

# Sedation-Free Pediatric Neuroimaging with Deep Learning-Reconstructed Deep Resolve 3D MR Sequences

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## Introduction

In this article, we evaluate whether 3D sequences with deep learning (DL)-based image reconstruction can replace 3D sequences without DL for pediatric<sup>1</sup> neuroimaging, and help achieve sedation-free MRI exams.

At Oslo University Hospital, we encounter a significant number of pediatric cases, which present unique challenges due to their specific needs. Sedation or general anesthesia are commonly used during MRI exams for younger patients to ensure they remain still throughout the scan.

Cutting-edge AI-based techniques like DL-based image reconstruction have significantly contributed to faster scans, which are crucial for every patient group [1–4]. Faster scans offer the advantage of producing clearer and more detailed images by reducing the occurrence of motion artifacts, leading to more accurate diagnoses and higher success rates of awake MRI scans [5]. Deep Resolve is a newly launched deep learning application that enables faster, more motion-robust scans. Deep Resolve Boost is a powerful denoising algorithm to mitigate noise enhancement due to higher acceleration factors. Deep Resolve Sharp is a DL-based interpolation to improve the image resolution by a factor of two along each spatial dimension.

When scanning younger children<sup>1</sup>, this can help reduce sedation rates, along with the associated risks and costs [6]. It also minimizes patient discomfort and can potentially improve the overall patient experience.

## Findings and procedure details

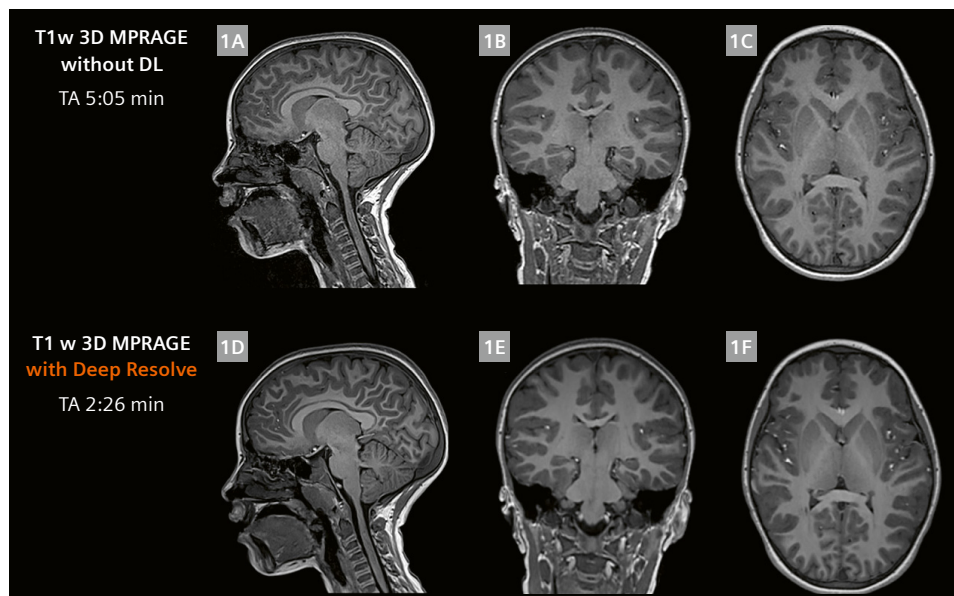
In addition to fast, motion-robust protocols such as Deep Resolve, proper patient preparation is a key element in enabling pediatric MRI without sedation or general anesthesia. Most of our neuro protocols include both 2D and 3D sequences. At our 3T MAGNETOM Skyra Fit (Siemens Healthineers, Erlangen, Germany), Deep Resolve is currently available for 2D sequences, and has been highly beneficial [7]. However, we are eager to have deep learning capabilities for 3D sequences. Currently, we are collaborating with Siemens Healthineers to implement work-in-progress (WIP) sequences<sup>2</sup> to use Deep Resolve in our 3D sequences. The two most commonly used and time-consuming 3D sequences are T1w 3D MPRAGE and T2w 3D SPACE FLAIR. Applying DL to these sequences would greatly assist in situations where patients struggle to remain in the scanner for extended periods.

<sup>1</sup>MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.

<sup>2</sup>Work in progress. The applications are currently under development and are not for sale in the U.S. and in other countries. Their future availability cannot be ensured

## Case 1

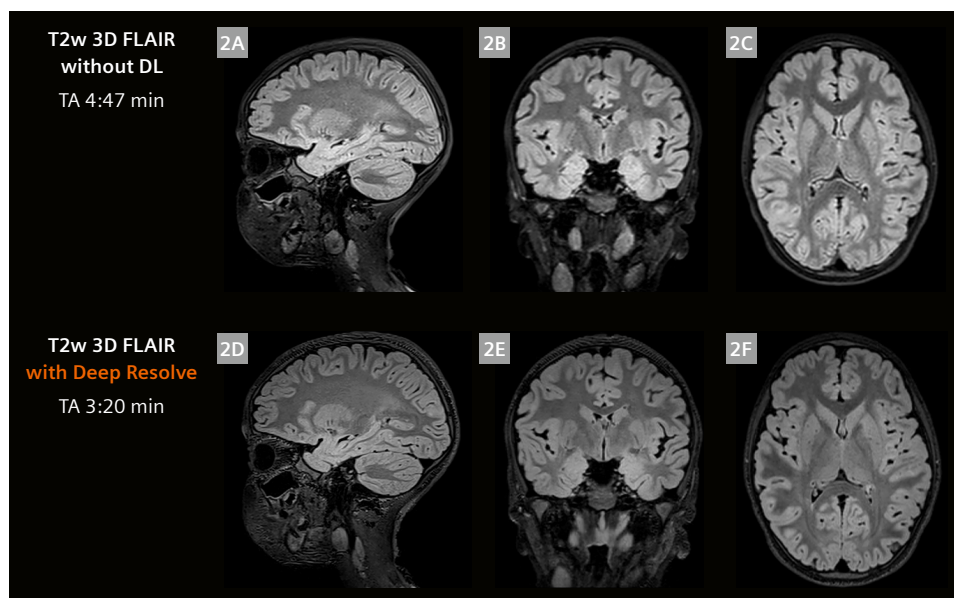
A 6-year-old girl with sickle cell anemia underwent an MRI of the brain prior to stem cell transplantation.



### 1 T1w 3D MPRAGE

This figure illustrates the difference between T1w 3D MPRAGE images with and without Deep Resolve deep learning (DL) image reconstruction. The conventional protocol uses PAT 2 and an isotropic resolution of  $1.0 \times 1.0 \times 1.0 \text{ mm}^3$  while the Deep Resolve protocol uses PAT 6 and an isotropic resolution of  $0.8 \times 0.8 \times 0.8 \text{ mm}^3$ . However, DL helps to reduce acquisition time by nearly 52%.

**1A** and **1D** show the initial orientation, while **1B**, **1C**, **1E**, and **1F** are multiplanar reconstructions (MPR).



### 2 T2w 3D FLAIR

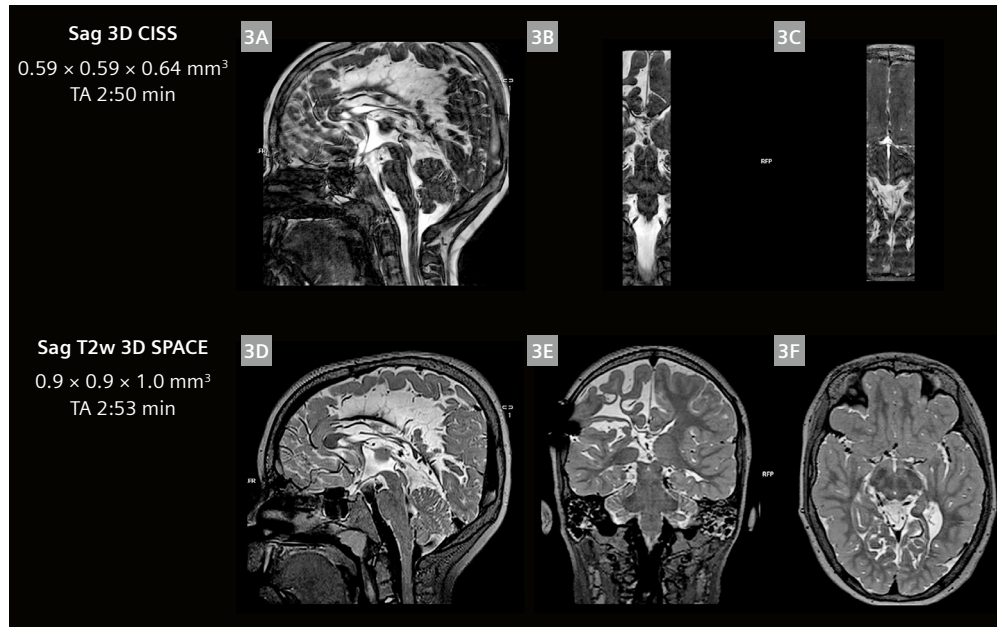
This figure demonstrates the difference between T2w 3D FLAIR images with and without Deep Resolve deep learning image reconstruction. The resolution and slice coverage are comparable in both sequences ( $0.9 \times 0.9 \times 0.9 \text{ mm}^3$ ). The conventional protocol uses PAT 4, while the Deep Resolve protocol uses PAT 6. With Deep Resolve, it was possible to reduce the acquisition time by approximately 30% for this sequence. **2A** and **2D** show the initial orientation; **2B**, **2C**, **2E**, and **2F** show the corresponding MPRs.

Using Deep Resolve, it was possible to reduce the scan time by 52% and 30% for MPRAGE and 3D FLAIR, respectively, while improving the apparent image quality. While Deep Resolve Boost helped maintain a great signal-to-noise ratio (SNR) despite the higher acceleration factor, Deep Resolve Sharp helped improve the image quality by reconstructing

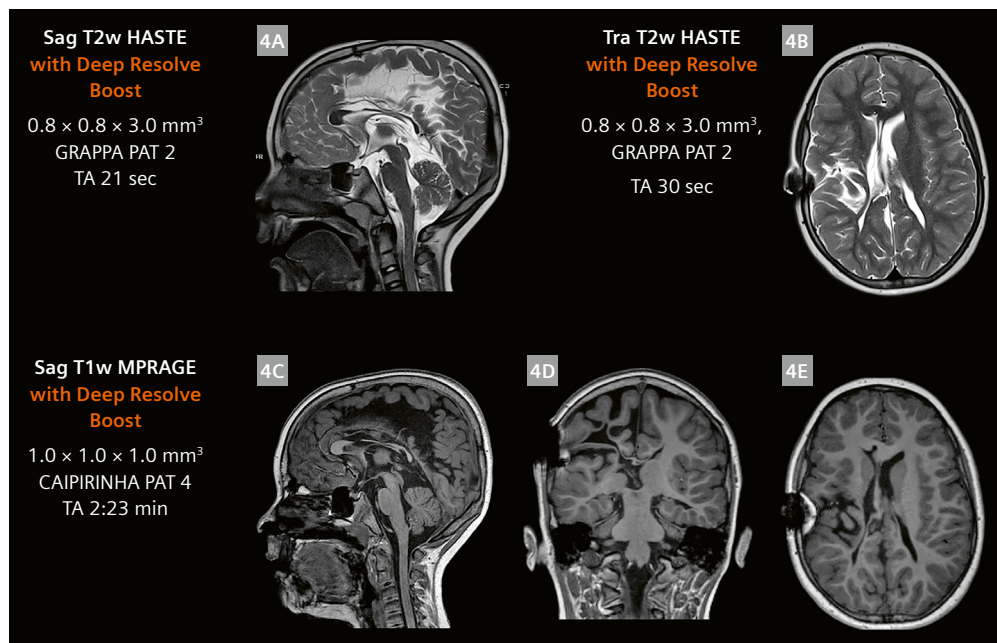
images with a super-resolution factor of 8. Since the resolution is improved in readout and phase-encoding direction by a factor of 2, we have a total factor of 4 in 2D imaging. In addition, with 3D Deep Resolve, you can add a factor of 2 in slice direction giving you an overall factor of 8.

## Case 2

Awake MRI examination of a 7-year-old boy with a porencephalic cyst and difficulty remaining still. The patient is being monitored following a shunt placement.



**3** The 3D CISS images (3A–3C) exhibit motion artifacts due to the patient's difficulty in remaining still. In contrast, the T2w 3D SPACE sequence (3D–3F) was successfully completed with good image quality. 3A, 3D initial sagittal orientation, 3B, 3C, 3E, and 3F corresponding coronal and transversal MPRs.

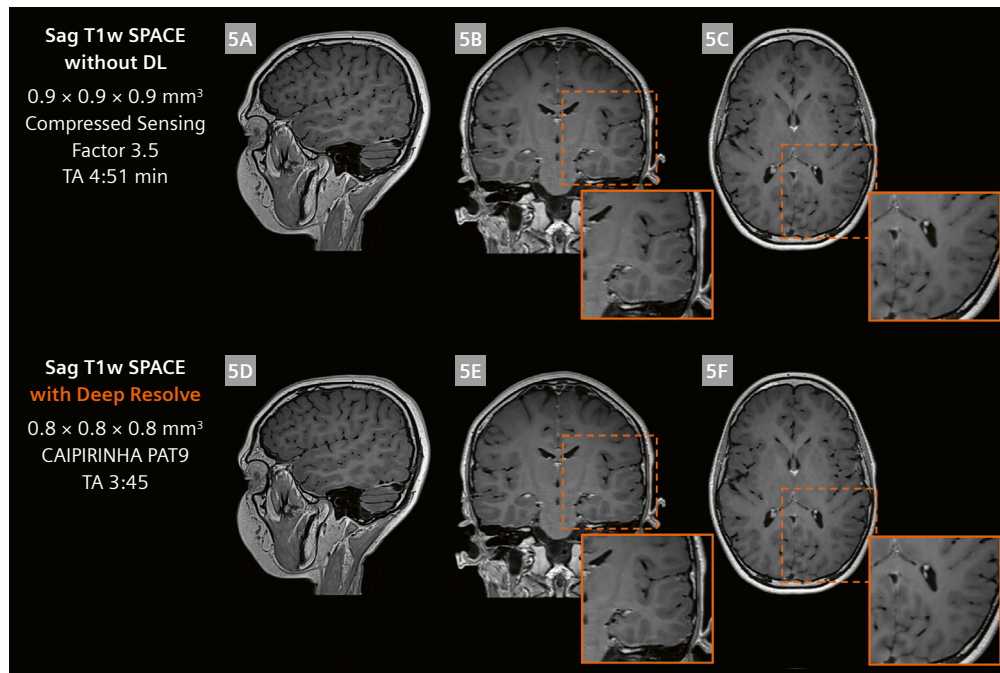


**4** Continued from Figure 3. The boy expressed a desire to leave after the previous scan, but agreed to stay a few more minutes. We then performed a T2w HASTE sequence with Deep Resolve (4A and 4B), which allowed us to obtain sharp images in just a few seconds. Finally, we conducted the T1w MPRAGE sequence with Deep Resolve (4C) as he reached his limit of tolerance. Figures 4D and 4E are MPR of 4C.

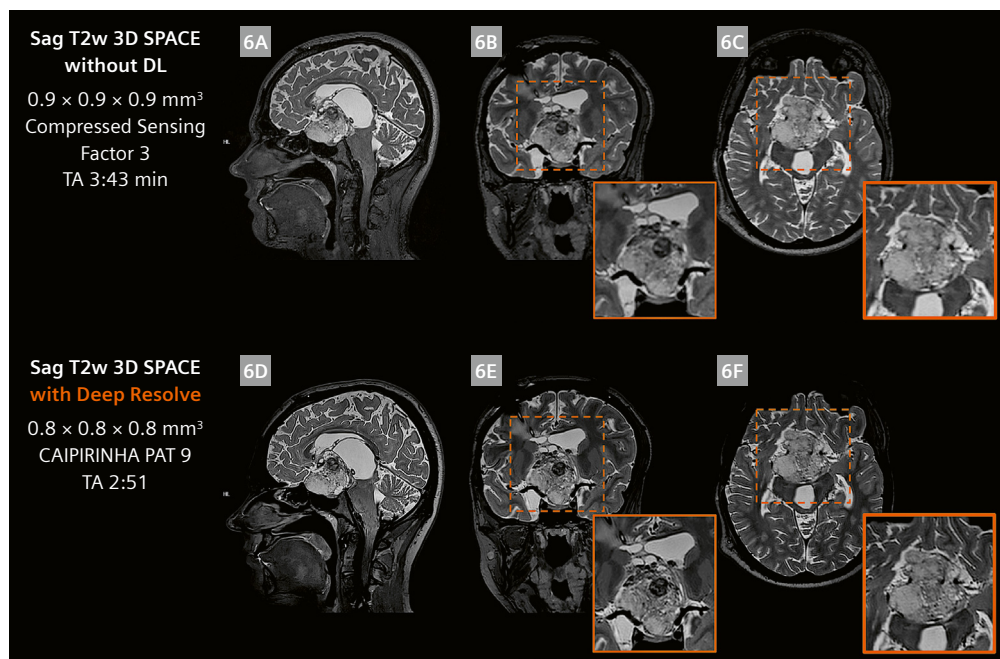
In this patient with limited cooperation, Deep Resolve was essential to performing a successful non-sedated MRI examination. Notably, without Deep Resolve, the routine T1w MPRAGE sequence, which typically requires approximately 5 minutes, would likely have been unfeasible in this case.

### Case 3

A 10-year-old boy underwent MRI without sedation for a known pilomyxoid astrocytoma in the suprasellar region.



**5** This figure highlights a key challenge of 3D volumetric imaging: The MPR views often appear less sharp than the initial imaging orientations, which in this case is the sagittal orientation. Using the T1w 3D SPACE sequence, we compared routine acquisitions (5A–5C) with images acquired using Deep Resolve (5D–5F). The results clearly demonstrate improved sharpness and clarity of the MPR view with Deep Resolve. 5A and 5D initial sagittal orientation, 5B, 5C, 5E, and 5F coronal and transverse MPRs respectively.



**6** Continued from Figure 5, we observe a similar effect with the T2w 3D SPACE sequence. The comparison between images without deep learning (6A–6C) and with Deep Resolve (6D–6F) reveals the same outcome: significantly sharper and clearer MPR views, without any signs of blurriness when applying Deep Resolve.

Here again, Deep Resolve allowed faster scans for both T1w and T2w SPACE while improving the image quality, especially when performing 3D reformatting.

## Conclusion

The use of Deep Resolve 3D for pediatric neuro imaging shows great potential to further reduce the overall exam time beyond what was possible with Deep Resolve 2D. It furthermore contributes to improving image quality and the apparent resolution of the images. This may contribute to avoiding sedation or general anesthesia in some pediatric patients, while contributing to improve the diagnostic accuracy.

## Contact

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To download 1.5T MAGNETOM Sola or 3T MAGNETOM Vida protocols (.exar1 & PDF) with Deep Resolve, please visit us at

[www.magnetomworld.siemens-healthineers.com/clinical-corner/protocols/pediatric-mri-protocols/deep-resolve-pediatric](http://www.magnetomworld.siemens-healthineers.com/clinical-corner/protocols/pediatric-mri-protocols/deep-resolve-pediatric)

**SIEMENS MAGNETOM 3.0T XQ NumarisX VASQA-01NG**

**1.5T\_Vida\_Fit\_bacsiemens\_pedimskknee\_ultraflex\_t8localizer\_dxt\***  
TA: 4 sec Coil Selection: Auto Voxel Size: 0.6×0.6×6.0 mm³ Acc: 2 Ref: SNR: 1.00

**Properties**

|                                               |                    |
|-----------------------------------------------|--------------------|
| Start measurement without further preparation | Off                |
| Wait for User to Start                        | Off                |
| Start measurements                            | Off                |
| Post Recon                                    | Single Measurement |
| Auto Open Index Display                       | On                 |
| Auto Close Index Display                      | Off                |
| Load Images to MRI ViewSQC                    | Off                |
| Auto Show Images                              | On                 |
| Load Images to Stamp Segments                 | On                 |
| Load Images to Graphic Segments               | On                 |
| Graphic: ungated                              | All Segments       |
| Online Mouse                                  | Off                |

**Resolution - Acceleration**

|                        |     |
|------------------------|-----|
| Acceleration Factor PE | 2   |
| Reference Lines PE     | 24  |
| Deep Resolve           | Off |
| Phase Partial Fourier  | Off |
| Supersample Echo       | Off |

**Resolution - Filter**

|                       |         |
|-----------------------|---------|
| Flow Filter           | Off     |
| Elliptical Filter     | Off     |
| POCS                  | Off     |
| Distortion Correction | Off     |
| Normalize             | 2D      |
| Thesion               | Thesion |
| Image Filter          | Off     |

**Routine**

|                    |             |
|--------------------|-------------|
| Scan Group         | 1           |
| Stacks             | 5           |
| Distance Factor    | 100 %       |
| Position           | Isocenter   |
| Orientation        | Transversal |
| Phase Encoding Dir | A ↔ P       |
| Phase Oversampling | 0 %         |
| Fov/ Head          | 330 mm      |
| Fov/ Phase         | 100.0 %     |
| Slice Thickness    | 6.0 mm      |
| TR                 | 7.0 ms      |
| TE                 | 3.00 ms     |
| Averages           | 1           |
| Consolidations     | 5           |
| AutoAlign          | On          |

**Contrast - Common**

|                    |          |
|--------------------|----------|
| T1                 | 7.0 ms   |
| T2                 | 3.00 ms  |
| T2*                | 0.00 ms  |
| MTC                | Off      |
| Magnet Preparation | None     |
| Flip Angle         | 20 deg   |
| Dark Band          | Standard |
| Contrasts          | 1        |
| Reconstruction     | Off      |
| MagNathic          | Off      |

**Contrast - Dynamic**

|                 |                  |
|-----------------|------------------|
| Dynamic Mode    | Standard         |
| Measurements    | 1                |
| Multiple Series | Each Measurement |

**Resolution - Common**

|                  |         |
|------------------|---------|
| Fov/ Head        | 330 mm  |
| Fov/ Phase       | 100.0 % |
| Slice Thickness  | 6.0 mm  |
| TR               | 7.0 ms  |
| TE               | 3.00 ms |
| Phase Resolution | 90 %    |
| Interpolation    | On      |

**Resolution - Acceleration**

|                   |            |
|-------------------|------------|
| Acceleration mode | GRAPPA     |
| Reference Scans   | Integrated |

**Geometry - Common**

|                    |             |
|--------------------|-------------|
| Scan Group         | 1           |
| Stacks             | 5           |
| Distance Factor    | 100 %       |
| Position           | Isocenter   |
| Orientation        | Transversal |
| Phase Encoding Dir | A ↔ P       |
| Phase Oversampling | 0 %         |
| Fov/ Head          | 330 mm      |
| Fov/ Phase         | 100.0 %     |
| Slice Thickness    | 6.0 mm      |
| TR                 | 7.0 ms      |
| Multi-Slice Mode   | Sequential  |
| Interleaved        | 5           |

**Geometry - AutoAlign**

|                     |             |
|---------------------|-------------|
| Scan Group          | 1           |
| Position            | Isocenter   |
| Orientation         | Transversal |
| Phase Encoding Dir  | A ↔ P       |
| Initial Position    | Isocenter   |
| Initial Rotation    | 0.0 deg     |
| Initial Orientation | 0.0 deg     |
| Initial Rotation    | 0.00 deg    |

**Geometry - Saturation**

|                  |          |
|------------------|----------|
| Saturation Mode  | Standard |
| Speed Saturation | None     |

**Geometry - Tim Planning Suite**

|                    |      |
|--------------------|------|
| Technique Protocol | Off  |
| Table Position     | 0 mm |
| Table Rotation     | 0 mm |
| Table Correlation  | Off  |

**System - Miscellaneous**

|                  |                    |
|------------------|--------------------|
| Coil Selection   | ALC: All but spine |
| MRSA             | S-C-T              |
| Refill           | R ↔ L              |
| Contrast         | A ↔ P              |
| Transversal      | M ↔ S              |
| Coil Combination | Additive Combine   |