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Surgery in Motion

Multiparametric Magnetic Resonance Imaging for the Detection of Clinically Significant Prostate Cancer: What Urologists Need to Know. Part 1: Acquisition

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Abstract

Background: Acquiring multiparametric magnetic resonance images of the prostate is not a simple "push-button" approach.
Objective: To show how image acquisition of prostate multiparametric Magnetic Resonance Imaging (mpMRI) can be optimized.
Design, setting, and participants: Image protocols, magnetic field strength choice, and the use of receiver coils are discussed. In addition, patient preparation and the recognition, prevention, and mitigation of artifacts are evaluated.
Surgical procedure: Based on expert prostate MRI technologists (MRI radiographers) opinion, the optimal protocol is reviewed, and potential artifacts are determined.
Measurements: The entire acquisition process is presented from initial patient preparation until the end of the imaging. The choice of the used equipment, pulse sequences, and prevention of patient- and imaging-related artifacts are presented. This will be shown in individual patients.
Results and limitations: Although the Prostate Imaging Reporting and Data System guidelines (2012 and 2016) describe minimal and optimal acquisition protocols for prostate mpMRI, these standards are not always met in daily practice. A major challenge in mpMRI is to obtain high image quality and reduce its variability for radiologic interpretations. A summary of evidence and guidelines for the acquisition of mpMRI of the prostate can set a basic guideline to reduce these variabilities.
Conclusions: This article and an accompanying video can be used as a guide by MRI technologists (MRI radiographers) to improve their image acquisitions by optimizing protocols, magnetic field strength choice, and use of receiver coils. We also discuss patient preparation and the recognition, prevention, and mitigation of artifacts.
Patient summary: In this first surgery-in-motion contribution, we will show how optimized image acquisition is performed to detect prostate cancer. Both MRI-dependent and patient related factors are discussed.

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1. Introduction

The success of multiparametric magnetic resonance imaging (mpMRI) for reliably detecting and localizing clinically significant (cs) prostate cancer (PCa) is highly dependent on image quality [1–4]. However, due to the variability of available MRI equipment including software levels and prostate MRI technologists' (MRI radiographers') experience, it can be challenging to consistently achieve good-quality images for detection, localization, staging, and follow-up of PCa.

The first step to improve quality and reduce variability is to implement optimized acquisition protocols. Therefore, the European Society of Urogenital Radiology (ESUR) published the Prostate Imaging Reporting and Data System (PI-RADS) guidelines in 2012, which included recommendations on minimal and optimal requirements for prostate mpMRI. In 2016, this was revised, and more recently PI-RADS v2.1 was published [5–7]. However, these requirements are only technical specifications, and did not describe patient preparation or how to avoid the most common artifacts that are known to affect image quality, which are described herein.

2. Magnetic field strength

One of the most frequently discussed topics of prostate mpMRI is whether to use 1.5T or 3T MRI field strength. The use of 3T machines is recommended [6]. MRI of 1.5T field strength should be considered when a patient has an MR-conditional implanted device, but its presence still may result in artifacts that could compromise image quality (eg, metallic hip-prosthesis) [6].

The reason for 3T MRI being preferred to 1.5T MRI is the increased "signal-to-noise ratio" (SNR), which results in increased spatial resolution and thus better image quality. The disadvantage of 3T MRI is the increased risk of artifacts, especially susceptibility (resulting in geometric distortion) and ghosting artifacts [8]. There are sequences that decrease these artifacts, but these can result in increased imaging time and/or decreased SNR.

A comparison between the 1.5T and 3T MRI by Ullrich et al [9] showed that the SNR and "contrast-to-noise ratio" (CNR) for T2-weighted images (T2WI) are comparable for both field strengths. However, for diffusion-weighted images (DWI), the SNR and CNR are significantly lower at 1.5T. As DWI is especially important for recognizing csPCa in the peripheral zone (PZ), 3T scanning is preferred. Further investigations are required to understand whether 1.5T has the same diagnostic value as 3T MRI on modern MRI systems for clinical decision making such as the need for biopsy and biopsy yields. Therefore, the use of 3T MRI for prostate imaging is recommended until further investigations shows, that the diagnostic value of 1.5T MRI is sufficient (Table 1). An example of 1.5T versus 3T MRI of the prostate in the same patient is shown in Figure 1.

3. Gradient strength

The SNR and CNR of images are also dependent on the maximum value- and rise-time of the magnetic field gradients. This is especially the case for DWI, where image

Table 1 – Summary of evidence and guidelines for the acquisition of mpMRI of the prostate [36].

	Summary of recommendations	Level of evidence	Grade
Magnetic field strength	3T MRI is preferred to 1.5T MRI	3	B
Gradient strength	Use the strongest gradients possible to increase image quality, especially DWI	3	B
Receiver coils	Use a body phased array and spine coil; an ERC is not necessary	1	A
Patient preparation	Check for MRI-related contraindications	2	B
	Administer antispasmodic agents unless there are contraindications	2	B
	Fasting is not necessary	5	D
	Consider the use of micro-enema prior to a prostate mpMRI examination	3	B
	Use a rectum catheter prior to a prostate mpMRI examination in patients with air in the rectum	5	D
	Ask the patient to refrain from ejaculation during 3 days prior to the MRI examination	2	B
Acquisition protocol	T2WI should always be obtained in the axial plane and at least one other orthogonal plane (sagittal or coronal)	3	B
	The prostate-rectal interface on the sagittal image can be used as a guide for angulation of the coronal plane	3	B
	The axial plane should be positioned perpendicular to the coronal plane	3	B
	DWI is acquired in the axial plane with a small shim box in exactly the same position and same phase encoding direction as the T2WI	3	B
	DWI sequence consists of multiple *b* values, typically b50–100, b400-500, b800 and a high *b* value* of at least b1400s/mm^2	3	B
	DCE-MRI is acquired in the axial plane, in exactly the same position and phase encoding direction as the T2WI and the DWI	3	B
	DCE-MRI is acquired with a high temporal resolution of $<$15 s	3	B
MRI technologist (MRI radiographer) training	Trained technologists (radiographers) specifically for prostate MRI are highly recommended	5	D

DCE = dynamic contrast enhanced; DWI = diffusion-weighted imaging; ERC = endorectal coil; mpMRI = multiparametric MRI; MRI = magnetic resonance imaging; T2WI = T2-weighted imaging.

* A high *b* value image can also be calculatyed from the DWI-series.

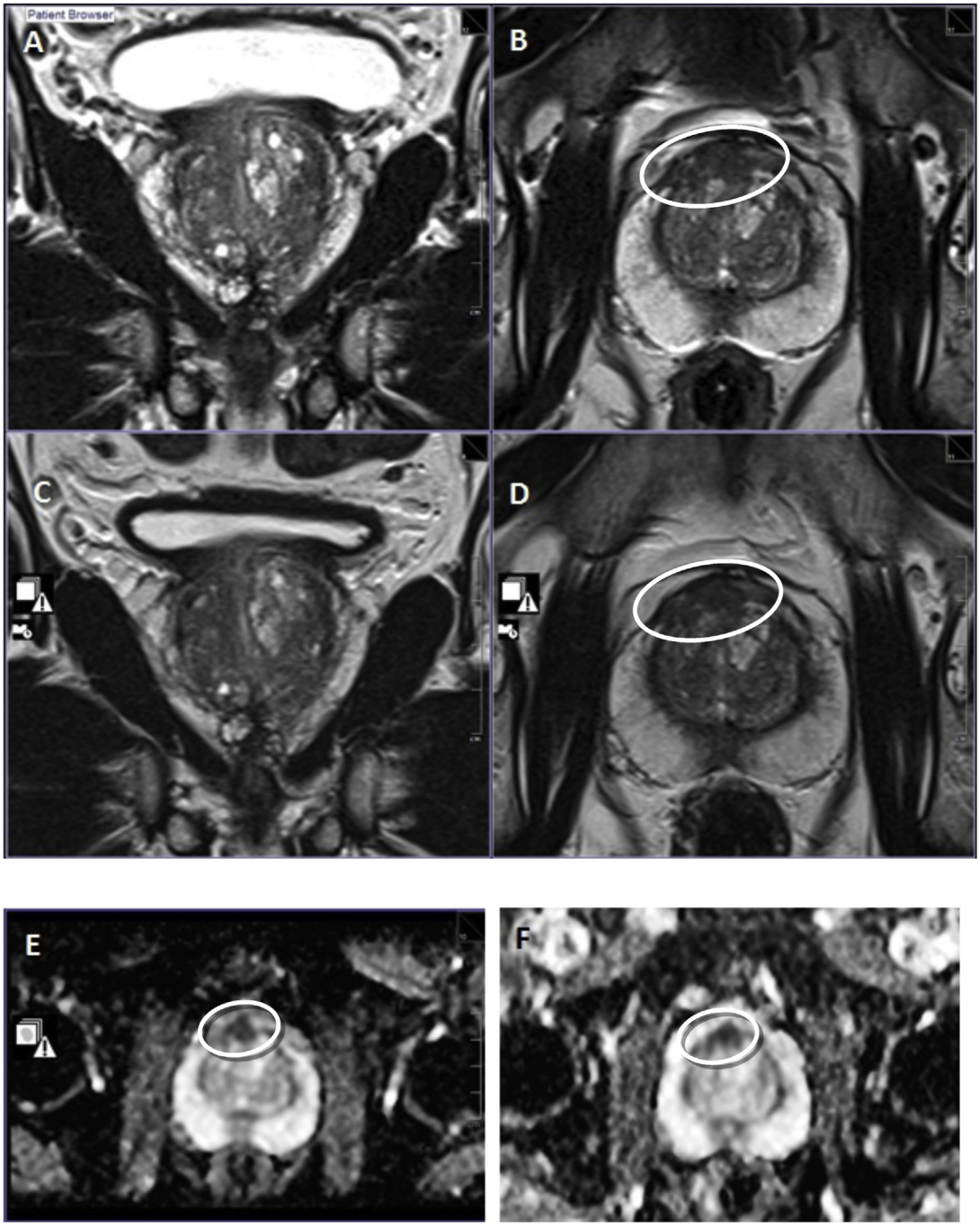

Fig. 1 – Magnetic field strength 3T versus 1.5T MRI: (A,B) 3T axial and coronal T2WI; (C,D) 1.5T axial and coronal T2WI (anterior TZ lesion [circle]); (E) 3T axial ADC map; and (F) 1.5T axial ADC map. Biopsy showed a GG1 (GS 3 + 3) anterior TZ cancer (c.: Professor A. Padhani).
ADC = apparent diffusion coefficient; GG = grade group; GS = Gleason score; MRI = magnetic resonance imaging; T2WI = T2-weighted imaging; TZ = transition zone.

quality highly depends on the gradient strength [10–13]. Stronger gradients allow shorter echo time (TE), enabling a higher SNR and thus better DWI quality [14,15]. However, scanners with higher gradient strength are more expensive, and as a result, many MRI scanners do not fulfill the requirement for short TE times for DWI sequences. As a result, a 3T scanner with low gradient strength will produce lower-quality DWI compared with a 1.5T scanner with high gradient strength. Therefore, strong gradients are preferred over higher magnetic field strength for prostate mpMRI (Table 1).

4. Receiver coils

The most commonly used receiver coil is a body phased array coil in combination with a spine coil. Many centers also employ an additional endorectal coil (ERC). An ERC is a receiver coil in a small balloon that is inserted in the rectum

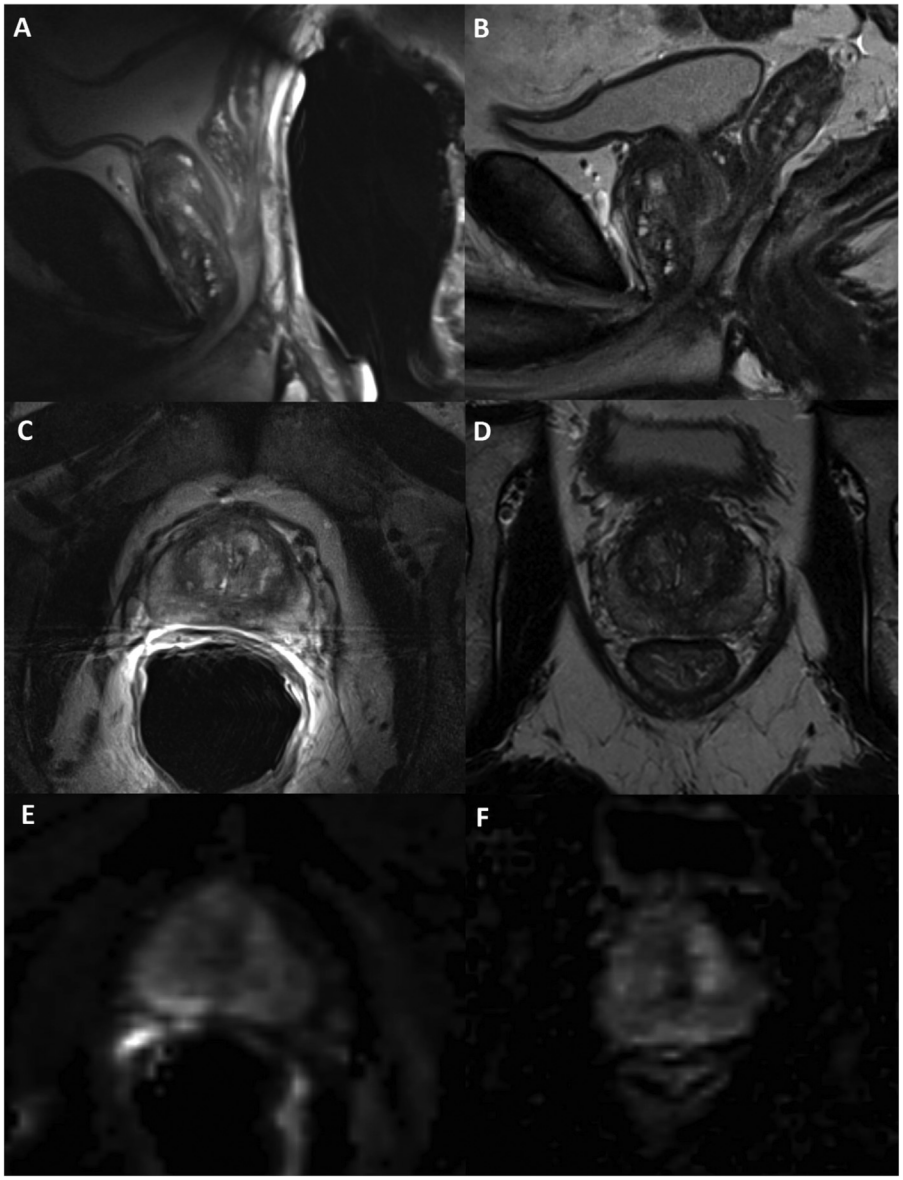

Fig. 2 – ERC versus non-ERC MRI of the prostate. This image shows a patient who underwent 3T MRI (A,C,E) with ERC and (B,D,F) without ERC. (A,B) T2WI sagittal, (C,D) T2WI axial, and (E,F) calculated b1400 images are shown. The images with the use of an ERC show image artifacts at the rectal-prostate interface, and the prostate is noticeably compressed. Whereas the images without an ERC are free from artifacts.
ERC = endorectal coil; MRI = magnetic resonance imaging; T2WI = T2-weighted imaging.

before the MRI examination. The value of an ERC coil for prostate MRI has been studied extensively [16–18]. Its value seems to be for lower field strengths and older MRI machines, where they can improve image quality due to increased SNR. However, major disadvantages of the ERC are artifacts. Research conducted by Husband et al [19] and Sosna et al [20] showed that ERC artifacts are the major causes of decreased image quality.

Recently, there have been multiple improvements in hardware and software, which allow good-quality prostate mpMRI to be obtained without using ERCs [6,21]. Many modern 1.5T MRI scanners do not require an ERC to ensure acceptable image quality. Accordingly, the PI-RADS Committee does not prescribe the use of ERC, stating that reliable, satisfactory results can be obtained with both 1.5T and 3T without the use of an ERC [6]. This position is supported by a systematic review performed by Fusco and colleagues [21] who concluded that new 1.5T and 3T MRI machines can obtain acceptable image quality without the use of an ERC. Figure 2 displays an example of a patient who underwent mpMRI of the prostate both with and without the use of an ERC. Without ERC there are no artifacts and prostate compression. Therefore, mpMRI of the prostate without an ERC is recommended (Table 1).

5. Patient preparation

PI-RADS v2 does not specify patient preparation, mentioning only image quality improvement through the use of antispasmodic agents, preparation enema, a rectum cathe-

Table 2 – Potential contraindications to MRI examination.

Potential contraindications
MRI-unsafe pacemakers, ICDs, neurostimulation systems, cochlear implants, or medication pumps
Metallic foreign bodies, for example, fragments (in the eye), bullets, or shrapnel
Ferromagnetic metallic vascular clips
Metal dental brace/implants
(Severe) claustrophobia
For gadolinium chelate contrast agent:
• Earlier contrast reaction to MRI contrast agent • Poor kidney function (GFR < 30 ml/min/1.73 m^2)

GFR = glomerular filtration rate; ICD = implantable cardioverter defibrillator; MRI = magnetic resonance imaging.

ter, and by refraining from ejaculation for 3 days prior to the MRI [6]. The different patient preparation methods for mpMRI of the prostate are discussed below. A summary of recommendations can be found in Table 1.

5.1. Contraindications

Before undergoing MRI, the patient must be screened for contraindications for MRI to prevent harm. Most important is to check for implants, metal foreign bodies, contrast allergies, and renal function. Shellock and Crues [22] published a review article describing the MR biologic effects and safety guidelines of MR procedures. A list of potential contraindications is listed in Table 2. In case of potential contraindications, this should be discussed with the radiologist. Guidelines concerning contraindications of contrast agents and renal function are described in the ESUR guidelines on contrast media [23].

Postbiopsy hemorrhage is no contraindication for mpMRI of the prostate; a study of Rosenkrantz et al [24] showed that extensive hemorrhage and short delay after biopsy did not negatively impact the accuracy for cs tumor detection using mpMRI. However, the most recent European Association of Urology (EAU) prostate guidelines recommend performing MRI prior to biopsy [25].

5.2. Antispasmodic agents

The administration of an antispasmodic agent such as hyoscine butyl bromide (Buscopan, Boehringer, Ingelheim, Germany) or Glucagon (GlucaGen, Novo Nordisk A/S, Bagsvaerd, Denemarken) can prevent blurring of images by decreasing bowel motility. This has the effect of decreasing peristalsis for a short time (usually around 15–20 min), which is just long enough to acquire the required images [15]. The effect of antispasmodic agents on mpMRI was investigated by Slough et al [26]. The patient group using the antispasmodic agent had significantly higher T2WI quality. Owing to the use of antispasmodic agents, there were less motion artifacts and blurring on the T2WI. However, there was no significant improvement in DWI image quality, or in the degree of DWI distortion or other artifacts. Thus, administration of antispasmodic agents improves image quality of the T2WI and is recommended as patient preparation for prostate MRI. Alternatively, Glucagon may be used when Buscopan is not available/licensed or contraindicated. Contraindications and side effects of antispasmodic agents should be considered. Always consult the medication leaflet before using antispasmodic agents to rule out contraindications and to warn the patient for side effects.

5.3. Fasting

Fasting is another patient preparation method used for abdominal MRI. However, fasting was not mentioned as a preparation method for prostate mpMRI in PI-RADS v2. Evidence for the use of fasting to decrease rectal air or bowel movement is lacking. Fasting is therefore not recommended as a patient preparation method for prostate mpMRI.

5.4. Preparation enema

Caglic and colleagues [27] investigated the effect of rectal distension on prostate mpMR image quality. Rectal distension had a significant negative effect on the quality of both T2WI and DWI. Thus, to optimize image quality, bowel preparation prior to prostate mpMRI should be considered. Lim et al [28] showed that preparatory cleansing enemas did not improve image quality or reduced artifacts in 3T prostate mpMRI. However, van Griethuysen et al [29] investigated the use of a preparatory microenema shortly before the DWI sequence. The microenema consisted of a 5 ml solution (Microlax, McNeil Healthcare, Ireland) that was self-administered by the patient ± 15 min prior to acquisition. Apart from the microenema, no bowel preparation or spasmolytic agents were applied. This significantly reduced both the incidence and the severity of gas-induced artifacts. As gas-induced artifacts especially decrease DWI quality, the use of a microenema prior to a prostate mpMRI examination could be considered where suitable toileting facilities are available.

5.5. Rectum catheter

Air within the rectum can cause susceptibility artifacts that distort DWI. Caglic et al [27] also reported on a strong positive correlation between increased rectal feces and air and DWI distortions/artifacts. Therefore, another option to reduce these artifacts is to decrease the amount of air in the rectum by inserting a rectal catheter prior to the MRI examination and to remove the air with a syringe as suggested by F. Cornud (Paris, France). Figure 3 shows the effect of using such a rectal catheter. Further investigations are required to evaluate whether the use of a rectum catheter could reduce both the incidence and the severity of gas-induced artifacts.

5.6. Refraining from ejaculation

Another preparation mentioned in the PI-RADS recommendations without consensus is the request to refrain

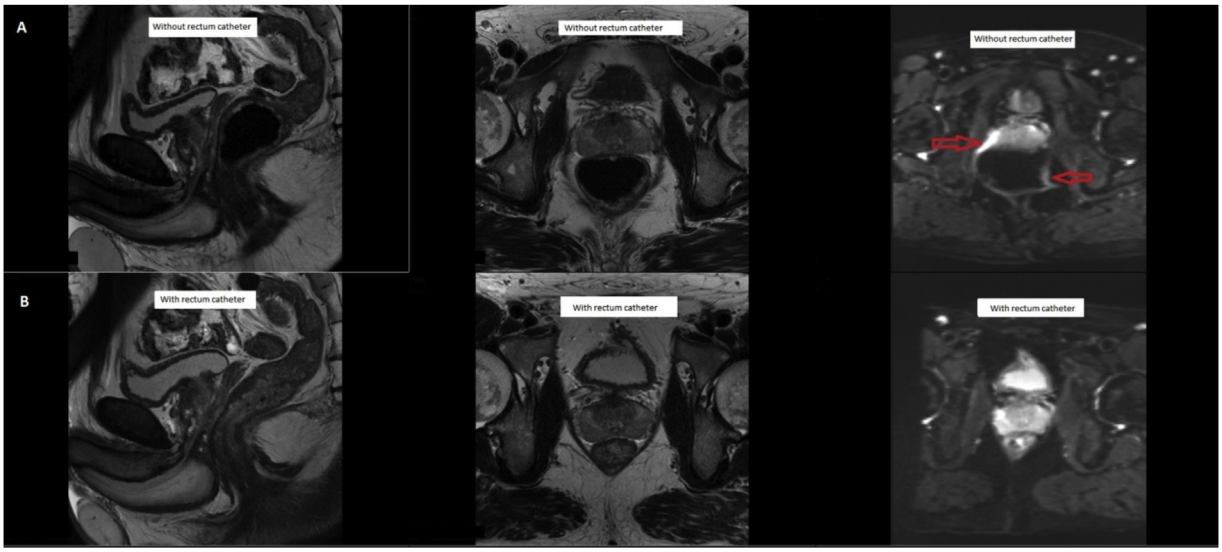

Fig. 3 – Rectum catheter versus no rectum catheter. This image shows a patient who underwent MRI of the prostate (A) without and (B) with the use of a rectum catheter. This demonstrates that, especially in the DWI (right column), susceptibility artifact is present distorting the images where the rectum catheter was not used (arrows), which is considerably improved when the rectum catheter was used.
DWI = diffusion-weighted imaging; MRI = magnetic resonance imaging; T2WI = T2-weighted imaging.

from ejaculation during 3 days prior to the MRI examination. Several articles have examined the influence of ejaculation prior to the MRI examination of the prostate. The main findings were a significant reduction in seminal vesicle (SV) volume after ejaculation and, therefore, decreased diagnostic evaluation of potential SV invasion in patients with known cancers [30–32]. In addition, a significant reduction of prostate apparent diffusion coefficient (ADC) value and significantly decreased T2-value of the PZ have been reported [31,32]. Concluding from these articles, it is reasonable to request that patients refrain from ejaculation for 3 days prior to the MRI examination.

6. Acquisition protocol

According to the PI-RADS v2.1 recommendations, the minimal protocol consists of a combination of high-resolution T2WI in at least two planes, always including an axial plane, and two functional MRI techniques: axial DWI and dynamic contrast enhanced (DCE) MRI [7]. To distinguish the position of a lesion on mpMRI of the prostate, it is important to use similar voxel, slice thickness, and slice positioning for matching between the different sequences. In addition, this will help determine the exact biopsy location. An overview of setting recommendations is presented in Table 1, and Table 3 presents an overview of the recommended minimal sequence parameters for 3T and 1.5T MRI scanners.

6.1. T2-weighted imaging

T2WI shows the prostate's anatomy and is used for the detection, localization, and staging of PCa. In the PZ, PCa can be recognized as a round or ill-defined lesion with low signal intensity on a background of high signal intensity of the normal PZ. Transition zone (TZ) PCa can be more difficult to recognize because low signal intensities of benign prostate hyperplasia can mimic PCa. High-quality T2WI is very important to classify TZ lesions, to evaluate extraprostatic extension, and for planning of fusion biopsies.

T2WI should always be obtained in the axial plane and at least one orthogonal plane (sagittal or coronal), and should include the whole prostate, irrespective of its size and shape, and a minimum of two-thirds of the SV. Angulation of the coronal and axial plane is crucial (although straight axial planes may be more helpful for fusion biopsy planning). For the coronal plane, the prostate-rectal interface on the sagittal image can be used as a guide. When the scan box is parallel to this line, the prostate is "heart shaped" on the coronal plane (Figure 4). This angulation enables optimal visualization of the tumor extension to the SV and comparison of whole-mount section radical prostatectomy slices with (axial) T2WI. The axial plane should be positioned orthogonal to the rectum, that is, perpendicular to the coronal plane [5].

To prevent mismatch between the T2WI axial plane and DWI axial plane, it is important to have a homogenous magnetic field in the prostate itself. To achieve this and to minimize influence of air or bowel movement, a small shim box is applied around the prostate (Figure 5).

The phase encoding direction is an important parameter for the T2WI sequence. A phase encoding direction from left to right is used in the coronal and axial planes to prevent overprojection of motion artifacts from the bowel into the prostate.

Table 3 – Minimal requirements for 3T and 1.5T mpMRI of the prostate.

Sequence	T2 TSE sagittal	T2 TSE coronal	T2 TSE axial	EPI DWI axial	DCE axial
Requirements for 3 T mpMRI of the prostate					
TR (ms)	5590	5000	5660	3200	3.62
TE (ms)	101	101	104	63	1.27
Flip angle (°)	160	160	160	–	14
Freq FOV (mm; phase FOV)	180	192	192	256	192
Matrix size	320	320	320	128	224
# Slices/thickness(mm)	19/3	15/3	19/3	19/3	26/3
Gap (%)	20	20	20	20	–
Voxel size (mm)	0.6 × 0.6 × 3	0.6 × 0.6 × 3	0.6 × 0.6 × 3	2 × 2 × 3	0.9 × 0.9 × 3
Averages/NEX	2	2	2	b50—3	–
				b400—8	
				b800—12	
Phase enc dir	H ≫ F	R ≫ L	R ≫ L	R ≫ L	R ≫ L
≅BW (Hz/Px)	200	200	200	1502	490
b values (s/mm^2; directions)	–	–	–	b50	–
				b400	
				b 800	
				b 1400 (calc.)	
Measurements	1	1	1	1	45
≅Time	2:31	2:15	2:33	4:50	2:50
Requirements for 1.5 T mpMRI of the prostate					
TR (ms)	6700	6500	6400	3700	4.36
TE (ms)	108	146	146	73	1.76
Flip angle (°)	160	160	160	–	12
Freq FOV (mm; phase FOV)	200	200	200	200	260
Matrix size	320	320	320	100	192
# Slices/thickness (mm)	19 /3.5	15/3.5	19/3	19/3	22/3
Gap (%)	20	20	20	20	–
Voxel size (mm)	0.6 × 0.6 × 3.5	0.6 × 0.6 × 3.5	0.6 × 0.6 × 3	2 × 2 × 3	1.4 × 1.4 × 3
Averages/NEX	2	2	2	b50—4	–
				b400—7	
				b800—18	
Phase enc dir	H ≫ F	R ≫ L	R ≫ L	R ≫ L	R ≫ L
≅BW (Hz/Px)	200	200	200	1428	300
b values (s/mm^2; directions)	–	–	–	b50	–
				b400	
				b800	
				b1400 (calc.)	
Measurements	1	1	1	1	40
≅Time	2:22	3:07	3:26	4:33	3:10

BW = band width; DCE = dynamic contrast enhanced; DWI = diffusion-weighted imaging; EPI = echo-planar imaging; FOV = field of view; mpMRI = multiparametric MRI; MRI = magnetic resonance imaging; NEX = number of excitations; Phase enc dir = phase-encoding direction; PX = pixel; TE = echo time; TR = repetition time; TSE = turbo spin echo.

6.2. *Diffusion-weighted imaging*

DWI is an essential sequence for detection and is a predictor of tumor aggression. It reflects the random motion of water molecules and is a key component of the prostate mpMRI examination [6]. PCa demonstrates high signal intensity on DWI at high *b* values (factor of strength and timing of gradients to generate DWI) and low signal intensity on ADC maps. As mentioned above, DWI is acquired in the axial plane with a small shim box in exactly the same position and same phase encoding direction as the T2WI [5]. A typical DWI sequence consists of multiple *b* values, typically b50–100, b400-500, b800, and a high *b* value of at least b1400 s/mm^2. This high *b* value can be acquired separately, but can also be calculated from the lower *b*-value images with monoexponential fitting of the signal decay curve. For the DWI, the ADC map is always calculated using *b* values $<$1000 s/mm^2. The reason for preferably starting with a b50 instead of a b0 is to prevent shine-through of the vessels, that is, to exclude the vascular signals. High *b*-value images are a valuable diagnostic tool in csPCa detection and crucial for mpMRI interpretation [33]. According to the PI-RADS v2.1 standard, a *b* value of $\geq$1400 s/mm^2 must be used for interpretation provided that SNR is sufficient [7].

The image quality of DWI depends on the SNR and the influence of artifacts. With an increased SNR more detailed images can be acquired. The SNR is affected by the following factors: magnetic field strength, proton density of tissues, voxel volumes, TR, TE, flip angle, number of excitations (NEX; also known as the number of signal averages or acquisitions), receiver bandwidth, and coil type [14]. Increasing the *b* values naturally decreases the SNR monoexponentially. To compensate for signal losses in higher *b* values, it is important to increase the NEX with increasing *b* value; for example, we use three NEX for b50, eight NEX for b400, and twelve NEX for b800 to maintain the SNR. Note that this does not alter ADC value calculations.

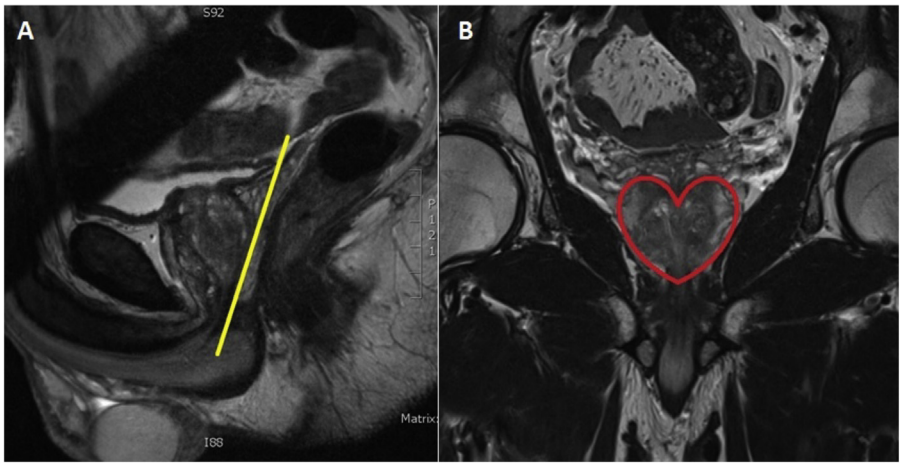

Fig. 4 – Angulation of the coronal plane. (A) Angulation of the coronal plane (yellow line). (B) Heart-shaped coronal view of the prostate with the correct angulation.

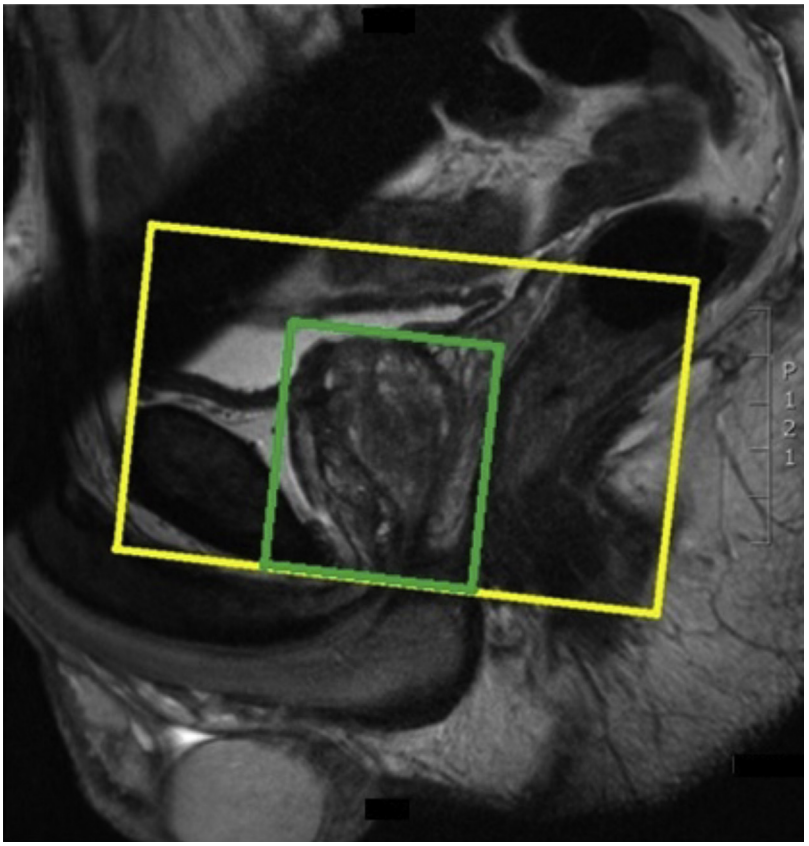

Fig. 5 – Angulation of the axial plane. Angulation of the axial plane (yellow box) and the application of a small shim box around the prostate (green box).

DWI is very sensitive for artifacts that are caused by field inhomogeneities. These inhomogeneities can be caused by a metal hip prosthesis or air in the rectum. Such artifacts can be minimized by using short TE, but they cannot be avoided completely [15]. However, it should be remembered that echo times should not be too short, in order to allow water diffusion to occur prior to the image being acquired. An example of good versus bad high *b*-value DWI image quality can be seen in Figure 6.

6.3. Dynamic contrast enhanced MRI

DCE-MRI during the administration of a gadolinium-containing contrast agent shows tissue vascularity and

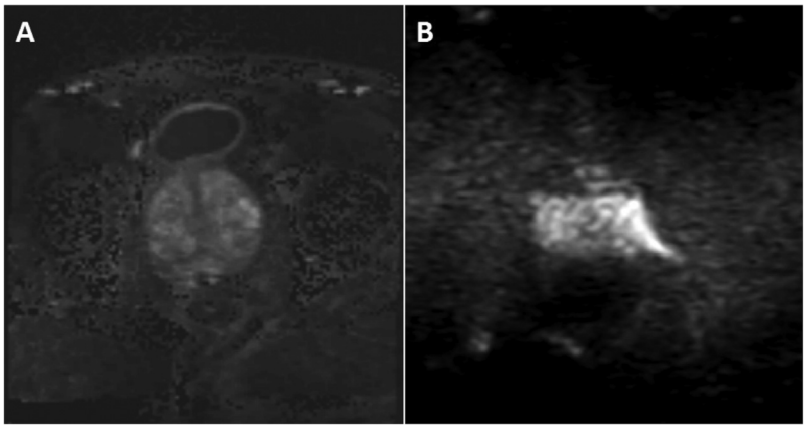

Fig. 6 – DWI image quality. (A) DWI b1400 axial image of the prostate with acceptable image quality. (B) DWI b1400 axial image of the prostate with no acceptable image quality because of a lot of noise and a susceptibility artifact.
DWI = diffusion-weighted imaging.

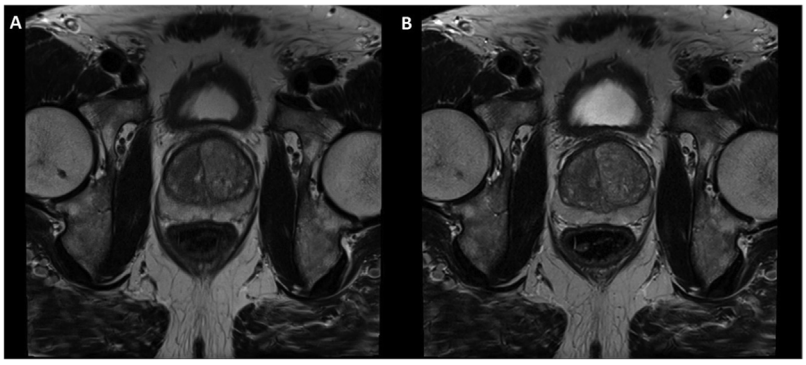

Fig. 7 – Motion artifact. (A) T2W axial image of the prostate with a motion artifact. (B) T2W image of the prostate in the same patient without motion artifacts.
T2W = T2 weighted.

microvessel permeability [5]. Before administrating gadolinium, contrast allergies and renal function should be checked. DCE-MRI is a series of sequential T1-weighted images acquired in the axial plane, in exactly the same position and phase encoding direction as the T2WI and the DWI. A high temporal resolution of $<$15 s is used to show the earlier enhancement of cancer compared with the PZ of the prostate [7]. Contrast enhancement alone is not definitive for csPCa, and absence of early enhancement does not exclude the possibility csPCa. Its value is diminished in TZ assessments. DCE-MRI should be included in all prostate mpMRI examinations so as not to overlook small csPCa [6]. However, the value of mpMRI for detecting csPCa prostate without DCE-MRI is debated [34]. Short MRI protocols without the use of a contrast agent can improve prostate MRI accessibility [35].

7. Artifact prevention

The most common artifacts in mpMRI of the prostate are motion, coil, or patient related. Motion causes blurring of images or ghosting artifacts, and is caused by bowel peristalsis, gland motion, bladder distension, or patient movement. Several approaches can be used to minimize artifacts. One of the most effective ways is good patient preparation. Make the patient as comfortable as possible, a pillow under the knees can help relax the patient and decrease movement of the legs. Clear instructions and communication are the key. Especially tensing of the buttocks and moving of the legs and feet can results in blurred images. As mentioned above, administration of an antispasmodic agent can decrease bowel movements. Decreasing acquisition time per sequence can also prevent motion artifacts. This can be done, for example, with the use of parallel imaging techniques. An example of a motion artifact is shown in Figure 7.

Susceptibility artifacts are another common type of artifacts in prostate MRI that cause distortion of the prostate, especially in DWI. The distortion is caused by local magnetic field inhomogeneities due to rectal air or metal implants (eg, metallic hip prosthesis) [15]. Figure 8 shows an example of distortion caused by rectal air. To

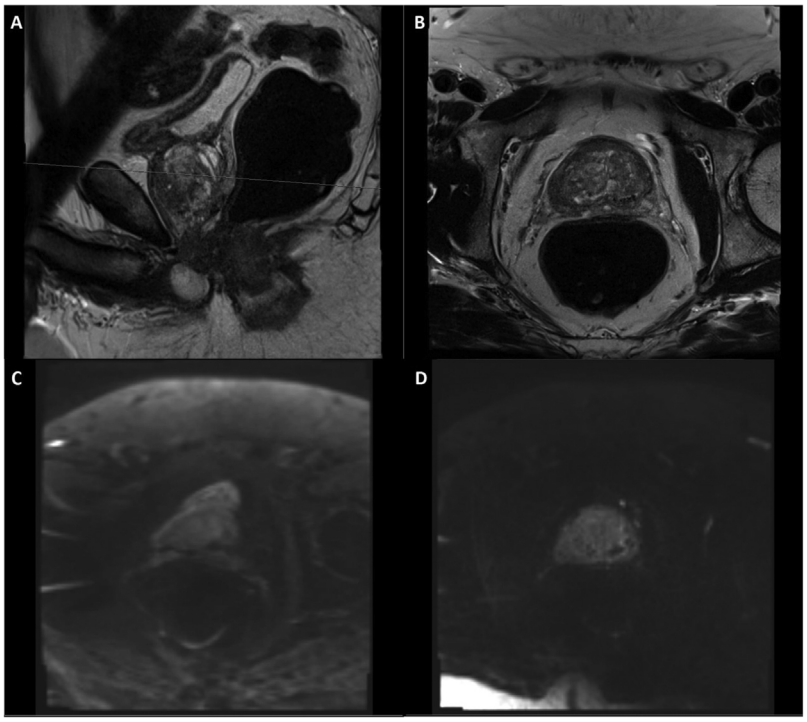

Fig. 8 – Distortion caused by rectal air. A large amount of air in the rectum is visible on the (A) T2 sagittal and (B) T2 axial images. The (C) DWI shows distortion of the prostate caused by rectal air. To decrease the distortion, (D) readout-segmented multishot (RESOLVE) DWI is scanned in the same patient.
DWI = diffusion-weighted imaging.

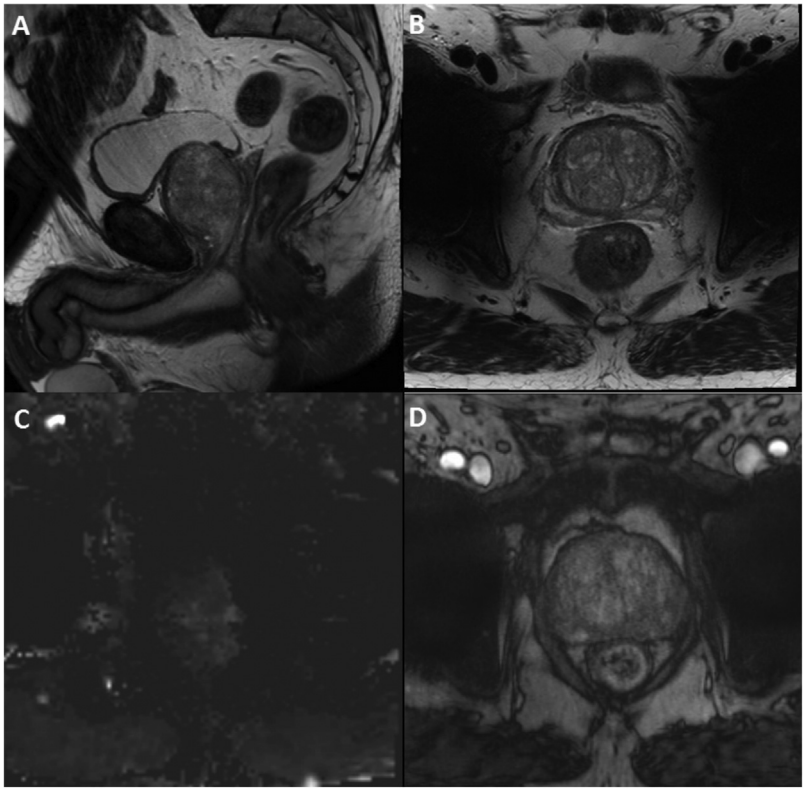

Fig. 9 – Influence of hip prosthesis on image quality. The (A) T2WI sagittal, (B) T2WI axial, and (D) DCE show good image quality to evaluate the prostate. The hip prostheses are displayed as black holes; however, they do not influence the quality of the image in the prostate itself. (C) The DWI is greatly degraded by artifacts and cannot be used for diagnosis.
DCE = dynamic contrast enhanced; DWI = diffusion-weighted imaging; T2WI = T2-weighted imaging.

prevent susceptibility artifacts caused by rectal air, air can be removed with a small rectal catheter (see section 5.5) but also by a small shim box around the prostate. Such a shim box creates a homogenous field in the prostate and prevents susceptibility artifacts.

Susceptibility artifacts caused by metal, for example, hip prosthesis, result in a black hole on T2WI and DWI distortions. Newer image techniques such as readout-segmented DWI might reduce these artifacts. They can also be minimized by using short TE as discussed above, but they cannot be avoided completely [15]. An example of a prostate MR image in a patient with a hip prosthesis is shown in Figure 9. An overview of recommendations for artifact reduction is presented in Table 1.

8. MRI technologists' training

Besides proper patient preparation and technical issues, knowledge and dedication of the performing MRI technologist (MRI radiographer) play a major role in obtaining optimal mpMRI of the prostate. To achieve good image quality, it is important that technologists (radiographers) are properly trained in prostate MRI. Knowledge of anatomy, pathology, and recognizing specific artifacts and technical knowledge will improve the image quality.

9. Conclusions

It is essential that mpMRI scans are PI-RADS v2 compliant and are performed by trained MRI technologists (MRI radiographers) using a standardized protocol consisting of T2WI, DWI, and DCE-MRI. Modern scanners allow obtaining more consistent and high-quality images. Owing to these improvements, an ERC is no longer regarded as necessary, which improves patient comfort and reduces costs. The PI-RADS v2.1 standard gives no specific advice regarding patient preparation. Proper patient preparation and prostate MRI–trained technologists (MRI radiographers) are essential for optimal image quality, and thereby increasing the diagnostic value. It is essential to make patients feel comfortable, with clear instructions and communication before and during the scanning procedure. The use of antispasmodics is recommended, as well as removing air from the rectum where possible. Artifacts can still degrade mpMRI images. By employing modern machines and -techniques, faster image protocols, and optimal patient preparation, these artifacts can be reduced to obtain the best images possible for any given patient. The better the image quality, the easier and better the interpretations by radiologists.

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Study concept and design: Engels, Israel, Barentsz.
Acquisition of data: Engels, Israel, Barentsz.
Analysis and interpretation of data: Engels, Israel, Padhani, Barentsz.
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Appendix A. Supplementary data

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