A Rapid, PI-RADS v2 Conform, Multi-parametric MRI Prostate Exam for Improved Patient Care

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The results of PROMIS, a prospective multicenter-paired validation study, clearly show the value of targeted prostate biopsy with MRI guidance over systematic transrectal ultrasound-guided biopsies (TRUS-Bx) in biopsy-naïve men [1]. Multi-parametric (mp)-MRI prior to first biopsy may not only help to avoid unnecessary biopsies in 30% of patients, it also may reduce the rate of overdiagnosis and overtreatment due to a detection bias of MRI towards significant disease.

Accordingly, mp-MRI to aid in the diagnosis and management of prostate cancer has been one of the fastest growing applications in MRI over the recent years [2]. The downside to this development is that radiological facilities have to manage the increasing number of mp-MRI referrals in their daily business. While a typical head or knee exam requires between 10–15 minutes, an mp-MRI exam of the prostate is commonly scheduled for 30–45 minutes with a net scan time of about 20 minutes.

Furthermore, there is still reluctance to incorporate MR imaging into general guidelines for prostate cancer detection because it is perceived to be an expensive technology. This is also reflected in a recent poll amongst US urologists: when asked if the cost of mp-MRI is prohibitive for its use, 59% of all respondents agreed or strongly agreed [3].

Previous joint and successful efforts by Massachusetts General Hospital and Siemens Healthcare to compare an ultrafast brain MRI protocol to the conventional protocol in motion-prone inpatient clinical settings with the aim to establish a clinically validated 5-minute routine brain

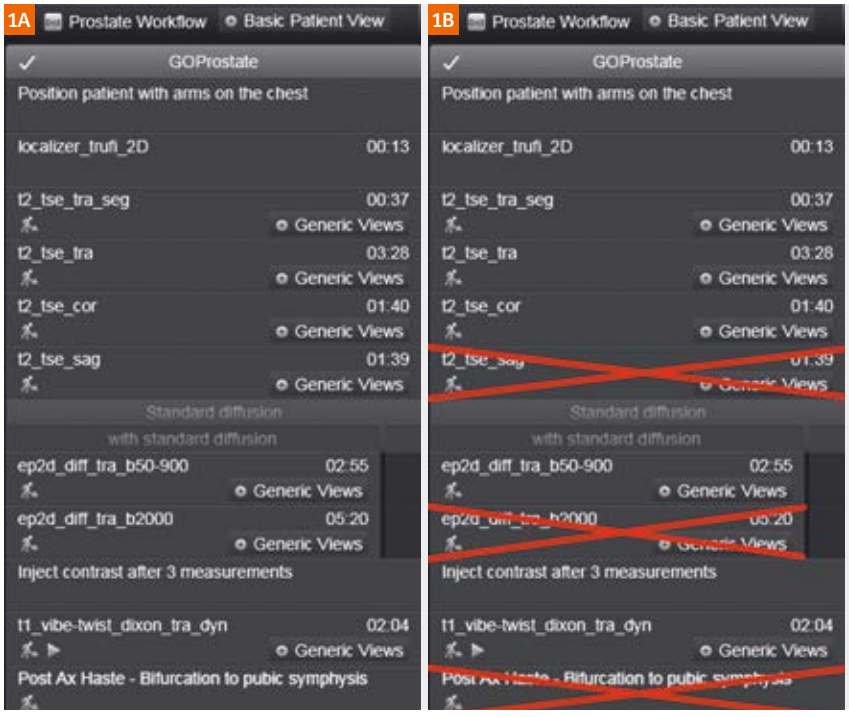

Figure 1:
(1A) Exam workflow of the institutional "full exam" mp-MRI prostate protocol.
(1B) Reduced sub-set of protocols considered in the "rapid exam" reflecting the requirements of PI-RADS v2.

protocol [4] also triggered the investigation of other GO (Generalized Optimized) exam strategies for other high volume MR indications.

For the purpose of developing a rapid prostate protocol, the general structured approach for developing a GO protocol proposed by Otto Rapalino [5] was followed:

1) Establish the time budget for a given core exam
Most high-volume imaging centers generally aim to have standard exam slots of 20–30 minutes per patient. Taking into account the time required for patient preparation and positioning, the net scan time should not exceed 15 minutes. Ideally, this time budget also should include some buffer to react to unanticipated events, e.g. rescans due to patient movement.

2) Define the set of required contrasts based on literature evidence / acceleration methods for acquisition
At our institution, mp-MRI of the prostate typically includes T2-weighted images in 3 orientations, axial diffusion-weighted imaging (DWI) with multiple b-values in a range of b=50 sec/mm^2 to 900 sec/mm^2 plus ADC map, a separately acquired, axial high b-value image with b=2000 sec/mm^2 and axial dynamic contrast-enhanced (DCE) imaging acquired over 2 minutes. All scans are acquired with a slice thickness of 3 millimeters. In addition, a post-contrast HASTE scan covering the pelvis from the aortic bifurcation to the pelvic symphysis is routinely performed at our institution (Fig. 1A). The resulting net acquisition time of our institutional routine protocol is about 22 minutes.

For mp-MRI of the prostate, PI-RADS v2 sets a clear standard as to the contrasts that have to be acquired and the technical requirements, e.g. spatial resolution, to be fulfilled for T2-weighted, DWI and DCE imaging. Applying these rules, a rapid exam protocol was extracted from our full protocol: By removing one T2w TSE orientation, the post-contrast HASTE and the measured high b-value image the net scan time was cut down to 12 minutes (Fig. 1B).

MR technologies which enable the realization of accelerated image acquisition include parallel imaging [6] with high channel density [7]. By using the combination of an 18-channel Body coil and a 32-channel Spine coil, PAT factors of 2 or 3 were applied for acquisition of the individual contrasts.

For increased consistency of scans and higher reproducibility of planning, the decision was taken to use a Works-in-Progress Prostate Dot Engine[1] to assist in the exams. This prototype performs an automatic segmentation of the prostate in a fast 37 seconds, axial T2-weighted TSE scan and derives the volume and outer dimensions of the gland. In addition the landmarks bladder neck and exit point of the urethra from the prostate are automatically detected, to align the slices of the later exams perpendicular to the line between these two landmarks. This enables efficient planning with reproducible automated scan volume positioning and automated coverage adaptation.

3) Test scans to assess image quality in terms of tissue contrast and signal to noise levels
The initial assessment of image quality was satisfactory, except for the contrast of calculated high b-value images: Artificial noise amplification in bony structures reduced the lesion conspicuity in comparison to measured high b-value images, where bony structures appeared less pronounced. This was addressed by using a Works-in-Progress version of the DWI sequence[1] with improved calculated b-value images.

4) Clinical validation of the rapid MR protocol
So far, 75 patients have been examined in a 3T MRI system (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany). Images were acquired with a combination of an 18-channel Body coil and a 32-channel Spine coil.

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[1] WIP, the product is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.

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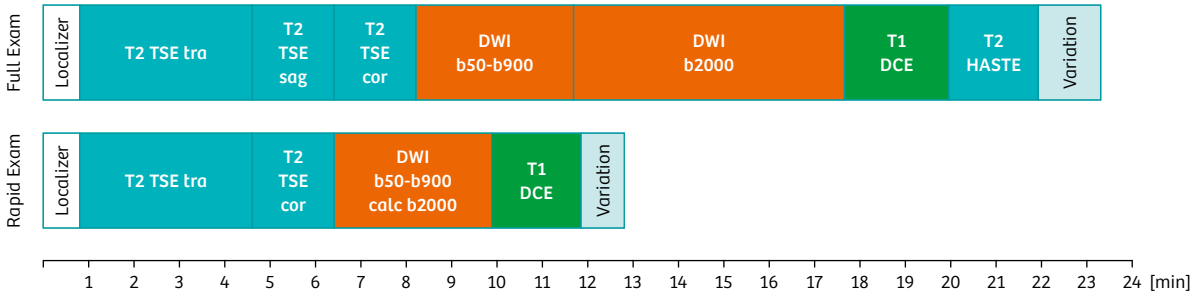
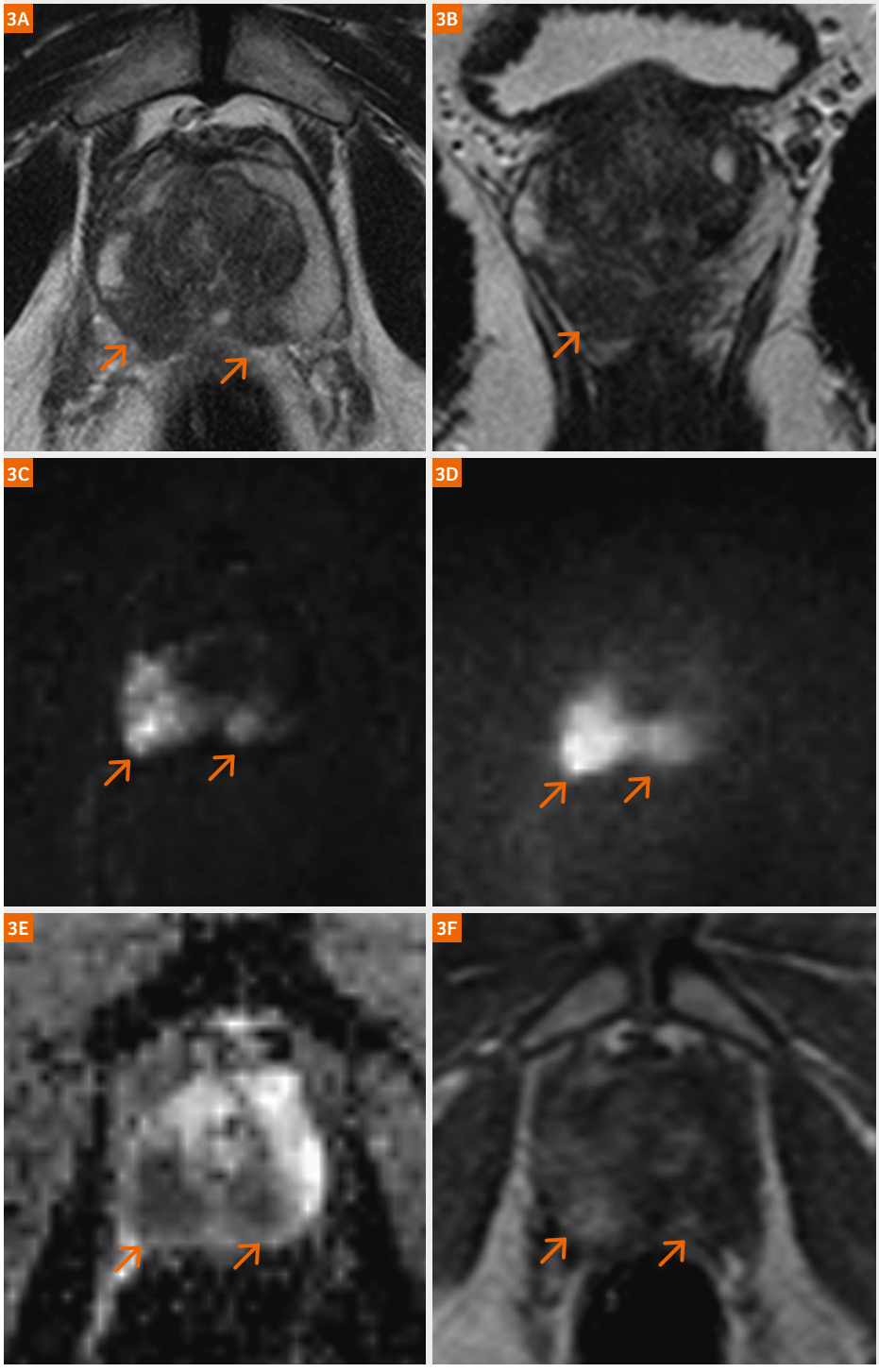


Figure 2: Comparison of exam times with the full and the rapid mp-MRI prostate protocol.

Case 1

Figure 3:
A 73-year-old man with no family history of prostate cancer and with a serum prostate specific antigen (PSA) of 4.5 ng/mL was referred for prostate MRI. mp-MRI revealed a 2.6 x 2.9 cm lesion in the right and left peripheral zone in the apex and mid gland, which was hypointense on axial and coronal T2w TSE **(3A and 3B)**, with a respective diffusion restriction in the calculated **(3C)** and measured **(3D)** high b-value image, corresponding low ADC value **(3E)** and early enhancement on DCE MRI **(3F)**. Accordingly the lesion was assessed as PIRADS 5. Subsequent MR-transrectal ultrasound (TRUS/MRI) fusion guided biopsy showed significant disease with seven out of eleven cores of Gleason 8 (4+4) with 80% to 95% involvement. The patient was offered radiation therapy and 2 years of hormonal therapy.

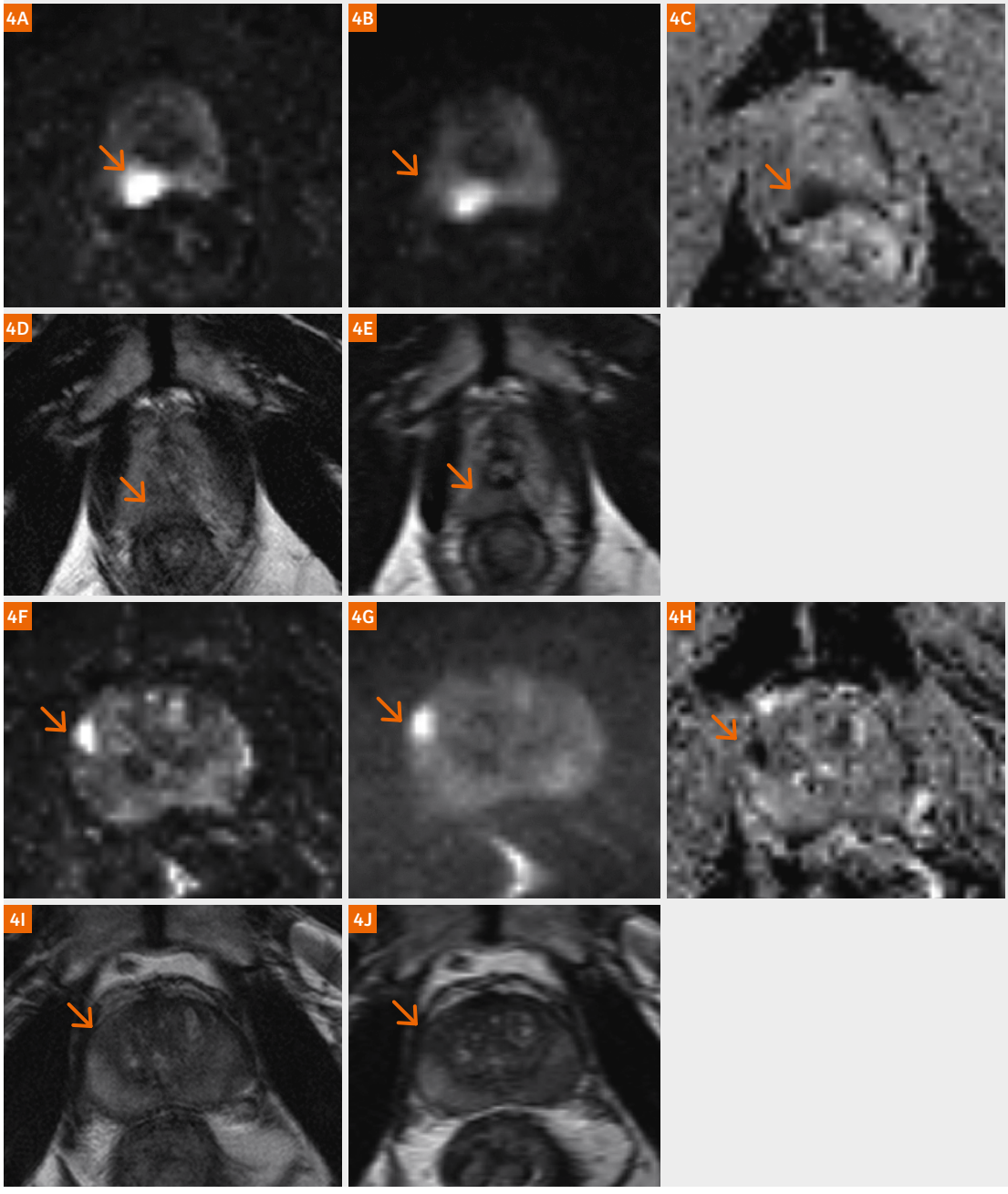


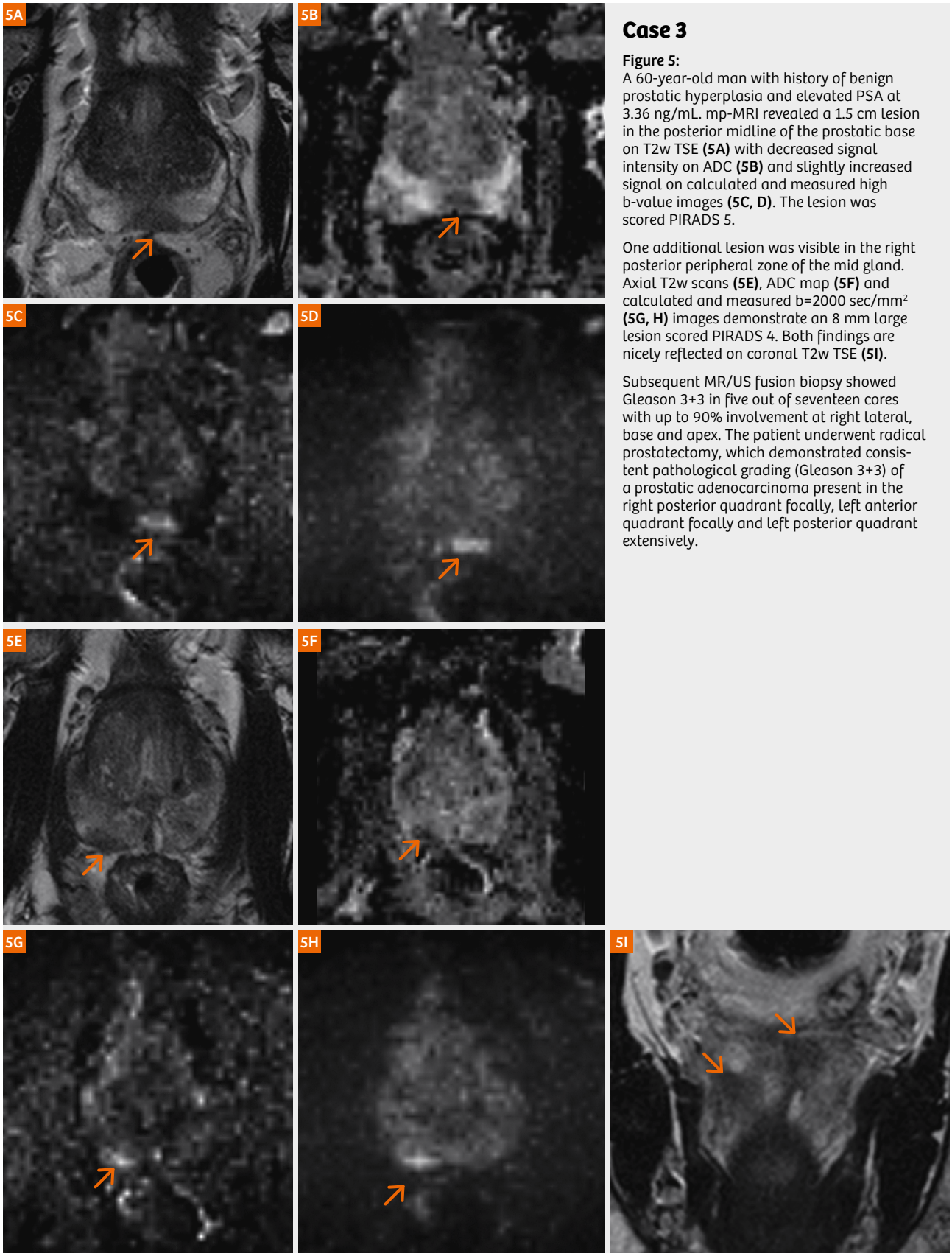
Case 2

Figure 4:
A 62-year-old man with family history of prostate cancer and with rising serum prostate specific antigen (PSA) from 2.8 to 5.6 ng/mL presented for mp-MRI. A dominant, 1.5 cm large lesion in the posterior peripheral zone at the level of right apical to mid gland was found, which showed strongly hyperintense signal in calculated and measured b=2000 sec/mm² images **(4A, B)** and low signal intensity on ADC **(4C)**. While the high-resolution axial T2w images **(4D)** did not allow confirmation of the DWI findings due to massive motion artifacts, the previously acquired, fast T2 TSE scans **(4E)** were sufficient to find a correlate in morphology. The lesion was scored PIRADS 5.

A second, smaller lesion was detected in the right anterior peripheral zone at the level of mid gland with a diameter of 1 cm. The lesion presented with high signal in the b=2000 sec/mm² images **(4F, G)** and restricted diffusion in ADC **(4H)**. Again, low-resolution, fast T2w scans (4J) helped in the correlation to morphology. The lesion was rated PIRADS 4.

Subsequent MR/US fusion biopsy showed Gleason 3+4 at right apex and right mid gland and Gleason 3+3 at right prostatic base, corresponding to the dominant and second lesion seen in MRI. The patient was offered to either undergo radical prostatectomy or external beam radiation with 6 months of androgen deprivation therapy.





Case 3

Figure 5:
A 60-year-old man with history of benign prostatic hyperplasia and elevated PSA at 3.36 ng/mL. mp-MRI revealed a 1.5 cm lesion in the posterior midline of the prostatic base on T2w TSE **(5A)** with decreased signal intensity on ADC **(5B)** and slightly increased signal on calculated and measured high b-value images **(5C, D)**. The lesion was scored PIRADS 5.

One additional lesion was visible in the right posterior peripheral zone of the mid gland. Axial T2w scans **(5E)**, ADC map **(5F)** and calculated and measured b=2000 sec/mm^2 **(5G, H)** images demonstrate an 8 mm large lesion scored PIRADS 4. Both findings are nicely reflected on coronal T2w TSE **(5I)**.

Subsequent MR/US fusion biopsy showed Gleason 3+3 in five out of seventeen cores with up to 90% involvement at right lateral, base and apex. The patient underwent radical prostatectomy, which demonstrated consistent pathological grading (Gleason 3+3) of a prostatic adenocarcinoma present in the right posterior quadrant focally, left anterior quadrant focally and left posterior quadrant extensively.

Statistical assessment of exam duration in 27 patients revealed the following: For the full exam, the median acquisition time was 22 minutes with a standard deviation of 3:18 minutes due to variations in the required number of slices to cover the entire prostate gland individually. The rapid exam took 12 minutes with a standard deviation of 1:55, resulting in a maximum acquisition time of 13 minutes (Fig. 2). Retrospective analysis also revealed, that as many as 17% of all individual scans were repeated by the technologists, probably due to motion of the patient during image acquisition.

Respective clinical examples can be found in Cases 1–3. Please also note, that motion substantially compromised the diagnostic assessability of the axial high-resolution T2w scans in Case 2. Only the correlation of DWI information with motion-robust, very fast T2w images (TA 37 seconds) allowed confident correlation of the findings with morphologic information.

Discussion and conclusion

With the rapid prostate exam proposed here, all clinically relevant contrasts for a PI-RADS v2 conform mp-MRI protocol can be reliably acquired in 12 to 13 minutes acquisition time. Guided, computer assisted positioning of slices facilitates efficient planning with high reproducibility. Even in the case of rescans the scan time should not exceed 16–17 minutes, giving enough leeway to react to unanticipated events and to stay in a 25–30 minute exam slot per patient. In conclusion, the rapid protocol has potential to address the need for improved patient management and reliable scheduling in light of constantly growing procedure volumes.

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Continuing our commitment to delivering high-density lightweight Tim 4G coils, this year we will be introducing a new, ultra-flexible coil design. Contour 24 is a 24-channel coil consisting of highly flexible coil elements encased in soft material to create a blanket-like feeling for the patient.

Contour 24 has a higher density of coil elements per scan field of view than most similar coils available today. It is highly flexible and can be used in various orientations depending on the imaging need.

Contour 24 uses SlideConnect technology and can be combined with the Spine coil. Two coils can even be connected to cover larger imaging fields.

510(k) pending. The product is not commercially available. Future availability cannot be guaranteed.

Contour 24 benefits:

- Lightweight and highly flexible coil with blanket-like feel
- Supports easy positioning and workflow
- Suitable for imaging of general anatomy, such as abdomen and pelvis in both sides and orientations