

Faster, Sharper, Smarter: Pediatric Neuro MRI with Deep Resolve Boost

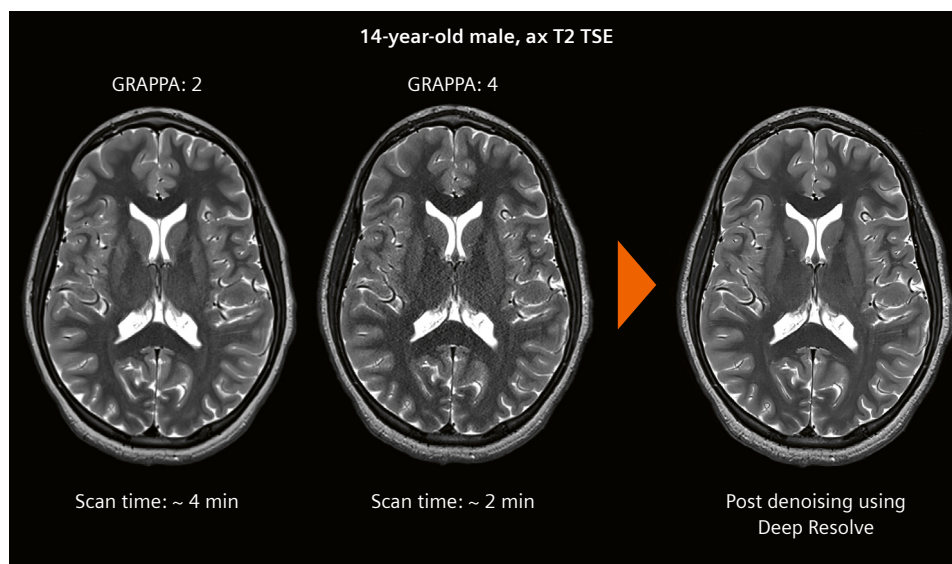
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The pediatric MRI challenge

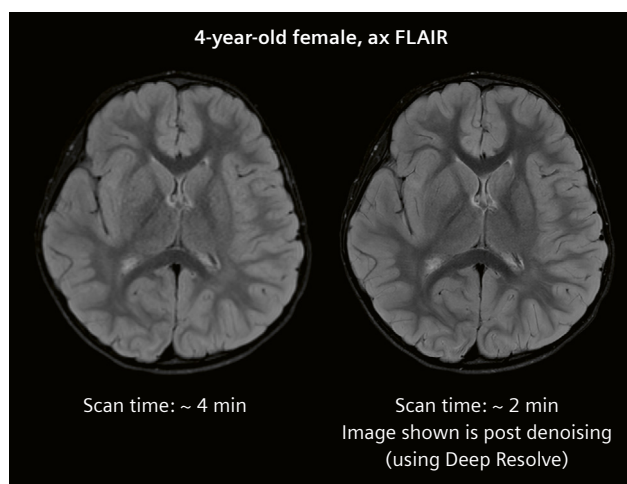
Magnetic resonance imaging (MRI) offers unparalleled soft tissue contrast without ionizing radiation, which is a key advantage for pediatric imaging. Yet one persistent limitation continues to shape clinical workflows: time. MRI acquisitions are inherently time intensive. Image formation typically depends on sequential k-space sampling, and overall scan time increases with the number of phase-encoding steps, repetitions, and number of sequences employed. A standard pediatric brain MRI examination that includes multiplanar T1-weighted, T2-weighted, FLAIR, diffusion-weighted, and post-contrast imaging can in total exceed 30 minutes.

For children, prolonged image acquisition time is more than an inconvenience; it can become a clinical barrier. Young patients may have difficulty remaining still, increasing the likelihood of motion artifacts, repeat sequences, and, in many cases, the need for sedation or anesthesia [1, 2]. Although sedation and anesthesia can facilitate successful imaging, they introduce additional risk, cost, and constrain access to MRI due to staffing and resource requirements.

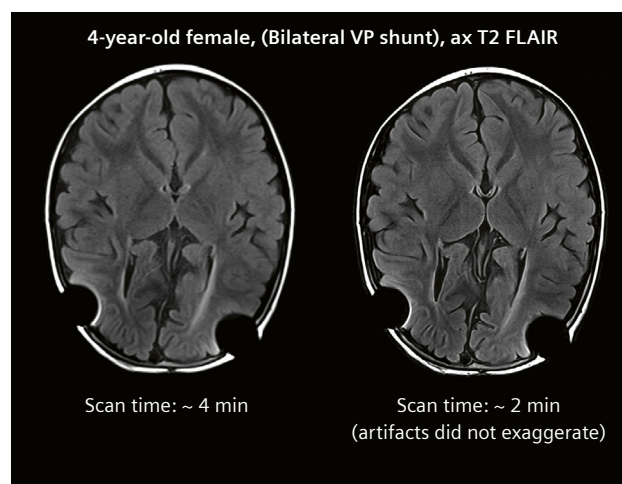


1 Deep learning-accelerated T2-weighted imaging.

Conventional axial T2-weighted TSE image of a 14-year-old boy acquired in approximately 4 minutes compared with a Deep Resolve-accelerated acquisition that took approximately 2 minutes. Despite increased acceleration and increased inherent noise (GRAPPA 4 versus 2), DL reconstruction reduces perceived image noise while preserving anatomic detail.



2 Deep learning-accelerated FLAIR imaging in pediatric brain MRI. Axial FLAIR images of a 4-year-old girl demonstrate preserved lesion conspicuity despite reduction in scan time from approximately 4 minutes to 2 minutes. A short acquisition may also reduce susceptibility to patient motion.



3 Patient with bilateral ventricular shunt. Axial T2-weighted FLAIR image of a 4-year-old girl with a bilateral ventriculoperitoneal (VP) shunt. Combined use of Deep Resolve Boost and Deep Resolve Sharp results in sharper images with less noise but does not exaggerate artifacts caused by the presence of metals.¹

Beyond conventional acceleration

In addition to conventional parallel imaging (e.g., GRAPPA), over the past decade, multiple strategies such as simultaneous multi-slice acquisition (SMS) and compressed sensing (CS) have been made clinically available to reduce scan time. These approaches work by acquiring less data, but at a cost. As acceleration becomes more aggressive, signal-to-noise ratio (SNR) decreases, and residual noise, blurring, or reconstruction artifacts may become more apparent [3–6]. This trade-off imposes a practical ceiling: Beyond a certain point, additional acceleration compromises diagnostic image quality.

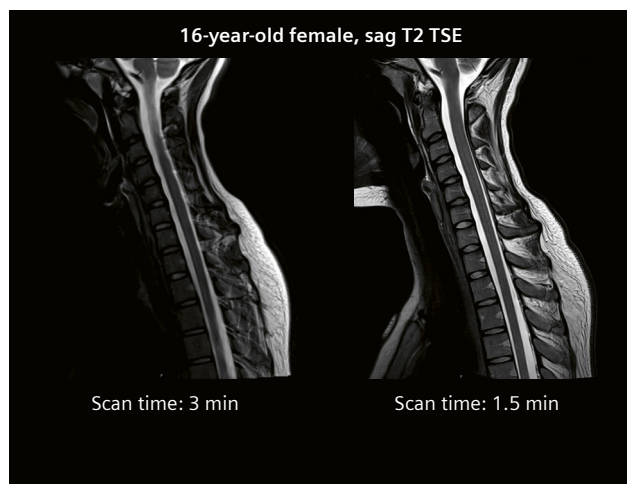
Deep learning-based denoising and reconstruction

Deep learning (DL)-based denoising reconstruction can change this trade-off by allowing more aggressive undersampling while mitigating the associated increase in image noise and loss of apparent image quality. Although conventional acceleration methods remain tightly limited by noise amplification as undersampling increases, modern DL-based approaches are designed to reconstruct diagnostically useful images from highly undersampled data [7–9] and can often be used in conjunction with more traditional image acceleration techniques. Deep Resolve Boost (DRB) is a more advanced generation of DL-based denoising

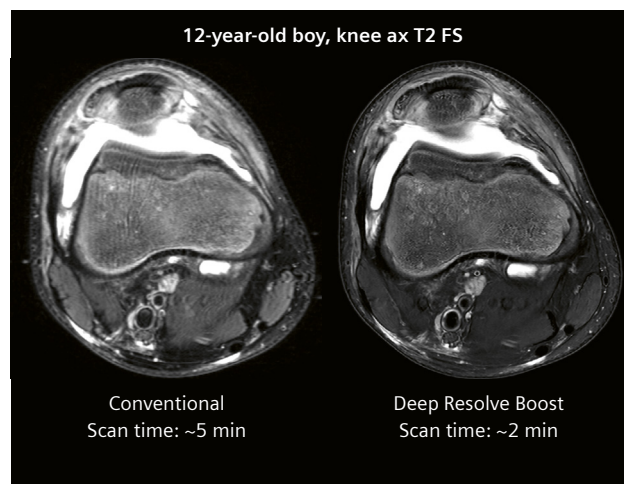
using a raw-data-to-image deep learning reconstruction method that utilizes undersampled k -space data and incorporates the acquired raw data throughout an iterative reconstruction process. A trained deep neural network is applied repeatedly during reconstruction to suppress noise while maintaining consistency with the measured data, allowing stronger denoising than conventional reconstruction and thereby supporting higher parallel-imaging acceleration factors. This approach is distinctly different from image-space denoising algorithms or image-space-only deep-learning methods, as it repeatedly incorporates the acquired k -space data through continuous data-consistency operations during the iterative reconstruction, constraining the reconstructed image to the measured MR signal and potentially reducing the risk of inappropriate modification of anatomic or pathologic features.

Deep Resolve Sharp (DRS) is a deep-learning-based super-resolution reconstruction method designed to increase image sharpness and spatial resolution. The neural network was trained using paired low- and high-resolution MR data and reconstructs a higher-resolution image from lower-resolution acquired data. Unlike traditional image-space interpolation, the reconstruction incorporates the acquired raw data to maintain data consistency. The combination of Deep Resolve Boost (DRB) and Deep Resolve Sharp (DRS) provides complementary noise reduction and spatial-resolution enhancement, respectively.

¹ The MRI restrictions (if any) of the metal implant must be considered prior to patient undergoing MRI exam. MR imaging of patients with metallic implants brings specific risks. However, certain implants are approved by the governing regulatory bodies to be MR conditionally safe. For such implants, the previously mentioned warning may not be applicable. Please contact the implant manufacturer for the specific conditional information. The conditions for MR safety are the responsibility of the implant manufacturer, not of Siemens Healthineers.



4 Spine imaging. Sagittal T2-weighted C-spine in a 16-year-old girl. DL reconstruction enables higher acceleration while preserving anatomical detail, facilitating shorter and potentially more motion-robust acquisitions.



5 Deep learning-accelerated musculoskeletal MRI. DL-reconstructed TSE images demonstrate higher spatial resolution and reduced perceived image noise compared with the conventional acquisition, with a substantial reduction in scan time. Fine structural details, including ligaments and cartilage, remain well delineated in the accelerated images.

Practical protocol implementation

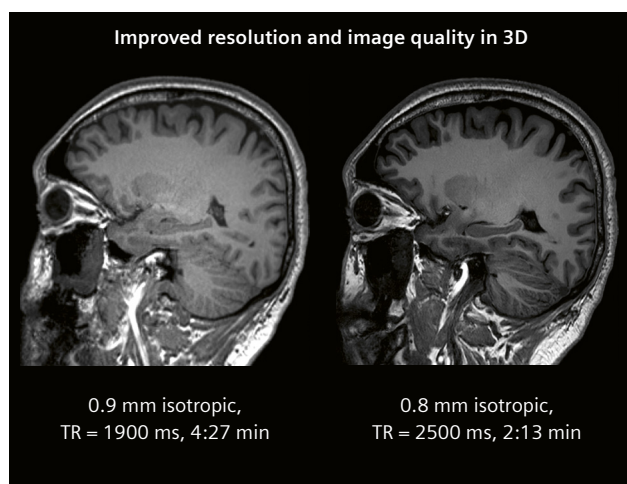
The objective is not simply to activate DRB while leaving the existing underlying protocol unchanged. Instead, implementation should involve deliberate re-optimization of acquisition parameters for the sequence and clinical task. Practical adjustments may include the following:

- **Increased acceleration:** DRB enables higher acceleration by reducing perceived noise and preserving diagnostically useful image information. When DRB is combined with DRS, the acquisition matrix and reconstructed spatial resolution may also be rebalanced to further optimize scan time while maintaining clinically acceptable or superior image quality and anatomic delineation.
- **Increased phase oversampling:** More aggressive acceleration or changes in acquisition geometry may increase susceptibility to wrap-around artifacts; increasing phase oversampling can help maintain adequate spatial coverage and reduce aliasing.
- **Increased readout bandwidth:** A higher receiver bandwidth can shorten echo spacing and reduce susceptibility-related distortion and blurring, although at the cost of lower SNR. This may be desirable in many clinical scenarios. By incorporating DRB, improved noise characteristics may provide greater flexibility in balancing bandwidth, SNR, and acquisition time.

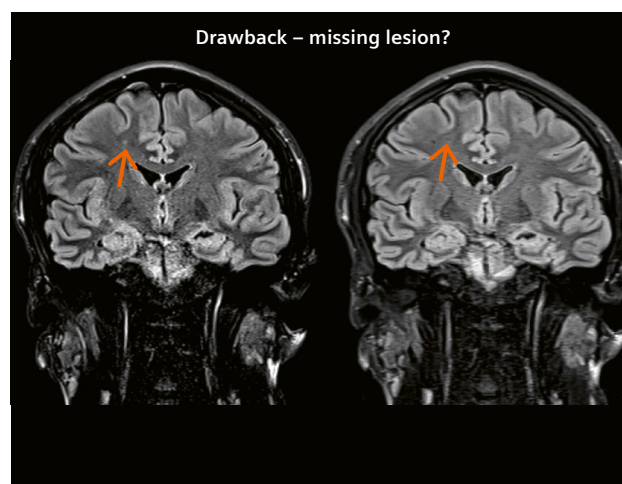
These adjustments should be performed on a sequence-by-sequence basis, with preservation of diagnostic image quality and lesion conspicuity remaining the primary consideration. DRB can be implemented as low, medium, or high strength. The choice of DRB strength would be based on the imaging scenario and the comfort of the radiologists in each center. In practice, the goal is not simply to make an existing sequence faster, but to use DRB, and where appropriate complementary DRS, to rebalance acceleration, spatial resolution, bandwidth, coverage, and motion sensitivity for the specific clinical task.

Clinical transformation in pediatric neuro MRI

Does faster imaging translate to better outcomes? Multiple early reports have demonstrated that DL sequences achieve diagnostic performance comparable to conventional imaging while reducing acquisition time, including in emerging pediatric applications [10, 11]. In our institutional experience of implementing DRB within routine pediatric neuro MRI protocols, many commonly used sequences have achieved approximately 30%–50% reductions in acquisition time while maintaining clinically acceptable or improved image quality (Figs. 1–4). Shorter acquisitions reduce the opportunity for patient motion and may decrease repeat imaging while increasing the likelihood of completing diagnostically adequate examinations.



6 **Deep learning-accelerated MPRAGE T1.** Sagittal T1-weighted MPRAGE images using conventional and DL-enhanced techniques. There is higher isotropic resolution, reduced blurring, and improved gray-white differentiation in the DL-enhanced image. Despite a longer TR and a higher resolution, the acquisition time of the DL-enhanced sequence is over 50% shorter.



7 **Potential lesion obscuration with image-domain-only deep learning reconstruction.** Comparison of conventional and DL-reconstructed MRI demonstrates a subtle small lesion that is visible on the standard acquisition but appears less conspicuous or is not visualized after image-domain-only DL denoising. This example does not represent Deep Resolve Boost; rather, it illustrates a broader potential limitation of image-domain-only denoising, in which aggressive smoothing may alter smaller low-contrast features. The example underscores the need for careful clinical validation and for radiologist awareness when implementing AI-based reconstruction or denoising methods.

Even modest reductions in individual sequence duration can have meaningful cumulative effects across a complete MRI examination, and outsized impacts in clinical practice. Faster acquisitions may also improve the feasibility of awake imaging protocols and may increase opportunities to use “feed-and-wrap” techniques in appropriately selected infants and child-centered imaging workflows [12]. In selected cases, some of the time savings can instead be traded for higher spatial resolution within a similar tolerance window. Beyond neuroimaging, similar practical benefits are observed in body and musculoskeletal MRI (Fig. 5). As DRB becomes available across a broader range of 3D sequences, further reductions in acquisition time and improvements in image quality may be achievable (Fig. 6).

Pitfalls and considerations

As with any new technology, careful adoption and clinical validation are essential. Radiologists should remain aware of potential DL-related artifacts, over-smoothing, altered noise texture, and subtle changes in image appearance. Importantly, improved perceived sharpness or reduced image noise should not be assumed to indicate improved diagnostic performance; accelerated protocols should be validated for the intended clinical indication and lesion types. Although DRB operates on raw *k*-space data rather than solely in image space, experience with other DL-based

denoising approaches underscores the broader need to validate lesion conspicuity rather than relying exclusively on perceived image sharpness or noise reduction. The example in Figure 7 represents image-domain-only DL denoising and is included to illustrate how aggressive image processing may alter the conspicuity of subtle low-contrast findings. Reviewing radiologists may also require an adjustment period as they become familiar with the appearance of DRB-reconstructed images at their site.

Conclusion

Deep learning-based reconstruction with Deep Resolve Boost provides an opportunity to rethink pediatric neuro MRI protocol design, rather than simply accelerating existing acquisitions. By enabling more aggressive acceleration while maintaining diagnostically useful image quality, DRB can substantially shorten individual sequences and may reduce total examination time. Its greatest value, however, lies in allowing acquisition parameters to be rebalanced according to the clinical task — trading time savings for spatial resolution, coverage, bandwidth, and motion sensitivity as appropriate. Careful sequence-specific optimization, clinical validation, and continued attention to subtle reconstruction-related image alterations remain essential as these techniques become more widely integrated into routine pediatric imaging.

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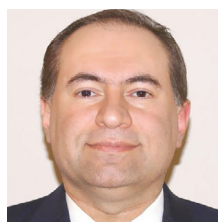
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