Optimization of Pre-biopsy bp-MRI of the Prostate

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Interprofessional teamwork and collaboration between diagnostic and therapeutic radiographers in the evolution of an MR radiotherapy-planning (MR RTP) service was pivotal to the success of this study, and to the eventual implementation of our current standard prostate-imaging protocol.

Key points

- Escalating demands in the early diagnosis and management of prostate cancer is placing considerable pressure on MRI departments across the UK.
- Adopting a combined approach to image optimization and investing in both technical and patient-related aspects to reduce artifacts can improve image quality and reduce scan times.
- Learning experiences in the development of an MR RTP service led to research to ascertain whether adminstration of a micro-enema before prostate imaging could influence image interpretation in diagnostics.
- Micro-enema administration demonstrates a significant benefit to image quality in bp-MRI of the prostate and should be considered as an integral part of the imaging procedure.

Introduction

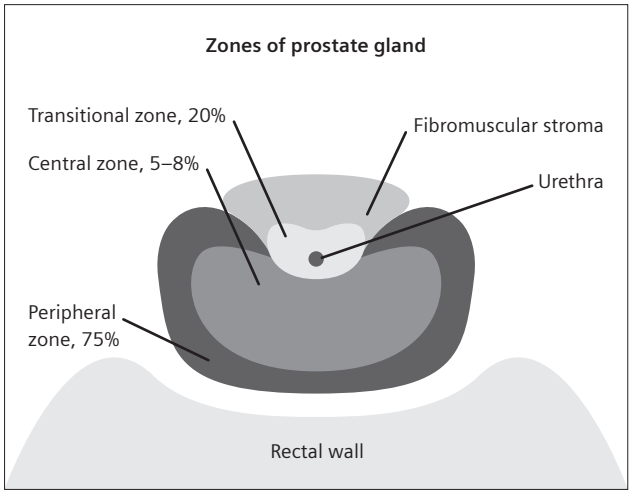
Prostate cancer is now the most common malignancy in men and the second leading cause of cancer in the UK [1]. The clinical behavior of prostate cancers can range from low-grade cancers that do not progress to lethal disease, to invasive tumors that rapidly progress and become metastatic [2]. With the incidence of prostate cancer expected to double by 2030 [3], early diagnosis of clinically significant disease, performed at reasonable cost and in achievable time frames, is of increasing importance.

The publication of the Prostate Imaging Reporting and Data System (PI-RADS) in 2012 [4] brought together the importance of standardizing optimal sequences, now widely known as multi-parametric MRI (mp-MRI), with structured reporting systems to aid interpretation and diagnostic evaluation of the prostate. The publication of PI-RADS v2 in 2015 [5] aimed to further standardize image acquisition and interpretation in mp-MRI, providing guidance on technical optimization, detailing the minimal acceptable sequences and parameters in image acquisition, with the current emphasis on the more widely available sequences. Accurate interpretation and staging of disease with mp-MRI is now considered to play an additional key role in identifying prognostic factors, such as extracapsular extension, seminal vesicle extension, and lymphovascular invasion. These significant image findings indicate a higher risk of recurrence [2], aiding in risk

stratification of cases and defining optimal treatment pathways for the large cohort of diagnosed patients.

Pre-biopsy mp-MRI now plays a central role in the management pathway of prostate cancer in the UK, being performed on up to 75% of men with a clinical suspicion of prostate cancer [6], so it is essential that diagnostic mp-MRI of the highest quality is increasingly accessible.

PI-RADS v2 does acknowledge that there are many challenges in achieving standardization of image acquisition. Equipment availability and capability, patient factors, and radiology interpretation all differ across imaging sites. To achieve excellence in clinical performance, diagnostic processes need to be robust, encompassing high-quality imaging by radiographers and accurate image interpretation by radiologists working together with urologists in multidisciplinary teams.

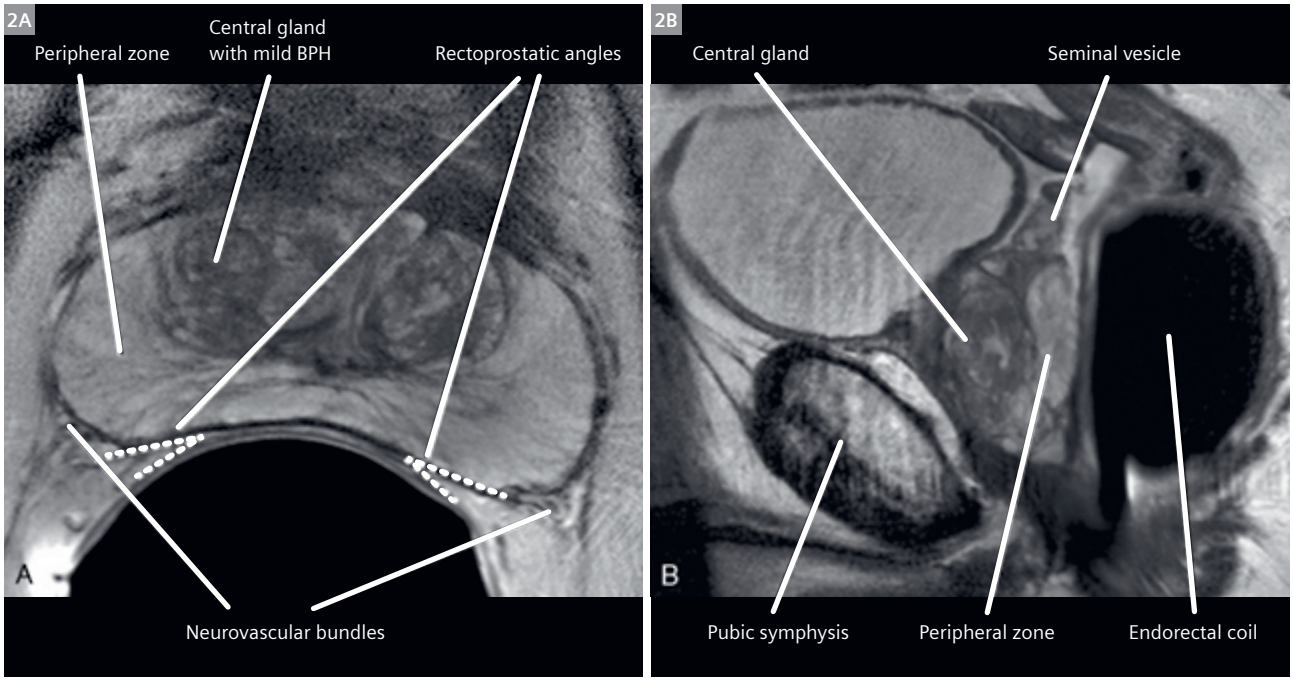


1 Anatomy of the zones of the prostate gland: schematic diagram in transverse plane with rectal wall at posterior aspect.

Zonal anatomy and key sequences

At least 75% of all prostate cancers occur in the peripheral zone (PZ), but when differentiating benign and malignant disease, and determining prognostic factors, special attention should also be given to the transitional zone (TZ), prostate capsule, seminal vesicles, neurovascular bundles, and rectoprostatic angles to identify any extracapsular extension [7]. Zonal anatomy of the prostate gland and MRI appearances of extracapsular structures are shown in Figures 1 and 2, respectively.

Sequence choice in prostate MRI is widely debated, but T2-weighted (T2W) high-resolution imaging is considered to be the preferable sequence for local staging and identification of cancers in the TZ, as it also identifies the presence of extracapsular extension and seminal vesicle involvement [7]. Diffusion-weighted imaging (DWI) provides functional information based on the tissue cellularity, measuring the movement of water molecules within tissue. DWI is considered to be the best-performing sequence for detection of cancers in the PZ, with a restricted water diffusion playing a key role in defining



2 MR images of extracapsular structures: **(2A)** sagittal T2W and **(2B)** axial T2W showing anatomical landmarks.
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high-grade cancers [7]. PI-RADS v2.1, which was published in 2019 [8], now places most emphasis on DWI for PZ lesions and on T2W for TZ lesions; additional sequences like dynamic contrast-enhanced (DCE) are considered to play a limited role in lesion characterization, and MR spectroscopy is considered to be impractical for widespread use. As such, the term bi-parametric MRI (bp-MRI) is rapidly gaining favor, and although effectively reducing overall examination time, achieving a fully optimized examination becomes even more important to the overall clinical outcome.

Combined approach to optimization

As MR radiographers working as an integral part of a multidisciplinary approach to cancer services, we must ensure that image quality is of the highest standard we can achieve, whilst also managing increasing clinical demand, often with limited scanner capability or resources. We have an array of tools at our disposal to optimize image quality. Primarily we consider image optimization to be technical in its approach, aiming to utilize a vast choice of sequences and imaging parameters to achieve artifact-free, high SNR and high-resolution images in reasonable scan times to provide good clinical outcomes, but this can be very dependent on the capability of the equipment available.

However, an important, yet often forgotten factor in overall image optimization can be the patient themselves. In prostate imaging, patient-related factors can be anything from gross patient movement or bowel peristalsis, to air and feces within the rectum. By addressing patient-related issues that may affect overall image quality due to artifacts or distortion, we can directly improve outcomes for our patients. The rest of this article will look at using a combined approach to image optimization.

Technical optimization of sequences

In focusing our efforts on bp-MRI only, it is imperative that the key sequences are fully optimized. The MAGNETOM Aera 1.5T system can easily achieve PI-RADS v2-compliant sequences in terms of SNR and resolution, but some specific sequence and parameter options are worth further consideration to ensure consistency across a wide range of patients.

All T2W and DWI sequences utilize GRAPPA to reduce scan times with relatively little compromise in SNR.

Where administration of an antispasmodic is contraindicated and the risk of motion artifacts from bowel movement is increased, T2W sequences are simply acquired with a lower resolution for speed, and interpolation is chosen to increase the apparent resolution. This has proved to be a robust alternative to BLADE, with radiology being more confident when tissue contrast is consistent with our standard protocol.

In DWI, distortion from metallic implants[1] may prove problematic. EPI sequences are usually preferred as they are more readily available and have the advantage of a higher SNR than some alternatives. However, in patients where distortion from metallic implants – e.g., total hip replacement (THR) – cannot be avoided, options like RESOLVE DWI may be preferred to take advantage of the superior distortion reduction and hopefully provide some correlation with the image appearances of T2W lesions.

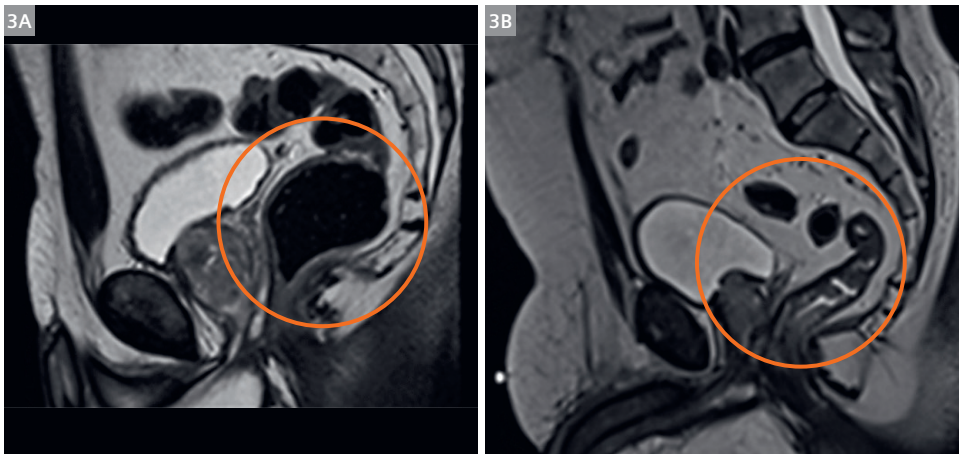
Choice of b-value in DWI is widely debated, with longer b-values ≥ 1400 s/mm^2 being considered optimal in prostate imaging. Some systems will have the option to calculate or extrapolate higher b-value images from multiple acquired data sets with lower b-values and higher SNR. However, Grant et al. [9] conclude that the image quality of calculated high b-value DWI relative to corresponding acquired DWI decreases with an increase in b-value, and the radiology preference in our department is to invest in acquiring data with a b-value of 1400 s/mm^2.

Reduction of patient-related artifacts

Bowel peristalsis: The use of anti-peristaltic drugs to reduce artifacts from bowel movement in the pelvis and abdomen does have implications for the overall service: There are additional costs to consider, additional time is required for cannulation, and medical support is often needed for administration and prescription. However, Slough et al. [10] conclude that the IV administration of hyoscine butylbromide (HBB) immediately prior to MRI significantly improves the image quality of T2W images, a key sequence in mp-MRI. They advocate its use in routine patient preparation prior to prostate MRI, with the acquisition of T2W sequences during a short window of effectiveness, usually approximately 20 minutes.

Rectal distention: There is wide acceptance in diagnostic MRI that an air-filled rectum can lead to considerable geometric distortion on DWI at air-tissue interfaces. Recent publications [11, 12] discuss the negative impact that rectal distention and loading can have on the quality of both T2W and DW images. Caglic et al. [12] propose the use of bowel preparation prior to prostate mp-MRI to optimize image quality. However, they also note that PI-RADS v2 highlights a lack of evidence to specifically inform on patient preparation prior to mp-MRI.

[1] *The MRI restrictions (if any) of the metal implant must be considered prior to patient undergoing MRI exam. MR imaging of patients with metallic implants brings specific risks. However, certain implants are approved by the governing regulatory bodies to be MR conditionally safe. For such implants, the previously mentioned warning may not be applicable. Please contact the implant manufacturer for the specific conditional information. The conditions for MR safety are the responsibility of the implant manufacturer, not of Siemens Healthineers.*



3 Comparison of rectal distension in diagnostic MRI (3A) and RTP MRI (3B): **(3A)** sagittal T2W diagnostic image with rectal distension; **(3B)** sagittal T2W RTP image with no rectal distension.

Research study: Optimization of bp-MRI of the prostate using a self-administered enema

Background

During our collaborative MR radiotherapy-planning (RTP) sessions, a significant reduction in air-filled rectal distension was observed in sagittal RTP images (see Fig. 3). This led to local discussions about the standard procedure for the imaging and treatment of all prostate patients undergoing radiotherapy at NWCC. Minimal bowel preparation in the form of a self-administered micro-enema is used just prior to all RT imaging and treatment to evacuate the rectum prior to all scans. This facilitates accuracy in gross-tumor-volume (GTV) contouring for RT treatment planning, and during all subsequent treatments to ensure reproducibility of the anatomical position of the prostate gland and promote positional accuracy of the treatment beam. RT experiences, including evidence in the literature [13], have proven this to be a cost-effective and minimally invasive patient procedure that is easily tolerated by patients. MR radiographers were keen to explore any potential benefit to diagnostic MRI protocols, and a local study was set up.

Rectal distention on Sag T2		Distortion on DWI + ADC		Confidence in lesion conspicuity	
Clear	0	None	0	Poor	0
Minimal	1	Minimal	1	Fair	1
Partial	2	Moderate	2	Good	2
Fully	3	Severe	3	Excellent	3

Table 1: Radiological scoring criteria

Aims and objectives

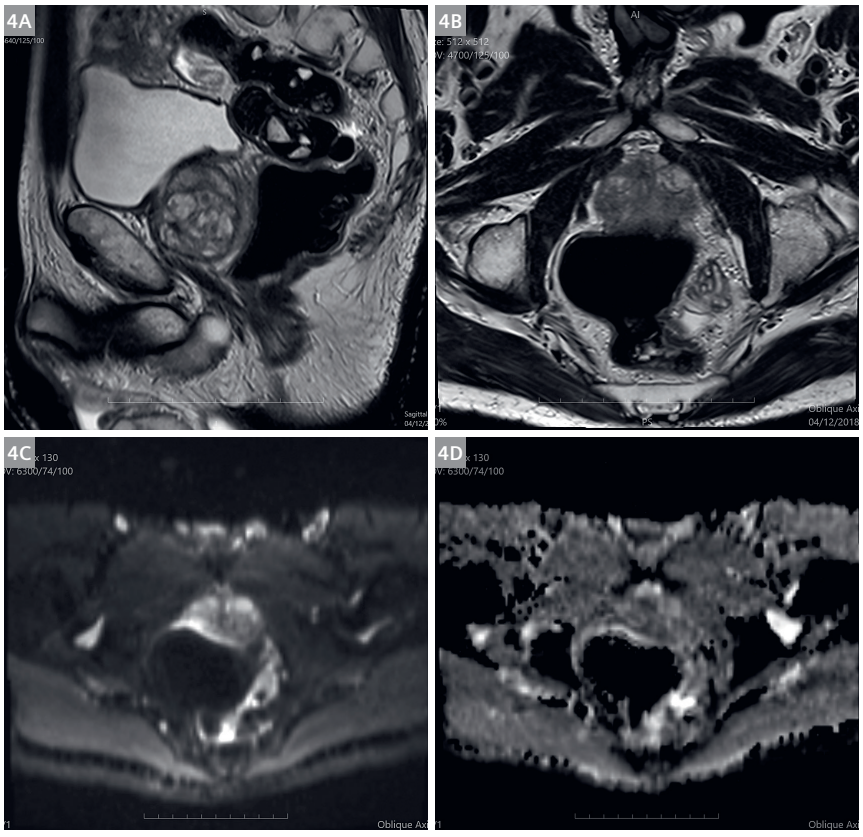
The aim of this research was to ascertain whether using a micro-enema before prostate imaging influences image interpretation. The main objectives were to collect data on prostate image interpretation with and without use of a micro-enema, to compare data, and to reach a conclusion on the efficacy of micro-enema use with respect to image quality in bp-MRI for pre-biopsy imaging.

Methodology

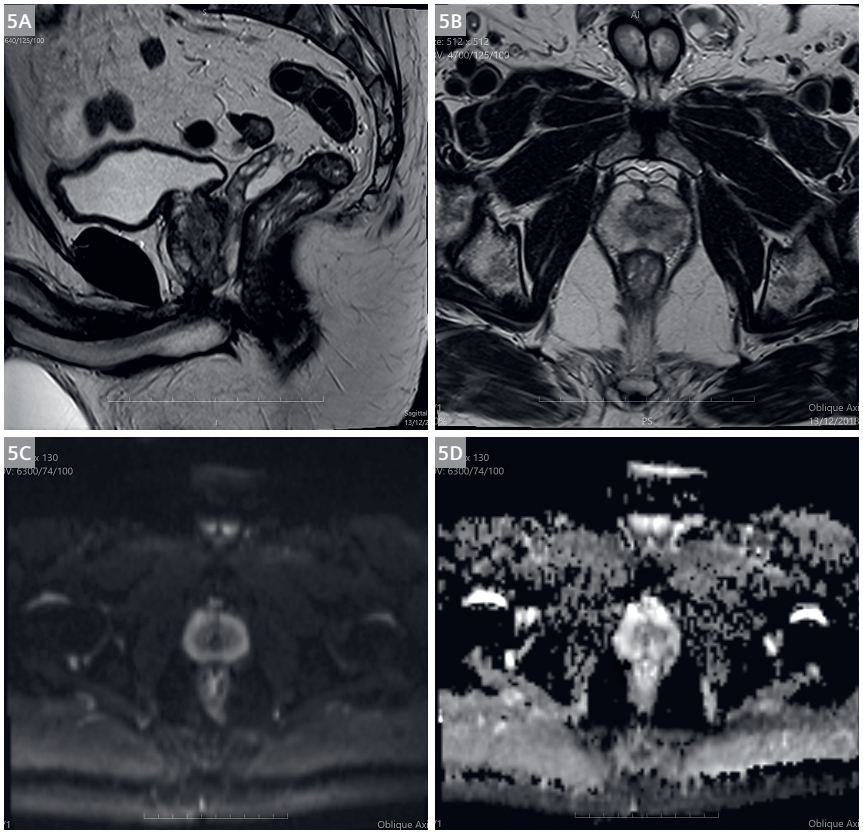
Thirty consecutive pre-biopsy referrals for prostate MRI were asked to attend their MRI appointment 45 minutes early to self-administer a micro-enema approximately 30 minutes prior to MRI scanning. Thirty consecutive patients scanned prior to the trial period, without preparation, acted as the control. To ensure comparable findings, exclusion criteria were applied to both groups and included patients with THR in situ and patients who presented with any contraindications to IV antispasmodic drugs. A standard NWCC high-resolution, PI-RADS v2-compliant protocol was carried out on all patients. Two consultant radiologists experienced in reporting prostate bp-MRI individually scored all images according to the criteria shown in Table 1. Cases were randomized on reporting workstations, with both radiologists blinded to use of micro-enema and their colleague's scoring.

Results

- Scores for rectal distension are highly correlated between the two radiologists for prepared and unprepared patients ($r = 0.82$ and $r = 0.86$, respectively). This indicates improved visibility of the prostate bed when a micro-enema is administered compared to unprepared patients ($p = 0.16$ and $p = 0.04$).
- Scores for distortion on DWI demonstrated moderately correlated scores ($r = 0.76$ and $r = 0.67$), with statistically high significance for prepared patients compared to unprepared patients ($p = 0.0$ and $p = 0.28$).



4 Sample images from control group (no bowel preparation):
(4A) Sag T2w TSE; **(4B)** Tra T2w TSE; **(4C)** Tra DWI b-value = 800 s/mm²; **(4D)** ADC map.



5 Sample images from study group (bowel preparation administered):
(5A) Sag T2w TSE; **(5B)** Tra T2w TSE; **(5C)** Tra DWI b-value = 1400 s/mm²; **(5D)** ADC map.

- Scores for distortion on apparent diffusion coefficient (ADC) maps also demonstrated agreement on moderately correlated scores (r = 0.54 and r = 0.59), and also high significance (p = 0.0), which proves that visibility for identifying distortion is better in the case of prepared patients.
- There is a high correlation in lesion visibility on DWI (r = 0.50) and an overall improvement in confidence (p = 0.36) for prepared patients.
- Radiologist 2 has a higher variance in scoring than Radiologist 1, irrespective of whether patients were prepared or not. However, variance in scoring is reduced in prepared patients, which indicates a higher level of confidence in lesion visibility among the radiologists (see Fig. 6).

Conclusion

Micro-enema administration demonstrates a significant benefit to image quality in bp-MRI of the prostate and should be considered as an integral part of the imaging procedure.

Study outcomes

Improvements in image quality and the clinical effectiveness of the radiological report, for both clinically significant and insignificant disease, were demonstrated in prepared patients. This led to a change in standard practice for bp-MRI prostate imaging at NWCC. Improved radiological confidence has reduced the imaging protocol, with the emphasis now on fully optimized bp-MRI rather than mp-MRI, leading to shorter scan times for patients and the potential for increased patient capacity. Improved confidence in the radiology findings at multidisciplinary meetings (MDMs) is proving especially beneficial for patients with insignificant or benign disease confirmed on MRI, and the potential to ensure progression to targeted biopsy is limited to equivocal cases only, e.g., PI-RADS 3. This places fewer clinical demands on the urology service overall. Utilizing a low cost, established technique that is easily tolerated by patients and involves minimal operational issues for staff has greatly improved the quality of our prostate imaging service.

6 Comparison of variance in radiologist scoring in prepared (micro-enema) and unprepared patients.

Patient Information on Use of Micro-enema prior to MRI
You will be asked to use a form of bowel preparation called a micro-enema on arrival for your MRI. It falls within a group of medicines called laxatives, and is administered as a single dose to patients as a self-administered enema. It is being used before your MRI scan to empty your rectum of stools and air to get better images of the prostate gland, and help the doctors plan any treatment you may need more carefully. It may not be advisable to use if you suffer from any inflammatory bowel conditions, such as Crohn's disease, IBS, or colitis, so please make the staff aware of this. A micro-enema allows the insertion of a liquid into your back passage to help your lower bowel empty. Instructions will be given to you by the MRI staff on arrival, and it is usually effective within 15 mins. Toilets are nearby for use.
How to Use a Micro-enema
• Sit on the toilet • Pull or twist the cap off the plastic tube • Squeeze a drop of the liquid onto the nozzle to help lubricate it. • Put the full length of the nozzle into your back passage, and gently squeeze the tube until it is empty. • Wait for 15 mins for the laxative to work.
As it's a single dose, there is no risk of using too much and there should be no risk of prolonged diarrhoea. Staff will be happy to answer any questions you may have.

Table 2: Patient information on use of micro-enema prior to MRI.

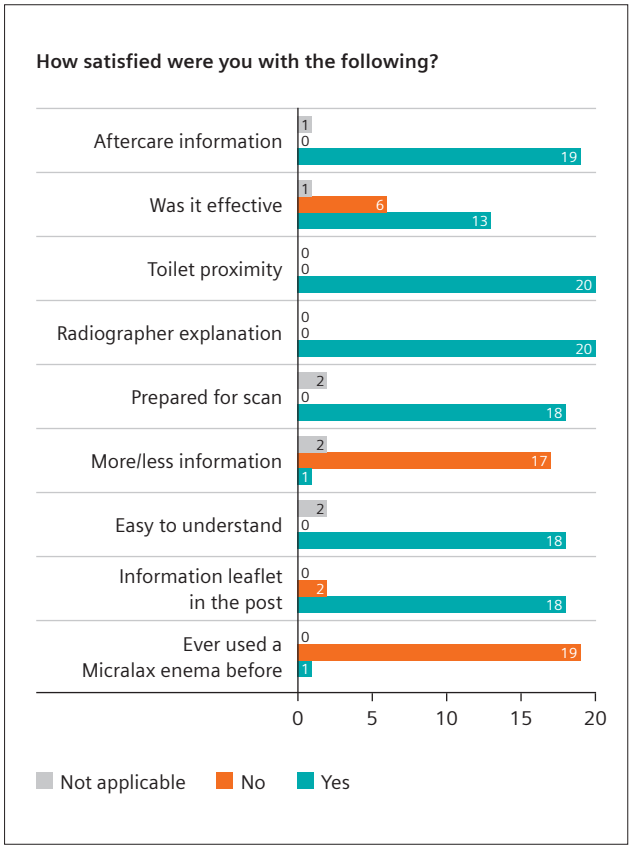
How we do it: NWCC's current standard procedure and MR imaging protocol

Referral

Patients are all pre-biopsy urology referrals based on raised prostate-specific antigen levels (PSA) > 5.

Patient preparation

Patients are asked to arrive 45 minutes before their appointment time, so the only scheduling complication is around the first slot of the day. Information leaflets are sent out with appointment letters to advise patients of the need for bowel preparation on arrival (see Table 2). On patient arrival, MR radiographers go through the patient safety checklist to ensure there are no contraindications to MRI scanning that may negate the need for the enema. A drug checklist is also completed to ensure there are no inflammatory bowel conditions that could be aggravated by the enema, and no contraindications to the antispasmodic drug HBB 20 mg/mL (Buscopan), which is administered intravenously by radiographers guided by a local patient group directive (PGD). Radiologists are asked to prescribe the enema and, if PGD conditions are not met, the intravenous Buscopan.



7 Outcomes of patient feedback audit.

An explanation of the procedure and its benefits for the imaging is provided to the patient in a private subwait area. If verbal consent is given, the patient is asked to proceed. Toilets are adjacent. A subsequent patient feedback audit demonstrated that most patients were well informed and tolerated the procedure well (see Fig. 7).

After 15–30 minutes, patients are brought in to have their IV cannulation for the Buscopan, which is administered once the patient is positioned on the scanner, due to its short-lived effect of only 15–20 minutes.

Additional patient preparation could be perceived as preventing radiographers from performing actual MR scans. However, as the bowel preparation is explained along with our MRI safety checklisting on arrival, and as radiographers insert all our cannulas anyway, it is seen as an integral part of the overall patient preparation procedure.

Equipment

Images were performed on a 24-channel 1.5T MAGNETOM Aera using an 18-channel Body Coil.

Patient positioning

Patients are always positioned supine, preferably head first unless claustrophobic, to ensure that whole-body SAR deposition is more accurately calculated.

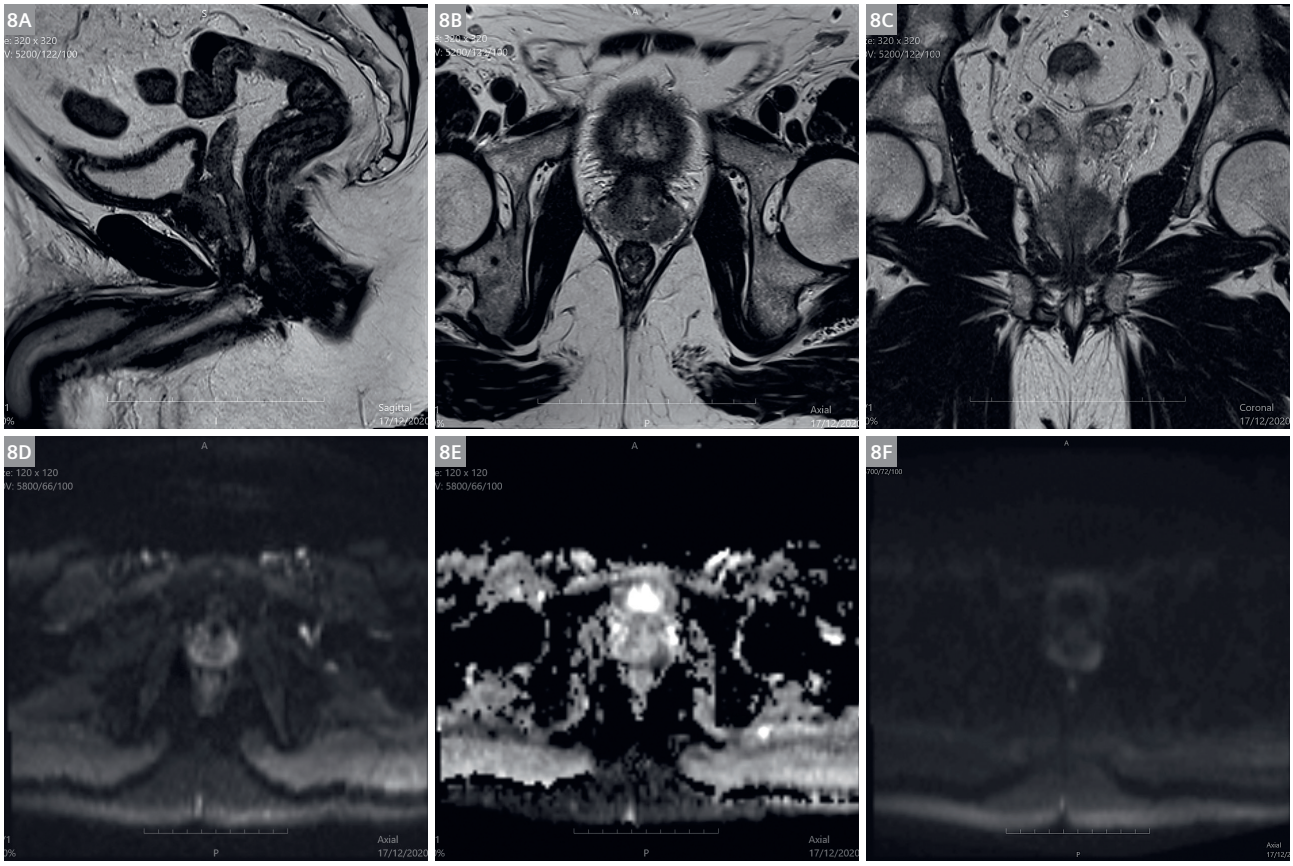
The 18-channel Body Coil is positioned longitudinally on the patient's abdomen. This is acceptable as most of the anatomy to be imaged is midline, and it allows additional upper abdominal coverage for para-aortic nodes whilst providing improved patient comfort. Two transversely positioned body array coils would take longer to position, add extra weight on the patient's abdomen, and restrict the space available for their arms within the bore. Additional straps and coil size would also restrict access to the IV cannula for administration of Buscopan immediately prior to isocenter positioning.

Acquisition

The Dot Cockpit is fundamental to conducting these examinations efficiently and with an easily reproducible protocol of sequences that achieve consistency when multiple operators rotate through the department. Decision strategies built into the workflow are utilized to allow radiographers to adapt the protocol to patient-related scanning needs – e.g., when antispasmodic drug administration is contraindicated, or choosing the RESOLVE DWI option when THR is in situ. Orthogonal slice orientations are preferred by radiology, as they are easily reproduced to ensure consistency in imaging and to enable optimal calculation of gland volume. Imaging parameters are detailed in Table 3, and examples of images are shown in Figure 8.

Sequence	TR	TE	FOV	Slices			Matrix	Voxel size	iPAT	b-values s/mm²	Averages	Scan time min.sec
				Number	mm	Gap						
Sag T2W TSE	5200	122	200 x 100	30	3	0	320 x 80%	0.6 x 0.6 x 3.0	2		3	4.48
Cor T2W TSE	5200	122	200 x 100	30	3	0	320 x 80%	0.6 x 0.6 x 3.0	2		3	4.48
Tra T2W TSE	5200	122	200 x 100	34	3	0	320 x 80%	0.6 x 0.6 x 3.0	2		3	4.48
TRA DWI (1) + ADC	5800	66	300 x 100	34	3	0	120 x 80%	2.5 x 2.5 x 3.0	2	50 400 800	1 4 6	4.46
TRA DWI (2)	7100	72	300 x 100	34	3	0	120 x 80%	2.5 x 2.5 x 3.0	2	1400	12	6.18

Table 3: Standard bp-MRI sequences and parameters; total acquisition time < 30 minutes.



8 Examples of standard optimized protocol: **(8A)** Sag T2W, no rectal distension; **(8B)** Tra T2W; **(8C)** Cor T2W; **(8D)** Tra DWI b-value = 800 s/mm²; **(8E)** Tra DWI ADC map; **(8F)** Tra DWI b-value = 1400 s/mm².

Conclusion

Fully optimizing bp-MRI in the assessment of prostate cancer using a combined technical and patient-focused approach has greatly increased our performance in several ways:

- A low-cost operational change with minimal impact on staff and patients has delivered a significant improvement in image quality, with reduced scan times.
- Dot delivers an efficient workflow to ensure a robust, easily reproduced protocol, which is acquired within 30 minutes and maximizes capacity.
- It has optimized patient flows within the department, minimizing the time patients spend on the scanner.
- Increased time spent with clinical staff prior to MRI has boosted patient confidence in the overall process and experience, and although no evidence is currently available, we do have a very low rate of claustrophobia and anxiety-related refusals.
- Much-improved and consistent image quality with minimal artifacts has increased confidence in diagnostic accuracy for radiologists, and in the decision strategies adopted for patient management at urology MDMs.

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