Deep Learning-Based MRI Reconstruction in Head and Neck Imaging: How the Wonderland of AI can Stop Us Feeling Like the White Rabbit

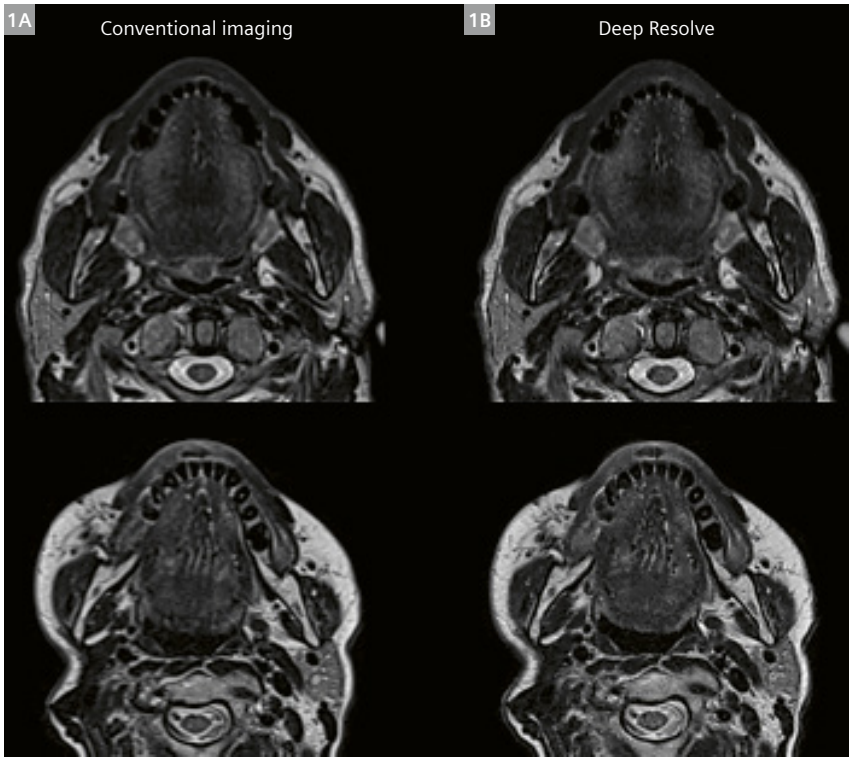
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Oh dear! Oh dear! I shall be late!" The White Rabbit in Alice in Wonderland* certainly felt the weight of time pressure on his shoulders. Similarly, radiologists and technologists can feel burdened by the clock when they are performing head and neck MRI scans.

Two main reasons contribute to this: First, MRI is increasingly used to stage and monitor head and neck (HN) cancers. This is due to its superior ability to distinguish neoplastic tissues from surrounding structures and to visualize the intricate anatomy of the head and neck region. However, these scans often involve long acquisition times. The growing demand for MRI therefore creates significant organizational pressures for departmental workflows.

* Alice's Adventures in Wonderland is a children's novel by Lewis Carroll from 1865. It tells the story of Alice, who falls down a rabbit hole into a place called Wonderland. One of the characters she meets is the White Rabbit, who always thinks that he is late.



1 Follow-up study in a 61-year-old patient who underwent surgical resection, flap reconstruction, and neck dissection for a skin squamous cell carcinoma of the right malar region. **(1A)** Conventional axial T2w TSE sequence acquired at two different levels. **(1B)** T2w TSE with Deep Resolve of the same patient at the same levels. Both sequences have optimal image quality, sharp margins, minimal noise, and almost no motion artifacts. Fine anatomical details are well depicted on both sequences, despite a dramatic difference in acquisition times. The readers were unable to distinguish between the two sequences. It is conceivable that, in compliant patients, Deep Resolve allows a reduction in acquisition time without loss of image quality.

Second, head and neck imaging is particularly susceptible to motion artifacts caused by breathing, swallowing, and other involuntary movements. These artifacts pose additional challenges for obtaining high-quality images. This can lead to repeat scans, which take extra time and increase costs. Notably, two separate studies estimated the annual financial impact of motion artifacts per MRI scanner to be $115,000 in 2015 and $364,000 in 2020 [1, 2].

Acceleration of MRI sequences could address these challenges. In the past two decades, various methods have been developed to tackle the problems posed by long acquisition times and motion artifacts.

Parallel imaging techniques such as GRAPPA [3] can reduce the number of phase-encoding steps during image acquisition, which significantly shortens acquisition times. However, these techniques also introduce anisotropic noise that increases proportionally to the square root of the parallel imaging factor.

Radial sampling of *k*-space (e.g., with BLADE and StarVIBE) effectively reduces the impact of motion artifacts. However, this comes at the cost of increased acquisition times and a lower signal-to-noise ratio (SNR), necessitating a limitation in spatial resolution.

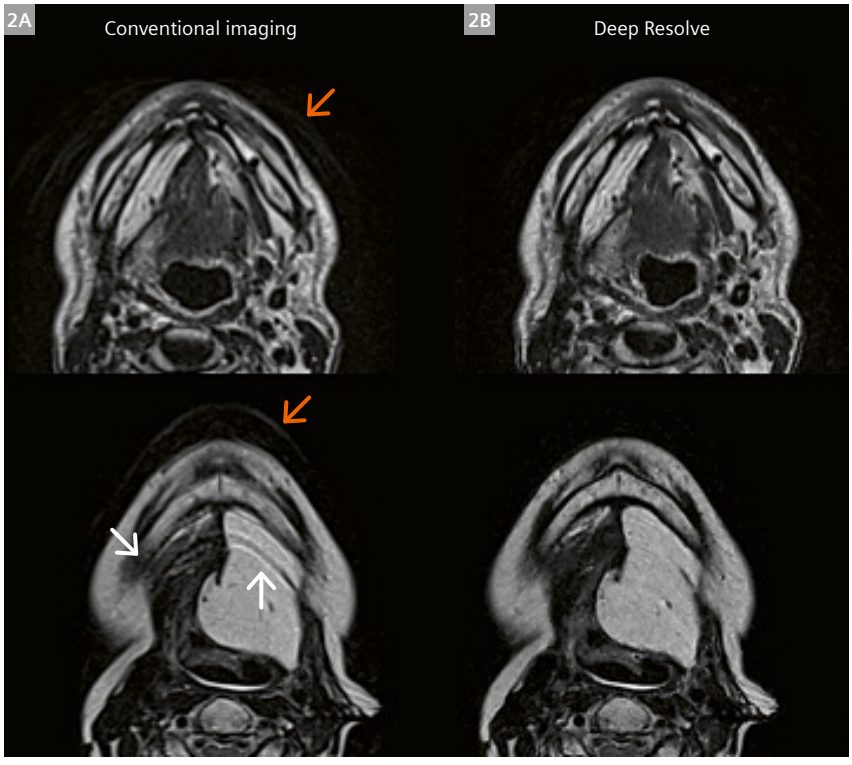
This is the scenario in which artificial intelligence has recently made its debut. It has created a kind of "Wonderland," where a myriad of strange and fascinating things occur. Don't worry if you don't fully understand how it works. It works!

Deep learning-based reconstruction performed by Deep Resolve uses intelligent denoising and convolutional neural networks to generate high-resolution and increased SNR images from low-resolution inputs. This allows acquisition times to be reduced without compromising image quality [4].

Deep Resolve has demonstrated its efficacy in many imaging fields, including neurological, musculoskeletal, breast, and orbital imaging [5–10].

A 1.5T MAGNETOM Sola MRI system was installed at our institution in May 2024. Since then, our group has been collecting data on Deep Resolve applied to HN imaging. Deep Resolve made it possible to shorten the acquisition time of TSE T2 from 2:30 minutes (Sequence A) to about 50 seconds (Sequence B). This is a threefold decrease. A similar time gain could be obtained by applying Deep Resolve to TSE T1 sequences. To test the impact of shortened acquisition times on image quality, we collected over 1,060 T2-weighted images, obtained with both Deep Resolve and a standard sequence, from 52 head and neck patients. Five radiologists with varying levels of experience and different vendor backgrounds evaluated the images. They were blinded to the sequence applied and they assigned a qualitative score to the images.

The radiologists used a three-point Likert scale (1–3) to assess the images for overall quality, artifacts, edge sharpness, and noise. They were also asked to identify the type of sequence.



2 Follow-up study in a 73-year-old patient who underwent left hemiglossectomy and free flap reconstruction for a squamous cell carcinoma of the oral cavity. **(2A)** Conventional T2w TSE sequence, acquired in the axial plane at two different levels. Arrows point out motion artifacts along the phase encoding direction, both inside and outside the anatomical volume. **(2B)** T2w TSE with Deep Resolve acquired on the same patient at the same levels. Motion artifacts are dramatically reduced, allowing a better evaluation of anatomical signals. It is conceivable that the significantly reduced acquisition time with Deep Resolve (50 seconds instead of 2:30 minutes) can improve the image quality in non-compliant patients.

The type of sequence was correctly identified in only 44% of the cases. The overall quality scores for sequences A and B were 2.63 and 2.52, respectively. The artifact scores were 2.61 and 2.55. The edge sharpness scores were 2.57 and 2.43, showing significant differences between sequences. The noise scores were 2.51 and 2.41.

Figures 1 and 2 are noteworthy examples of Deep Resolve sequences compared to their conventional counterparts. The images speak for themselves.

Acquiring a standard head and neck examination in half the time may increase departmental productivity without compromising diagnostic quality. Moreover, saving time on relatively simple examinations allows greater allocation of resources to more complex studies that may require more sequences. Finally, reducing scan times may improve patient compliance, particularly in head and neck patients, who are often clinically fragile and difficult to manage.

Significant further benefits are likely if Deep Resolve is applied to gradient-echo 3D and BLADE sequences, which are an important part of most head and neck protocols.

Alice's Wonderland was a dream. But the Wonderland that AI has created is real. We're at the start of an exciting journey — one that could reduce time pressure for all of us working in MRI.

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