MR / White Paper

Prospective Clinical Evaluation of Novel Deep Learning Denoising Reconstruction for Improved Image Quality in Musculoskeletal Magnetic Resonance Imaging

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Introduction

Over the last few years, deep learning has been widely applied to magnetic resonance image reconstruction (1-10). It has been demonstrated that deep learning-based reconstruction (DLR) may provide performance gains when compared to conventional reconstruction methods (11). In MRI, a high resolution and signal-to-noise ratio (SNR) are desired clinically for better delineation of subtle anatomical and pathological features that are critical in making a clinical diagnosis. Higher resolution and SNR require longer scan times, which is often less desired in a clinical environment. Deep learning techniques may have great potential. Through the denoising process, image quality and SNR gain could assist clinicians in providing flexibility in scan parameters and be used to improve resolution and/or shorten scan time.

In this paper, Advanced Clear-IQ intelligent Engine (AiCE) DLR was prospectively evaluated, in which the results suggest that AiCE DLR gains in image quality, denoising, and SNR may help clinicians in providing flexibility in scan parameters and be used to improve resolution and/or shorten scan time in comparison to images routinely acquired at the Institution.

Evaluation in a Clinical Setting

This prospective clinical study was performed in a clinical site in the USA, in which images acquired from 137 sequences in 40 patients (10 hips, 10 shoulders, 20 knees) were collected. The study was carried out on a 3T MRI scanner (Canon Vantage Galan) with approved IRB. Each sequence was imaged twice: first with a standard clinical protocol (reference sequence, or "REF"), then with a modified protocol that improved resolution by 48% and shortened scan time by 8%. The modified protocol was reconstructed with Advanced intelligent Clear-IQ Engine (AiCE) DLR ("DLR") (10) and three other clinically used reconstruction filters (named NL2, GA43, and GA53) resulting in a total of five reconstructions for each sequence. As a blinded, randomized clinical image review, all reconstructions were de-identified and randomized before sharing with three experienced American Board-Certified MSK radiologists for review. Representative images for the reference images and images reconstructed with different reconstruction methods are shown in Figure 1, in which arrows indicate pathologies identified by one of the radiologists.

For image quality assessment, radiologists were asked to assign scores of image quality based on the entire image and on specific anatomical and pathological features they observe in the image (Table 1). The reviewers were also asked to rank the images in order of preference for different reconstruction methods, in which 5 means the most preferred and 1 means the least preferred.

The average reader score was highest for DLR across all eight scoring criteria and the forced ranking compared to the other reconstruction methods (Figure 2).

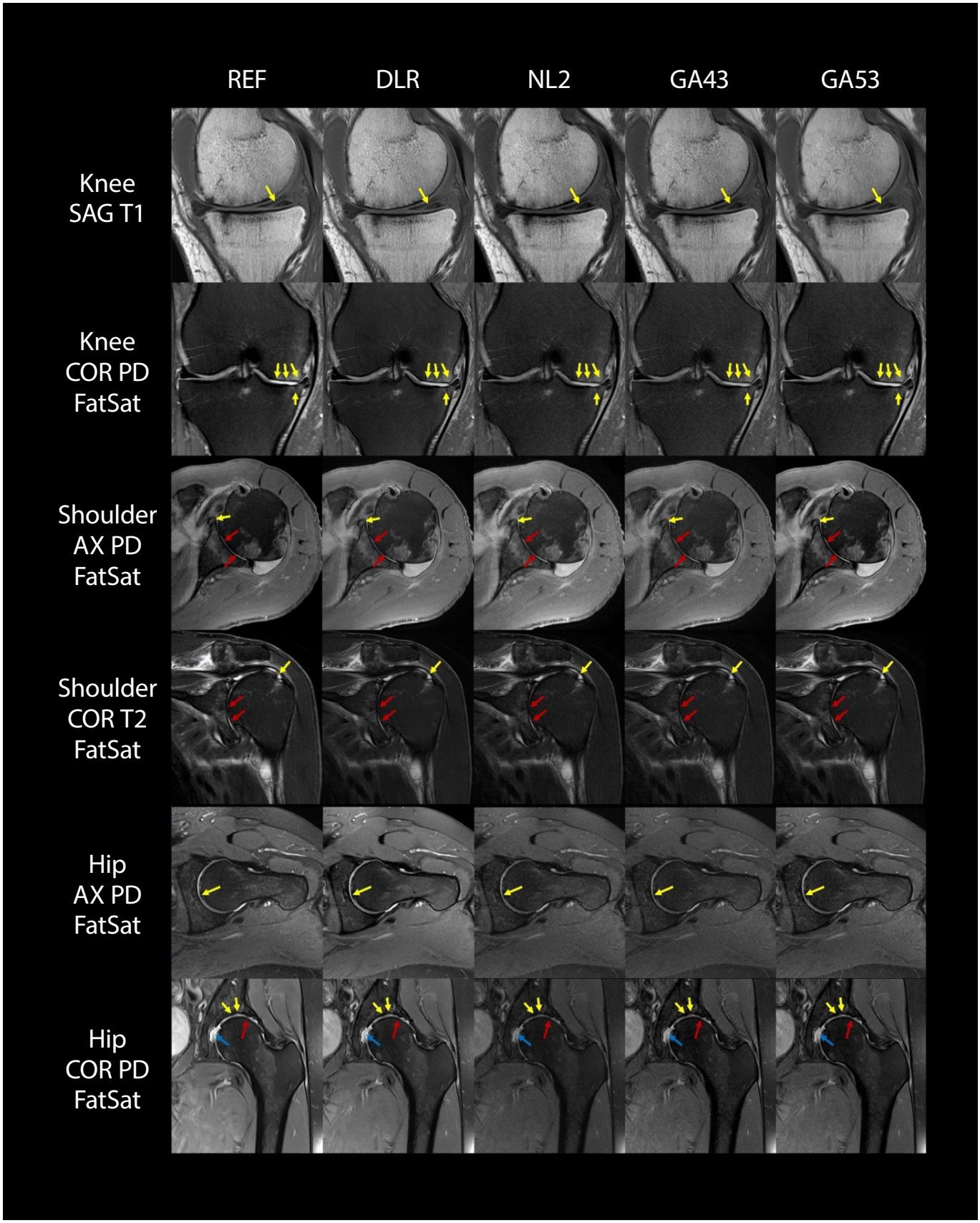

Figure 1: Representative images acquired with the standard clinical protocol (reference image, "REF") and those acquired using a modified protocol for higher resolution and/or shorter scan time and reconstructed with DLR and conventional reconstructions (NL2, GA43, and GA53). Arrows represent pathologies identified by one of the radiologists.

	Overall Image Quality Assessment				Assessment of Specific Anatomical & Pathological Features			
Score	Overall Image Noise	Overall Image Sharpness	Overall Image Degradation/ Artifacts	Overall Diagnostic Confidence	Features Sharpness	Features Contrast	Features Conspicuity	Features Diagnostic Confidence
1	All structures are too noisy	All structures are not sharp on most images	All structures are degraded	Diagnostic confidence is very poor	Sharpness of features is very poor	Contrast between features and surrounding is very poor	Features conspicuity is very poor	Diagnostic confidence for the reviewed features is very poor
2	Most structures are too noisy	Most structures are not sharp on some images	Most structures are degraded	Poor	Poor	Poor	Poor	Poor
3	A few structures are noisy on most images	Most structures are sharp on some images	A few structures are degraded on most images	Fair	Fair	Fair	Fair	Fair
4	A few structures are noisy on a few images	Most structures are sharp on most images	A few structures are degraded on a few images	Good	Good	Good	Good	Good
5	There is no appreciable noise on any of the relevant images	All structures are sharp on all relevant images	There is no appreciable image degradation on any of the relevant images	Excellent	Excellent	Excellent	Excellent	Excellent

Table 1: Scoring criteria and scoring instructions

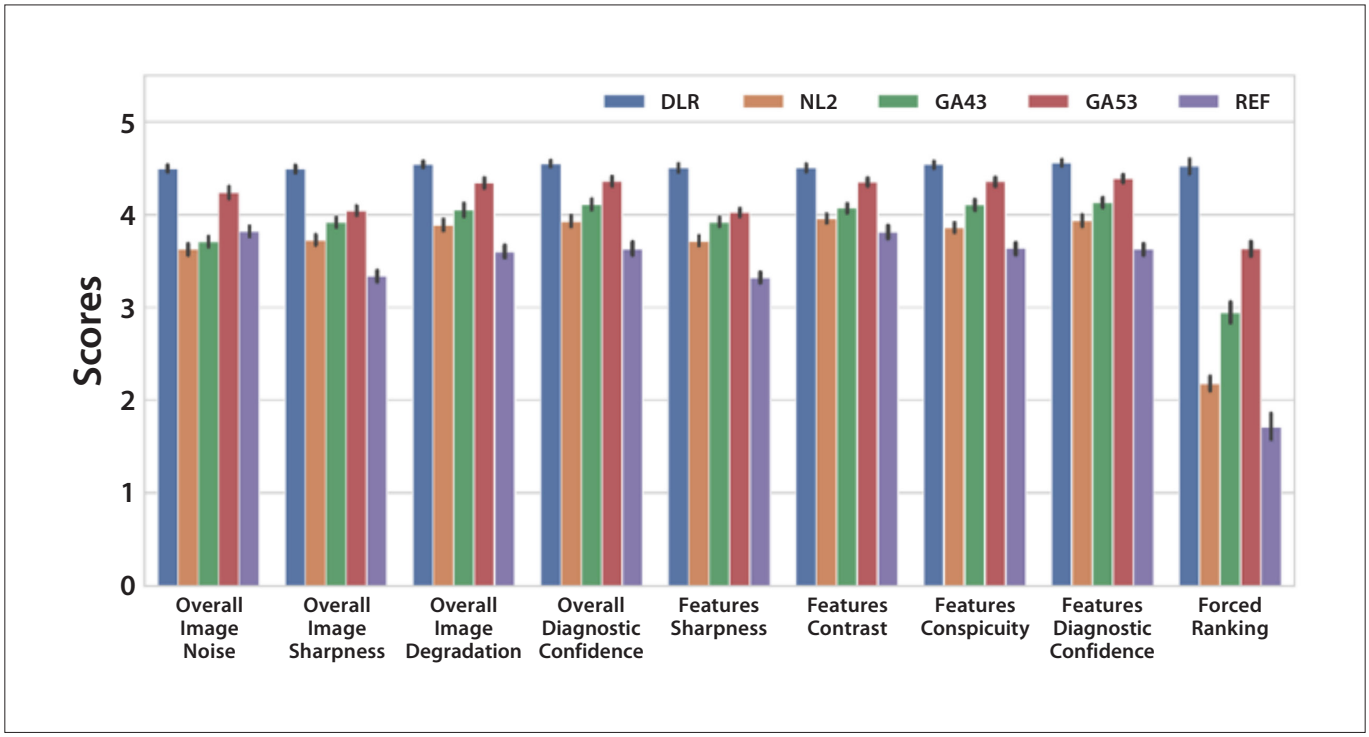

Figure 2: Average scores of three musculoskeletal radiologist readers for the five reconstruction methods. DLR was rated significantly higher across all eight scoring criteria and the forced ranking compared to the other reconstruction methods.

Summary

AiCE DLR removes noise, hence improved SNR.* The SNR improvement may help clinicians in providing flexibility in scan parameters and be used to help alleviate the fundamental tradeoffs between SNR, resolution, and scan time. This prospective clinical evaluation showed that AiCE DLR may enable clinicians to increase resolution and/or shorten scan time while allowing preferred image quality.

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The clinical results described in this paper are the experience of the authors. Results may vary due to clinical setting, patient presentation and other factors.

* AiCE provides higher SNR compared to typical low pass filters.

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