Helpful Hints for Using Deep Learning Image Reconstruction

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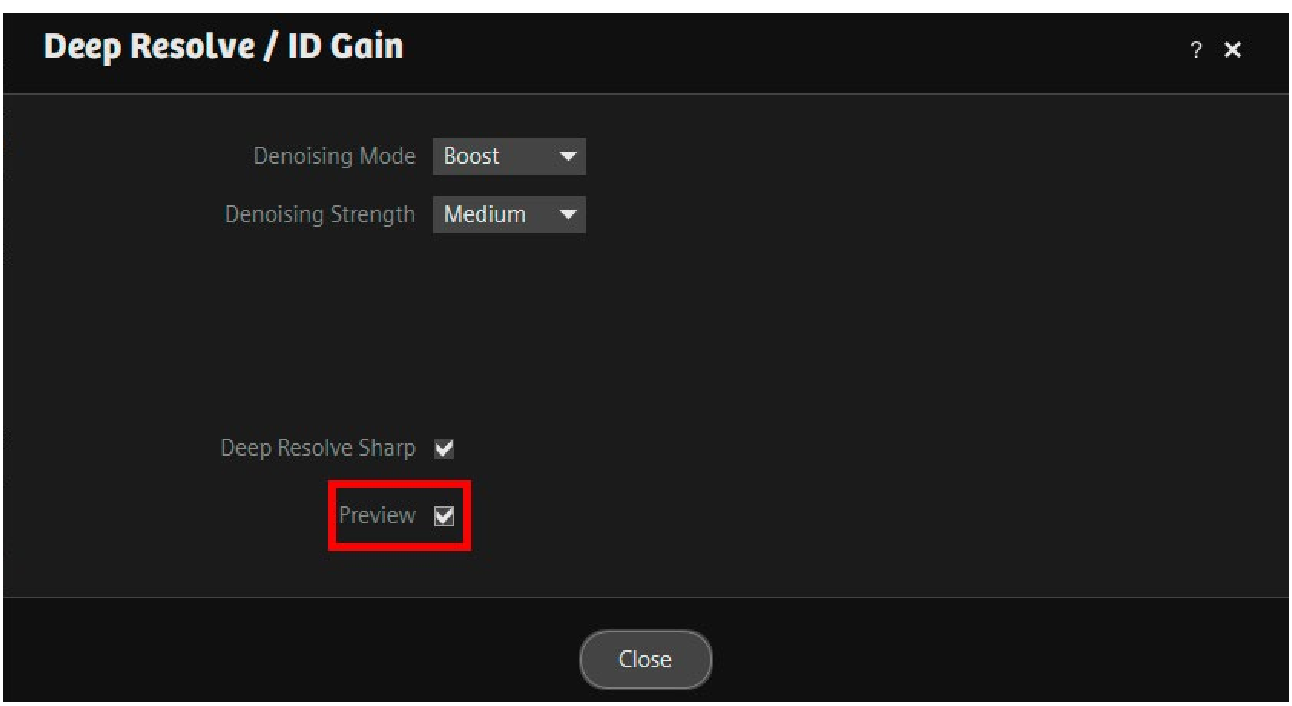
Deep Resolve Boost can perform parallel imaging reconstructions with an improved signal-to-noise ratio. This means it can potentially reduce scan times more than conventional parallel imaging algorithms, such as GRAPPA.

Deep Resolve Boost was trained to denoise data. However, it also has built-in data consistency constraints, which force it to be consistent with the acquired raw data. To achieve both denoising and consistency, it tends to smooth regions that would be very noisy with conventional imaging methods. This smooth image impression can be misleading to radiologists and technologists who have been trained on conventional imaging methods.

To address this issue when setting up new protocols, we provide a preview function (starting from *syngo* MR XB10A), which can be activated in the Deep Resolve sub-dialog box (Fig. 1).



1 You can activate the preview option in the Deep Resolve sub-dialog box.

The preview option triggers a conventional GRAPPA/CAIPIRINHA parallel imaging reconstruction (Fig. 2A) before the Deep Resolve Boost reconstruction (Fig. 2B).

This allows you to better judge whether the chosen parameters are reasonable.

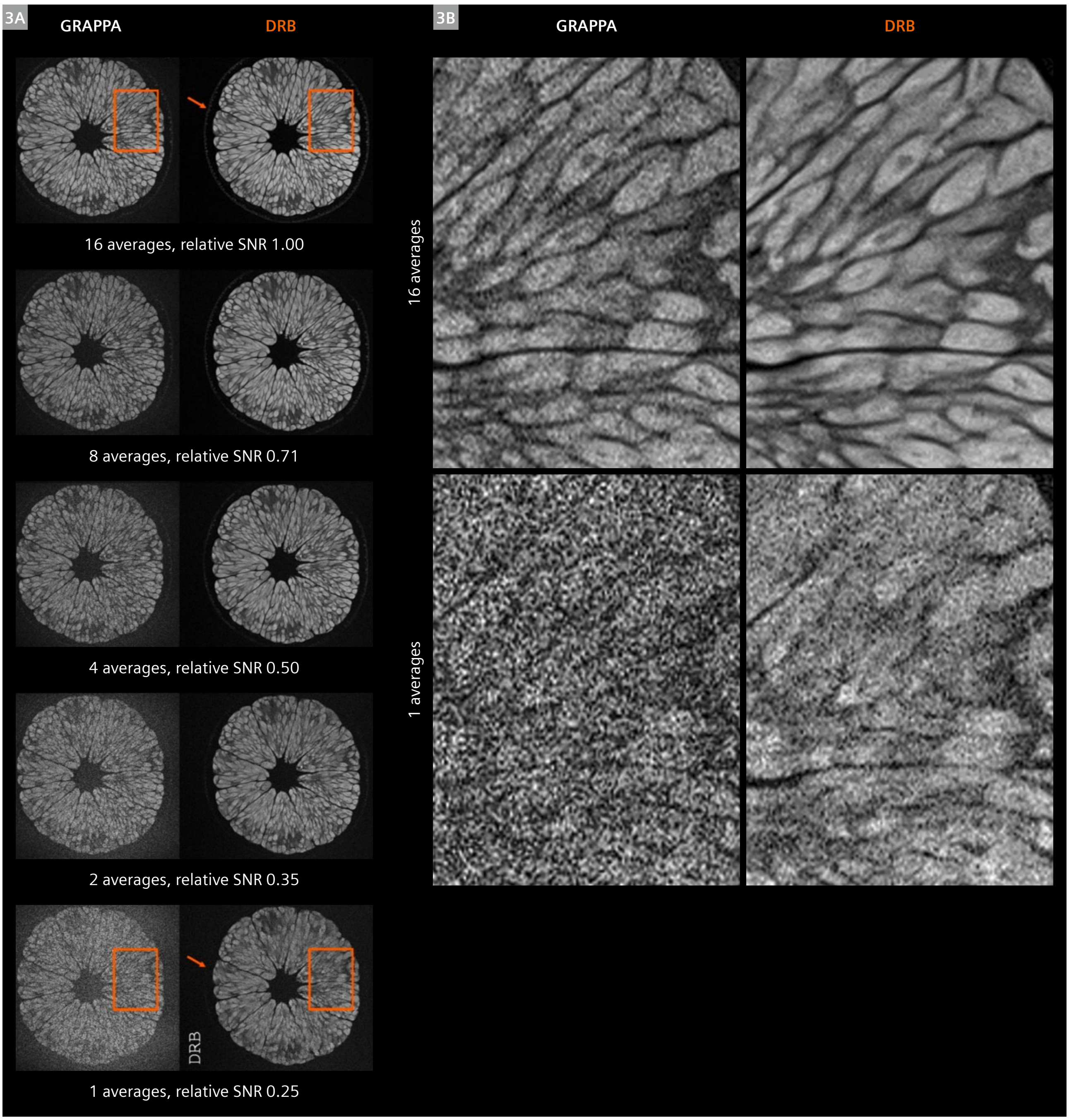
The following table offers some helpful hints on which imaging parameters affect SNR as SNR is a primary indicator for good performance of Deep Resolve Boost.

2 Two image series produced by the preview option. **(2A)** Conventional parallel imaging reconstruction. **(2B)** Deep Resolve Boost reconstruction. The preview series has the suffix "_Preview." Would you still feel confident making a clinical decision using the preview series? If not, the settings are probably too ambitious.

Action	Relative SNR
Decreasing slice thickness from 2 mm to 1 mm	0.5
Decreasing averages from 4 to 1 (i.e. reducing measurement time by 75%)	0.5
Increasing PAT acceleration factor from 1 to 4	0.5
Doubling base resolution (e.g., from 320 to 640) while keeping phase resolution at 100%	0.35
Doubling base resolution (e.g., from 320 to 640) while keeping phase resolution at 50%	0.5
(Relative SNR indicates the SNR ratio as compared with the unmodified protocol. A relative SNR of 0.5 corresponds to 50% less SNR)	

Table 1: Which imaging parameters affect SNR.

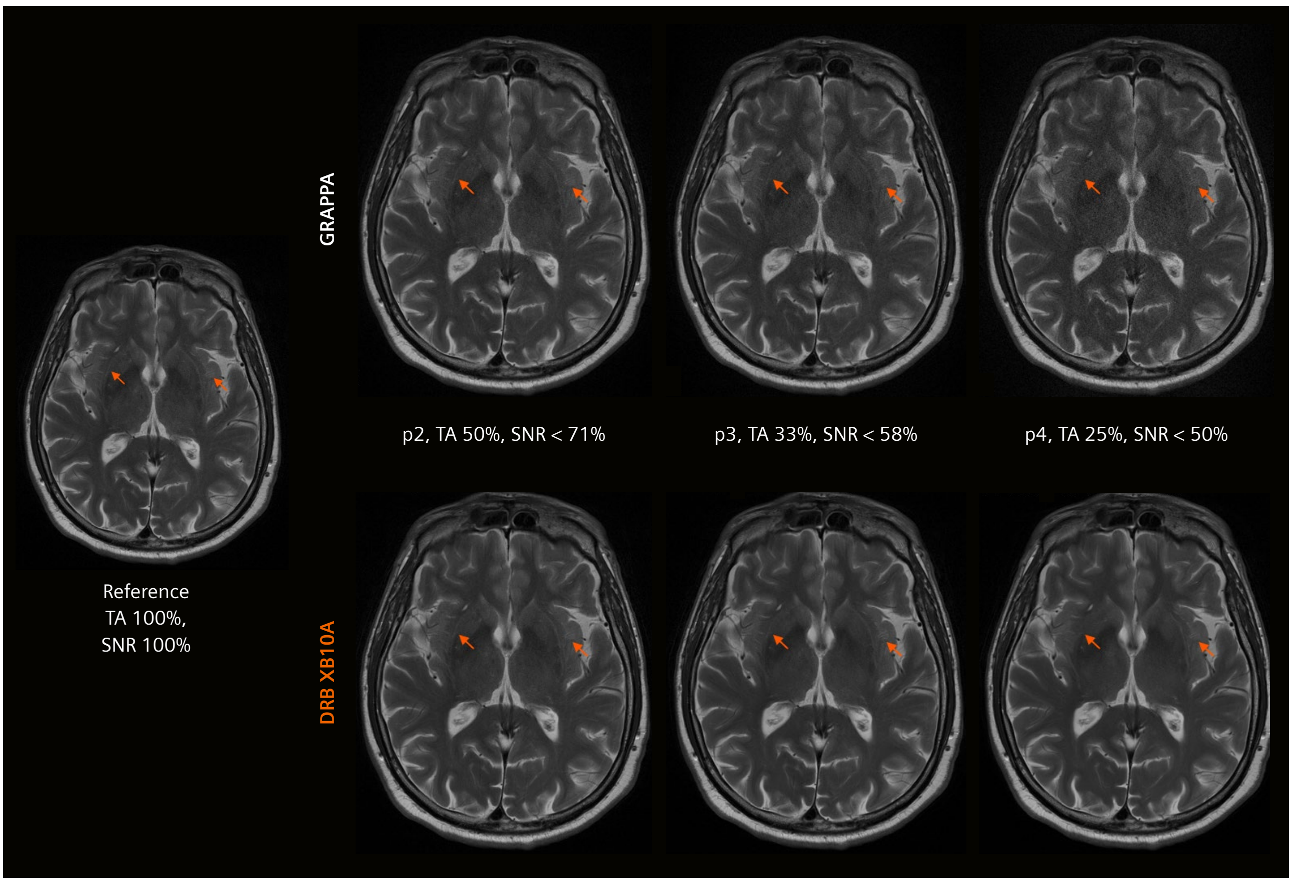
Starting with insufficient SNR may cause a loss of image features, as you can see in Figure 3. SNR can also be reduced at high acceleration factors due to the coil geometry. You can check the relative change in SNR in the top right corner of the protocol dialog.



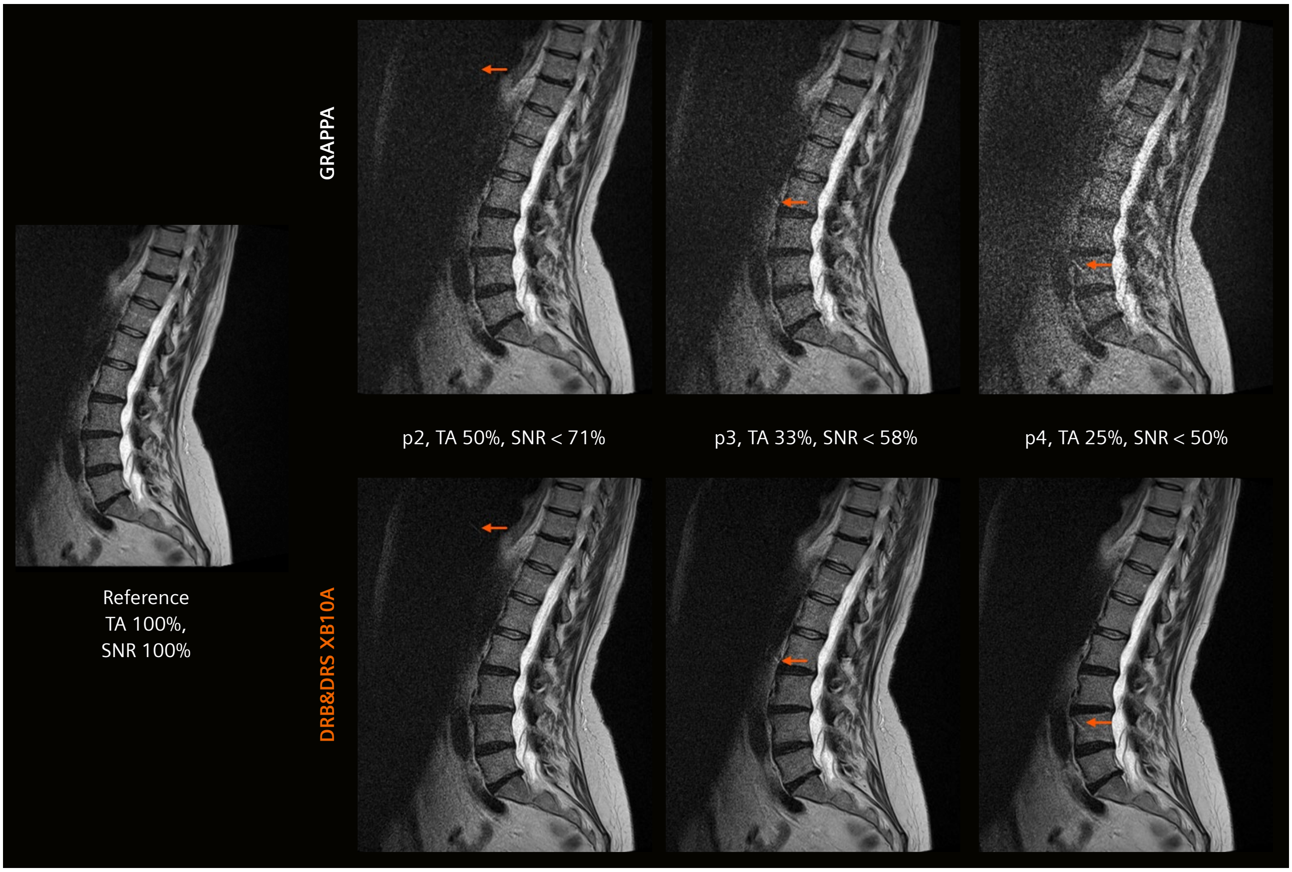
3 **(3A)** Impact of decreasing the number of averages from 16 to 1 and therefore the relative SNR from 1.00 to 0.25 for GRAPPA (left) and Deep Resolve (right). **(3B)** Magnifications of the areas marked in orange from 3A. For one average, the GRAPPA image (left) contains mainly noise, the Deep Resolve image (right) preserves coarse structures but smoothes detailed structures.

We stated that the signal-to-noise ratio (SNR) scales with the square root of the number of acquired *k*-space samples. Increasing the PAT factor to reduce the acquisition time also reduces the number of *k*-space lines. The effect on the image quality and SNR can be seen in Figure 4. For conventional GRAPPA acquisitions, the images become noisier. For Deep Resolve acquisitions the noise level is reduced, although very fine image feature may be subject to increased blurring.

In parallel imaging, there is an additional source of noise: g-factor noise amplification. This effect is region-specific and depends on multiple factors including the number and arrangement of coil elements, the phase-encoding direction, or patient weight and size [1]. It can lead to significant SNR variations in the image, exceeding the theoretical square root-dependent SNR loss.



4 Increasingly removing k-space samples with parallel imaging leads to increased noise for GRAPPA reconstructions (top). For Deep Resolve, small image features may be subject to increased blurring if the SNR is too low.



5 Effect of g-factor noise amplification due to coil geometry. For GRAPPA, regionally varying noise clouds increase with increasing PAT factor. For Deep Resolve, these noisy regions are not obvious due to the denoising.

Figure 5 shows reconstructions of a spine acquisition from a 0.55T MAGNETOM Free.Star system. In GRAPPA reconstructions, increasing the PAT factor leads to varying noise amplification ("noise clouds"), which can compromise diagnostic confidence at high acceleration factors. In Deep Resolve reconstructions, there might be a loss of detail due to blurring in these regions. Therefore, the g-factor noise amplification must be considered when optimizing protocols.

Additionally, denoising might accentuate known artifacts due to the reduced noise floor. The spatial location of these artifacts changes depending on the PAT factor. Examples include infolding artifacts from regions outside of the field of view (FOV) in coronal or sagittal acquisitions (as indicated by the arrows in Figure 5), as well as pulsation artifacts appearing in unexpected locations at higher acceleration factors.

In summary, Deep Resolve represents a highly powerful and clinically proven acceleration technique that is used worldwide on an day to day basis to make MRI examinations faster, more robust, and more patient-friendly — while maintaining or even increasing the level of diagnostic image quality. As with any MR acceleration method, however, its benefits come with the responsibility of reasonable parameter selection and an informed interpretation of image appearance. Understanding how reduced SNR, denoising, and data consistency constraints can influence image texture and artifact manifestation is essential to using Deep Resolve optimally. When applied with this awareness, Deep Resolve unfolds its full potential as a robust and reliable clinical tool that significantly advances modern MRI.

To learn more, please refer to the **Deep learning image reconstruction** chapter in your **Diagnostic MR Imaging Operator Manual.**

Reference

1 Breuer F, Blaimer M, Griswold M, Jakob P. Controlled Aliasing in Parallel Imaging Results in Higher Acceleration (CAIPIRINHA). ↗ MAGNETOM Flash.2012;1:135–142.