Computed Diffusion-Weighted MR Imaging for Prostate Cancer Detection: Optimization of b-Value Combinations for Generating High b-Value Images.

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Introduction: Computed DWI (cDWI) is a recently proposed computational technique that produces any b-value images from DWIs acquired with at least two different b-values (1). It is reported that cDWI at b=2000 s/mm^2 generated from DWIs with b=0 and 1000 s/mm^2 achieved a diagnostic ability for prostate cancer (PCa) comparable to a real acquired DWI at b=2000 s/mm^2 (2). However, it remains unclear which combination of b-values is optimal for generating high-b-value images. We hypothesize that appropriate b value selection for cDWI can improve image quality and detection capability on cDWI as compared with actual DWI with ultra-high b value. The aim of our study was therefore to determine the appropriate b-value combination for generating cDWI at b=2000 s/mm^2 to improve pPCa detection, when compared with actual DWI at b=2000 s/mm^2 ($aDWI_{2000}$) on a 3T MR system.

Materials and Methods: 31 consecutive pathologically diagnosed PCa patients (mean age, 65 years) underwent DWI obtained at four different b-values (0, 500, 1000, 2000 s/mm^2) at 3T MR system before surgical treatment. The histopathological findings revealed 121 PCa-positive sites and 127 PCa-negative sites. Then, cDWIs at b=2000 s/mm^2 were generated from the following four b-value combinations: 1) between 0 and 500 s/mm^2; $cDWI_{0-500}$, 2) between 0 and 1000 s/mm^2; $cDWI_{0-1000}$, 3) between 100 and 1000 s/mm^2; $cDWI_{100-1000}$, and 4) between 500 and 1000 s/mm^2; $cDWI_{500-1000}$, respectively.

For qualitative comparison of image quality among all cDWIs and $aDWI_{2000}$, image quality of each DWI images was assessed by 5-point visual scoring system. To determine the contrast resolution for each DWI as quantitative assessment, contrast ratios (CR) between PCa and non-PCa sites were calculated. To compare the detection capability among all DWIs, the probability of presence of PCa at each site was assessed by 5-point visual scoring system. For evaluation of qualitative image quality among all DWIs, each image quality score was compared among all DWIs by using Tukey's HSD test. To assess contrast resolution on all DWIs, CRs were compared each other by means of Turkey's HSD test. To detremine the feasible threshold value for detection, ROC analyses were performed. Finnaly, sensitivity, specificity and accuracy of each DWI were compared by using McNemar's test. A p value less than 0.05 was considered as signiifcant on each statistical analysis.

Results: Representative case is shown in Figure 1. Image quality score of $cDWI_{0-500}$ was significantly lower than that of other DWIs ($cDWI_{0-500}$: 3.3±0.7; $cDWI_{0-1000}$: 4.2±0.3; $cDWI_{100-1000}$: 4.2±0.4; $cDWI_{500-1000}$: 4.0±0.6 and $aDWI_{2000}$: 4.1±0.3). CRs of each cDWI ($cDWI_{0-500}$: 0.53±0.2; $cDWI_{0-1000}$: 0.45±0.2; $cDWI_{100-1000}$: 0.47±0.2 and $cDWI_{500-1000}$: 0.49±0.1) were significantly higher than that of $aDWI_{2000}$ (0.32±0.1, p<0.05). Area under the curve (Az) of $cDWI_{0-500}$ (Az=0.66) was significantly smaller than that of others ($cDWI_{0-1000}$: Az=0.72, p<0.05; $cDWI_{100-1000}$: Az=0.73, p<0.05; $cDWI_{500-1000}$: Az=0.79, p<0.05; $aDWI_{2000}$: Az=0.75, p<0.05). When applied each feasible threshold value, accuracy of cDWI500-1000 (71.3%) was significantly higher than that of $cDWI_{0-500}$ (64.1%, p<0.05), $cDWI_{100-1000}$ (69.0%, p<0.05) and $aDWI_{2000}$ (69.0%, p<0.05). (Table 1)

Conclusion: $cDWI_{500-1000}$ had better diagnostic specificity and accuracy than $cDWI_{0-500}$ and $aDWI_{2000}$, and demonstrated high image quality and contrast resolution.
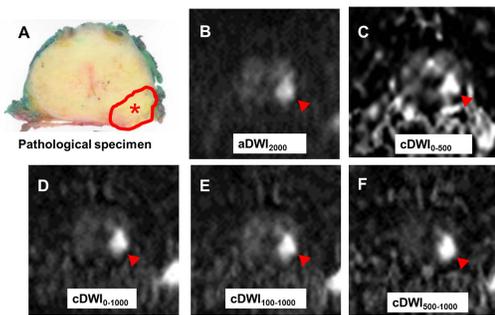
Figure 1.
68-year-old PCa patient with Gleason score of 4+3=7 PCa, pT3a, initial PSA of 6.8ng/ml
Pathological specimen (A) confirms PCa in the left lobe of PZ (asterisk area). Abnormal signal intensity (arrow head) was shown in the left lobe of PZ on $aDWI_{2000}$ (B), $cDWI_{0-500}$ (C), $cDWI_{0-1000}$ (D), $cDWI_{100-1000}$ (E) and $cDWI_{500-1000}$ (F).
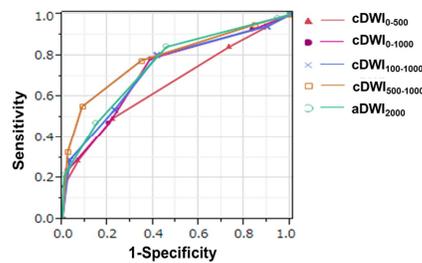
Figure 2.
ROC curves of five protocols for PCa diagnosis
Az of cDWI $_{0-500}$ was significantly lower than that of other DWIs (p<0.05).

Table 1. Results of comparison of diagnostic performance among all methods.

	Sensitivity	Specificity	Accuracy	PPV	NPV	Az
$cDWI_{0-500}$	49.5% (60/121)	78.0% (99/127)	64.1% (159/248)	68.2% (60/88)	61.9% (99/160)	0.66*
$cDWI_{0-1000}$	78.5%* (95/121)	61.4%* (78/127)	69.8%* (173/248)	66.00% (95/144)	75.00% (78/104)	0.72*
$cDWI_{100-1000}$	80.2%* (97/121)	58.3%* (74/127)	69.0%* (171/248)	65.00% (97/150)	75.60% (74/98)	0.73*
$cDWI_{500-1000}$	77.7%* (94/121)	65.3%* (83/127)	71.3%*,*** (177/248)	68.10% (94/138)	75.40% (83/110)	0.79*,**,***
$aDWI_{2000}$	84.3%*, **, **** (102/121)	54.3%*,**, **** (69/127)	69.0%*, **** (171/248)	63.80% (102/160)	78.40% (69/88)	0.75*

*: Significant difference with $cDWI_{0-500}$ (p<0.05), **: Significant difference with $cDWI_{0-1000}$ (p<0.05), ***: Significant difference with $cDWI_{100-1000}$ (p<0.05), ****: Significant difference with $cDWI_{500-1000}$ (p<0.05). PPV: positive predictive value, NPV: negative predictive value, Az: area under the ROC curve

References:
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2. Ueno Y. et al. European Radiology. 2013: [Epub ahead of print] doi 10.1007/s00330-013-2958-z