$_{2000}$	87.2 *	75.9 *.**	77.5*.**	73.2	83.0
	(266/313)	(230/327)	(496/640)	(266/363)	(230/277)

* Significant difference with T2WI alone ($p<0.05$).
**Significant difference with T2WI+$mDWI_{1000}$ ($p<0.05$)

References:
1. Ueno Y, et al. JMRI. 2012 (In press).
2. Kitajima K, et al.JMRI. 2012;36(1):198-205.
3. Blackledge et al., Radiology. 2011; 261,2:573-581.
4. Kimura et al. proc. of 20th ISMRM: pp3574