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Deep Learning Reconstruction in Pediatric Knee MRI: Evaluation of Image Quality, Reader Preference, and Acquisition Time

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Abstract

Background

Deep learning–based reconstruction can accelerate MR image acquisition while potentially preserving image quality. Faster imaging is particularly helpful in pediatric patients, who may be more susceptible to motion-related degradation during prolonged examinations.

Objective

To compare image quality, reader preference, and acquisition time between Deep Resolve–accelerated and conventional turbo spin-echo (TSE) sequences in pediatric knee MRI and to assess inter-reader agreement for the detection of knee abnormalities.

Materials and methods

This retrospective, institutional review board–approved study included pediatric patients who underwent clinical knee MRI with both conventional and Deep Resolve–accelerated TSE sequences. Two pediatric radiologists independently evaluated the paired image sets for overall image quality, contrast resolution, motion, artifacts, diagnostic confidence, and delineation of bone, articular cartilage, ligaments, and tendons. Reader preference and qualitative image-quality assessments between accelerated and conventional sequences were compared. Inter-reader agreement for detection of knee abnormalities was assessed, and acquisition times were compared.

Results

Eighty-five paired sequences from 60 patients were included (mean age, 14.2 years; SD, 2.4 years). Deep Resolve was preferred over conventional imaging in 96.2% of Reader 1 assessments and 96.4% of Reader 2 assessments. Deep Resolve received the highest overall image-quality score in 92.5% and 96.4% of assessments, respectively, compared with 17.5% and 14.5% for conventional images. Overall image-quality scores were significantly higher for DRB than for conventional imaging for both readers (both $P < 0.001$). Interreader agreement for abnormality detection was excellent (97.6% agreement; kappa, 0.934; 95% CI, 0.838–1.000). Deep Resolve–accelerated sequences reduced acquisition time by approximately 50% to 77% across sequence types.

Conclusion

Deep Resolve–accelerated TSE sequences substantially reduced acquisition time and were strongly preferred by both readers for image quality and contrast resolution. Interreader agreement for

abnormality detection was excellent, supporting deep learning–accelerated reconstruction as a practical approach to shortening pediatric knee MRI examinations while preserving diagnostic assessment.

Introduction

Magnetic resonance imaging (MRI) is the preferred imaging modality for evaluating internal derangement of the knee, including abnormalities of the menisci, ligaments, articular cartilage, and osseous structures (1,2). Standard knee MRI protocols predominantly rely on multiplanar two-dimensional (2D) turbo spin-echo (TSE) sequences that, while diagnostically robust, can require acquisition times of 10–20 minutes (Table 1) (2, 3). Prolonged scan times can limit patient throughput, reduce scanner availability, increase healthcare costs, and diminish patient comfort. These considerations are particularly relevant in pediatric and young adult populations, in whom discomfort or anxiety may increase motion-related image degradation (4).

Table 1

Acquisition-time comparison. Comparison of typical acquisition times between conventional and Deep Resolve–accelerated sequences by sequence type. Absolute and percentage reductions in acquisition time are shown.

Sequence	Conventional protocol (min:sec)	Deep Resolve protocol (min:sec)	Absolute time reduction (min:sec)	Approx. percentage time reduction (%)
Axial T2W FS	5:38	1:17	4:21	77
Sagittal T2W FS	5:01	1:39	3:22	67
Coronal PDW FS	4:35	2:18	2:17	50
Sagittal PDW	4:41	1:45	2:56	63
Coronal T1W	2:41	1:21	1:20	50

T2W: T2-weighted, PDW: proton density–weighted, FS: fat-saturated, T1W: T1-weighted, min: minutes, sec: seconds. Scan times are approximate and based on the protocol implemented on a 3-T MRI system (Vida, Siemens Healthineers, Malvern, PA, USA). The protocol is provided in the appendix for detailed acquisition parameters.

Several acceleration strategies have been developed to address these limitations. Parallel imaging and compressed sensing can be applied independently or in combination to achieve three- to eightfold acceleration of TSE sequences (2, 3, 5, 6). However, at higher acceleration factors, these conventional techniques are constrained by noise amplification and residual reconstruction artifacts that may compromise diagnostic image quality (7, 8). This signal-to-noise ratio (SNR) penalty has historically imposed a ceiling on the degree of acceleration achievable without sacrificing spatial resolution and/or diagnostic confidence (8).

Deep learning (DL)-based reconstruction uses convolutional neural networks trained on large datasets to reconstruct high-quality images from undersampled k-space data, potentially reducing acquisition time while preserving spatial resolution and SNR (8, 9). Deep Resolve (Siemens Healthineers, Erlangen, Germany) is a commercially available DL-based reconstruction that can be applied to conventional 2D TSE sequences to enable higher acceleration factors while maintaining SNR.

Early clinical validation studies of DL-reconstructed knee MRI have yielded strong results. Johnson et al. demonstrated diagnostic equivalence between prospectively accelerated DL-reconstructed and conventional knee MRI at 3T, with a nearly twofold reduction in scan time with improved overall image quality ratings (4). Herrmann et al. reported that DL-accelerated 2D TSE knee MRI reduced acquisition time by approximately 50% while achieving excellent image quality with lower noise and improved sharpness, and equivalent diagnostic performance for internal derangement (9). Multi-reader, multi-vendor studies have further confirmed that DL-based reconstruction preserves lesion detection for meniscal tears, ligament injuries, and cartilage defects across different scanner platforms (10). More recently, sub-5-minute DL-accelerated knee MRI protocols have demonstrated high diagnostic performance validated against arthroscopy in pediatric and adolescent patients (4, 11).

However, most validation studies have been conducted in adult populations, and vendor-specific DL reconstruction platforms require independent evaluation to establish generalizability in pediatric practice. Bedoya et al. evaluated DL-based reconstruction in knee and ankle MRI of children and young adults and reported similar diagnostic performance and same-or-better image quality compared with conventional sequences at approximately half the acquisition time (12). Further validation in independent pediatric cohorts using clinically implemented knee-specific protocols remains warranted.

The purpose of this study was to compare image quality, reader preference, interreader diagnostic agreement, and acquisition time between Deep Resolve–accelerated and conventional TSE knee MRI sequences in pediatric patients.

Methods

Study population: A search of the institutional radiology database identified consecutive patients who underwent clinically indicated knee MRI between August 2025 and May 2026. Patients were included if the examination contained matched conventional and Deep Resolve–accelerated 2D TSE sequences. Examinations were excluded if a matched sequence was missing or acquisition was incomplete (Fig. 1).

MRI acquisition: MRI examinations were performed on a 3-T scanner (Vida, Siemens Healthineers, Erlangen, Germany) using a dedicated knee coil. Each examination included conventional and matched Deep Resolve–accelerated 2D TSE sequences. Accelerated sequences were reconstructed using Deep Resolve Boost (DRB). Acquisition times are summarized in Table 1.

Image analysis: Conventional and Deep Resolve Boost (DRB)–accelerated image sets were independently reviewed by two experienced, board-certified pediatric radiologists. Readers were blinded

to the original radiology report and to each other's assessments.

Image-quality assessment: Readers scored overall image quality, contrast resolution, diagnostic confidence, motion, artifacts, and delineation of bone, articular cartilage, ligaments, and tendons using a 4-point Likert scale, with higher scores indicating better image quality. For each sequence pair, readers also classified the Deep Resolve–accelerated image as worse than, equivalent to, or better than the conventional image for each qualitative feature. Readers recorded the presence or absence of predefined abnormalities, and inter-reader agreement for abnormality detection was calculated. Discordant interpretations were reviewed in consensus to determine whether differences reflected lesion conspicuity, motion, artifact, or reader variability. Acquisition times were compared between protocols.

Statistical analysis: Continuous variables were summarized using mean and standard deviation, with median and range reported where applicable. Categorical and ordinal reader assessments were summarized as counts and percentages. Inter-reader agreement for binary and categorical variables was assessed using percent agreement and Cohen/Conger kappa, as appropriate. For ordinal variables, linearly weighted kappa statistics were calculated. Agreement estimates were reported with corresponding 95% confidence intervals. Differences in overall image-quality scores between conventional and Deep Resolve Boost (DRB) images were evaluated separately for each reader using the Wilcoxon signed-rank test. All statistical tests were two-sided, and a P value less than 0.05 was considered statistically significant. Statistical analyses were performed using Stata version 19 (StataCorp LLC, College Station, TX, USA).

Results

Study population: A total of 85 paired conventional and Deep Resolve–accelerated sequences from 60 patients were included (mean age, 14.2 ± 2.4 years; 31 female). Four studies from 2 patients were excluded due to age of the patients being over 18.

Image-quality assessment: Both readers strongly favored Deep Resolve–accelerated over conventional imaging, selecting Deep Resolve–accelerated as the preferred series in 96.2% of assessments (Fig. 2). The highest overall image-quality score (4 of 4) was assigned to Deep Resolve–accelerated in 92.5% and 96.4% of assessments, compared with 17.5% and 14.5% for conventional images. Contrast resolution favored Deep Resolve–accelerated in 98.8% and 94.0% of assessments.

The paired Wilcoxon signed-rank tests demonstrated that Deep Resolve–accelerated images received significantly higher overall image-quality scores than conventional images for both readers (Reader 1: $z = -7.47$, $P < 0.001$; Reader 2: $z = -7.94$, $P < 0.001$). Diagnostic confidence was rated better with Deep Resolve–accelerated in 83.8% of Reader 1 assessments and 60.2% of Reader 2 assessments; it was rated the same in 15.0% and 39.8% respectively, and worse in only one Reader 1 assessment (Fig. 3). Bone delineation was rated better with Deep Resolve–accelerated in 92.5% and 96.4% of assessments; ligament delineation in 82.5% and 98.8%; and tendon delineation in 79.7% and 98.8% (Fig. 4). Motion was

absent in 93.8% and 94.0% of assessments, and artifacts were absent in 98.8% and 95.2%, respectively (Fig. 5).

Inter-reader agreement: Agreement between the two readers for abnormality detection was 97.6%, with excellent chance-corrected agreement (kappa, 0.934; 95% CI, 0.838–1.000) (Table 2). Agreement on series preference was 95.0%; however, the corresponding kappa was lower (0.295; 95% CI, − 0.224 to 0.814), reflecting the marked predominance of Deep Resolve–accelerated preference. Weighted kappa for overall image quality was 0.433 (95% CI, 0.197–0.669) for conventional images and 0.645 (95% CI, 0.270–1.000) for DRB images. Additional inter-reader agreement statistics are summarized in Table 3.

Table 2
Qualitative image-quality assessment. Reader-specific qualitative assessments comparing conventional and DRB images.

Measure	Reader 1	Reader 2
Series preference: DRB	82/85 (96.2%)	82/85 (96.2%)
Overall IQ, conventional: score 4	15/85 (17.5%)	12/85 (14.5%)
Overall IQ, DRB: score 4	79/85 (92.5%)	82/85 (96.4%)
Contrast resolution: DRB preferred	84/85 (98.8%)	80/85 (94.0%)
Diagnostic confidence: better	71/85 (84.0%)	51/85 (60.2%)
Diagnostic confidence: same	13/85 (15.0%)	34/85 (39.8%)
Diagnostic confidence: worse	1/85 (1.2%)	0/85 (0%)
Bone delineation: better	79/85 (92.5%)	82/85 (96.4%)
Articular cartilage delineation: better	71/85 (84.0%)	79/85 (92.5%)
Ligament delineation: better	70/85 (82.5%)	84/85 (98.8%)
Tendon delineation: better	68/85 (79.7%)	84/85 (98.8%)
Motion absent	80/85 (93.8%)	80/85 (94.0%)
Artifacts absent	84/85 (98.8%)	81/85 (95.2%)

Table 3
Inter-reader agreement. Percent agreement and Cohen/Conger kappa statistics for reader assessments. Weighted kappa was used for ordinal measures. Confidence intervals are 95% CIs.

Measure	Percent agreement	Cohen/Conger κ	95% CI	P value
Positive findings	97.6%	0.934	0.838–1.000	< 0.001
Series preference	95.0%	0.295	−0.224–0.814	0.261
Overall IQ - conventional	89.4%	0.433*	0.197–0.669	< 0.001
Overall IQ - DRB	96.3%	0.645*	0.270–1.000	0.001
Contrast resolution	95.0%	0.298*	−0.212–0.808	0.248
Motion	93.8%	0.458*	0.063–0.852	0.024
Artifacts	96.3%	0.222*	−0.208–0.651	0.307
Diagnostic confidence	73.8%	0.097*	−0.038–0.232	0.155
Bone delineation	96.3%	0.366*	0.018–0.713	0.039
Ligament delineation	90.0%	0.088*	−0.070–0.246	0.271
Tendon delineation	88.0%	−0.023*	−0.069–0.022	0.307
*Linearly weighted kappa.				

Acquisition time: Deep Resolve–accelerated sequences had substantially reduced acquisition times compared with corresponding conventional imaging sequences. Approximate sequence-specific reductions ranged from 50% to 77% (Table 1 and **Fig. 6**).

Discussion

Deep Resolve–accelerated TSE imaging of the pediatric knee substantially shortened acquisition time and was strongly preferred by both readers for overall image quality and contrast resolution (Fig. 6). Deep Resolve–accelerated received the highest overall image-quality rating in more than 90% of assessments by both readers, while inter-reader agreement for abnormality detection was 97.6% (kappa, 0.93). Anatomic delineation and diagnostic confidence were generally maintained or improved relative to conventional imaging. These findings provide strong evidence that Deep Resolve–accelerated improved perceived image quality relative to conventional sequences in pediatric patients.

These findings are consistent with prior studies. Bedoya et al. reported similar diagnostic performance and same-or-better image quality in pediatric knee and ankle MRI at approximately half the acquisition time (12). Vashistha et al. also found improved or equivalent depiction of small structures in most DL-TSE knee examinations, with scan-time reductions of up to 52% (13). Similar preservation of diagnostic confidence has been reported in accelerated DL-reconstructed spine MRI (14).

Shorter acquisition times are particularly valuable in pediatric MRI because they may improve patient comfort, reduce motion-related degradation in addition to increasing scanner throughput. However, DL reconstruction must preserve true anatomy without suppressing or introducing findings. Prior studies have reported occasional apparent discrepancies between DL-reconstructed and conventional images, most often attributed to motion, aliasing, or Gibbs ringing rather than true reconstruction-related alteration (12).

This study has few limitations, including its retrospective, single-center design, use of a vendor-specific reconstruction method, evaluation by two readers, and lack of an independent reference standard. Some patients contributed more than one paired sequence, and the analyses did not account for within-patient clustering. In addition, the inclusion of young adults and the relatively small number of younger children may limit generalizability to the pediatric age groups most likely to experience motion or require sedation. The study was not designed to establish lesion-specific sensitivity or specificity. Overall, Deep Resolve–accelerated knee MRI appears to be a practical approach to shortening pediatric examinations while maintaining diagnostic image quality and confidence.

Conclusion

Deep Resolve–accelerated TSE imaging of the pediatric knee substantially reduced acquisition time and was strongly preferred by both readers for image quality and contrast resolution. Inter-reader agreement for abnormality detection was excellent, and anatomic delineation and diagnostic confidence were generally maintained or improved. These findings support Deep Resolve–accelerated imaging as a practical approach to shortening pediatric knee MRI examinations.

Declarations

Author Contribution

D.B. and S.S. wrote the main manuscript and prepared the figures. D.B., H.A., and V.H. did the scoring. J.L. and S.S. collected the data. W.L. did the statistical analysis. All authors reviewed the manuscript.

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Figures

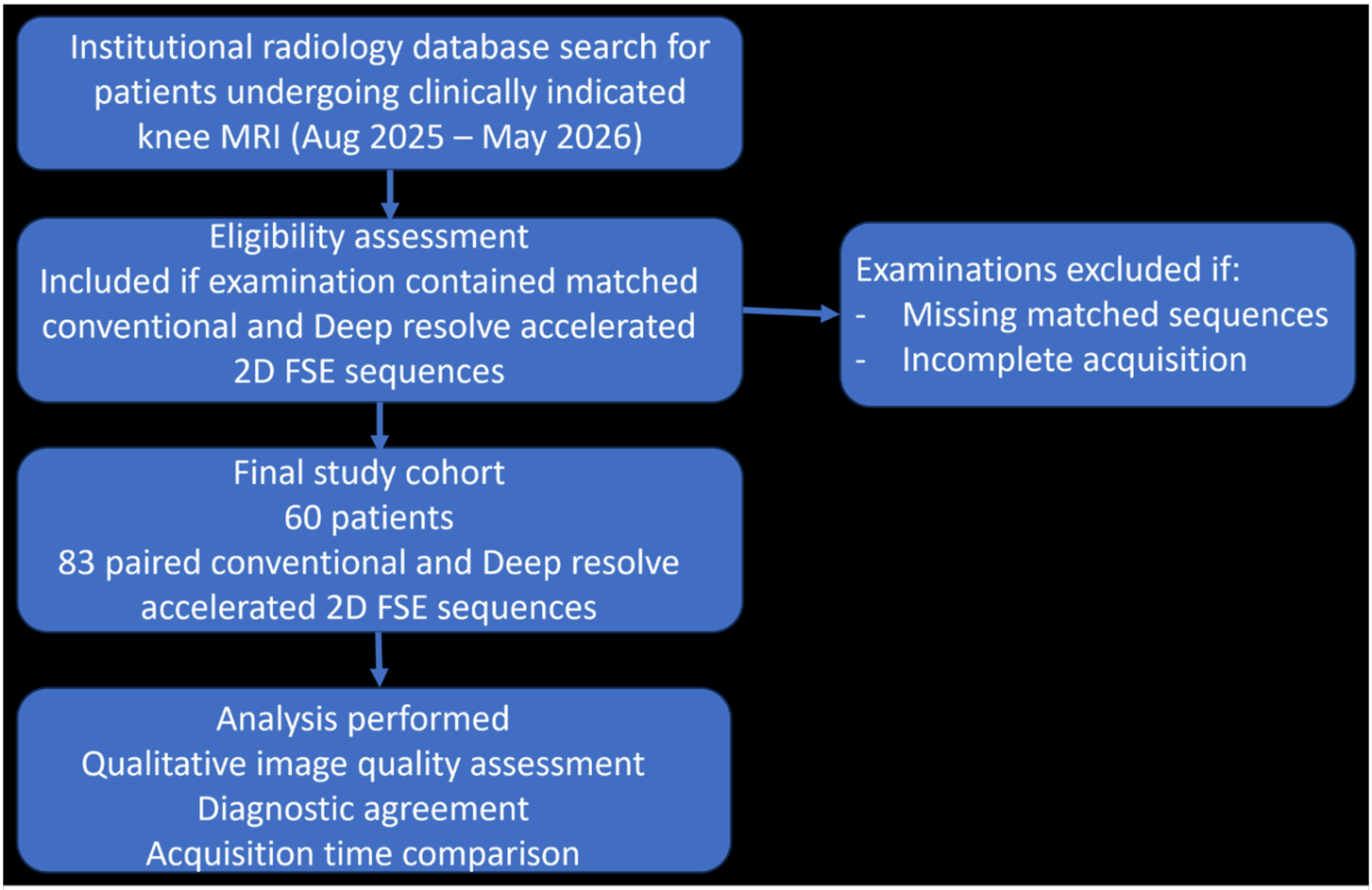


Figure 1

Study flow diagram. Flow diagram showing patient identification, exclusions, and the final study cohort. A total of 60 patients contributed 85 paired conventional and Deep Resolve–accelerated turbo spin-echo sequences for image-quality and diagnostic-agreement analyses.

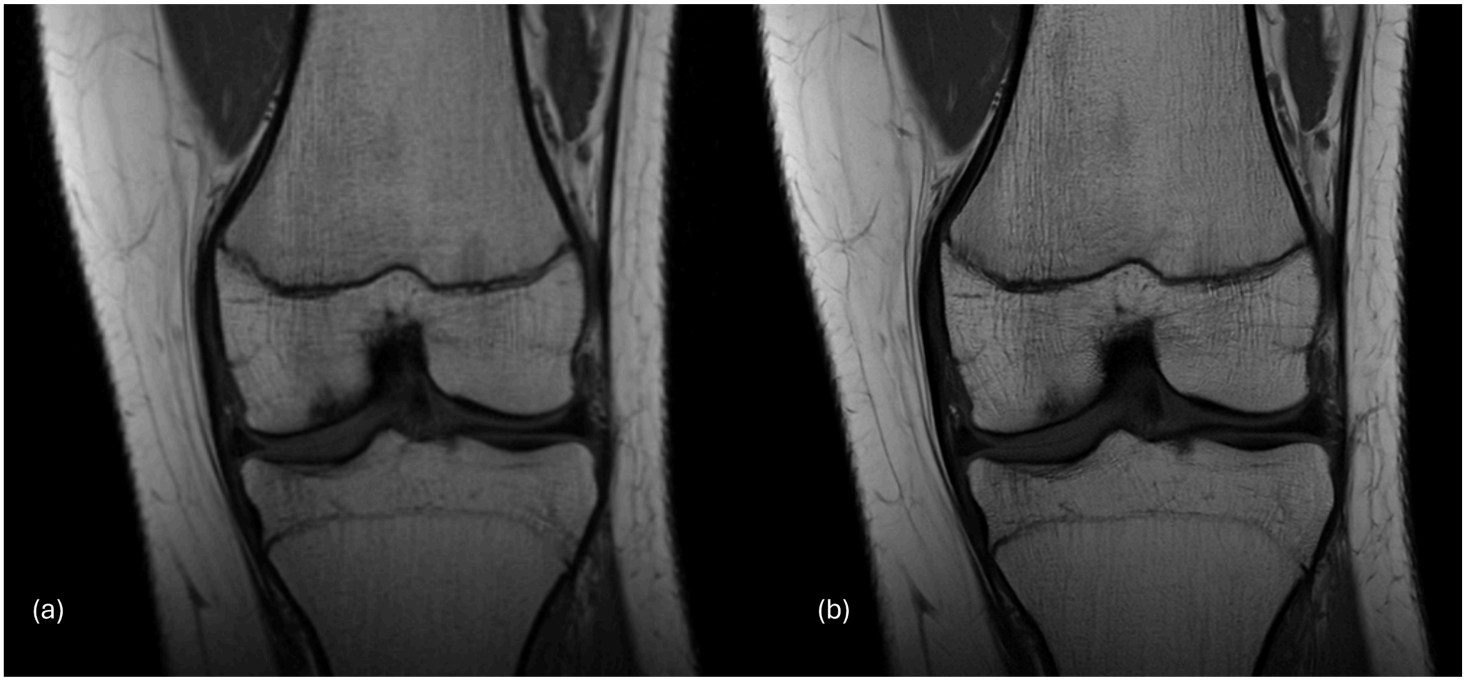


Figure 2

Representative normal knee examination. Representative coronal T1-weighted images from a 15-year-old girl with no abnormality. (a) Conventional TSE image (scan time, 2 min 40 s) and (b) corresponding Deep Resolve–accelerated image (scan time, 1 min 20 s). The Deep Resolve–accelerated image was acquired in less time while maintaining diagnostic image quality.

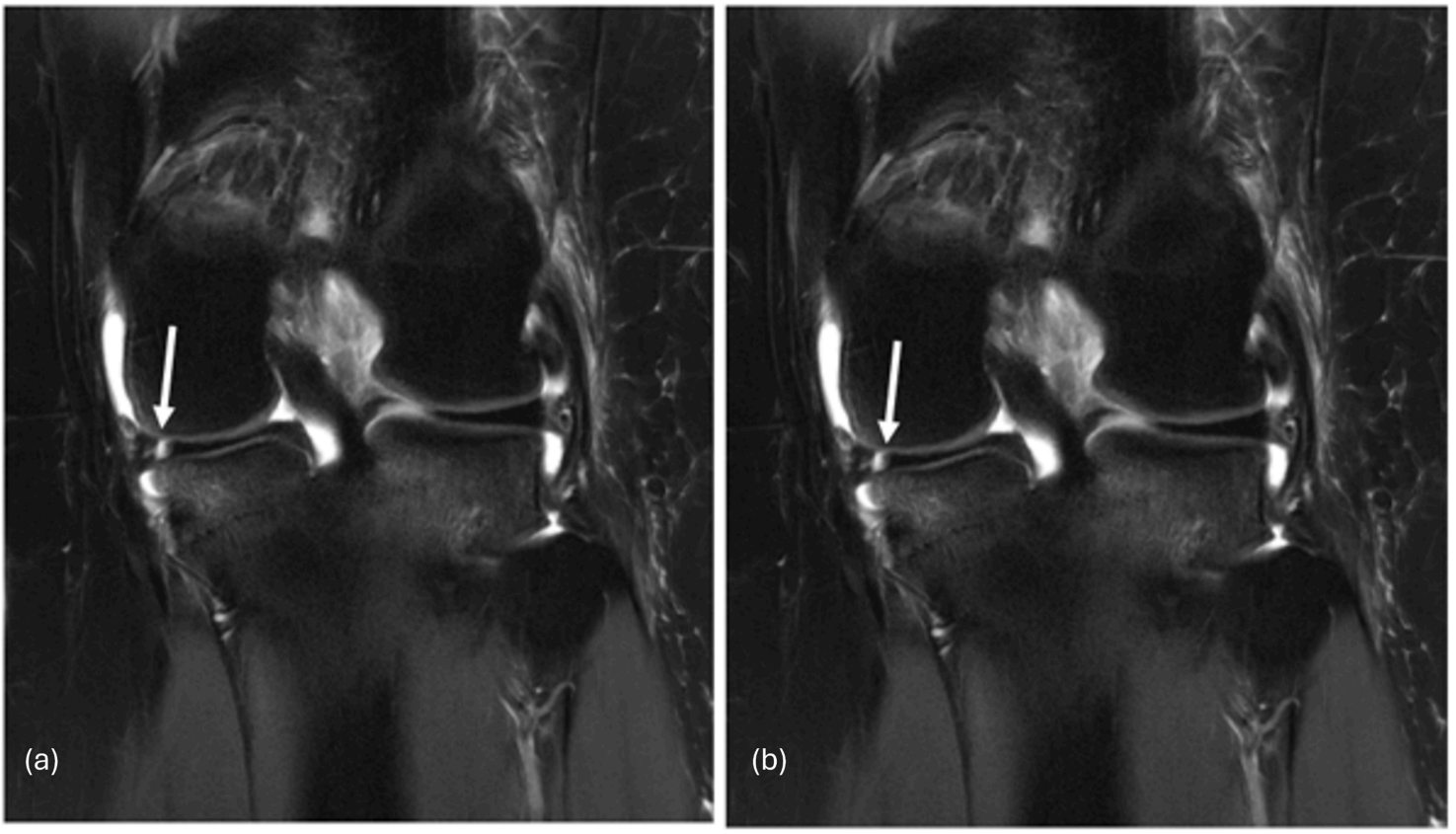


Figure 3

Representative pathologic finding. Representative coronal proton density weighted fat saturated images from a 14-year-old girl with longitudinal ACL tear. The finding is similarly demonstrated on the conventional turbo spin-echo image (a) and Deep Resolve–accelerated image (b). Arrows indicate tear at the junction of the posterior horn and body of the lateral meniscus with vertical increased signal extending to the tibial articular surface.

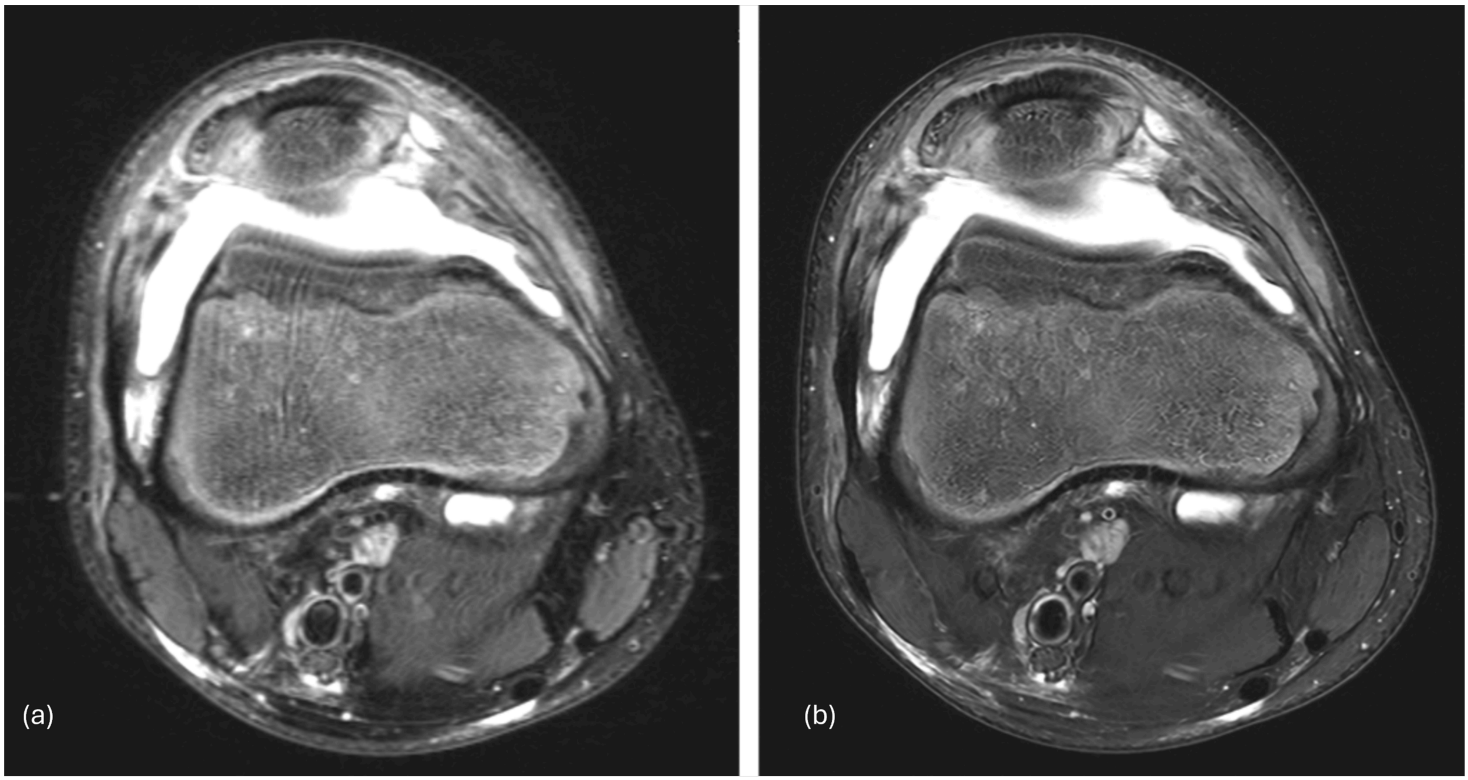


Figure 4

Improved image quality with Deep Resolve reconstruction. Representative axial T2-weighted fat-saturated images from a 12-year-old boy. Compared with the conventional image (a), the Deep Resolve–accelerated image (b) demonstrates reduced image noise and motion with improved sharpness and anatomic delineation while preserving tissue contrast and diagnostic confidence.

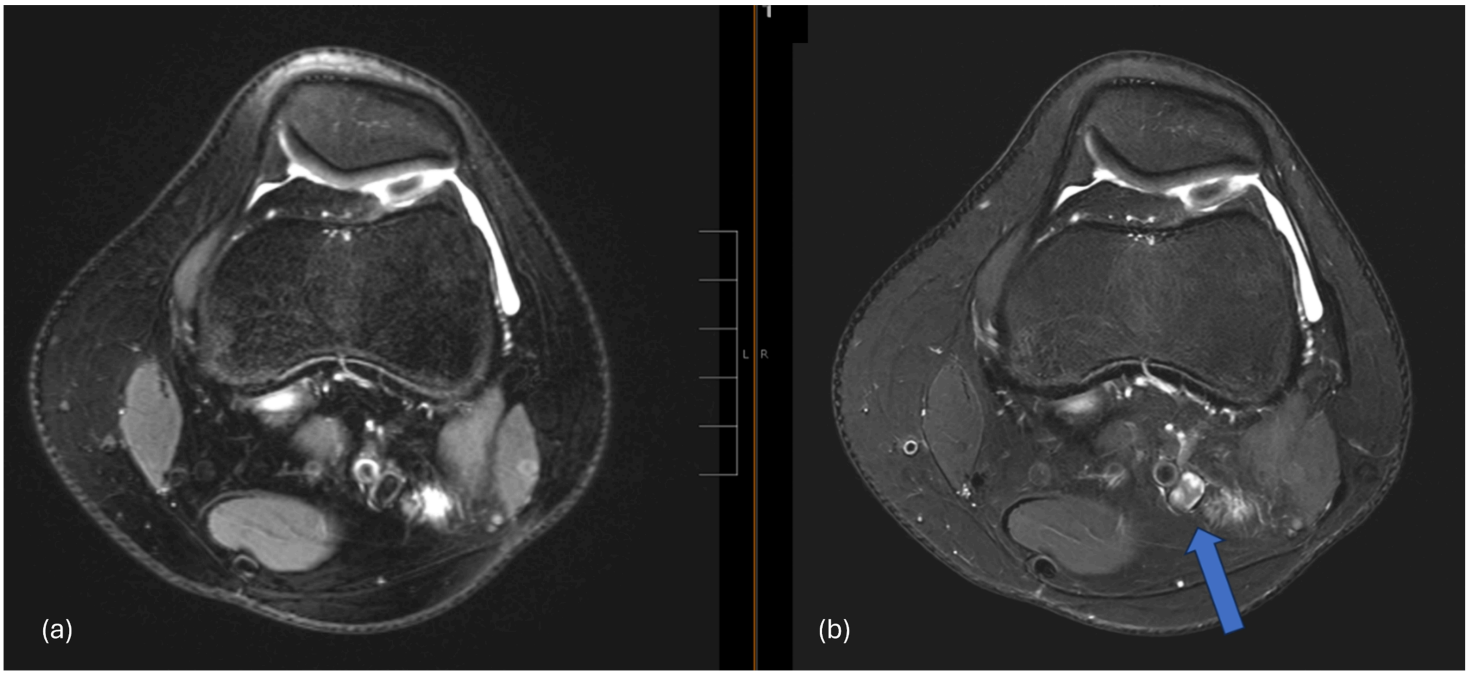


Figure 5

Representative artifact or discordant case. Representative axial T2W fat saturated images from a 15-year-old girl (a). Arrows indicate abnormal lobulated contour of inner margin of the vein that is present on the Deep Resolve–accelerated image (b), and can be mistaken for pathology. Despite the potential artifact, the clinically relevant finding remained visible on both image sets.

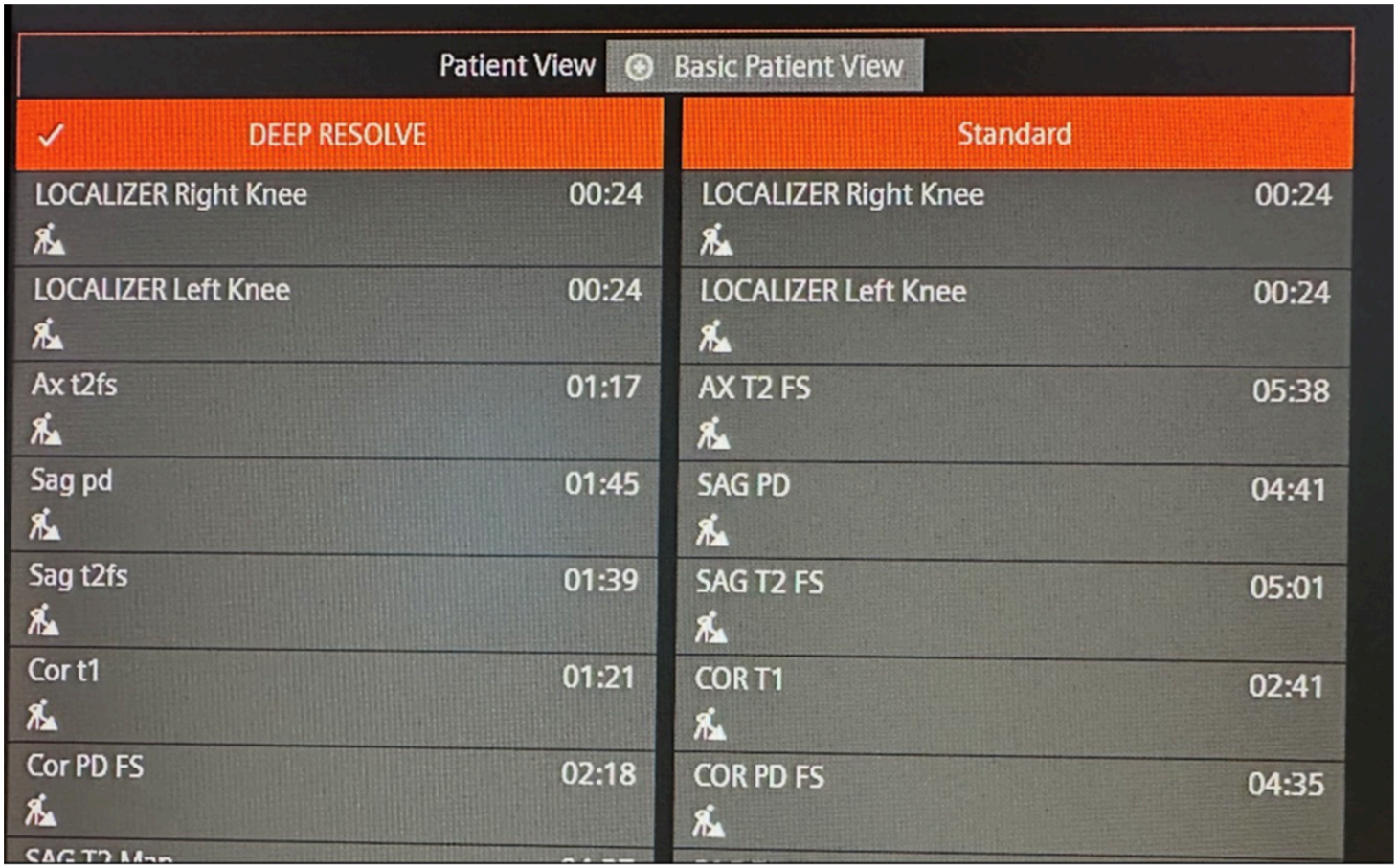


Figure 6

Comparison of acquisition times. Scanner protocol screenshot comparing acquisition times for conventional and Deep Resolve–accelerated TSE sequences. Deep Resolve reconstruction reduced acquisition time across the evaluated sequence types. The protocol is provided in the appendix for detailed acquisition parameters.