High-Resolution Computed DWI with High b-Value: A Preliminary Study for Improving Prostate Cancer Detection at 3T MR System

Yoshiko Ueno[1], Satoru Takahashi[2], Yoshiharu Ohno[2,3], Katsusuke Kyotani[4], Masao Yui[5], Yoshimori kassai[5], Kazuhiro Kitajima[6], and Kazuro Sugimura[1]

[1]Department of Radiology, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, [2]Department of Radiology, Kobe University Graduate School of Medicine, Hyogo, Japan, [3]Advanced Biomedical Imaging Research, Kobe University Graduate School of Medicine, Hyogo, Japan, [4]Division of Radiology, Kobe University Hospital, Hyogo, Japan, [5]MRI Systems Development Department, Toshiba Medical Systems Corp, Tochigi, Japan, [6]Department of Radiology, Hyogo College of Medicine, Hyogo, Japan

Introduction: In the last decade, computed diffusion weighted imaging (cDWI) is proposed as a new technique that produces any b-value images from DWI acquired with at least two different b-values [1,2]. It is reported that a diagnostic ability for prostate cancer (PCa) of cDWI at b=2000 s/mm^2 generated from DWIs with b=0 and 1000 s/mm^2 was comparable to that of a real acquired DWI at b=2000 s/mm^2 [2]; cDWI was generated from acquired DWI (aDWI) with conventional voxel size. Recently, several reports suggested that high-resolution DWI of the prostate has potential to improve Pca depictability and diagnostic sensitivity [3,4]. However, signal-to-noise and contrast-to-noise ratios decrease on high-resolution DWI especially for that with high b-value. We hypothesized that cDWI with high b-value may provide good image quality and capability for detection of PCa, when its voxel size are reduced. Our aim was to assess the clinical utility of high-resolution cDWI (HR-cDWI) with high b-value for prostate cancer (PCa) detection at 3T by adding to really acquired DWI as compared with really acquired conventional high-resolution DWI.

Materials and Methods: Twenty patients with pathologically-proven PCa (65±5.6y) underwent prostate MRI at 3T system including T2WI (TR/TE 4000/130 ms; 0.7×0.7×3.0mm), DWI with conventional voxel size (TR/TE 7000/65ms; acquisiton voxel size 3.5×2.8×3.0mm; b-value 0, 2000 s/mm^2) and DWI with recuced voxel size (i.e. HR-DWI: TR/TE 7000/65ms; acquisiton voxel size 2.2×2.2×3.0mm; b-value 0, 800, 2000 s/mm^2). Computed HR-DWI at b=2000 s/mm^2 (HR-cDWI$_{2000}$) was generated from HR-DWIs at b=0 and 800 s/mm^2 according to the mono-exponential model. Aquired DWI at b=2000 s/mm^2 with conventional voxel size (aDWI$_{2000}$), HR-DWIs at b=800 and 2000 s/mm^2, (HR-aDWI$_{800}$, HR-aDWI$_{2000}$), and HR-cDWI$_{2000}$ were evaluated in this study. For qualititative image quality assessment, image quality on each DWI was evaluated by 5-point scoring system. For quantitative assessment of contrast between cancerous and non-cancerous lesions, contrast ratio (CR) between them on each DWI was measured. Then, image quality and CR were compared among all DWIs by Tukey-Kramer's test. To determine the capability of DWIs with adding T2WI for PCa detection, diagnostic capabilities of aDWI$_{2000}$ alone (protocol A), combined aDWI$_{2000}$ with HR-aDWI$_{800}$ (protocol B), combined aDWI$_{2000}$ with HR-aDWI$_{2000}$ (protocol C), and combined aDWI$_{2000}$ with HR-cDWI$_{2000}$ (protocol D) were compared by receiver operating characteristic analyses on a per site basis. Then, sensitivity, specificitiy and accuracy were compared each other by McNemar's test.

Results: Representative case is shown in Figure 1. For qualitative image quality assessment, HR-cDWI$_{2000}$ showed significantly higher image scale (3.6±0.5) than aDWI$_{2000}$, HR-aDWI$_{800}$, and HR-aDWI$_{2000}$ (aDWI$_{2000}$: 3.0±0.3, p=0.03, HR-aDWI$_{800}$: 3.1±0.1, p=0.04, HR-aDWI$_{2000}$: 3.2±0.5, p=0.04). For quantitative contrast assessment, CR of HR-cDWI$_{2000}$ (0.35±0.1) was significantly higher than that of other DWIs (aDWI$_{2000}$: 0.20±0.1, p=0.01, HR-aDWI$_{800}$: 0.08±0.01, p<0.0001, HR-aDWI$_{2000}$: 0.22±0.1, p=0.03). For assessment of diagnostic performance, area under the curve (Az) of protocol D (Az=0.79) was significantly larger than that of other protocols (A: Az=0.74, p=0.04, B: Az=0.74, p=0.04, C: Az=0.72, p=0.03). Furthermore, specificity of protocol D (88.0% [79/90]) was significantly higher than that of protocol A (66.0% [59/90] %, p=0.02). ROC curves are shown in Figure 2.

Discussion: To our knowledge, no published study has applied cDWI technique for high-resolution DWI. In this assessment in PCa patients, many measures relating to artifacts and anatomic clarity, and CR showed improvements when applying this technique for high-resolution DWI with high b-value. Generally, high-resolution DWI suffers from signal loss and several artifacts especially with high b-value. Computed DWI technique has potential to reduce such problems on high-resolution DWI with high b-value because it can generate high b-value images from low b-value images. In addition, the combination of HR-cDWI$_{2000}$, aDWI$_{2000}$, and T2WI could improve diagnostic specificity for PCa. It may be because HR-cDWI$_{2000}$ can provide high CR with high spatial resolution. Further research in clinical patients is needed to assess whether this benefit translates to improved tumor localization, as well as staging, especially in assessing the extra-prostatic extension (T3 disease).

Conclusion: HR-cDWI$_{2000}$ is useful for improving the diagnostic capability for PCa by adding to aDWI$_{2000}$ and T2WI due to its good image quality.

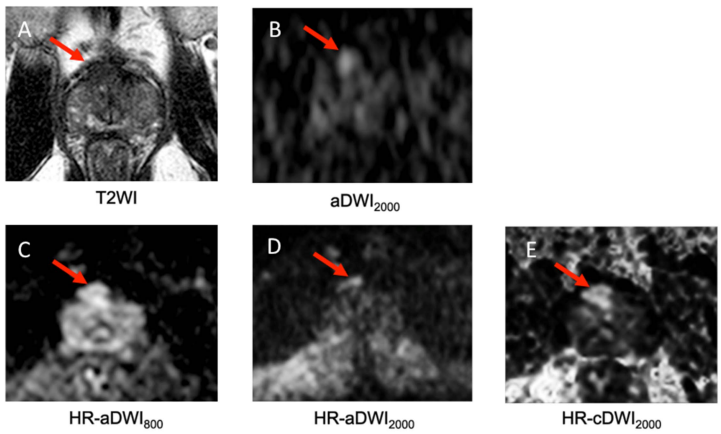

Figure 1: 67-years-old male with PSA 6.5 ng/ml. Pathological specimen (not shown) revealed a cancer in the right side of TZ.
A) T2WI, B) aDWI$_{2000}$: Abnormal signal in the right side of transitional zone (TZ) is suspious for cancer. **C)HR-aDWI$_{800}$:** Signal of prostate pharenchyma is not suppressed enough and the contrast between cancer and normal tissue is reduced. **D) HR-aDWI$_{2000}$:** Abnormal signal in the right side of TZ is weakend. **E) HR-cDWI$_{2000}$:** Abnormal signal in the right side of TZ is depectied clearly.

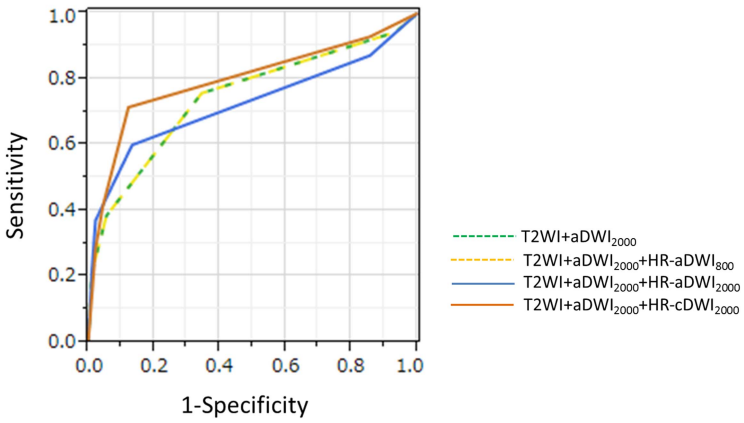

Figure 2: ROC curves ofeach protocol for PCa diagnosis.
The protocol using T2WI, aDWI$_{800}$, and HR-cDWI$_{2000}$ demonstrates the highest AZ.

References: 1. Blackledge M et al. Radiology. 2011; 261,2:573-581. 2. Ueno Y et al. Eur Radiol. 2013;23:3509-3516. 3. Metens T et al. Eur Radiol. 2012;22:703-9. 4. Medved M et al. AJR Am J Roentgenol. 2014; 203: 85-90.