Case study 3: Deep Resolve Boost in prostate imaging on Siemens Sola (XA31)

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Introduction

This work was carried out at the Newcastle upon Tyne NHS Foundation Trust (NUTH) at the Freeman Hospital which is a tertiary referral centre. The protocol chosen to be optimised using the new deep resolve software was our routine diagnostic prostate protocol. In one week, we scan approximately 7 prostates on the scanner which has the deep resolve boost software, and this is likely to increase with a new initiative called "direct to scan", whereby the patient is referred directly from the prostate clinic for an MRI scan.

Although the image quality in the diagnostic protocol was satisfactory there were significant time burdens. The appointment slot for each patient is currently 50 minutes and it is hoped this could be significantly reduced by applying deep resolve and simultaneous multi slice techniques to appropriate sequences. We aimed to reduce the scan time by approximately 30 % and observe if we could gain any improvement in image quality.

Methods – Staffing, Scanner and Sequence Information

Deep resolve boost is available on both of our 1.5 T Siemens Sola systems, both of which are at software version XA51. In this case study we evaluated the use of deep resolve boost and sharp and simultaneous multi slice (SMS) acceleration techniques to both improve image quality and reduce overall scan time per sequence.

We currently have 1.5 whole time equivalent MRI Physicists working within NUTH. There is 1 MR Physicist who is leading on the implementation of deep resolve alongside a team consisting of 3 senior radiographers (one from diagnostic radiology, one from neuroradiology and one from radiotherapy physics). There is also a radiotherapy physicist, who has a keen interest in MR involved in optimisation of the sequences applicable to radiotherapy. We chose to optimise the deep resolve sequences on one of the Sola scanners based in radiotherapy physics as this has dedicated research activity one day per week, and initially scanned healthy controls until we were happy with a given sequence. This sequence was then transferred to the main diagnostic scanner and was trialled in the clinical protocol, this was performed one sequence at a time against the original sequence, this ensured the overall scanning time per patient was not significantly increased in the optimisation stage. After several patients were scanned using both the original and deep resolve sequences, an MR physicist, senior radiographer and radiologists reviewed the images and decided if they were of good enough quality to replace the original diagnostic sequence or if more optimisation work needed to be performed.

To further evaluate the effect of deep resolve boost on image quality we anonymised 5 data sets which contained original and deep resolve images and an experienced radiologist (with > 15 years' experience in reviewing prostate MRI images) to score the images for subjective image quality (1-5; 1 – Poor, 5 – Excellent), for presence of artifact (1-5, 1-severe artifact, 5 – no artifact) they were also asked to subjectively comment which image they believed had better diagnostic quality.

Protocol Information and Scan Parameters

In our diagnostic prostate protocol we acquire: three 2D T2 weighted turbo spin echo (TSE) sequences in the sagittal, coronal and axial orientations respectively, a single shot 2D diffusion weighted sequence acquired axially (with 4 different b values: 50, 400, 800 s/mm^2 and a calculated b

= 1400 s/mm^2), a single shot 2D diffusion weighted sequence acquired axially with a b value of 1400 s/mm^2, a 2D T1 weighted TSE sequence acquired axially which covers the lymph nodes within the pelvic area. Finally, if contrast is administered a fat supressed 2D T1 weighted gradient echo VIBE sequence is acquired axially in a dynamic acquisition. If no contrast is administered, then a high resolution 2D T1 TSE is acquired axially. All images are acquired with an 18 channel receive only body torso-coil. As DRB can only be currently applied to 2D TSE sequences this gives a total of 5 sequences which the DRB technique can be applied to in the current protocol. To further optimise the diffusion weighted sequences the calculated b = 1400 s/mm^2 was removed and an actual b = 1400 s/mm^2 was implemented into the original sequence. Furthermore, simultaneous multi slice imaging was applied to this sequence to further reduce the scan time.

Table 1 shows the original diagnostic sequences alongside their parameters, including acquisition time.

Sequence Name	Field of View (mm)	Base Resolution	Phase Oversampling (%)	iPAT	Number of Signal Average	Repetition Time/Echo Time (ms)	Slice Thickness (mm)	Acquisition Time (mm:ss)
T2 turbo spin echo (sagittal)	220 x 220	336	100	GRAPPA: 2	3	5410/90	3.5	03:05
T2 turbo spin echo (coronal)	220 x 220	336	100	GRAPPA: 2	3	4060/90	3.5	04:38
T2 turbo spin echo (axial)	220 x 220	336	100	GRAPPA: 2	3	4060/90	3.5	04:38
Diffusion weighted sequence	260 x 260	192	20	GRAPPA: 2 Partial Fourier: 7/8	Per b-value: 50 s/mm^2=2 400 s/mm^2=4 800 s/mm^2=10 Calculated b = 1400 s/mm^2	5000/70	3.5	04:57
Diffusion weighted sequence	260 x 260	192	20	GRAPPA: 2 Partial Fourier: 7/8	Per b-value: 1400 s/mm^2=12	6000/75	3.5	05:20
T1 turbo spin echo (axial) Large field of View	320 x 320	352	80	GRAPPA: 3 SMS: 2	2	400/20	5	02:23
T1 VIBE (dynamic contrast)	220 x 176	192	30	GRAPPA: 2 Partial Fourier: 6/8	1	4.3/1.63	3	02:23
T1 turbo spin echo (axial) Lymph nodes	200 x 200	256	100	-	1	650/10	3.5	02:41

Table 1: Parameters from original diagnostic prostate protocol.

Table 2 shows the sequences for the new protocol and their corresponding parameters, including acquisition time.

Sequence Name	Field of View (mm)	Base Resolution	Phase Oversampling (%)	iPAT	Number of Signal Average	Repetition Time/Echo Time (ms)	Slice Thickness (mm)	Acquisition Time (mm:ss)
T2 turbo spin echo (sagittal)	220 x 220	320	200	DRB: On DRS: On Denoising: Medium GRAPPA: 4	3	5410/89	3.5	02:05
T2 turbo spin echo (coronal)	220 x 220	320	100	DRB: On DRS: On Denoising: Medium GRAPPA: 4	3	4060/89	3.5	02:41
T2 turbo spin echo (axial)	220 x 220	320	100	DRB: On DRS: On Denoising: Medium GRAPPA: 4	3	4060/89	3.5	02:41
Diffusion weighted sequence	260 x 260	192	20	SMS: 2 Partial Fourier: 7/8	Per b-value: 50 s/mm^2=2 400 s/mm^2=4 800 s/mm^2=10 b = 1400 s/mm^2=12	3500/75	3.5	06:49
T1 turbo spin echo (axial) Large field of view	320 x 320	352	80	GRAPPA: 4 SMS: 2	2	400/20	5	01:52
T1 VIBE (dynamic contrast)	220 x 176	192	30	GRAPPA: 2 Partial Fourier: 6/8	1	4.3/1.63	3	02:23
T1 turbo spin echo (axial) Lymph nodes	200 x 200	320	100	GRAPPA: 4	1	650/11	3.5	01:29

Table 2: Parameters from diagnostic prostate protocol with deep resolve boost and simultaneous multi slice techniques applied.

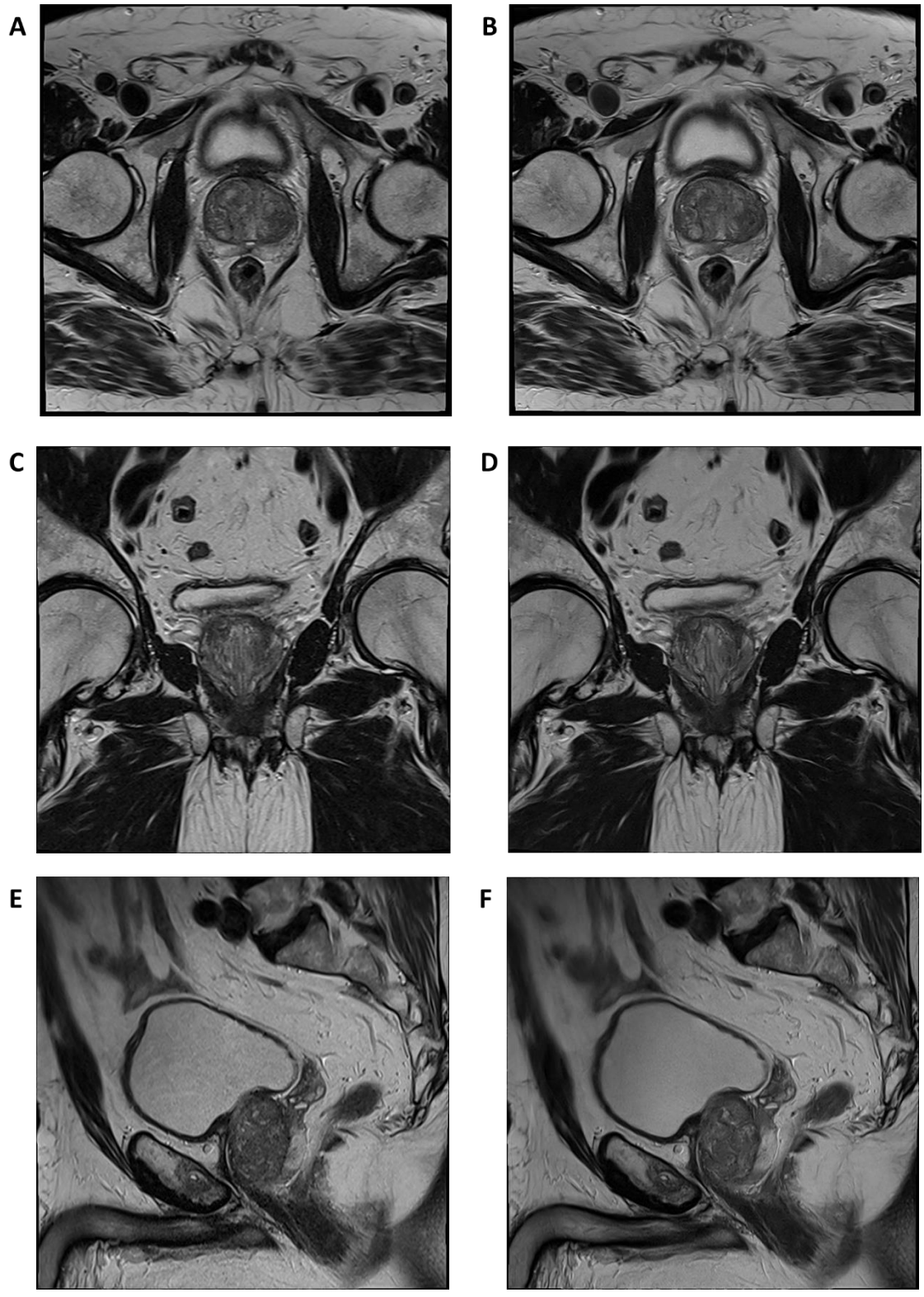
Reduction in Overall Scan Time

For the original diagnostic protocol, the overall scan time if contrast was administered was 27 minutes and 24 seconds, if contrast was not administered it was 27 minutes and 42 seconds. For the new protocol the total scanning time if contrast was administered is 18 minutes and 31 seconds and without contrast administration it is 17 minutes and 37 seconds. This is an overall reduction of 8 minutes and 53 seconds if contrast is administered and 10 minutes and 5 seconds without contrast administration.

The original appointment time for the patient is approximately 50 minutes, with this reduction on scan time it is hoped that the new appointment time which can be offered is 35 minutes. This will allow us to significantly improve throughput on this system and offer the patients a better appointment time. If we currently scan 7 patients per week at 50 - 55 minutes per patient this is approximately 6 hours and 25 minutes of scanning, with the new appointment slot of 35 minutes this could be reduced to approximately 4 hours and 5 minutes of scanning, saving approximately 2 hours and 20 minutes of scanning per week. This equates to an extra 4 prostate patients per week. Or this extra time can be used to scan other anatomies.

Image quality

Example images comparing both the original diagnostic image and the image with acceleration techniques applied are shown in figures 1A-J.



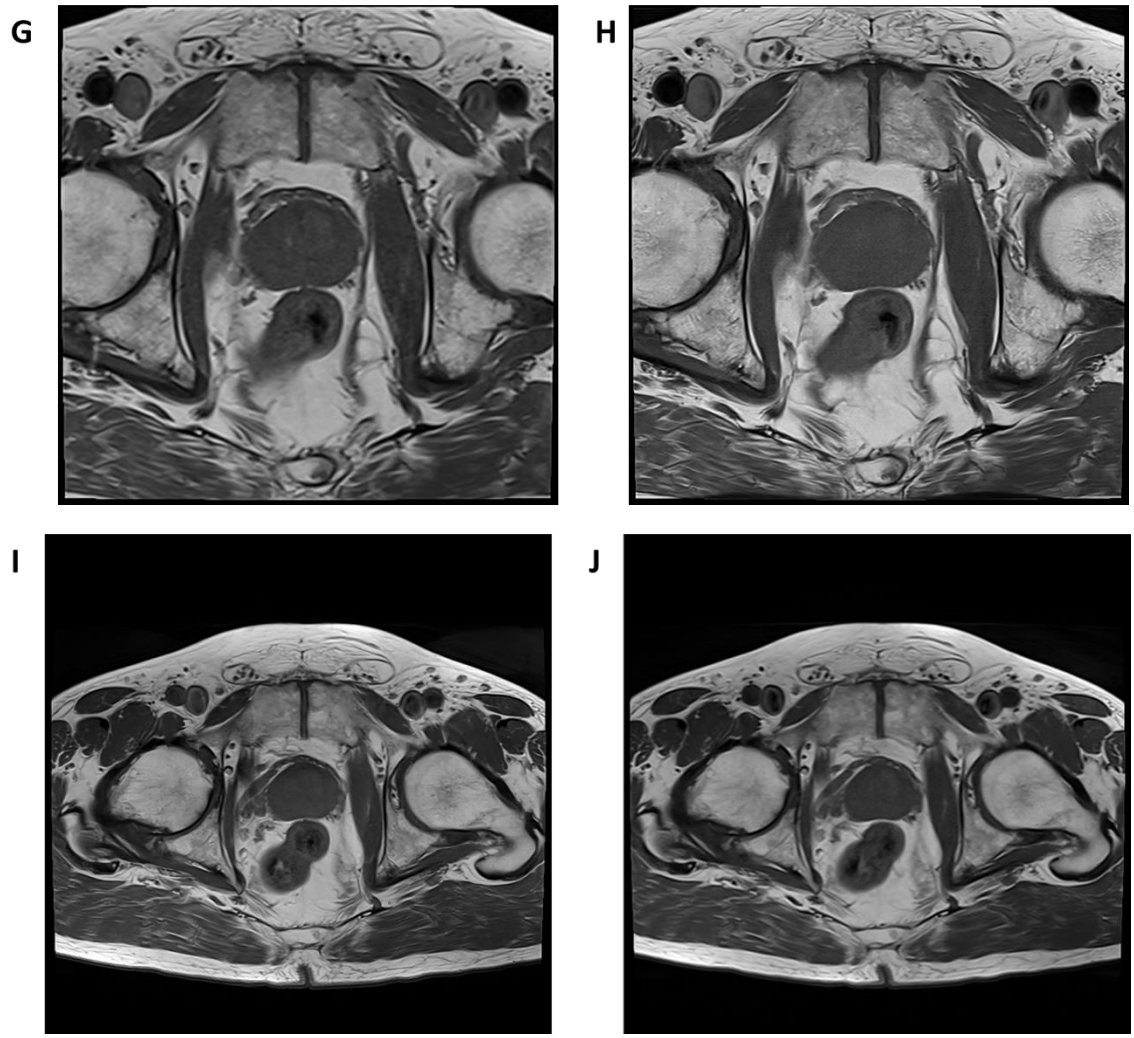


Figure 1: *Example images with and without Deep Resolve Boost applied, in each case the image is the middle slice of the 2D stack of images. Images A & B) Axial T2 weighted 2D TSE with and without DRB applied respectively. Images C & D) Coronal T2 weighted 2D TSE with and without DRB applied respectively. Images E & F) Sagittal T2 weighted 2D TSE with and without DRB applied respectively. Images G & H) Axial T1 weighted 2D TSE with and without DRB applied respectively. Images I & J) Large field of view axial T1 weighted 2D TSE with and without DRB applied respectively.*

Subjectively images acquired with DRB and DRS on appear sharper and have boosted signal. To further evaluate this, we asked an experienced radiologist to score 5 sets of anonymised images for each type of sequence (axial T2, coronal T2, sagittal T2, axial T1 large field of view and axial T1 lymph nodes). The images were scored on subjective image quality, presence of artifact and the radiologist was asked which image they had more diagnostic confidence in.

The scoring for the subjective image quality across all patients and sequences was 98/125 for the original sequences and 117/125 for the deep resolve sequences, for presence of artifact the scores were 97/125 for the original sequence and 108/125 for the deep resolve sequences, this demonstrates that deep resolve sequences had improved subjective image quality and lower presence of artifact. The radiologist had more diagnostic confidence in the deep resolve images 96 % of the time, meaning in only one image set from one patient the original image set was preferred. Graphs below show the overall subjective image quality and artifact scores across all patients for each sequence.

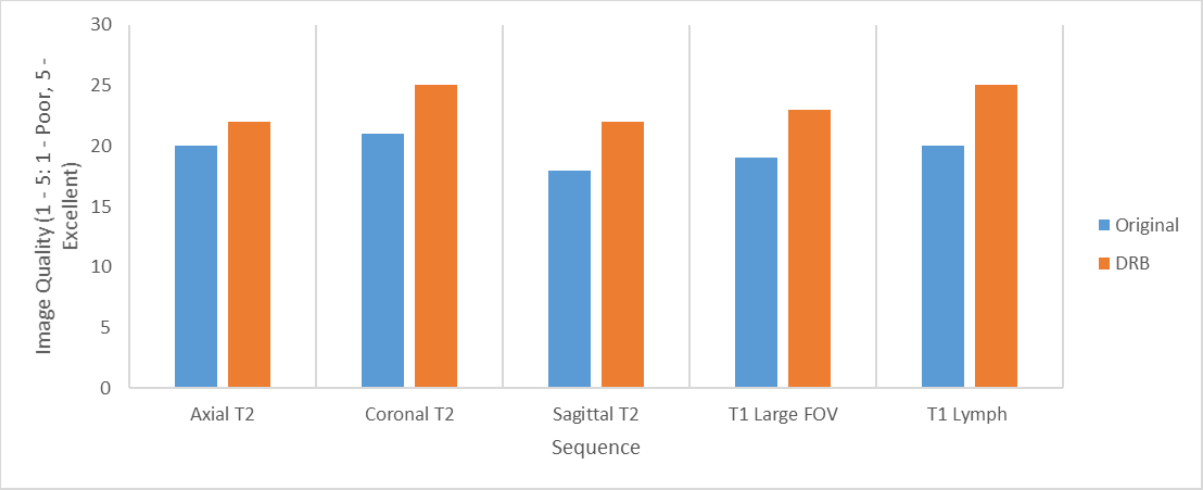


Figure 2: *Overall scores for subjective image quality between original and deep resolve sequences. Scores are collated from each patient for each sequence.*

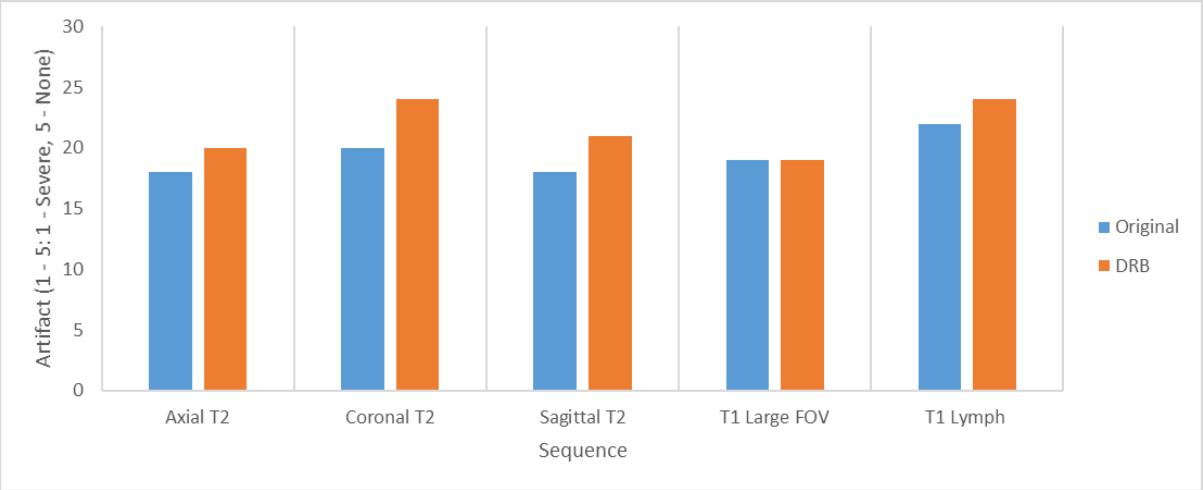


Figure 3: *Overall scores for artifact between original and deep resolve sequences. Scores are collated from each patient for each sequence.*

Some of the images acquired in the sagittal plane with DRB and DRS applied demonstrated wrapping artifact. This was resolved by ensuring that the phase encoding direction was set to foot-head and by applying 200 % phase oversampling, also making radiographers aware not to change the phase oversampling which is more than they are used to seeing on a sequence of this kind. An example wrap artifact is shown in figure 2.

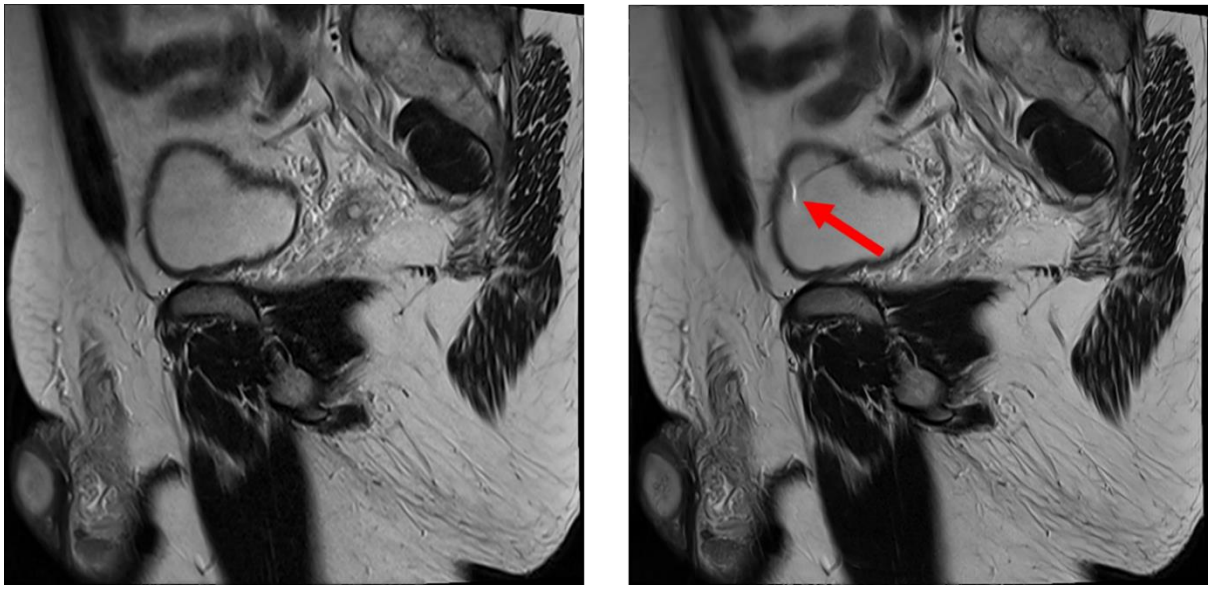


Figure 4: *Example image of artifact caused by DRB. Left) Original diagnostic image. Right) Image acquired with DRB applied with 100 % phase oversampling and phase encoding direction foot-head showing wrap artifact in the bladder (red arrow).*

Conclusions and Future Work

The implementation of DRB, DRS and SMS in the prostate diagnostic protocol has reduced the overall out-patient appointment slot by around 15 minutes and significantly improved the image quality. This has allowed for extra patients to be scanned within the working week. In the future we would like to conduct an audit to further assess what impact the reduction in appointment slot times has had on the MR service. We would also like to explore if we could further reduce the appointment time by using a reduced number of averages in the scans, however this would require careful evaluation by a radiologist to maintain diagnostic confidence.