Feasibility of shortening the scanning time for lumbar MRI using deep learning-based reconstruction

Nobuo Kashiwagi [1], *Yuichi Yamashita* [2], *Katsusuke Kyotani* [2], *Azusa Miura* [3], *Hiroto Takahashi* [4], *Hisashi Tanaka* [5], *Noriyuki Tomiyama* [6]

(1) Department of Future Diagnostic Radiology, Osaka University Graduate School of Medicine

(2) Canon Medical Systems Corporation

(3) Department of Radiology, Osaka University Graduate School of Medicine

(4) Center for Twin Research, Osaka University Graduate School of Medicine

(5) Department of Medical Physics and Engineering Division of Health Science, Osaka University Graduate School of Medicine

Background and Purpose

Since the first report by Zhang et al. [1], many deep learning-based denoising methods for brain MR imaging has been proposed [2–13] . Generally, MR images vary with differences in the scan protocol, field strength, and anatomical location, however, the applicability of these denoising methods to these variations has not yet been validated. For robustness against the variations, Kidoh et al. [14] proposed a denoising method using deep learning-based reconstruction (dDLR), which performs denoising in high-frequency components, while leaving low-frequency components containing the image contrast information.

The purpose of this study is to apply the proposed dDLR (AiCE Canon Medical Systems) trained by brain and knee 3T MR images to lumbar 1.5T MR images, and to validate its feasibility for shortening the scanning time.

Material and Methods *MRI data acquisition*

- Standard turbo spin-echo T2-weighted sequence with an acquisition time of 228 s, as used for clinical routine examination. (Standard)
- Accelerated T2-weighted sequence with an acquisition time of 68 s by reducing the number of excitations and applying compressed sensing. (Fast)
- Accelerated sequence with application of dDLR <AiCE canon>. (dDLR -Fast)

Parameter	Standard sequence	Fast sequence
TR/TE (ms)	3400/84	
Slice thickness (mm)	3	
FOV phase × read (mm)	300 × 270	
NEX	2	1
CS factor	None	1.8
Scan time (seconds)	228	68

NEX: number of excitations CS: compressed sensing

Material and Methods

- *Region-of-interests (ROIs)*

ROIs of 30 mm^2 were placed on the muscle,vertebra, disc, spinal cord, CSF, and fat.

- *Quantitative image analysis*

Nonuniformity (NU) value of tissue was calculated using the following formula [17] :

NU = SD/SI × 100 *NU: nonuniformity, SI: mean signal intensity , SD; standard deviation*

- *Qualitative image analysis*

Three independent neuroradiologists assessed perceived SNR, sharpness, contrast, delineation of the normal structures, artifact, and overall image quality using a 5-point scale. (1 = obviously inferior; 2 = slightly inferior; 3 = equivalent; 4 = slightly superior; 5 = obviously superior)

Results

- *Quantitative analysis*

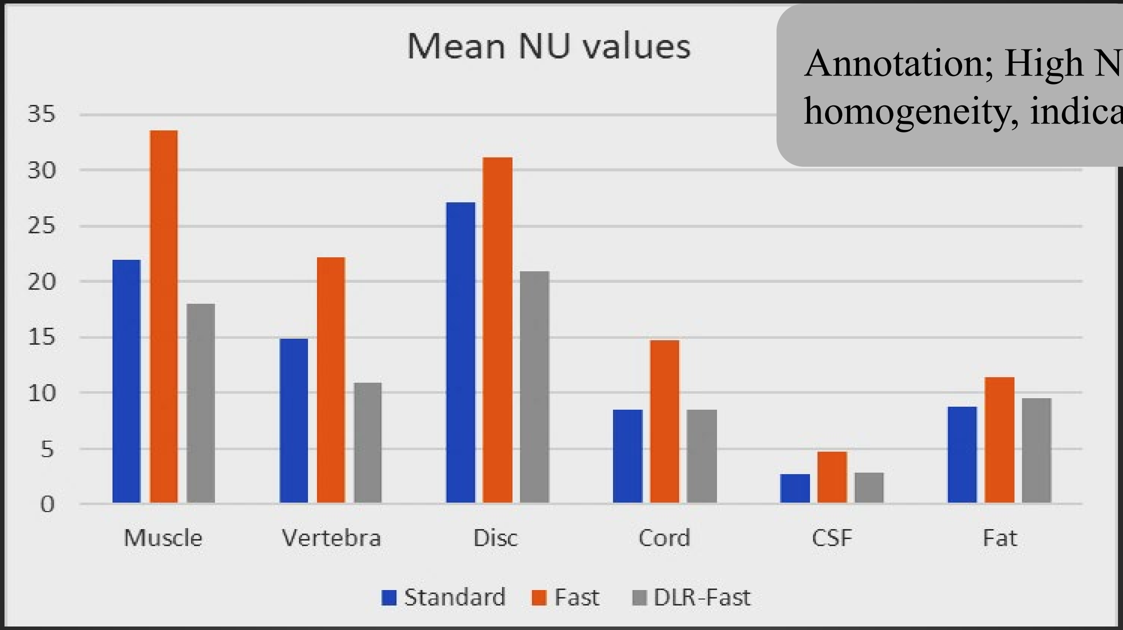
The NU values for the vertebrae on dDLR-fast was significantly lower than on Standard. The NU values for other tissues did not differ significantly between dDLR-fast and Standard, indicating a preservation of image uniformity on dDLR-FAST.

Annotation; High NU values reflect reduced signal homogeneity, indicating image degradation.

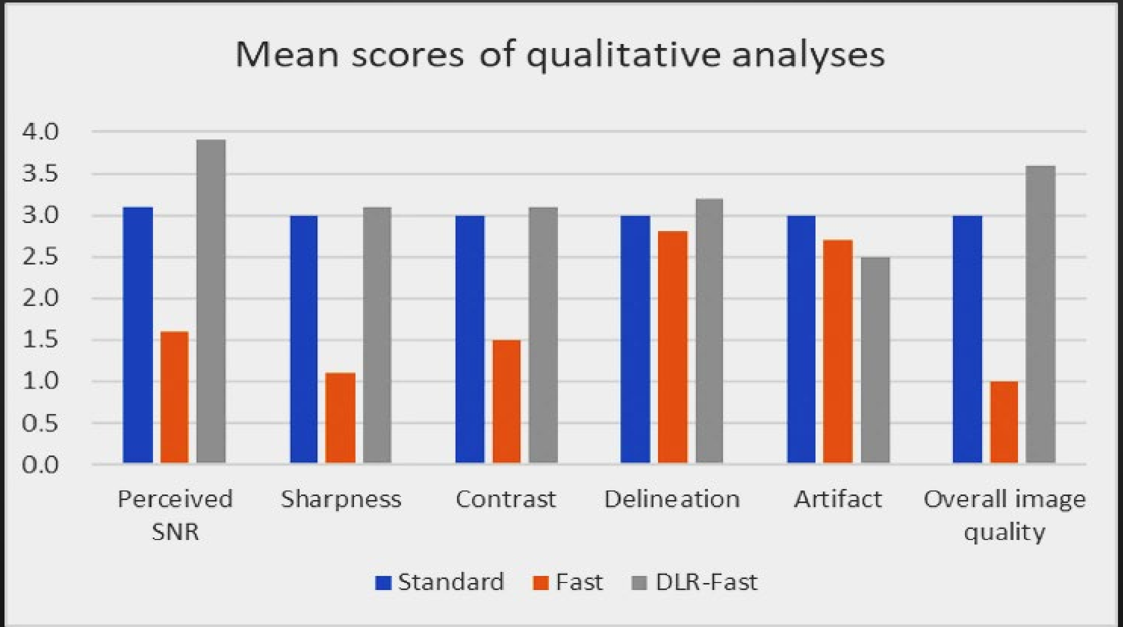
- *Qualitative analysis*

The scores for perceived SNR, sharpness, and delineation, and overall image quality higher on dDLR-Fast than on Standard with or without significant difference, indicating preservation of adequate image quality on dDLR-Fast .

Results

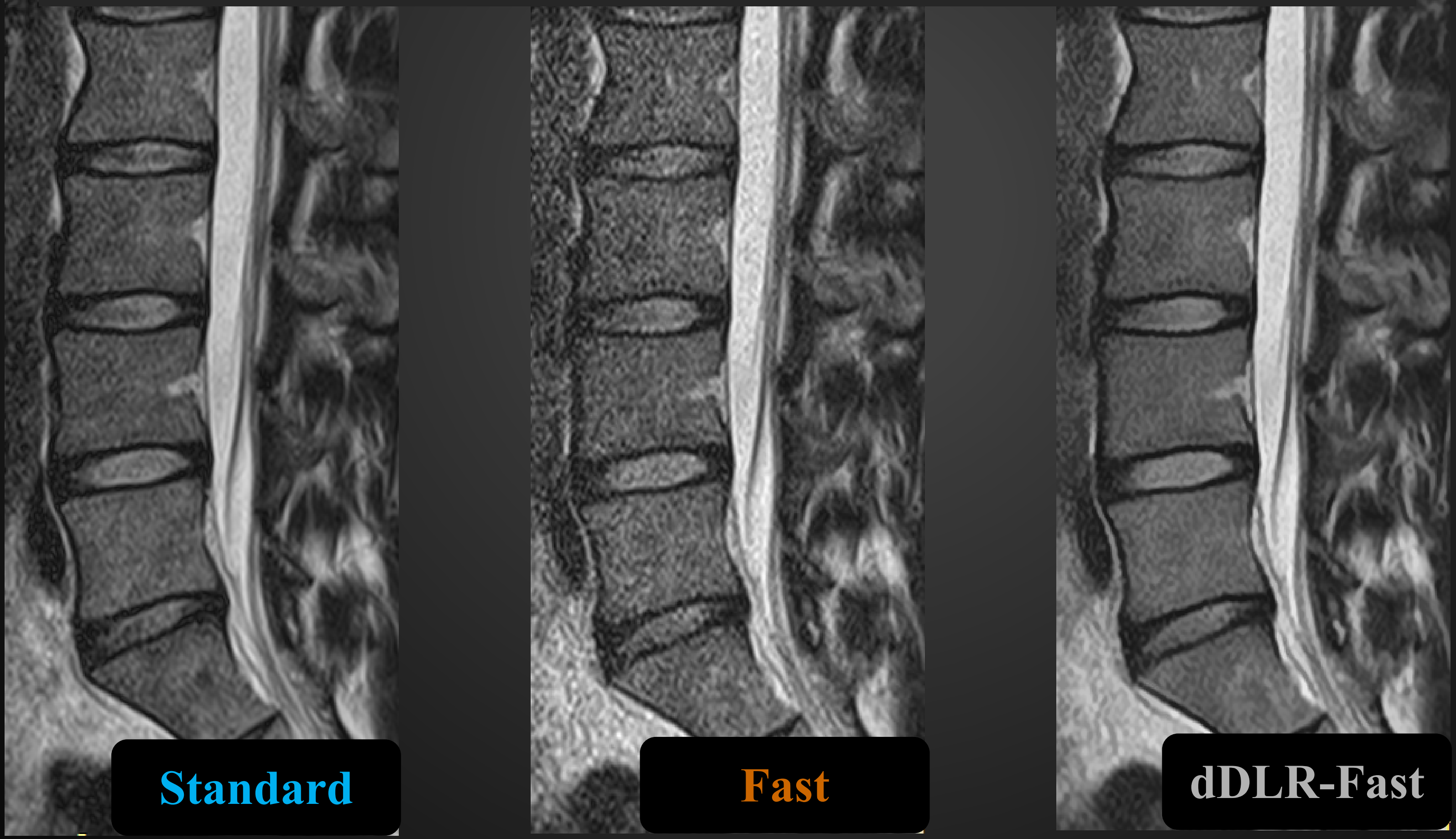


Annotation; High NU values reflect reduced signal homogeneity, indicating image degradation.



Results *Representative images*

After the application of the dDLR, the image quality of dDLR-Fast is equal to or better than that of Standard.



Discussion *Application of the dDLR trained by MR images acquired at 3T to MR images acquired at 1.5T.*

We were concerned that Inherent lower noise level of imaging acquired at 1.5T may affect the feasibility of the dDLR. In the preceding study evaluating 3T MR images, the scanning time was shortened by simply reducing NEX [14]. In that condition, the accompanying image degradation was mainly caused by signal decrease [20]. In contrast, the scanning time of the present study was shortened by not only reducing NEX but also applying compressed sensing. The image degradation accompanying compressed sensing is caused mainly by noise amplification [16,21] .

Therefore, we assume that the noise amplification caused by the compressed sensing well brought out the ability of the dDLR, resulting in equal ability for shortening the scanning time in comparison to 3T MR image.

Discussion *Application of the dDLR trained by brain and knee images to spinal images.*

Because spinal MR images using the phased-array surface coil have a higher noise strength toward the deeper portions from the deeper surface [15,22], the greater inhomogeneity of noise strength in spinal MR images may affect the feasibility of the dDLR. In addition, the coexistence of both high- (fat and CSF) and low-contrast objects (cord and muscle) in identical slices on lumbar T2-weighted MR images might expose the blurring effect caused by denoising [23].

However, the overcoming performance which the dDLR showed in this study confirmed that selective denoising in high-frequency components achieved robustness against the greater inhomogeneity of noise strength and preserved the inherent MR signal of tissues.

Conclusion

Application of the dDLR (AiCE) trained by brain and knee MR images at 3T to lumbar MR images at 1.5T allows using one-third of the standard acquisition time while preserving the image quality, indicating the generalizability of the proposed dDLR.