


Prostate imaging reporting and data system version 2 (PI-RADS v2): a pictorial review

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Abstract

The most recent edition of the prostate imaging reporting and data system (PI-RADS version 2) was developed based on expert consensus of the international working group on prostate cancer. It provides the minimum acceptable technical standards for MR image acquisition and suggests a structured method for multiparametric prostate MRI (mpMRI) reporting. T1-weighted, T2-weighted (T2W), diffusion-weighted (DWI), and dynamic contrast-enhanced (DCE) imaging are the suggested sequences to include in mpMRI. The PI-RADS version 2 scoring system enables the reader to assess and rate all focal lesions detected at mpMRI to determine the likelihood of a clinically significant cancer. According to PI-RADS v2, a lesion with a Gleason score ≥ 7 , volume > 0.5 cc, or extraprostatic extension is considered clinically significant. PI-RADS v2 uses the concept of a dominant MR sequence based on zonal location of the lesion rather than summing each component score, as was the case in version 1. The dominant sequence in the peripheral zone is DWI and the corresponding apparent diffusion coefficient (ADC) map, with a secondary role for DCE in equivocal cases (PI-RADS score 3). For lesions in the transition zone, T2W images are the dominant sequence with DWI/ADC images playing a supporting role in the case of an equivocal lesion.

Prostate adenocarcinoma, with an estimated 180,890 new cases in 2016, is the most common noncutaneous malignancy and the second most common cause of cancer-related mortality in men in the United States [1].

There is significant biologic heterogeneity of prostate adenocarcinoma; some tumors are aggressive with high morbidity and mortality, while others remain indolent [2]. Given this range of clinical behavior, it is beneficial to the patient to attempt to prospectively differentiate clinically significant tumors (Gleason score ≥ 7 , volume > 0.5 cc, or extraprostatic extension) that would be candidates for therapy from clinically insignificant tumors that can safely undergo active surveillance.

Prostate adenocarcinoma is typically diagnosed using nontargeted random transrectal ultrasound (TRUS)-guided biopsy in the setting of an abnormal digital rectal examination or elevated prostate-specific antigen (PSA). Since TRUS-guided biopsy randomly samples the gland, it is possible that the biopsy results may not accurately detect the most aggressive tumor within the gland [3, 4]. Because of this potential for not detecting clinically significant cancer, new approaches for MR-defined targeted biopsy based upon improved MR imaging techniques have been proposed [5].

Traditionally, pelvic MRI has been used for treatment planning and monitoring with loco-regional staging of a biopsy-proven prostate cancer [6]. However, physiologic and functional sequences [diffusion-weighted imaging (DWI), dynamic contrast-enhanced imaging (DCE), and MR spectroscopy] are now added to the traditional sequences (T1- and T2-weighted images) to create current state of the art multiparametric MRI (mpMRI). This multiparametric approach expanded the role of MRI from only loco-regional staging to also include prostate adenocarcinoma detection, localization, and characterization. As mpMRI became more widely validated, the European Society of Urogenital Radiology (ESUR) developed the prostate imaging reporting and data system version 1 (PI-RADS v1) to provide standardized guidelines for image acquisition and interpre-

Table 1. PI-RADS v2 scoring system

Imaging sequence and score	Description
T2-weighted, PZ	
1	Uniform hyperintense signal intensity (normal)
2	Linear or wedge-shaped hypointensity or diffuse mild hypointensity, usually indistinct margin
3	Heterogeneous signal intensity or noncircumscribed, rounded, moderate hypointensity
4	Includes others that do not qualify as 2, 4, or 5
4	Circumscribed, homogenous moderate hypointense focus/mass confined to prostate and <1.5 cm in greatest dimension
5	Same as 4 but ≥ 1.5 cm in greatest dimension or definite extraprostatic extension/invasive behavior
T2-weighted, TZ	
1	Homogeneous intermediate signal intensity (normal)
2	Circumscribed hypointense or heterogeneous encapsulated nodule(s) (BPH)
3	Heterogeneous signal intensity with obscured margins
4	Includes others that do not qualify as 2, 4, or 5
4	Lenticular or noncircumscribed, homogeneous, moderately hypointense, and <1.5 cm in greatest dimension
5	Same as 4, but ≥ 1.5 cm in greatest dimension or definite extraprostatic extension/invasive behavior
DWI	
1	No abnormality (i.e., normal) on ADC and high b-value DWI
2	Indistinct hypointense on ADC
3	Focal mildly/moderately hypointense on ADC and isointense/mildly hyperintense on high b-value DWI
4	Focal markedly hypointense on ADC and markedly hyperintense on high b-value DWI; <1.5 cm in greatest dimension
5	Same as 4 but ≥ 1.5 cm in greatest dimension or definite extraprostatic extension/invasive behavior
DCE	
Negative	No early enhancement, diffuse enhancement not corresponding to a focal finding on T2 and/or DWI, or focal enhancement corresponding to a lesion demonstrating features of BPH on T2WI
Positive	Focal, and earlier than or contemporaneously with enhancement of adjacent normal prostatic tissues, and corresponds to suspicious finding on T2W and/or DWI

DWI, diffusion-weighted imaging; DCE, dynamic contrast-enhanced; PZ, peripheral zone; TZ, transition zone; BPH, benign prostatic hyperplasia

tation [7]. PI-RADS v1 allowed for equal weighting for all acquired sequences (including MR spectroscopy), with a total maximum score of 20 (5 points for each sequence). PI-RADS v1 was demonstrated to have good accuracy, and moderate interobserver agreement with superior performance in the peripheral zone compared to the transition zone [8]. However, several investigators have noted that the use of MR spectroscopy and DCE sequences may not add significant value to the interpretation of mpMRI [9–11]. In part to address the

shortcoming of PI-RADS v1 in the transition zone, and to reflect the concept of a dominant sequence to assess a lesion based on primary anatomic location within the prostate gland, an updated version of PI-RADS was proposed in early 2015 [12, 13]. This new version of PI-RADS has been validated in several studies and shown to have moderate interobserver variability [14, 15].

In this review, we provide an overview of PI-RADS v2 using a case-based approach and discuss and illustrate common pearls in the interpretation of mpMRI.

Table 2. Suggested multiparametric prostate MRI protocol at 3 Tesla^a

	Axial T1W	T2W (multiplanar)	Axial DWI	Axial DCE
Pulse sequence	Spin echo or gradient echo \pm fat suppression	Fast spin echo	Free-breathing spin echo (Echo planar imaging sequence + spectral fat saturation)	2D or 3D T1 gradient echo
TR(ms)	385 ^b	3500 ^b	≥ 3000	<100
TE(ms)	6.2 ^b	102 ^b	≤ 90	<5
FOV(cm)	16 ^b	12–20	16–22	Encompass the entire prostate gland and seminal vesicles
ST(mm)	3 ^b	3	≤ 4	3
Spacing(mm)	0 ^b	0	0	0
In plane dimension (phase(mm) \times frequency (mm))	$\leq 0.7 \times \leq 0.4^b$	$\leq 0.7 \times \leq 0.4$	$\leq 2.5 \times \leq 2.5$	$\leq 2 \times \leq 2$
Remarks		In order to avoid blurring, excessive echo train lengths should be avoided	b-values ≥ 1400 s/mm ²	Preferred temporal resolution is <7 s, total observation rate: >2 min

^a These parameters are optimized for an examination utilizing both a phased array surface coil and an endorectal coil

^b Institutional recommendations

TR, repetition time; TE, echo time; ms, millisecond; FOV, field of view; ST, slice thickness

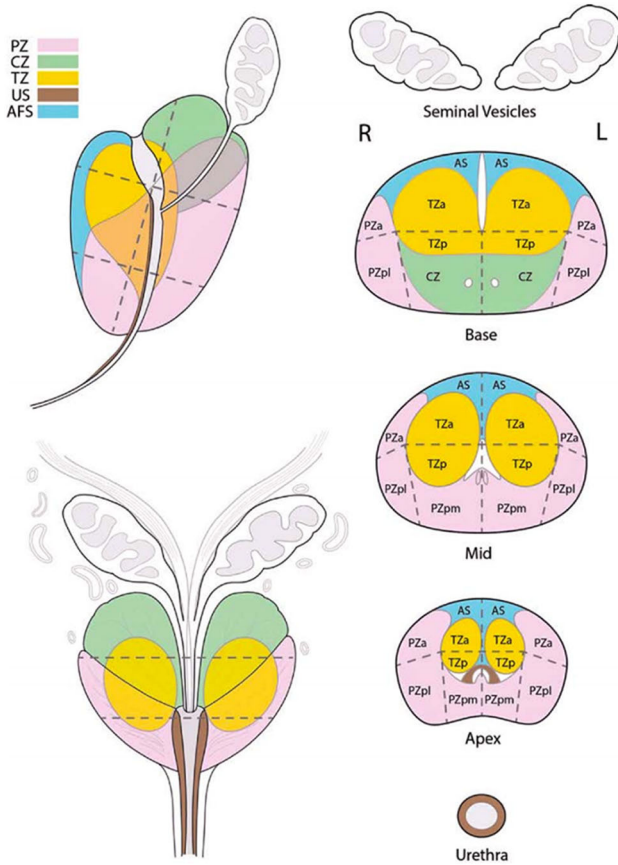


Fig. 1. Sector map used in PI-RADS v2. *AFS*(*AS*) anterior fibromuscular stroma, *CZ* central zone, *TZ* transition zone, *PZ* peripheral zone, *US* urethral sphincter. *a* anterior, *p* posterior, *m* medial, *l* lateral. From American College of Radiology. MR Prostate Imaging Reporting and Data System version 2.0. Accessed March 2016, from <http://www.acr.org/Quality-Safety/Resources/PIRADS/>.

TZ lesion		Overall PIRADS score		PZ lesion
T2W score				DWI score
1	→	1	←	1
2	→	2	←	2
3	→	3	←	3
4	→ <i>DWI score 5</i>	4	← <i>DCE +</i>	4
5	→	5	←	5

Fig. 2. Stepwise approach to assign an overall PI-RADS score based on zonal location. *TZ* transition zone, *PZ* peripheral zone.

Background

PI-RADS v2 is designed to improve focal lesion detection, localization, characterization, and risk stratification in patients with suspected cancer and consists of technical recommendation for MRI acquisition and a scoring system for image interpretation. PI-RADS v2 uses a scale of 1–5 to report the overall probability of clinically significant prostate cancer on mpMRI. The use of PI-RADS v2 is limited to treatment naïve patients and it should not be used for staging, assessment of treatment outcome, recurrence, or progression during surveillance. The scoring algorithm is summarized in Table 1.

PI-RADS v2 recommends including T1W, T2W, high b-value DWI (≥ 1400) with corresponding ADC map, and DCE sequences in mpMRI (Table 2). Although a magnetic field strength of 3T is suggested, scanning at 1.5T with updated/optimal protocols would also result in acceptable image quality, and therefore, is not discouraged. The use of an endorectal coil is an institutional decision with the goal of obtaining optimal images.

Steps in lesion identification and scoring

To simplify the use of PI-RADS v2, we recommend utilizing a three-step approach: (1) Lesion localization based on PI-RADS v2 39-sector map (Fig. 1), (2) lesion measurement, and (3) location-based scoring (Table 1, Fig. 2). PI-RADS v2 uses an algorithmic approach to arrive at the overall score based on the zonal location of the lesion. DWI with corresponding ADC map is the dominant sequence in the peripheral zone that will determine the overall suspicion score (Fig. 3). There is a secondary role for DCE in the peripheral zone in equivocal cases (PI-RADS 3), where a positive DCE score can upgrade the lesion to a PI-RADS 4 (Fig. 4). T2W imaging is the dominant sequence in the transition zone that will determine the overall suspicion score (Fig. 5). There is a secondary role for DWI in the transition zone in equivocal cases (PI-RADS 3), where a large corresponding diffusion signal abnormality (PI-RADS 5, > 1.5 cm) can upgrade the lesion to an overall PI-RADS 4. A lesion in the anterior fibromuscular stroma or central zone should be scored using the transition zone scoring algorithm. Additional example cases of PI-RADS 2 and 3 lesions are shown below (Figs. 6, 7, 8).

PI-RADS pearls

Measurement

The maximum lesion diameter is the key feature in discriminating between an overall PI-RADS suspicion score

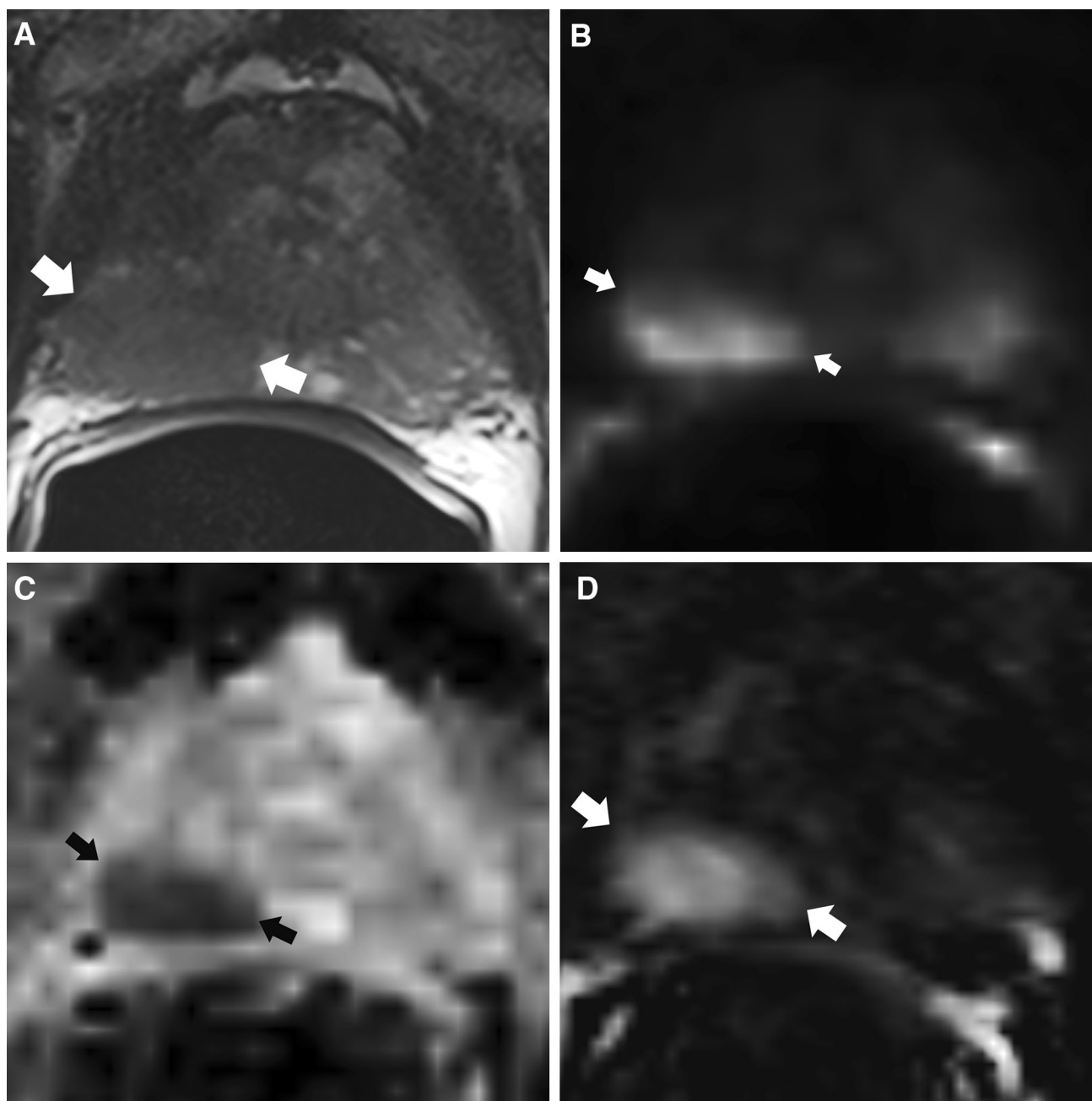


Fig. 3. Assigning a PI-RADS v2 score for a lesion in the peripheral zone. Multiparametric prostate MRI images from a 59-year-old man with elevated PSA **A–D**: **A** Axial T2W image **B** Axial b1400 DWI image **C** Corresponding ADC map **D** Axial DCE image. Step 1 (localization-zone and sector): The mass (*arrows*) is located in the right midgland in sectors PZpl and PZpm (**A–D**). Step 2 (measurement): The mass

measures 1.60 cm in the greatest dimension (**D**). Step 3 (provide an overall score): DWI score = 5 (Focal markedly hypointense on ADC and markedly hyperintense on high b-value DWI >1.5 cm). DCE = positive (focal early enhancement). T2W score = 5 (Circumscribed, homogenous moderate hypointense mass >1.5 cm). Overall PI-RADS score = 5.

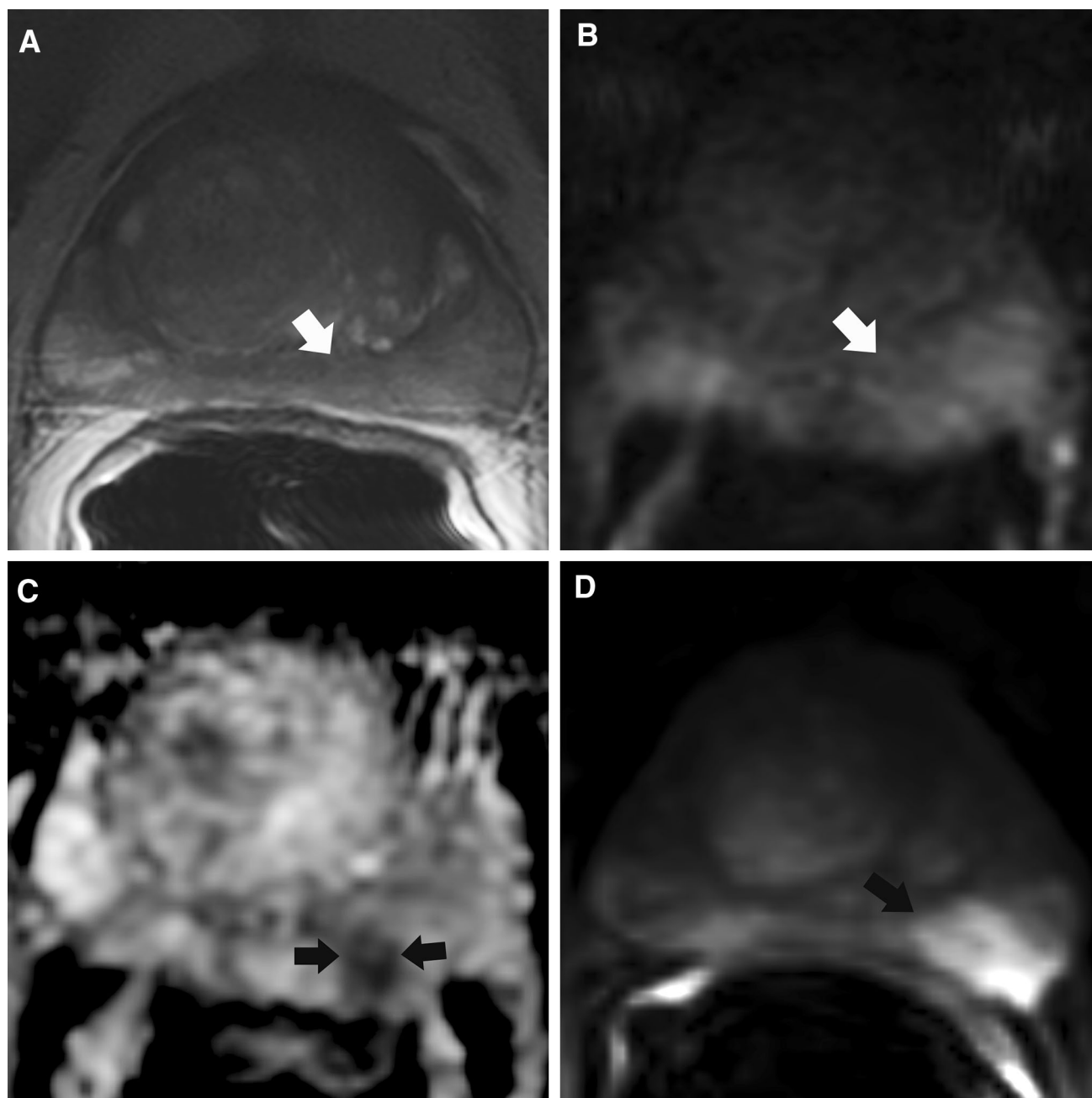


Fig. 4. Upgrading an equivocal lesion in the peripheral zone (PI-RADS 3) to a significant lesion (PI-RADS 4) based on focal early enhancement. Multiparametric prostate MRI images from a 53-year-old man with elevated PSA (**A–D**). Axial DWI image (**B**) and corresponding ADC map (**C**) demonstrate a 0.7 cm lesion that is moderately hypointense on ADC (*ar-*

rows) but mildly hyperintense to isointense on DWI (*arrow*) (**B**). The mass is seen on the T2W image as a noncircumscribed moderately hypointense region (*arrow*) (**A**). Based on these images, the lesion would be a PI-RADS 3. However, it demonstrates early focal enhancement (*arrow*) (**D**). This upgrades the overall PI-RADS score from 3 to 4.

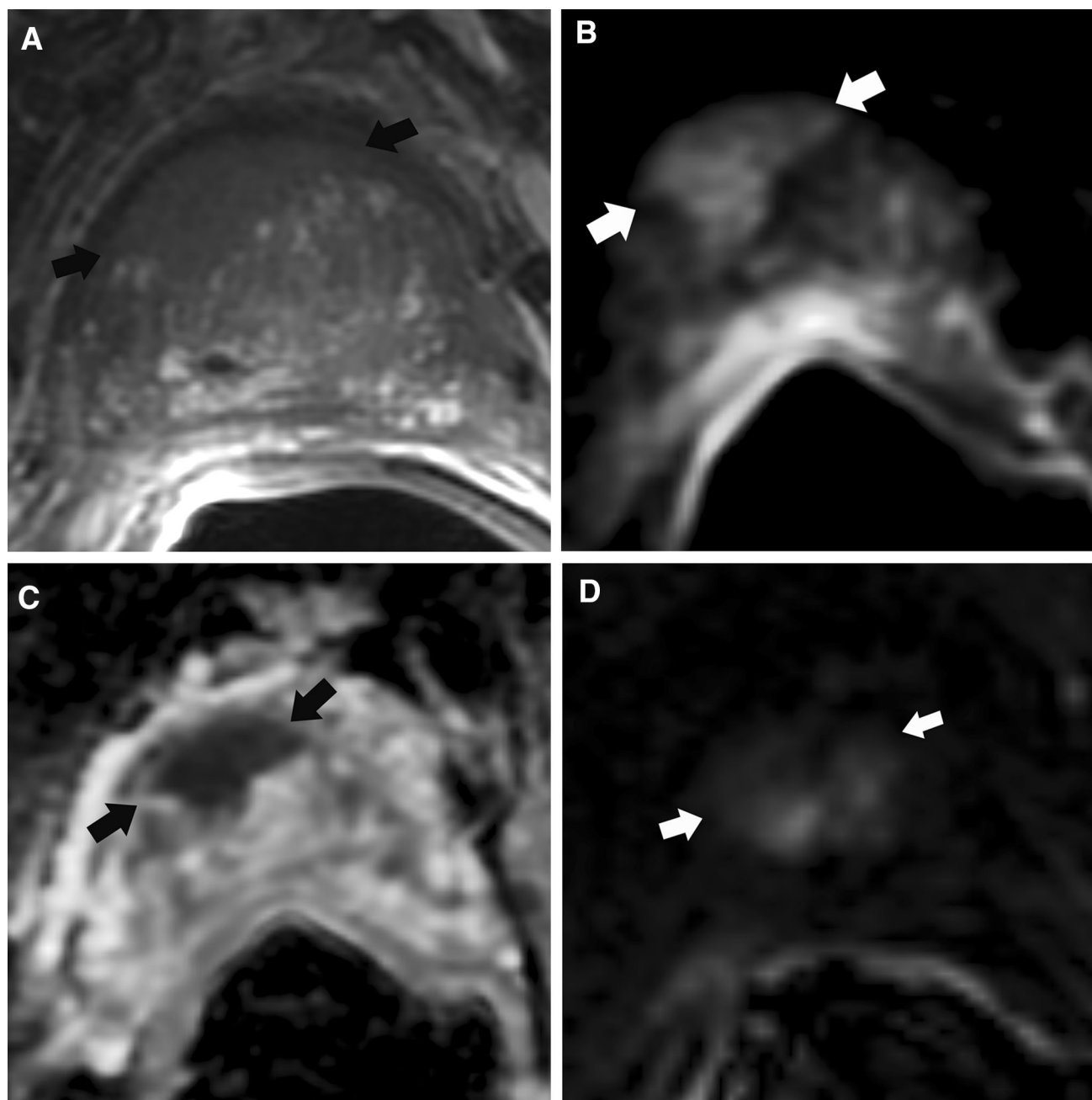


Fig. 5. Assigning a PI-RADS v2 score to a lesion in the transition zone. Multiparametric prostate MRI images from an 80-year-old man with elevated PSA (**A–D**) **A** axial T2W, **B** axial b-value 1400 DWI, **C** ADC map, **D** axial DCE image. Step 1 (localization-zone and sector): The mass is located in the transition zone at the base and midgland in the AFS, TZa, and TZp sectors (*arrows*) (**A–D**). Step 2 (measure-

ment): The lesion measures 2.0 cm in maximum diameter (**A**). Step 3 (Provide an overall score): T2W score = 5 (Lenticular, homogeneous, moderately hypointense mass > 1.5 cm). DWI score = 5 (Focal markedly hypointense on ADC and markedly hyperintense on high b-value DWI > 1.5 cm). DCE = positive (focal early enhancement). Overall PI-RADS score = 5.

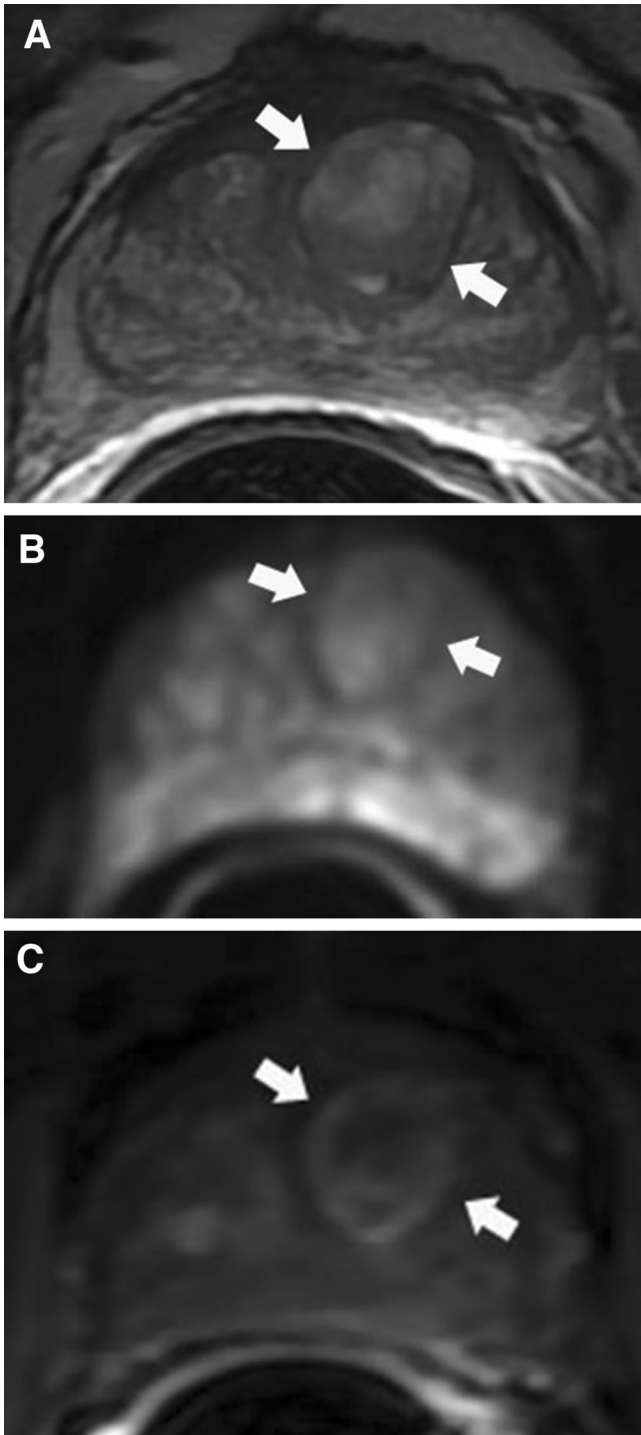


Fig. 6. A 64-year-old man with elevated PSA. Axial T2-weighted images show typical appearance of changes of glandular and stromal hyperplasia in the transition zone (*arrows*) (**A**). These typical BPH nodules demonstrate mildly increased signal on high b-value diffusion-weighted images (*arrows*) (**B**) and enhance earlier than the surrounding normal prostatic tissue (*arrows*) (**C**). This lesion would be assigned a PI-RADS score of 2. Note: *BPH* benign prostatic hyperplasia, *PSA* prostate-specific antigen.

of 4 or 5. The ADC map is the preferred sequence for measuring peripheral zone lesions, whereas T2-weighted images are the suggested sequence to measure lesions in the transition zone. However, if a lesion is difficult to measure or obscured on the recommended sequence, measurement should be carried out using the sequence or plane with the best lesion conspicuity (Fig. 9).

DWI scoring

In the peripheral zone, evaluating the signal intensity of a lesion on high b-value DWI allows the reader to distinguish between PI-RADS DWI scores of 3 and ≥ 4 . To assign a score of ≥ 4 for DWI, the lesion must be hyperintense on DWI with corresponding hypointensity on the ADC map (Fig. 3B, C). A lesion with low signal on ADC map but with isointensity or mild hyperintensity on DWI will receive a PI-RADS score of 3 (Fig. 4B, C).

T2W scoring

The dominant sequence in the transition zone is T2-weighted imaging. Clinically significant cancers (PI-RADS ≥ 4) are typically lenticular or noncircumscribed, homogeneous, and moderately hypointense on T2-weighted images. In contrast, equivocal tumors (PI-RADS 3) may be more heterogeneous on the T2-weighted images and have obscured margins. Benign findings in the transition zone (benign prostatic hyperplastic nodules) are circumscribed, while tumors traditionally have been described as having a “smudged charcoal” appearance. In fact, obscure margins, lack of capsule, and homogenous hypointensity are characteristics of a high score lesion (Fig. 10).

Conclusion

By using this simplified algorithmic approach, readers of varying levels of experience with prostate MRI should be able to confidently provide an overall suspicion score for each focal lesion detected at mpMRI.

PI-RADS v2 represents an improvement over PI-RADS v1 as it has increased the standardization of prostate MRI reporting by providing an overall assessment based on the appearance of a lesion on T2-weighted, DWI, and DCE sequences [15]. This clinically useful information, along with simplified image interpretation utilizing a binary score for DCE and the concept of a dominant sequence based on zonal anatomy, should hopefully increase utilization and lead to improved patient care [15]. Although it has only recently been introduced into routine clinical practice, several studies

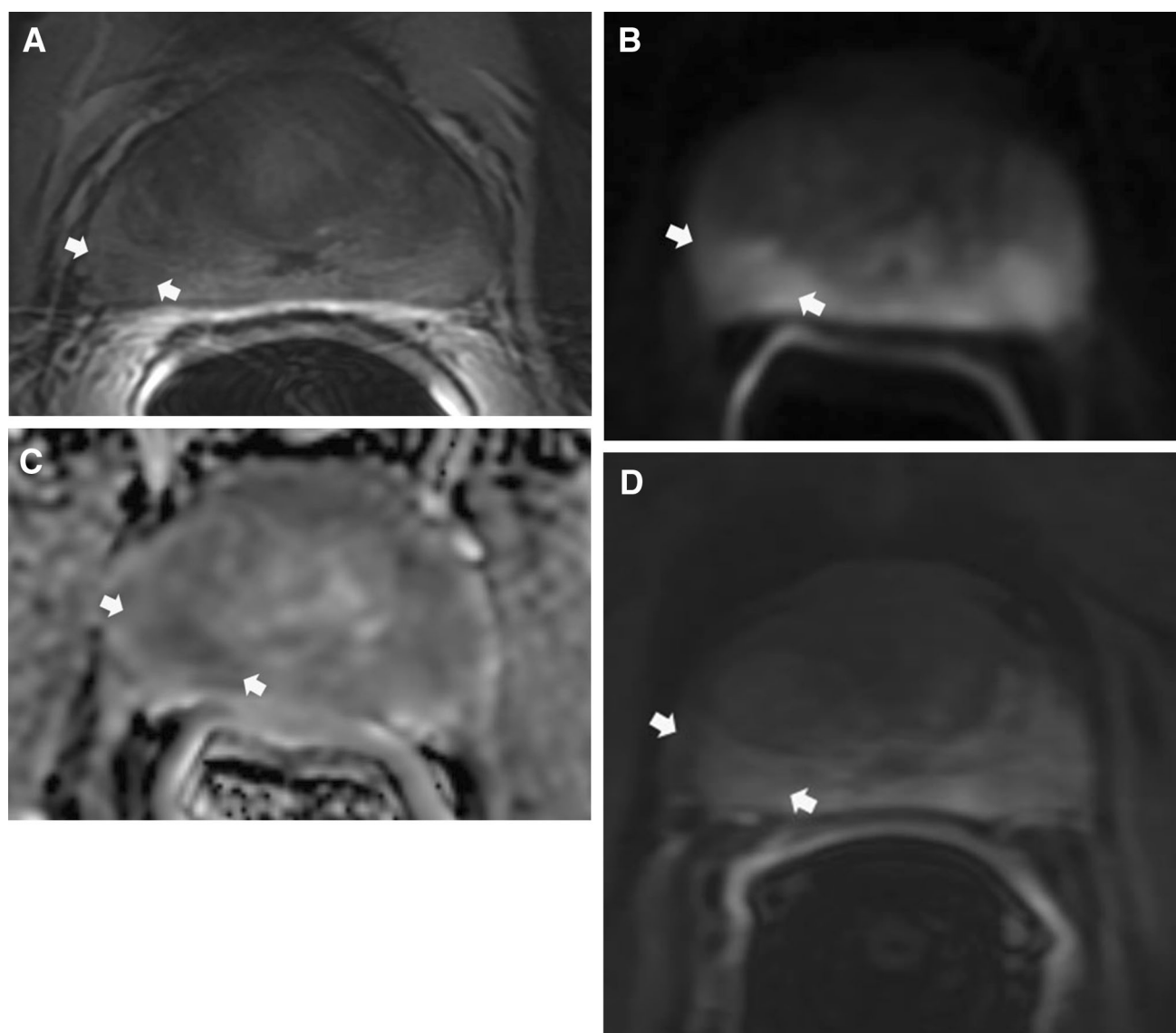


Fig. 7. PI-RADS 3 lesion in the right peripheral zone in a 59-year-old man with an elevated PSA. Axial T2-weighted image demonstrates a noncircumscribed rounded moderate signal intensity lesion in the right peripheral PZpl sector (*ar-*

rows) (**A**). The lesion is mildly hyperintense on high b-value diffusion-weighted image (**B**) and mildly hypointense on ADC map (*arrows*) (**C**). DCE is negative as there is no focal enhancement (*arrows*) (**D**). The overall PI-RADS score is 3.

have evaluated the performance characteristics of PI-RADS v2 and these compare favorably to what has been achieved with PI-RADS v1 [16, 17]. In a single-center study of five readers, PI-RADS v2 had moderate agreement ($\kappa = 0.46$) for the overall suspicion score in a cohort of treatment naïve patients [14]. This same study also demonstrated an equivalent sensitivity and specificity in the transition zone and the peripheral zone, an improvement over PI-RADS v1 [14]. In a two-reader retrospective cohort study, Kasel-Siebert et al.' study had substantial inter-reader agreement ($\kappa = 0.68$) with

slightly superior performance in the peripheral zone compared to the transition zone [18]. Finally, a more recent study utilizing six experienced readers at multiple centers demonstrated moderate reproducibility with improved agreement in the peripheral zone compared to the transition zone [19].

Similar to the other RADS (i.e., BI-RADS, LI-RADS, etc.), PI-RADS is a living document that is designed to be edited and revised in response to changes in technology and clinical practices. BI-RADS is currently in its 6th version and it is fully expected that version 3 of

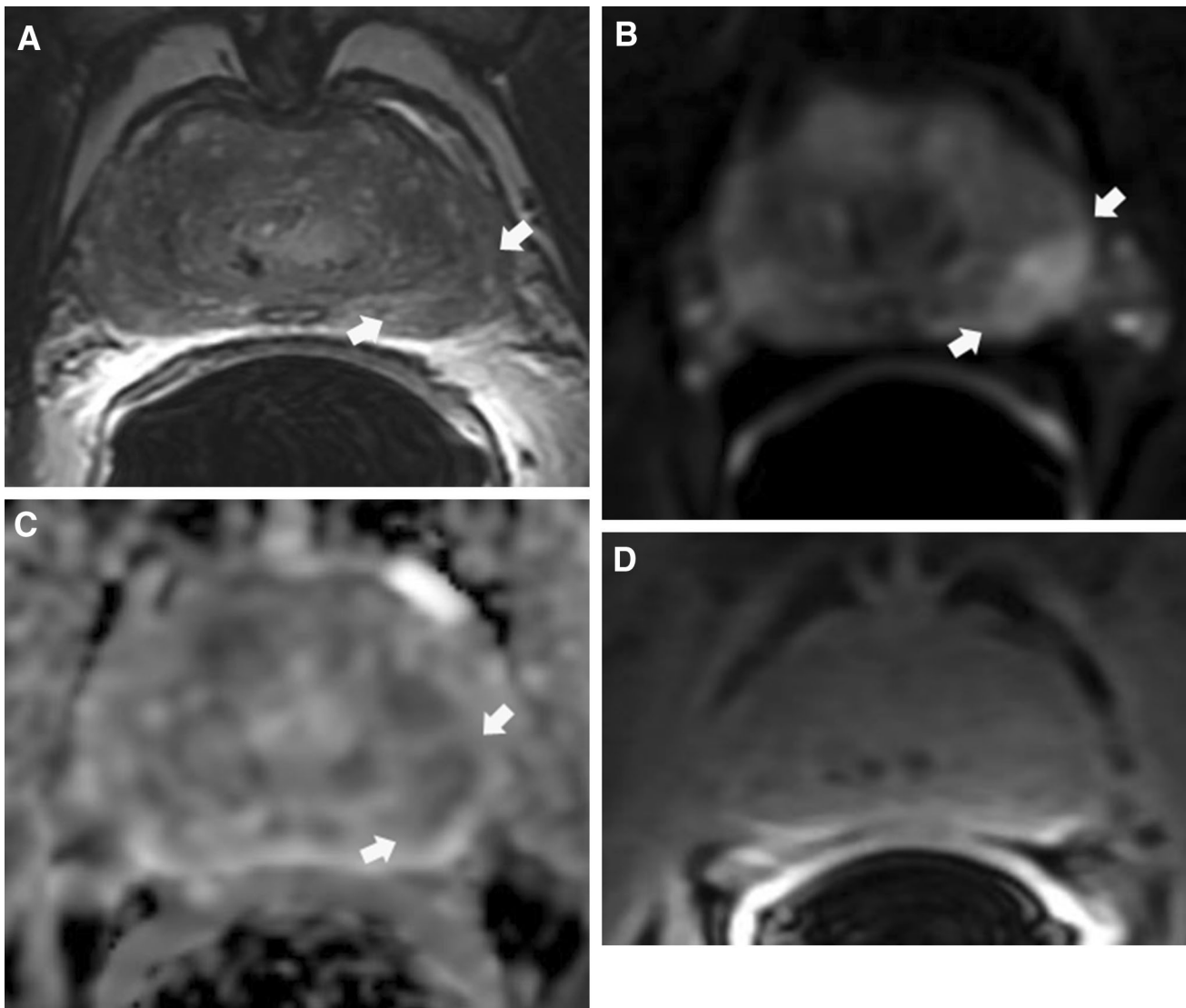


Fig. 8. PI-RADS 3 lesion in the left peripheral zone in a 65-year-old man with elevated PSA. Axial T2-weighted image demonstrates a heterogenous noncircumscribed lesion in the left peripheral zone posterolateral sector PZpl (arrows) (A).

The lesion is mildly hyperintense on high b-value diffusion-weighted image (arrows) (B) and mildly hypointense on ADC map (arrows) (C). DCE is negative as there is no focal enhancement (D). The overall PI-RADS score is 3.

PI-RADS will appear within the next few years. One current issue already under discussion is that of gadolinium. Specifically—is it really needed, what is the risk, benefit, and is it worth the extra cost? In PI-RADS v1, the analysis of the gadolinium sequence involved full DCE curve evaluation (wash-in, wash out, and other PK parameters such as K_{trans}) in all lesions. In PI-RADS v2, this has been considerably simplified to a binary decision of whether the lesion enhances before the normal adjacent prostatic tissue or not. As described in this review, the role of the DCE sequence in PI-RADS v2 is limited

to assessment of focal lesions in the peripheral zone which are initially felt to be assessment score 3 by DWI. In this situation, if the lesion enhances (DCE+), it will lead to a change of assessment to an overall assessment 4. DCE is not used in any other situation, so it has a limited and thus questionable long-term viability as a critical must obtain sequence. A second area of increased interest is the option to include quantitative data to the current qualitative assessment. The most reported quantitative variable is the ADC from the b1400 or higher sequence. Hassanzadeh et al. have shown in early

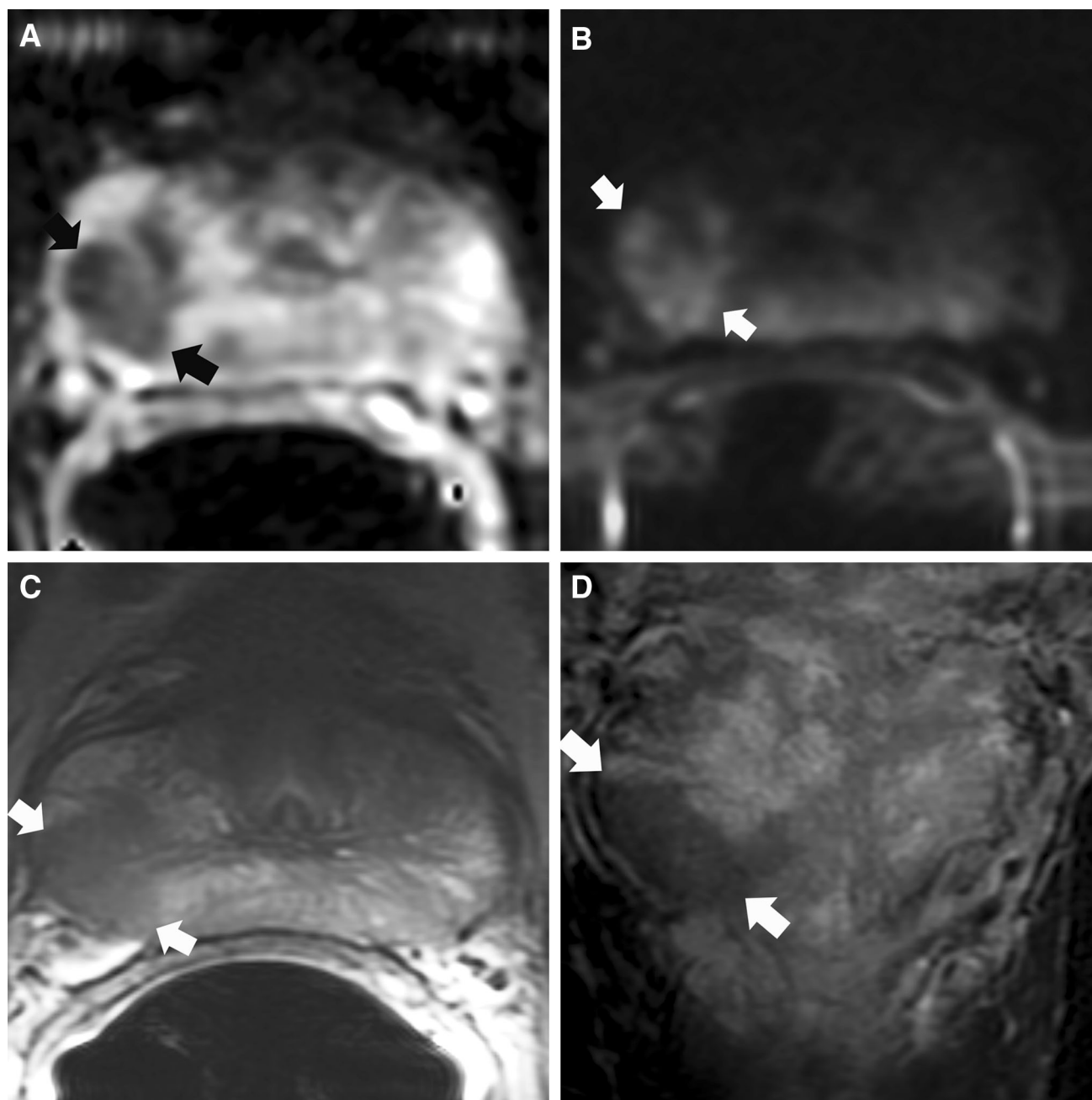


Fig. 9. A peripheral zone mass in a 50-year-old man with elevated PSA that measures <1.5 cm on the axial images and >1.5 cm on the coronal images. Multiparametric prostate MRI images from a 50-year-old man with elevated PSA demonstrate a 1.3 cm mass (*arrows*) in the right peripheral zone that is markedly hypointense on ADC (**A**), markedly

hyperintense on corresponding DWI image (**B**) and circumscribed, moderately hypointense on axial T2W (**C**). Based on this measurement, the lesion would be assigned a PI-RADS score of 4. However, this lesion is actually larger in the coronal plane, measuring 1.8 cm (**D**). Therefore, the overall PI-RADS score is 5 rather than 4.

work the value of calculating and reporting the mean ADC [20].

PI-RADS v2 is the most recent guideline for prostate cancer mpMRI image acquisition and interpretation. The overall PI-RADS suspicion score of a lesion should

convey the probability of a clinically significant cancer. Interpreting radiologists should be aware of common mimics of clinically significant cancer as well as imaging pearls to aid in cancer detection and diagnosis. Optimization of technical considerations and image

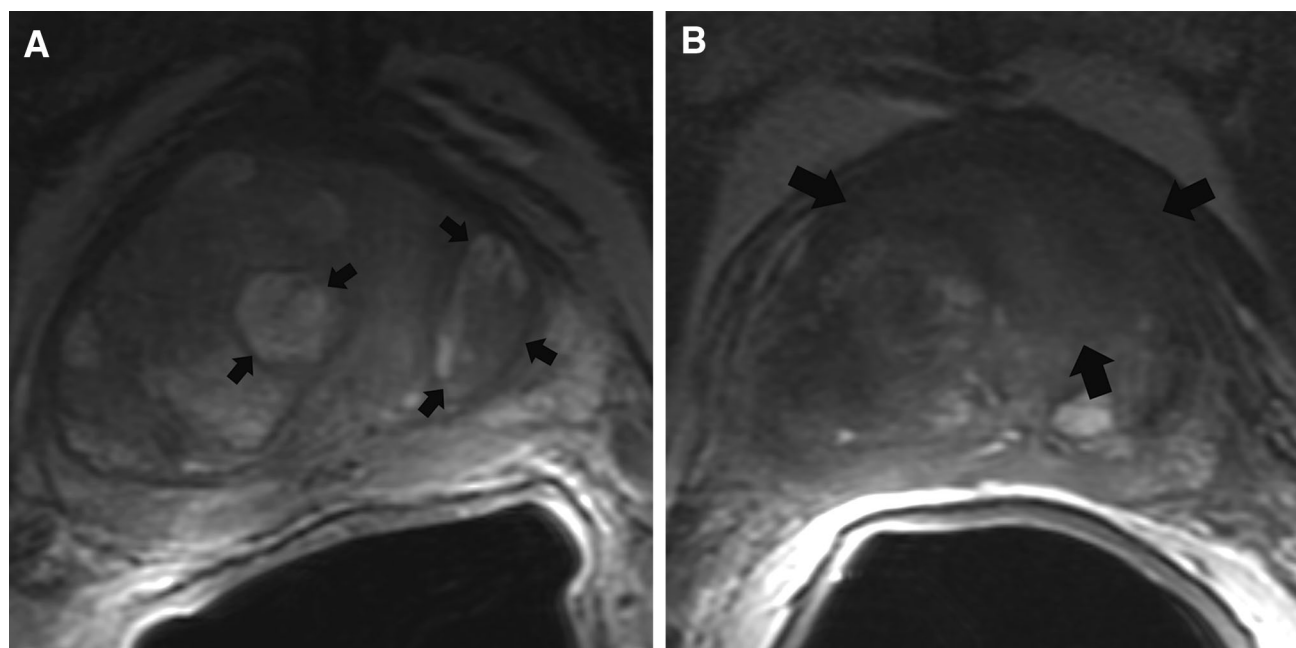


Fig. 10. BPH nodules appear different from a tumor in the transition zone on T2-weighted imaging. To confidently make the diagnosis of a BPH nodule, the lesion should always be encapsulated but can be hypointense or heterogeneous on T2W image. The typical appearance of BPH nodules (*arrows*)

is shown on the left, and these would be assigned a PI-RADS score of 2 (**A**). In contrast, a tumor (*arrows*) will be ill-defined and more homogeneously hypointense (**B**). This mass measured > 1.5 cm and should be assigned a PI-RADS score of 5. Note: *BPH* benign prostatic hyperplasia.

acquisition will also improve study quality. In summary, PI-RADS v2 can be used to aid prostate mpMRI interpretation for cancer detection and risk stratification in treatment naïve patients with suspicious cancer.

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Compliance with ethical standards

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Conflict of interest The authors declare no conflict of interest.

Ethical approval The study was HIPAA compliant and approved by the Institutional Review Board. Informed consent was waived because of the retrospective nature of the study.

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