High-Resolution Accelerated Prostate TSE Axial Imaging with Deep Learning Reconstruction at 3 Tesla

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Introduction

Multiparametric MRI is a crucial tool for prostate cancer detection, staging, active surveillance, and now also prior to biopsies (MRI-targeted biopsies). The guidelines for prostate imaging (PI-RADS [1]) currently recommend a protocol that consists of several MR sequences: T2-weighted (T2w), diffusion-weighted imaging (DWI), and dynamic contrast-enhanced (DCE) imaging. Notably, the T2w turbo spin echo (TSE) sequence should be acquired in the axial plane, with a slice thickness of 3 mm without gaps, and high in-plane spatial resolution. The increased demand for prostate MRI examinations observed in the past years requires to adequately respond by reducing the examination times in order to increase throughput on the one hand and to minimize the table time for the patient on the other. Indeed, this is especially problematic as prostate cancer commonly affects elderly men, who may have difficulties remaining motionless during long MRI examinations.

Deep learning reconstruction has played a key role in tackling this challenge, as it has been proven to reduce acquisition times with comparable, and often improved, image quality and diagnostic accuracy compared to standard reconstruction techniques [2–4]. Initially Siemens Healthineers' deep learning reconstruction solution, Deep Resolve, consisted of Deep Resolve Gain and Deep Resolve Sharp.

- Deep Resolve Gain [5] mitigates thermal noise by incorporating prior knowledge of the noise characteristics into the image reconstruction, performing denoising of the data in image space. The enhanced SNR can be used to accelerate the acquisition by either increasing the acceleration factor in parallel imaging or by reducing the number of averages.
- Deep Resolve Sharp improves the image sharpness by reconstructing a high-resolution image from low-resolution data using a deep neural network. In particular it suppresses truncation artifacts in *k*-space and allows to avoid conventional *k*-space filtering. This enables to achieve image resolutions that would not be possible to achieve using conventional reconstruction.

When we first tested Deep Resolve Gain and Sharp at the Henri Mondor hospital, we were convinced by the results and decided to immediately implement it in our clinical practice. Deep Resolve is indeed now the standard of operation for prostate MR imaging at our institution.

This deep learning reconstruction technology has now gone one step further with the introduction of Deep Resolve Boost, which is even more powerful, bringing the results to a new level.

Deep Resolve Boost for TSE

Deep Resolve Boost replaces the conventional image reconstruction with a deep neural network [2]. The network architecture has similarities to an iterative image reconstruction and receives undersampled raw data as well as pre-estimated coil sensitivity maps as input. High quality images are then obtained by alternating between a parallel imaging model that relates images to acquired data and a deep learning-based regularization that enhances image quality. The main benefit of this technology is the ability to reduce the acquisition time without compromising SNR or image quality, as described in several publications [3, 6]. The outcome of the reconstruction can be further improved by combining Deep Resolve Boost with Deep Resolve Sharp.

Materials and methods

At our institution we had access to a research implementation of Deep Resolve Boost for TSE[1]. All patients underwent a prostate examination in our clinical 3T MR system (MAGNETOM Vida; Siemens Healthcare, Erlangen, Germany) with XT gradients, an 18-channel body array and a 72-channel spine array. We acquired three MR sequences:

- Transverse 2D T2w TSE reconstructed with Deep Resolve Gain and Sharp
- Transverse 2D T2w TSE reconstructed with the research implementation of Deep Resolve Boost[1]
- Transverse 2D diffusion single-shot EPI with 3 b-values (50, 1000, 1500 s/mm^2)

The acquisition parameters of the T2-weighted sequences are shown in Table 1.

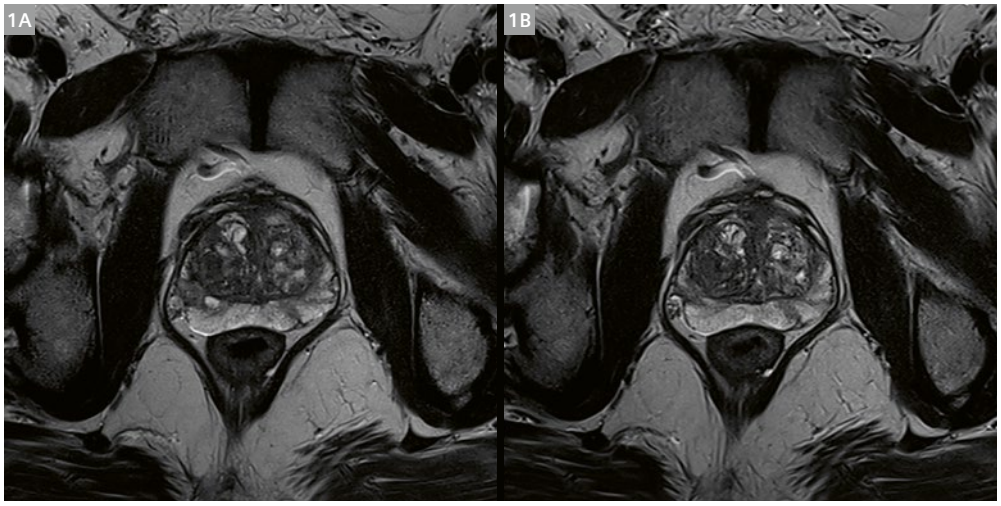
We present a series of clinical cases which show that Deep Resolve Boost for TSE provides at least similar image quality and diagnostic information as the more time-intensive Deep Resolve Gain and Sharp TSE acquisition, which is now the clinical standard at our institution.

[1] *With software version syngo MR XA50 Deep Resolve Boost is available for MAGNETOM Vida.*

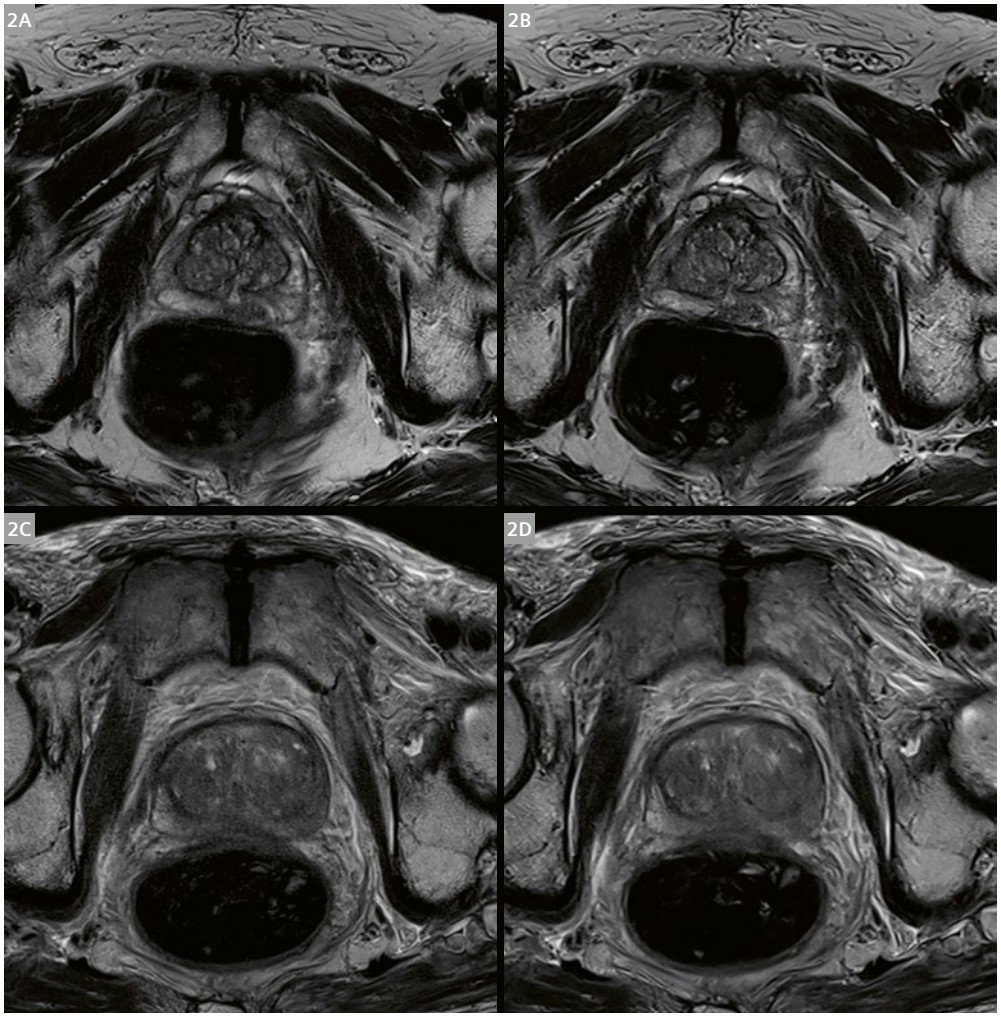
	Deep Resolve Gain and Sharp TSE	Deep Resolve Boost TSE
Scan time (min:s)	**3:16**	**1:50**
FOV (mm^2) / phase oversampling	160 × 160 / 145%	180 × 180 / 200%
TE (ms)	116	104
TR (ms)	3380	3850
Reconstructed voxel size (mm^3)	0.26 × 0.26 × 3	0.24 × 0.24 × 3
Nb excitations	**2**	**1**
Matrix size	304 × 304 × 26	368 × 368 × 26
Acceleration technique	GRAPPA 2 (Auto -32)	GRAPPA 3 (TSE/Sep -24)
Flip angle (°)	133	160
Turbo factor	23	25
Phase resolution (%)	85	85
Bandwidth (Hz/Px)	201	200
Nb concatenations	2	2

Table 1: Acquisition parameters of the T2-weighted sequences.

Cases



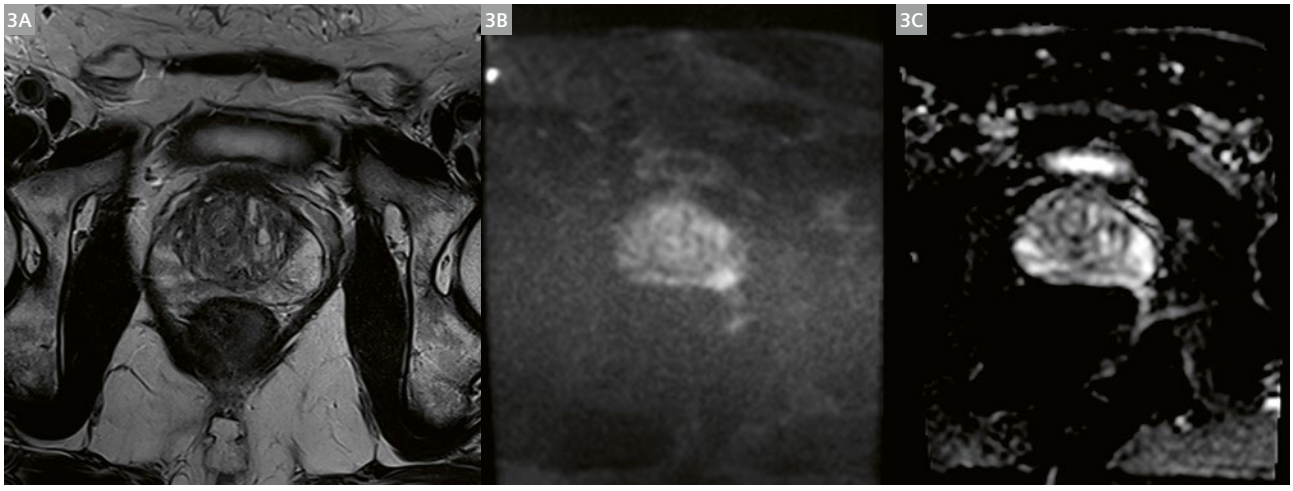
1 A 72-year-old patient (Density PSA = 0.09 ng/ml²) with bilateral PI-RADS 2 lesions in the middle peripheral zones of the prostate. T2-weighted TSE using **(1A)** Deep Resolve Gain and Sharp and **(1B)** Deep Resolve Boost. Deep Resolve Boost provides comparable image quality with a 41% scan time reduction.



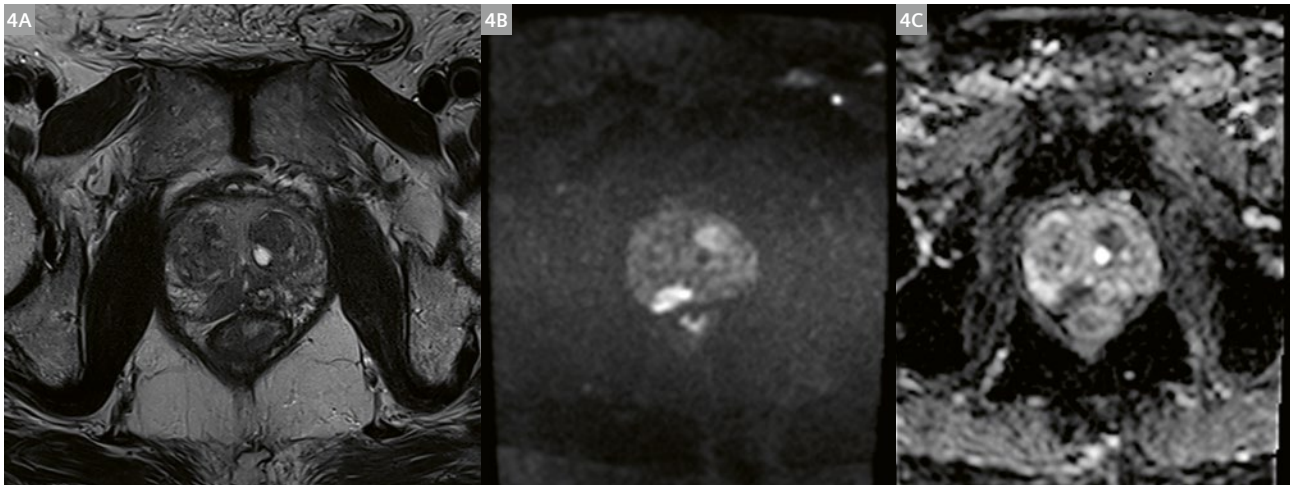
2 A 77-year-old patient (PSA = 1.7 ng/ml; density PSA = 0.05 ng/ml²) with bilateral PI-RADS 2 lesions in the middle peripheral zones of the prostate. T2-weighted TSE using **(2A)** Deep Resolve Gain and Sharp and **(2B)** Deep Resolve Boost.

An 83-year-old patient (PSA =14.8 ng/ml; density PSA = 0.29 ng/ml²) with a PI-RADS 4 lesion in the right postero-medial middle peripheral zone of the prostate. T2-weighted TSE using **(2C)** Deep Resolve Gain and Sharp and **(2D)** Deep Resolve Boost.

For both patients, motion artefacts in the Deep Resolve Boost images are reduced thanks to the shorter acquisition time (1 average), allowing sharper delineation of the anatomical structures.



3 A 59-year-old patient (PSA: 4.2 ng/mL; density PSA = 0.10 ng/ml^2) with bilateral PI-RADS 2 lesions in the middle peripheral zones of the prostate. T2-weighted TSE using **(3A)** Deep Resolve Boost. **(3B)** Trace DWI image with b-value 1500 s/mm^2, **(3C)** ADC map.



4 A 81-year-old patient (PSA: 12 ng/mL; density PSA = 0.33 ng/ml^2) with a PI-RADS 5 lesion in the right posteromedial apical peripheral zone of the prostate. T2-weighted TSE using **(4A)** Deep Resolve Boost. **(4B)** Trace DWI image with b-value 1500 s/mm^2, **(4C)** ADC map.

Conclusion

Compared to Deep Resolve Gain and Sharp, Deep Resolve Boost allowed us to decrease the acquisition time of the T2w TSE acquisition by 41% (Fig. 1), as only 1 average was acquired compared to the 2 averages of the Deep Resolve Gain and Sharp scan, with comparable image quality. One of the benefits of the shorter acquisition time was the reduction of artefacts due to either voluntary or involuntary patient motion (Fig. 2), which is one of the challenges of prostate imaging. No evident artefacts were observed. There is an increasing body of evidence from clinical studies and scientific publications that these physics-guided deep learning reconstruction approaches provide reliable and robust image information with anatomical fidelity.

These results are also in line with the published literature, which has reported significant time savings, as well as comparable image quality and diagnostic confidence for staging prostate lesions when compared to conventional acquisitions [2–4, 7].

The adoption of Deep Resolve in our clinical workflow has helped us to match the increased demand of prostate MRI examinations at our institution and we are confident that further improvements in acquisition time and spatial resolution can be achieved.

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