PI-RADS Version 2: A Pictorial Update[1]

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Abbreviations: ADC = apparent diffusion coefficient, DWI = diffusion-weighted imaging, PI-RADS = Prostate Imaging Reporting and Data System, PSA = prostate-specific antigen

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Discuss the main changes in PI-RADS version 2 for the assessment of prostatic lesions at multiparametric MR imaging.
- Identify the key MR pulse sequences for the characterization of abnormalities in the prostate.
- Describe the PI-RADS version 2 assessment categories.

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The Prostate Imaging Reporting and Data System (PI-RADS) is the result of an extensive international collaborative effort. PI-RADS provides a comprehensive yet practical set of guidelines for the interpretation and reporting of prostate multiparametric magnetic resonance (MR) imaging that will promote the use of this modality for detecting clinically significant prostate cancer. The revised PI-RADS version (PI-RADS version 2) introduces important changes to the original system used for assessing the level of suspicion for clinically significant cancer with multiparametric MR imaging. For peripheral zone abnormalities in PI-RADS version 2, the score obtained from the apparent diffusion coefficient (ADC) map in combination with diffusion-weighted imaging (DWI) performed with high *b* values (≥1400 sec/mm^2) is the dominant parameter for determining the overall level of suspicion for clinically significant cancer. For transition zone abnormalities, the score obtained from T2-weighted MR imaging is dominant for overall lesion assessment. Dynamic contrast material–enhanced MR imaging has ancillary roles in the characterization of peripheral zone lesions considered equivocal for clinically significant cancer on the basis of the DWI-ADC combination and in the detection of lesions missed with other multiparametric MR pulse sequences. Assessment with dynamic contrast-enhanced MR imaging is also simplified, being considered positive or negative on the basis of qualitative evaluation for a focal area of rapid enhancement matching an abnormality on DWI-ADC or T2-weighted MR images. In PI-RADS version 2, MR spectroscopic imaging is not incorporated into lesion assessment. In this article, a pictorial overview is provided of the revised PI-RADS version 2 assessment categories for the likelihood of clinically significant cancer. PI-RADS version 2 is expected to evolve with time, with updated versions being released as experience in the use of PI-RADS version 2 increases and as new scientific evidence and technologies emerge.

Introduction

In 2012, building on an initiative of the AdMeTech Foundation's International Prostate MRI Working Group, the European Society of Urogenital Radiology (ESUR) published clinical guidelines for multiparametric prostate magnetic resonance (MR) imaging that were based on evidence from the literature and consensus expert opinion (1). These guidelines included a structured reporting system known as the Prostate Imaging Reporting and Data System (PI-RADS).

TEACHING POINTS

- For peripheral zone lesions, the score assigned on the basis of the lesion's appearance on the ADC map and at DWI with high *b* values (≥1400 sec/mm²) is the dominant parameter.
- For abnormalities in the transition zone, the overall assessment category is based primarily on the score assigned at T2-weighted MR imaging.
- The interpretation and scoring of DWI and ADC maps are based primarily on qualitative visual assessment of the signal intensity of a lesion compared with that of the surrounding normal prostatic tissue in the same anatomic zone. Focal abnormalities measuring less than 1.5 cm in greatest dimension that are markedly hypointense on ADC maps and markedly hyperintense on high–*b* value diffusion-weighted images receive a DWI-ADC score of 4; focal abnormalities with these signal intensity characteristics at DWI-ADC that measure 1.5 cm or more or demonstrate definite extraprostatic extension or invasive behavior receive a DWI-ADC score of 5.
- Homogeneity, a lenticular or waterdrop shape, an indistinct margin, and evidence of invasion of other structures on T2-weighted MR images are characteristics that favor the diagnosis of cancer in the transition zone, whereas heterogeneity, a round shape, and a well-defined margin on T2-weighted MR images favor a benign diagnosis.
- With the new guidelines, lesions identified at dynamic contrast-enhanced MR imaging no longer receive a 1–5 score on the basis of the kinetic pattern of enhancement. Instead, a lesion will be considered positive at dynamic contrast-enhanced MR imaging in the presence of a focal abnormality with early and intense enhancement that corresponds to a focal abnormality at T2-weighted MR imaging and/or DWI-ADC. A lesion will be considered negative at dynamic contrast-enhanced MR imaging in the absence of early enhancement relative to surrounding prostatic tissue or when there is diffuse enhancement encompassing an area that does not correspond to an abnormality at T2-weighted MR imaging and/or DWI-ADC.

During the ensuing years, the American College of Radiology, ESUR, and the AdMeTech Foundation collaborated to develop an updated version, known as PI-RADS version 2, which incorporates many important changes compared with the original version of PI-RADS. Among the goals of PI-RADS version 2 are *(a)* establishing minimum acceptable technical parameters for prostate MR imaging; *(b)* standardizing radiology reports to enhance communication among radiologists and referring physicians; *(c)* developing assessment categories that summarize levels of suspicion or risk for clinically significant prostate cancer, so that they can be used to triage patients to appropriate management; and *(d)* promoting research and quality assurance that will ultimately lead to improvement in patient outcomes. The critical components of the new PI-RADS version 2 are a standardized lexicon facilitating consistent use of a uniform terminology for describing imaging findings, revised systems for scoring the level of suspicion with individual MR pulse sequences, and development of a standardized scheme for deriving an overall assessment category that is based on the scores assigned to the findings from pulse sequences.

The aim of this article is to highlight the main changes of PI-RADS version 2, review selected terminology, and illustrate the individual imaging patterns used in the assessment system for multiparametric MR imaging of the prostate. All of the images presented were obtained at a single institution by using a 3-T MR imaging system and a pelvic phased-array coil. The types of imaging included conventional multiplanar fast (turbo) spin-echo T2-weighted MR imaging; single-shot echo-planar diffusion-weighted imaging (DWI) with *b* values of 50, 400, 900, and 1500 sec/mm²; reconstruction of the apparent diffusion coefficient (ADC) map; and dynamic contrast material–enhanced MR imaging performed at a temporal resolution of 8.6 seconds, with reconstruction of pharmacokinetic (PK) maps (including PK Primary [DynaCAD for Prostate; Invivo, Gainesville, Fla], forward volume transfer rate constant [K^{trans}], and reverse reflux rate constant [K_{ep}] maps) that are based on compartment pharmacokinetic modeling to assist in the visual assessment of the enhancement.

Overall Assessment Categories

In the first version of PI-RADS, abnormalities in the prostate received a score ranging from 1 to 5 on the basis of their appearance with use of each individual pulse sequence of the multiparametric MR imaging examination, including T2-weighted MR imaging, DWI, dynamic contrast-enhanced MR imaging, and, optionally, MR spectroscopic imaging. In addition, each lesion was given an overall score to predict its likelihood of being a clinically significant cancer. This system, however, did not determine how the scores assigned with each of the MR pulse sequences would contribute to the determination of the final overall score. Given the lack of a clearly defined scheme for assigning an overall score, this step was performed inconsistently across centers. For instance, some investigators report simply adding the individual pulse sequence scores to obtain a "sum score" ranging from 1 to 15 (or from 1 to 20 when including spectroscopy) (2,3), whereas others have attempted to provide an overall score that is also on a 1–5 scale (4–6), although the process of deriving a summary 1–5 score has also been variable across studies. Although an approach for providing an overall interpretation score was subsequently proposed, this approach was not formally incorporated into the initial PI-RADS version (version 1) (7).

PI-RADS version 2 includes several changes to the original scoring system (8). One of the main

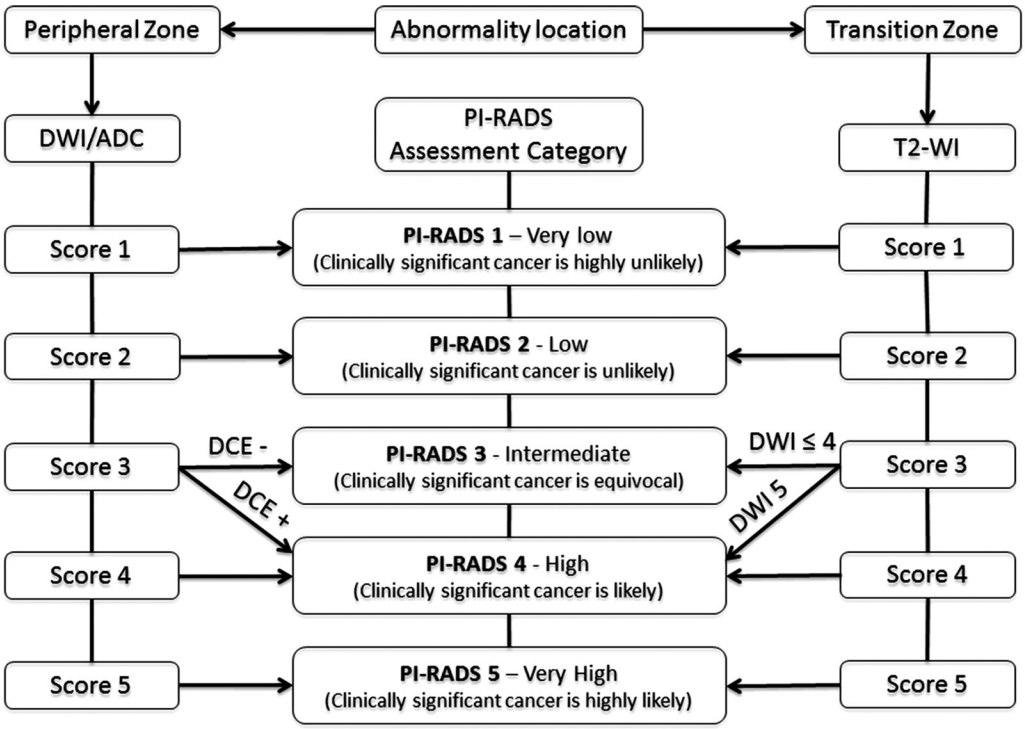


Figure 1. Flowchart showing the PI-RADS version 2 assessment categories. *DCE* = dynamic contrast-enhanced MR imaging, *T2-WI* = T2-weighted MR imaging.

changes is the creation of specific recommendations to assign the overall PI-RADS assessment category (Fig 1) that ultimately determines the level of suspicion for clinically significant prostate cancer, which PI-RADS version 2 defines as a tumor with a Gleason score of 7 or more (either 4 + 3 or 3 + 4 with a prominent Gleason 4 component) and/or volume greater than 0.5 cm^3 and/or extraprostatic extension. The Gleason score is based on a grading system used to determine the degree of differentiation of prostate cancer that takes into account one of five histologic patterns. The most common and the second most common patterns identified at light microscopy are summed to obtain the Gleason score (eg, 3 + 4). If a single pattern is identified, its number is doubled to obtain the Gleason score (eg, 4 + 4). In clinical practice, only patterns 3, 4, and 5 are considered relevant, and therefore the lowest Gleason score is 6 (ie, 3 + 3), and the maximum Gleason score is 10 (ie, 5 + 5). It is generally accepted that prostate cancers with a Gleason score of 6 are highly unlikely to be clinically significant, and they are increasingly being managed with active surveillance; and those with a Gleason score of 7 or more (especially those with a dominant pattern 4 or any pattern 5) are more likely to be treated.

In the new system of PI-RADS version 2, only the DWI-ADC combination (Table 1) and T2-weighted MR imaging (Tables 2, 3) are scored by using a 5-point scale. The scores from these two pulse sequences serve as the dominant parameters to determine the level of suspicion for clinically significant cancer, depending on the zonal location of the abnormality. For peripheral zone lesions, the score assigned on the basis of the lesion's appearance on the ADC map and at DWI with high *b* values (≥1400 sec/mm^2) is the dominant parameter. For instance, if the score assigned for a lesion in the peripheral zone with DWI-ADC is 4, then the overall assessment category for the lesion is also 4, meaning that clinically significant cancer is likely to be present. Dynamic contrast-enhanced MR imaging assumes a secondary role and is used as an ancillary parameter, affecting the overall level of suspicion solely for peripheral zone lesions that are deemed equivocal for clinically significant cancer on the basis of DWI-ADC. Specifically, for peripheral zone lesions that receive a score of 3 at DWI-ADC, a dynamic contrast-enhanced MR imaging score of "positive" (as described subsequently) may result in an overall assessment category of 4.

For abnormalities in the transition zone, the overall assessment category is based primarily on the score assigned at T2-weighted MR imaging. DWI-ADC assumes a secondary role in these cases and is considered an ancillary feature solely for transition zone lesions that are deemed equivocal for clinically significant cancer on the basis of T2-weighted MR imaging. Specifically, for

Table 1: Scoring Scheme within PI-RADS Version 2 for Peripheral and Transition Zone Abnormalities on the Basis of Their Appearance on ADC Maps and High–*b* Value Diffusion-weighted MR Images

DWI-ADC Score	Findings in the Peripheral and Transition Zones at DWI-ADC
1	No abnormality (ie, normal) on ADC maps or high–*b* value diffusion-weighted MR images
2	Abnormality that is indistinctly hypointense on the ADC map
3	Focal abnormality that is mildly to moderately hypointense on ADC maps and isointense to mildly hyperintense on high–*b* value diffusion-weighted MR images
4	Focal abnormality that is markedly hypointense on ADC maps and markedly hyperintense on high–*b* value diffusion-weighted MR images and measures less than 1.5 cm in greatest dimension
5	Same as score of 4, but abnormality measures 1.5 cm or more in greatest dimension or has definite extraprostatic extension or invasive behavior

Table 2: Scoring Scheme within PI-RADS Version 2 for Peripheral Zone Abnormalities on the Basis of Their Appearance on T2-weighted MR Images

T2-weighted Imaging Score	Appearance of Peripheral Zone Abnormalities at T2-weighted MR Imaging
1	Uniformly hyperintense (normal)
2	Linear, wedge-shaped, or diffuse mild hypointensity, usually indistinct margin
3	Noncircumscribed, rounded, moderate hypointensity
4	Circumscribed, homogeneous moderately hypointense focus or mass confined to the prostate and less than 1.5 cm in greatest dimension
5	Same as score of 4, but abnormality measures 1.5 cm or more in greatest dimension or has definite extraprostatic extension or invasive behavior

Table 3: Scoring Scheme within PI-RADS Version 2 for Transition Zone Abnormalities on the Basis of Their Appearance on T2-weighted MR Images

T2-weighted Imaging Score	Appearance of Transition Zone Abnormalities at T2-weighted MR Imaging
1	Homogeneous intermediate signal intensity (normal)
2	Circumscribed hypointense or heterogeneous encapsulated nodule or nodules (benign prostatic hyperplasia)
3	Heterogeneous signal intensity with obscured margins
4	Noncircumscribed, homogeneous, moderately hypointense, and less than 1.5 cm in greatest dimension
5	Same as score of 4, but abnormality measures 1.5 cm or more in greatest dimension or has definite extraprostatic extension or invasive behavior

transition zone lesions that receive a score of 3 at T2-weighted MR imaging, a DWI-ADC score of 5 results in an overall assessment category of 4.

Unlike the previous version of the PI-RADS system (version 1), PI-RADS version 2 does not incorporate findings from MR spectroscopic imaging. This technique requires special expertise and is time consuming, which makes it impractical for widespread adoption. Thus, its use will likely remain limited to those departments that have the necessary expertise and resources to reliably acquire, postprocess, and interpret MR spectroscopic imaging data.

The abnormality with the highest PI-RADS assessment category should be identified as the index lesion. If two or more lesions receive the highest PI-RADS version 2 assessment category, then the index lesion should be the one that is largest or shows extraprostatic extension (9,10). The current system does not include specific recommendations for whether to perform a biopsy on the basis of the PI-RADS version 2 assessment category. Such

recommendations may be incorporated once data assessing the risk for clinically significant prostate cancer associated with each of the PI-RADS assessment categories become available.

Pulse Sequences of the Multiparametric Evaluation

Diffusion-weighted Imaging

Given the evidence showing significant associations between the findings from DWI-ADC and the aggressiveness of prostate cancer (11–16), this pulse sequence assumes a greater importance relative to the others for the evaluation of lesions in the peripheral zone, which is where 70%–80% of prostate cancers arise (17). Most cases of clinically significant prostate cancer demonstrate restricted diffusion relative to normal glandular tissue. The degree of restriction can be qualitatively or quantitatively assessed on ADC maps. Tumor ADC values obtained from these maps correlate inversely with the histologic Gleason score for the tumor (11,12) and are also associated with clinical outcomes (18,19).

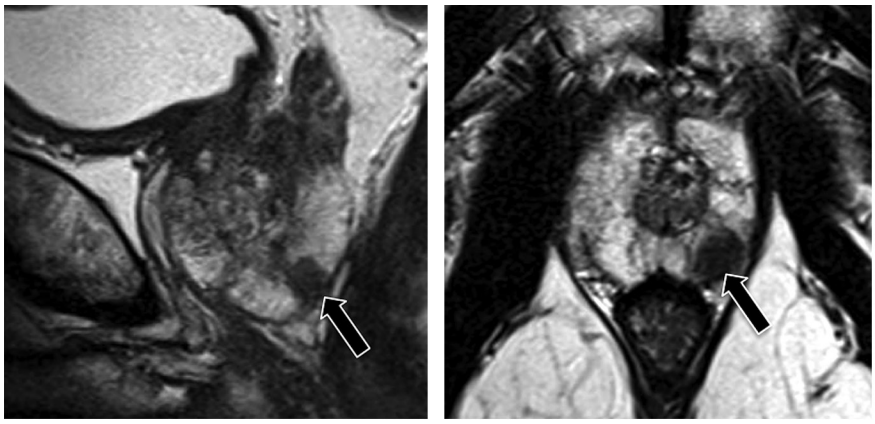
One of the most important imaging acquisition parameters influencing the results obtained at DWI and from ADC maps is the selection of *b* values (20,21), which reflect the strength of the diffusion weighting applied during use of the sequence. For the purpose of creating ADC maps, PI-RADS version 2 recommends use of at least two different *b* values: a *b* value of 50–100 sec/mm^2 and a *b* value of 800–1000 sec/mm^2. Additional intermediate *b* values within this range are noted to potentially improve the performance of DWI but are nonetheless considered optional. In addition, the guidelines recommend the inclusion of high–*b* value images (*b* values of 1400–2000 sec/mm^2), which can either be computed from the lower–*b* value images or obtained directly, although as a separate acquisition from that which is used to perform the ADC map computation. On the high–*b* value ($\geq$1400 sec/mm^2) images, the signal intensity of the normal prostate tissue background is low, whereas clinically significant cancers demonstrate high signal intensity because of restricted diffusion. In comparison, at a *b* value of approximately 1000 sec/mm^2, the normal prostate tissue may show increased signal intensity, thereby reducing the conspicuity of tumors (21,22).

The interpretation and scoring of DWI and ADC maps are based primarily on qualitative visual assessment of the signal intensity of a lesion compared with that of the surrounding normal prostatic tissue in the same anatomic zone (Table 1). Focal abnormalities measuring less than 1.5 cm in greatest dimension that are markedly hypointense on ADC maps and markedly hyperintense on high–*b* value diffusion-weighted images receive a DWI-ADC score of 4 (Fig 2); focal abnormalities with these signal intensity characteristics at DWI-ADC that measure 1.5 cm or more or demonstrate definite extraprostatic extension or invasive behavior receive a DWI-ADC score of 5 (Fig 3). The lesion size threshold of 1.5 cm to discriminate between DWI-ADC scores of 4 and 5, as selected by the consensus panel, still requires validation.

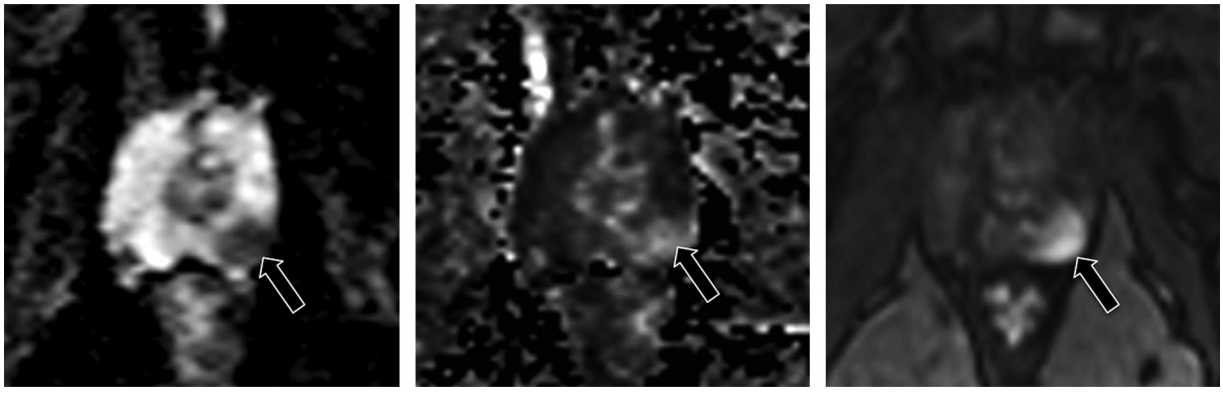
One change that will likely decrease variability in scoring at DWI-ADC is the creation of a specific description for lesions that receive a DWI-ADC score of 3. In the previous PI-RADS system (version 1), this score was assigned for lesions not meeting the criteria for categories 1, 2, 4, or 5, thereby encompassing a wide and heterogeneous spectrum of abnormalities (23). With the revised system of PI-RADS version 2, the DWI-ADC score of 3 is assigned to focal abnormalities that have mildly to moderately low signal intensity on ADC maps and are isointense to mildly hyperintense on high–*b* value diffusion-weighted MR images (Fig 4).

The new recommendations recognize the use of a quantitative approach to DWI by using ADC values to try to facilitate the distinction between cancers and benign lesions with mildly restricted diffusion (eg, prostatitis in the peripheral zone). The guidelines acknowledge substantial overlap of ADC values—for instance, among stromal hyperplasia, low-grade cancer, and high-grade cancer—as well as substantial variability in ADC values, depending on multiple technical factors such as vendor, field strength, and DWI acquisition parameters. Nonetheless, in PI-RADS version 2, a threshold of 750–900 mm^2/sec is suggested; lesions with an ADC value that is less than this range tend to represent clinically significant prostate cancer. However, given the noted variability, each center should identify its own thresholds that are based on internal data and comparisons with histopathologic findings.

In a few studies, investigators have suggested better performance of DWI than other sequences in estimating tumor volumes of prostate cancer (24,25). Thus, to facilitate standardization of lesion measurements between centers, as well as improved correlation of reported lesion sizes at multiparametric MR imaging with the histopathologic findings, the current system advises measurement of peripheral zone lesions on the ADC map. The largest dimension of the lesion in the axial plane, and in any other plane if the lesion is larger than in the axial plane, should be reported, along with the series and image numbers from which the measurement was obtained.



a. b.



c. d. e.

Figure 2. Images of a 65-year-old man with a prostate nodule discovered at digital rectal examination who had an elevated prostate-specific antigen (PSA) level (5.3 ng/mL). **(a, b)** Sagittal **(a)** and axial **(b)** T2-weighted MR images show a circumscribed or well-defined focal nodule with low signal intensity (arrow) in the left posteromedial peripheral zone at the apex, abutting the capsule but without definite evidence of extraprostatic extension (T2-weighted imaging score: 4). **(c, d)** ADC map **(c)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(d)** show a 1-cm focal nodule that is markedly hypointense on the ADC map (arrow on **c**) and markedly hyperintense on the diffusion-weighted MR image (arrow on **d**) (DWI-ADC score: 4). **(e)** Axial dynamic contrast-enhanced T1-weighted image shows early enhancement (or early phase wash-in) of the lesion (arrow) relative to the rest of the gland, a finding that matches the area of signal intensity abnormalities identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because DWI-ADC is the dominant parameter for peripheral zone abnormalities, this focal nodule was assigned a PI-RADS assessment category of 4. The findings from software-based MR imaging/US fusion–guided biopsy of this lesion disclosed prostate cancer with a Gleason score of 4 + 3.

If the lesion cannot be adequately measured on the ADC map, it should be measured on the images obtained with the pulse sequence that allows the best depiction of the lesion.

For some examinations, the images obtained at DWI may not be of diagnostic quality—for instance, because of artifact from a metallic hip implant or anatomic distortion relating to marked rectal distention. If repeating DWI does not remediate the problem or is not possible, then the overall assessment category assigned for abnormalities in the peripheral zone should be based primarily on the score assigned at T2-weighted MR imaging, with dynamic contrast-enhanced MR imaging continuing to serve as an ancillary parameter. Specifically, when the findings at DWI are nondiagnostic, for a peripheral zone lesion that receives a score of 3 at T2-weighted MR imaging, a dynamic contrast-enhanced MR imaging score of "positive" may result in an overall assessment category of 4. The nondiagnostic nature of DWI in such instances should be clearly acknowledged in the examination report.

T2-weighted MR Imaging

Multiplanar T2-weighted MR imaging provides the most detailed depiction of the zonal anatomy of the prostate gland and its capsule (26). T2-weighted MR imaging is also a key for the evaluation of seminal vesicle invasion, extraprostatic extension of prostate cancer, and invasion of the neurovascular bundle (Fig 5) (27). Prostate cancer often demonstrates a focal low to intermediate signal intensity on T2-weighted MR images. However, abnormalities in the peripheral zone identified at T2-weighted MR imaging should be evaluated in conjunction with T1-weighted MR imaging, especially in patients who have undergone

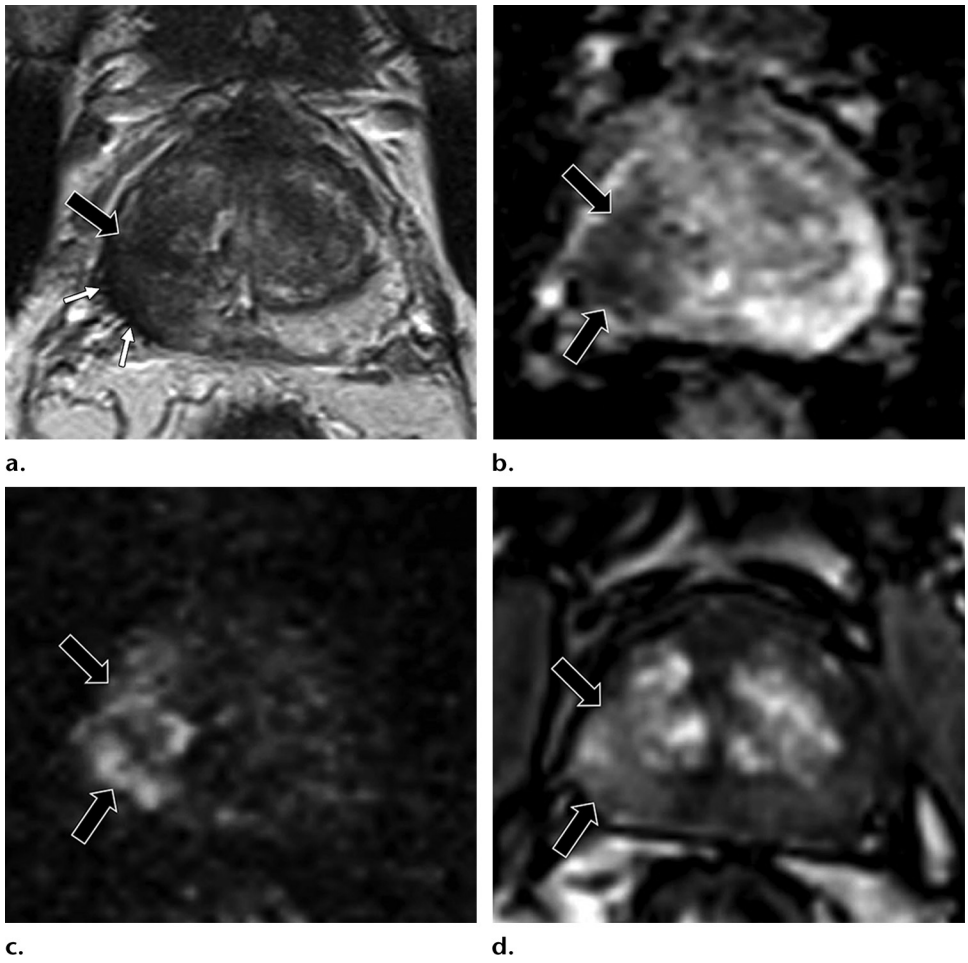


Figure 3. Images of a 62-year-old man with prostate cancer (Gleason score, 4 + 4) detected at systematic transrectal ultrasonography (US)–guided biopsy, who was referred for multiparametric MR imaging for staging. **(a)** Axial T2-weighted MR image shows a hypointense focal lesion (black arrow) in the right posterolateral and anterior peripheral zone at the midgland; the lesion has an irregular or spiculated margin (white arrows) and a tumor-capsule interface of more than 1 cm, findings consistent with extraprostatic extension (T2-weighted imaging score: 5). **(b, c)** ADC map **(b)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(c)** show a 2.3-cm lesion that is markedly hypointense on the ADC map (arrows on **b**) and markedly hyperintense on the diffusion-weighted MR image (arrows on **c**) (DWI-ADC score: 5). **(d)** Axial dynamic contrast-enhanced T1-weighted MR image shows early enhancement (or early phase wash-in) of the lesion (arrows) relative to the rest of the gland, a finding that matches the area of signal intensity abnormalities identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because DWI-ADC is the dominant parameter for peripheral zone abnormalities, this focal lesion was assigned a PI-RADS assessment category of 5, consistent with the biopsy-proven clinically significant cancer in this region.

prostate biopsy. Postbiopsy hemorrhage in the peripheral zone can produce low signal intensity on T2-weighted MR images that can mimic cancer or hinder the detection and staging of cancer (28). In comparison, at T1-weighted MR imaging (with or without fat suppression), hemorrhage has a characteristic high signal intensity, unlike cancer, which is often spared from this process (Fig 6). Besides hemorrhage, several other common benign conditions (such as prostatitis, atrophy, and scarring) can exhibit low T2 signal intensity in the peripheral zone. Therefore, other techniques (especially DWI-ADC) are necessary to improve specificity in the identification of peripheral zone cancer, in comparison with T2-weighted MR imaging alone.

In the transition zone, the detection of prostate cancer is even more difficult because of the substantial overlap in signal intensity characteristics between cancer and benign prostatic hyperplasia (29). The stromal component of the hyperplastic nodule can have low signal intensity on T2-weighted MR images, similar to that of cancer. In addition, because of its highly cellular nature and its increased vascularity, benign prostatic hyperplasia commonly shows restricted diffusion at DWI-ADC and abnormal perfusion at dynamic contrast-enhanced MR imaging, respectively.

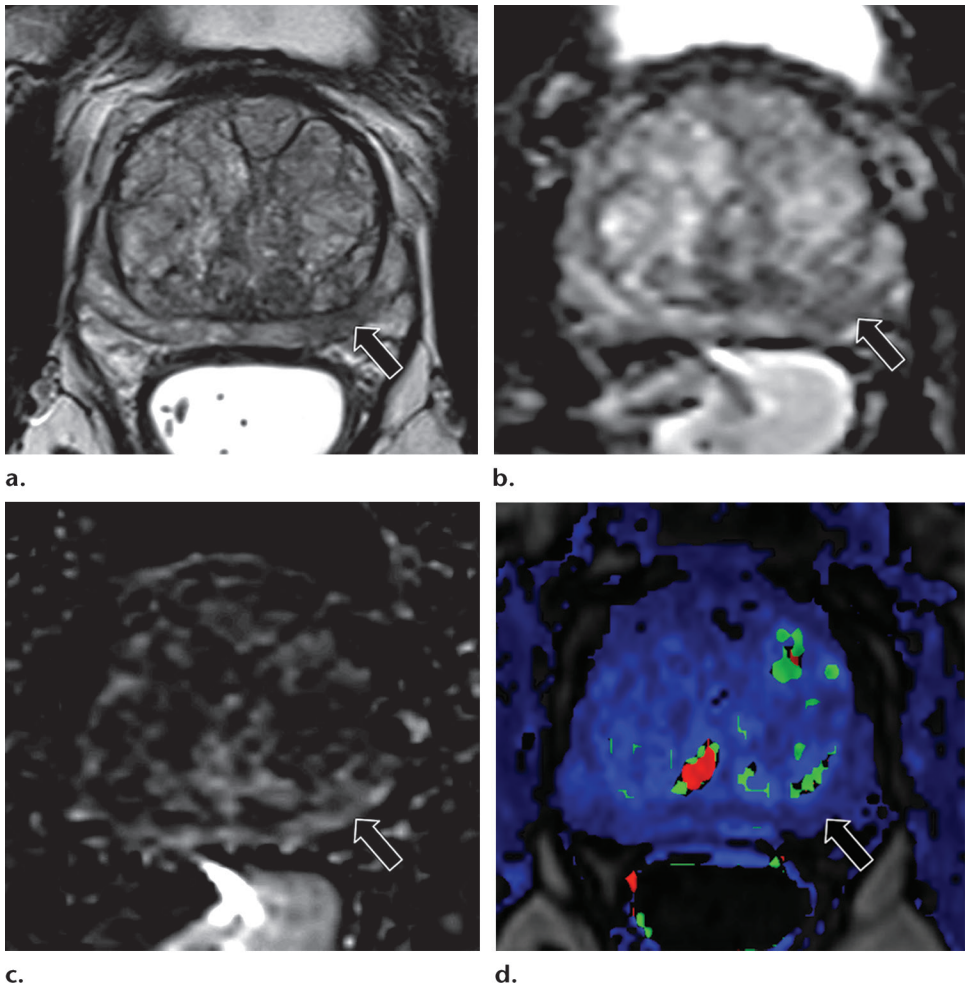


Figure 4. Images of a 67-year-old man with an elevated PSA level (8.7 ng/mL) who had undergone two previous prostate biopsies with normal findings. **(a)** Axial T2-weighted MR image shows a hypointense focal abnormality (arrow) with noncircumscribed margins in the left posterolateral peripheral zone at the midgland, abutting the prostate capsule but without evidence of extraprostatic extension (T2-weighted imaging score: 3). **(b, c)** ADC map **(b)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(c)** show a 1.2-cm lesion that is moderately hypointense on the ADC map (arrow on **b**) and mildly hyperintense on the diffusion-weighted MR image (arrow on **c**) (DWI-ADC score: 3). **(d)** Axial dynamic contrast-enhanced T1-weighted MR image with color-coded overlay (normal enhancement coded in blue) shows no early enhancement (arrow) to correspond with the abnormality seen at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: negative). Because DWI-ADC is the dominant parameter for peripheral zone abnormalities, this focal lesion was assigned a PI-RADS assessment category of 3. The findings at software-based MR imaging/US fusion–guided biopsy of the lesion disclosed prostate cancer with a Gleason score of 3 + 3.

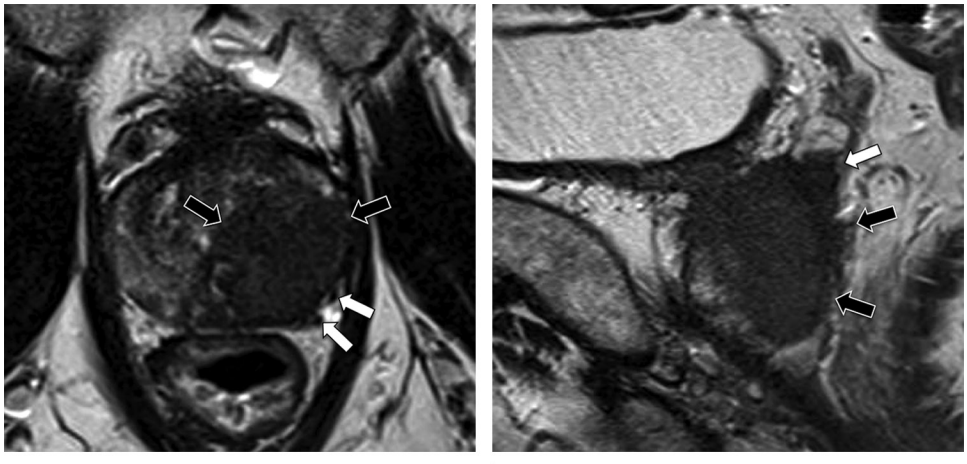


Figure 5. Images of a 58-year-old man with prostate cancer (Gleason score, 5 + 4) detected at systematic transrectal US–guided biopsy, who was referred for multiparametric MR imaging for staging. Axial **(a)** and sagittal **(b)** T2-weighted MR images show a 4.3-cm low-signal-intensity irregularly shaped mass (black arrows) diffusely involving the transition and peripheral zones of the left lobe of the prostate, with extraprostatic extension (T2-weighted imaging score: 5). Note the involvement of the ipsilateral neurovascular bundle (white arrows on **a**), which is asymmetrically thickened compared with the right neurovascular bundle, as well as the invasion of the ipsilateral seminal vesicle (white arrow on **b**). Because of the extraprostatic extension, this focal lesion was assigned a PI-RADS assessment category of 5, consistent with the biopsy-proven clinically significant cancer in this region.

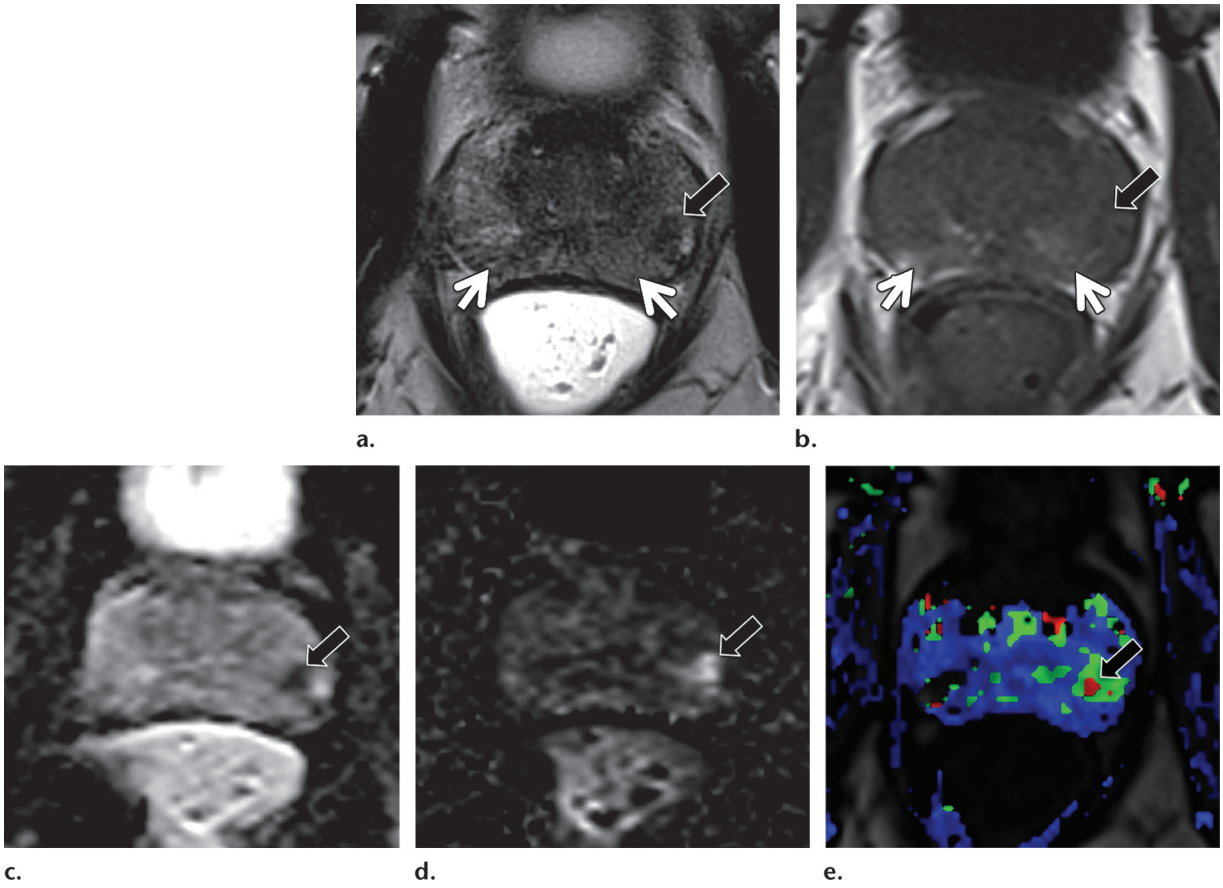


Figure 6. Images of a 52-year-old man with fluctuating elevation of the PSA level (as high as 9 ng/mL) 5 weeks after he had undergone systematic transrectal US–guided biopsy with normal findings. **(a)** Axial T2-weighted MR image shows mild diffuse low signal intensity (white arrows) in the peripheral zone at the midgland, as well as a focal low-signal-intensity lesion with indistinct margins (black arrow) in the left posterolateral peripheral zone at the same level (T2-weighted imaging score: 3). **(b)** Axial T1-weighted MR image shows mildly increased T1 signal intensity (white arrows) corresponding to the areas of mild T2 hypointensity, a finding that represents residual post-biopsy hemorrhage. The area (black arrow) corresponding to the focal lesion on T2-weighted MR images is spared from the increased signal intensity at T1-weighted MR imaging. **(c, d)** ADC map **(c)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(d)** show a 1.0-cm lesion that is markedly hypointense on the ADC map (arrow on **c**) and markedly hyperintense on the diffusion-weighted MR image (arrow on **d**) (DWI-ADC score: 4). **(e)** Axial dynamic contrast-enhanced T1-weighted MR image with color-coded overlay shows early enhancement (or early phase wash-in) (arrow) coded in red in the area corresponding to the focal lesion identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because DWI-ADC is the dominant parameter for peripheral zone abnormalities, this focal lesion was assigned a PI-RADS assessment category of 4. The findings at software-based MR imaging/US fusion–guided biopsy of this lesion disclosed prostate cancer with a Gleason score of 3 + 4. Additional systematic transrectal US–guided biopsy cores obtained from the other peripheral zone sextants demonstrated chronic inflammation.

For these reasons, DWI and dynamic contrast-enhanced MR imaging have a limited role for the evaluation of transition zone abnormalities in PI-RADS version 2. In comparison, the results of studies have shown that reasonable performance can be achieved in differentiating benign stromal hyperplasia and transition zone tumors on the basis of differences in the shape, texture, margins, and invasiveness of such lesions. Therefore, the main features that help to identify transition zone tumors are the morphologic structure of the lesion on T2-weighted MR images and the presence of invasive behavior (Fig 7). Homogeneity, a lenticular or waterdrop shape, an indistinct margin (the "erased charcoal" sign), and evidence of invasion of other structures (ie, the urethral sphincter or anterior fibromuscular stroma) on T2-weighted MR images are characteristics that favor the diagnosis of cancer in the transition zone (Fig 8), whereas heterogeneity, a round shape, and a well-defined margin on T2-weighted MR images favor a benign diagnosis (29–31) (Figs 9, 10).

Data suggest that high–*b* value diffusion-weighted MR images may incrementally increase the sensitivity for detection of prostate cancer in the transition zone, compared with T2-weighted MR imaging alone (32). For this reason, abnormalities in this zone that would be assigned an equivocal probability of representing clinically significant cancer (score of 3) on the basis of T2-weighted MR imaging alone are overall considered likely to represent clinically significant cancer (PI-RADS assessment category of 4) if also receiving a score of 5 at DWI-ADC.

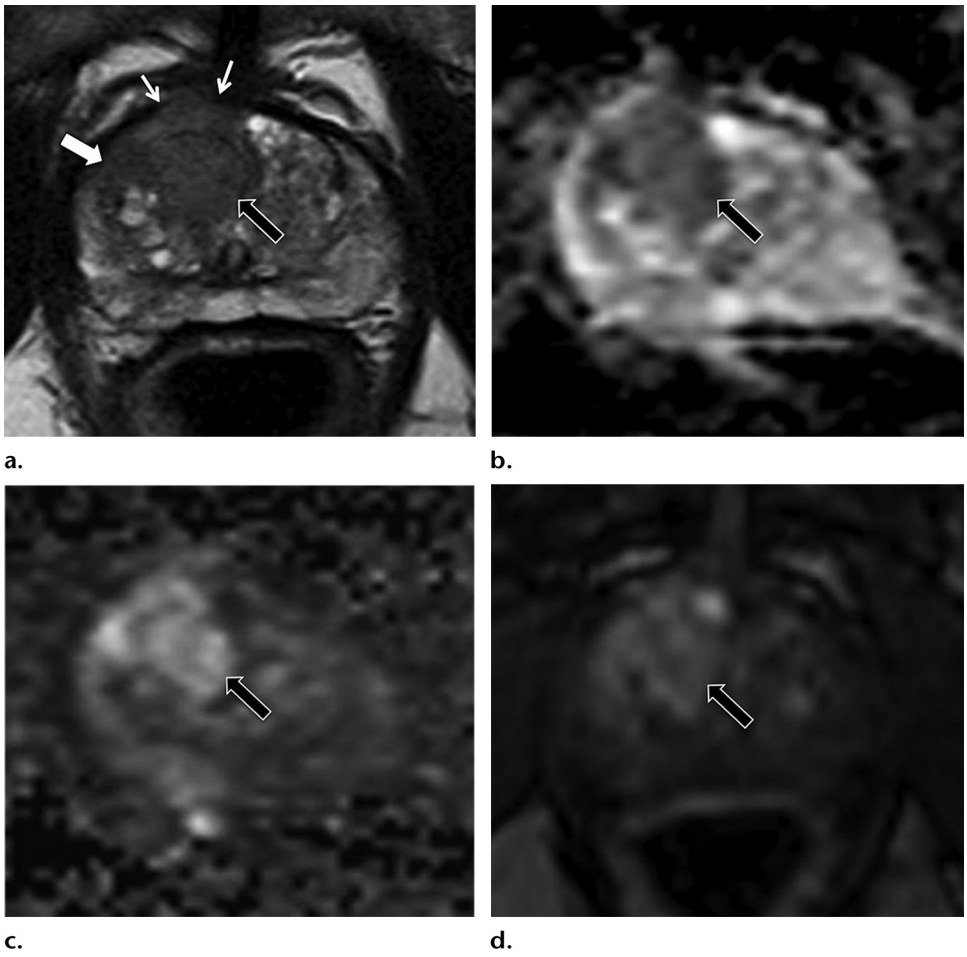


Figure 7. Images of a 68-year-old man with an elevated PSA level (14.4 ng/mL) who had undergone three previous systematic transrectal US–guided biopsies with normal findings. **(a)** Axial T2-weighted MR image shows a 2.5-cm low-signal-intensity irregularly shaped focal lesion (black arrow) centered in the right anterior transition zone at the midgland, with invasion into the adjacent ipsilateral anterior peripheral zone (thick white arrow) and through the anterior fibromuscular stroma (thin white arrows) (T2-weighted imaging score: 5). **(b, c)** ADC map **(b)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(c)** show that the lesion is markedly hypointense on the ADC map (arrow on **b**) and markedly hyperintense on the diffusion-weighted MR image (arrow on **c**) (DWI-ADC score: 5). **(d)** Axial dynamic contrast-enhanced T1-weighted MR image shows early enhancement (or early phase wash-in) of the lesion (arrow) relative to the rest of the gland, a finding that matches the area of signal intensity abnormality identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because there is definite evidence of extraprostatic extension, this lesion was assigned a PI-RADS assessment category of 5. The findings at software-based MR imaging/US fusion–guided biopsy of this lesion disclosed prostate cancer with a Gleason score of 3 + 4, and the patient elected to receive radiation therapy.

For measurement of transition zone lesions, T2-weighted MR imaging is the preferred pulse sequence. As with peripheral zone lesions, the largest dimension of the lesion in the axial plane, along with the diameter in any other plane if it is larger than the dimension in the axial plane, should be reported.

Dynamic Contrast-enhanced MR Imaging

On dynamic contrast-enhanced MR images, prostate cancer commonly exhibits early and intense enhancement, followed by washout of the contrast material (24,33,34). However, the enhancement pattern is fairly variable, with some cancers retaining the contrast material longer (35). Furthermore, prostatitis in the peripheral zone and benign prostatic hyperplasia in the transition zone commonly demonstrate an enhancement pattern similar to that of cancer (36). These factors, in part, explain the limited role that dynamic contrast-enhanced MR imaging plays in the overall assessment categories in PI-RADS version 2.

With the new guidelines, lesions identified at dynamic contrast-enhanced MR imaging no longer receive a 1–5 score on the basis of the kinetic pattern of enhancement. Instead, a lesion will be considered positive at dynamic contrast-enhanced MR imaging in the presence of a focal

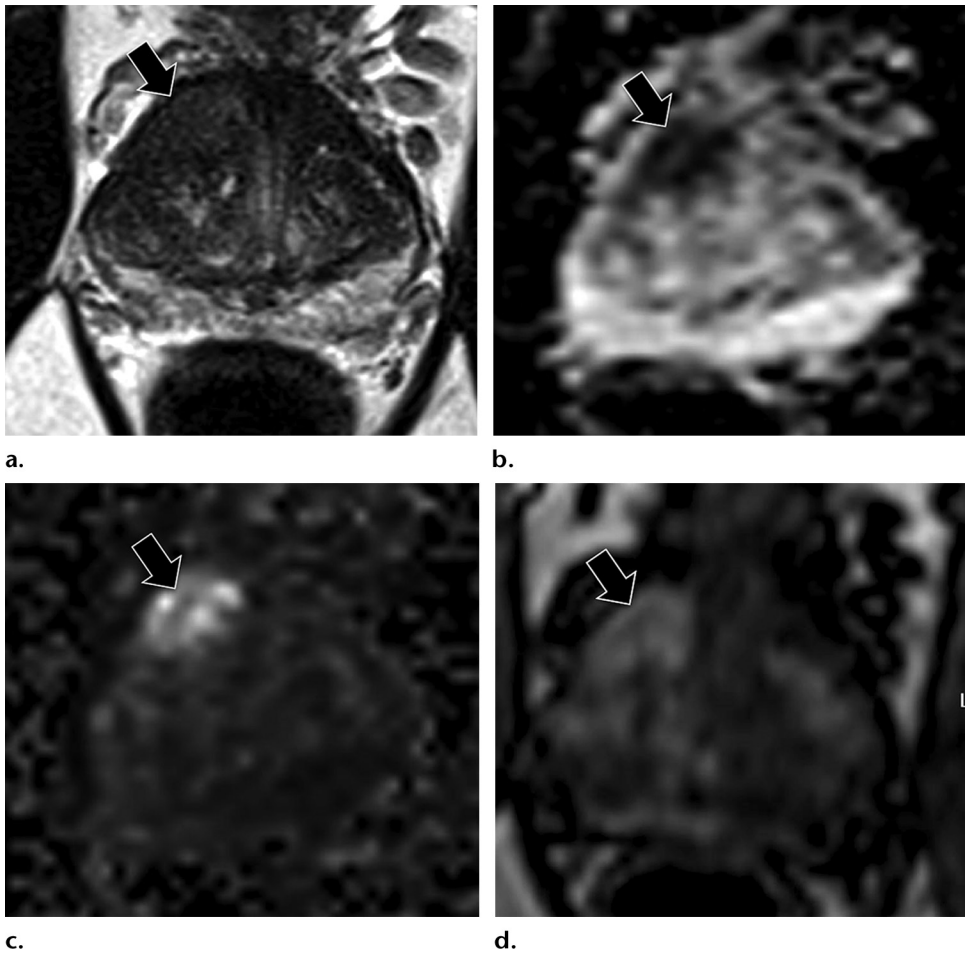
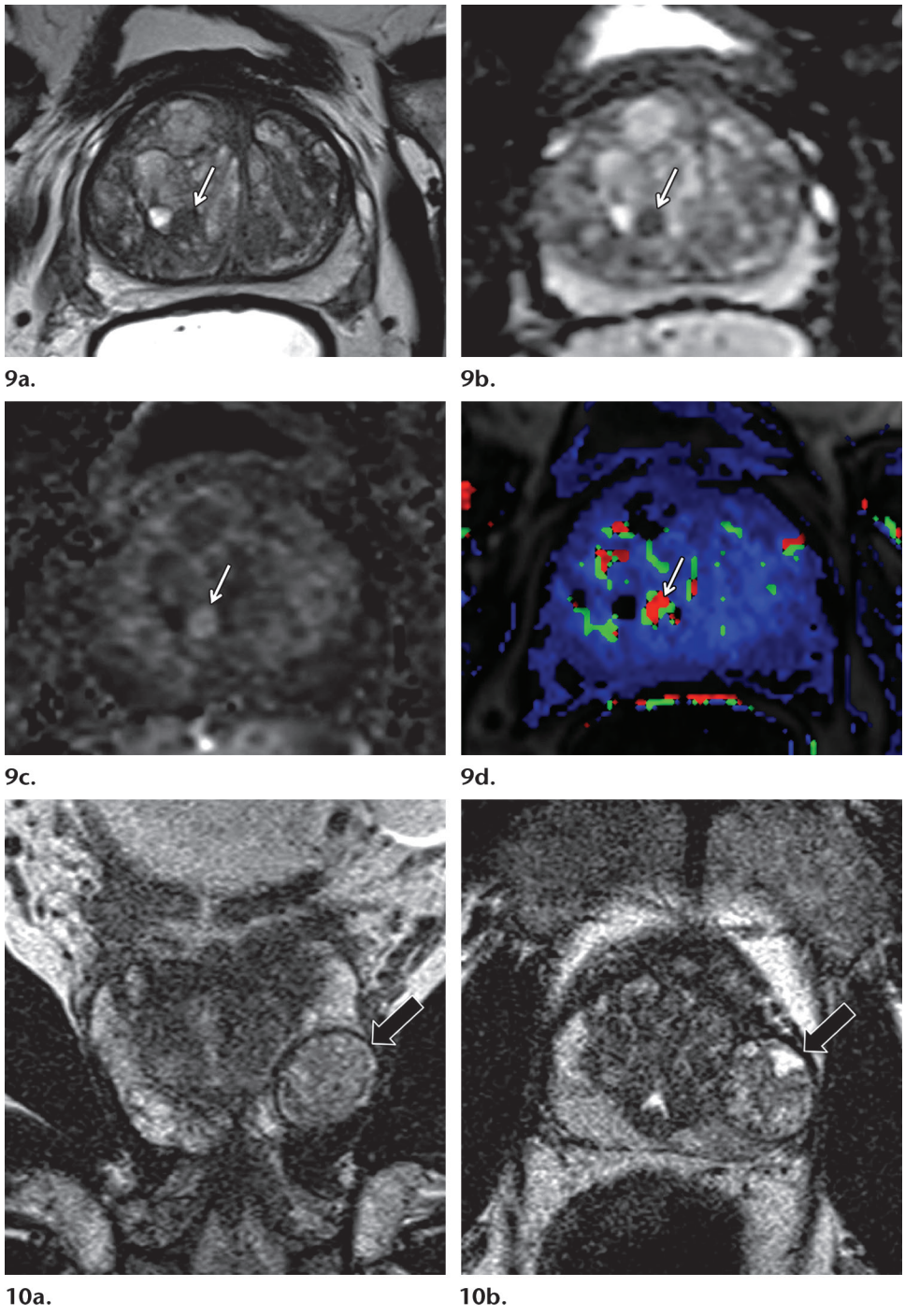


Figure 8. Images of a 55-year-old biopsy-naïve man with an elevated PSA level (4.1 ng/mL) and a family history of prostate cancer, who was referred for MR imaging before possible MR imaging–targeted biopsy. **(a)** Axial T2-weighted MR image shows a 1.3-cm lenticular-shaped lesion (arrow) with indistinct margins and homogeneous low signal intensity in the right anterior transition zone at the midgland (T2-weighted imaging score: 4). **(b, c)** ADC map **(b)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(c)** show that the lesion is markedly hypointense on the ADC map (arrow on **b**) and markedly hyperintense on the diffusion-weighted MR image (arrow on **c**) (DWI-ADC score: 4). **(d)** Axial dynamic contrast-enhanced T1-weighted MR image shows early enhancement (or early phase wash-in) (arrow) in the area that corresponds to the abnormality identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because T2-weighted MR imaging is the dominant parameter for transition zone abnormalities, this focal lesion was assigned a PI-RADS assessment category of 4. The findings at software-based MR imaging/US fusion–guided biopsy of this lesion disclosed prostate cancer with a Gleason score of 4 + 3, and the patient elected to undergo a radical prostatectomy.

abnormality with early and intense enhancement that corresponds to a focal abnormality at T2-weighted MR imaging and/or DWI-ADC (Fig 11). A lesion will be considered negative at dynamic contrast-enhanced MR imaging in the absence of early enhancement relative to surrounding prostatic tissue or when there is diffuse enhancement encompassing an area that does not correspond to an abnormality at T2-weighted MR imaging and/or DWI-ADC. As previously noted, findings on dynamic contrast-enhanced MR images influence the overall PI-RADS assessment category solely by increasing the assessment category of a peripheral zone lesion that otherwise would be assigned a 3 on the basis of DWI-ADC (or T2-weighted MR imaging when DWI is inadequate or not available) to a 4 when dynamic contrast-enhanced MR imaging is also positive. Although dynamic contrast-enhanced MR imaging has a limited role in the assignment of overall assessment categories in PI-RADS version 2, dynamic contrast-enhanced MR images should still be carefully evaluated for potential abnormalities, with such areas then compared with T2-weighted MR images and DWI-ADC images, because inspection of dynamic contrast-enhanced MR images may help to initially identify small lesions that otherwise may be subtle on images obtained with the other pulse sequences (37,38). When both dynamic contrast-enhanced MR imaging and DWI yield inadequate



Figures 9, 10. (9) Images of a 70-year-old man with an elevated PSA level (6.9 ng/mL) and prostate cancer (Gleason score, 3 + 3), whose cancer had been managed with active surveillance for 3 years. **(a)** Axial T2-weighted MR image shows an enlarged transition zone with multiple nodules of variable signal intensity creating the "organized chaos" pattern characteristic of benign prostatic hyperplasia. Some of these benign prostatic hyperplasia nodules have internal areas of low T2 signal intensity (arrow) (T2-weighted imaging score: 2). **(b, c)** ADC map **(b)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(c)** show that some of these nodules are also markedly hypointense on the ADC map (arrow on **b**) and markedly hyperintense on the diffusion-weighted MR image (arrow on **c**) (DWI-ADC score: 4). **(d)** Axial dynamic contrast-enhanced fat-suppressed T1-weighted MR image shows early enhancement (or early phase wash-in) (arrow) in the area that corresponds to the abnormality identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because T2-weighted MR imaging is the dominant parameter for transition zone abnormalities, a PI-RADS assessment category of 2 was assigned, and no MR imaging–targeted biopsy was performed. The patient's known tumor (Gleason score, 3 + 3) was not depicted. **(10)** Images of a 72-year-old man with an elevated PSA level (6.3 ng/mL) who had a palpable nodule detected at digital rectal examination of the prostate. Coronal **(a)** and axial **(b)** T2-weighted MR images show a well-circumscribed oval nodule with a thin hypointense rim (encapsulated) (arrow) insinuating from the transition zone into the left peripheral zone at the midgland, an area that corresponded to the region of the palpable nodule. Because the features of the nodule support the diagnosis of an extruded benign prostatic hyperplasia nodule within the peripheral zone, a PI-RADS assessment category of 2 was assigned regardless of the findings at DWI-ADC and dynamic contrast-enhanced MR imaging, an assessment category that is consistent with a caveat included within the PI-RADS version 2 guidelines. The findings at systematic transrectal US–guided biopsy of the prostate disclosed no cancer.

findings or are not available, the MR imaging study should be limited to the determination of extraprostatic extension for staging purposes.

In PI-RADS version 2, the evaluation of enhancement is based on a qualitative visual assessment of the individual time points at dynamic contrast-enhanced MR imaging. This approach is simplest and can be accomplished by using a standard picture archiving and communication system (PACS). Although the identified

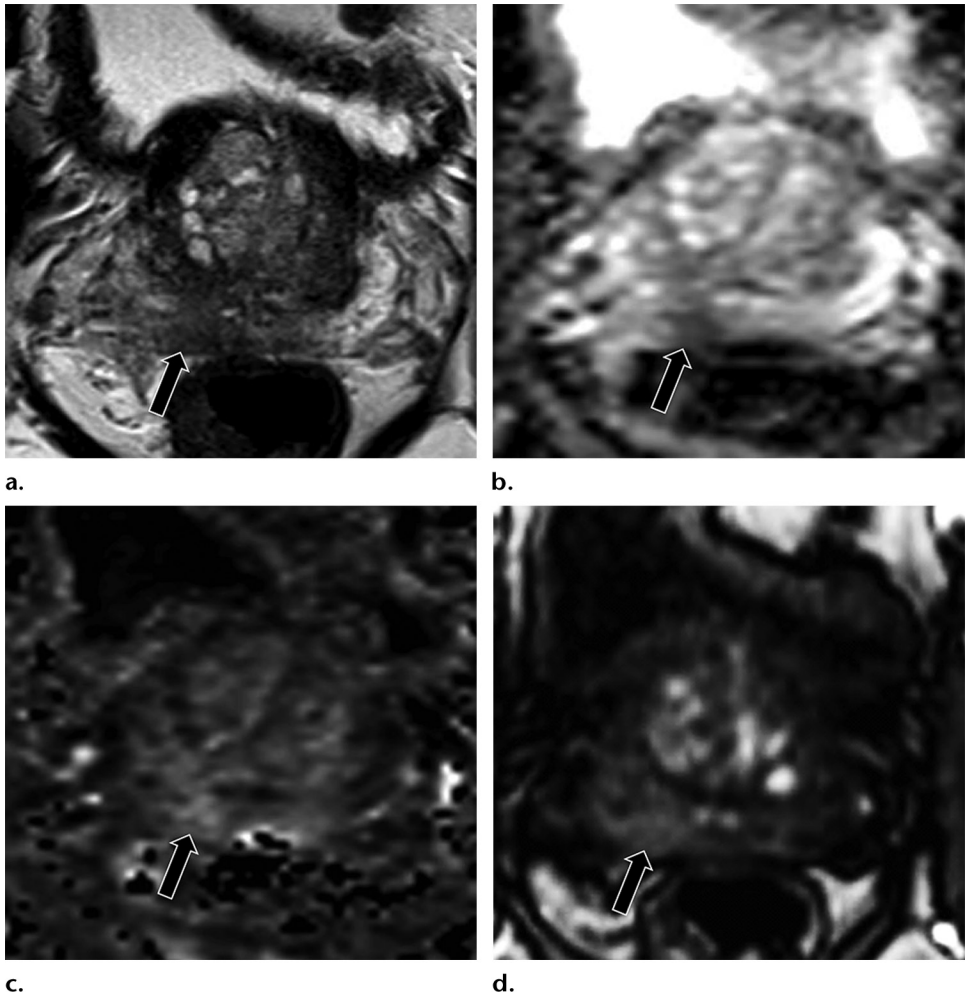


Figure 11. Images of a 69-year-old man with prostate cancer (Gleason score, 3 + 3) that had been detected at systematic transrectal US–guided biopsy and was being managed with active surveillance, who had an increasing PSA level (6.8 ng/mL). **(a)** Axial T2-weighted MR image shows a focal hypointense lesion with indistinct margins (arrow) in the right posteromedial peripheral zone at the base (T2-weighted imaging score: 3). **(b, c)** ADC map **(b)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(c)** show that the lesion measures 0.8 cm and is moderately hypointense on the ADC map (arrow on **b**) and mildly hyperintense on the diffusion-weighted MR image (arrow on **c**) (DWI-ADC score: 3). **(d)** Axial dynamic contrast-enhanced fat-suppressed T1-weighted MR image shows early enhancement (or early phase wash-in) (arrow) corresponding to the abnormality identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced T1-weighted MR imaging: positive). Because the DWI-ADC score was 3 and the dynamic contrast-enhanced MR imaging was positive, this focal peripheral zone lesion was assigned a PI-RADS assessment category of 4. The findings at software-based MR imaging/US fusion–guided biopsy of this lesion disclosed prostate cancer with a Gleason score of 3 + 4. The patient elected to undergo radical prostatectomy, and the findings confirmed the presence of tumor with the same Gleason score.

abnormalities should always be evaluated on the source images, PI-RADS version 2 recognizes that the assessment of dynamic contrast-enhanced MR images may be facilitated by using software to create color-coded parametric maps to depict enhancement patterns or to generate enhancement kinetic curves that plot the signal intensity of a lesion as a function of time (Figs 12, 13). However, the three types of kinetic curves used for generating a dynamic contrast-enhanced MR imaging score ranging from 1 to 5 in the initial PI-RADS system (version 1) are not included in the current guidelines. Instead, the type 2 curve (rapid wash-in and plateau) and the type 3 curve (rapid wash-in and washout of contrast material) described in the original PI-RADS system may be considered to correspond to a positive dynamic contrast-enhanced MR imaging assessment if they represent a focal abnormality that corresponds with an abnormality at T2-weighted MR imaging and/or DWI-ADC.

A quantitative approach to dynamic contrast-enhanced MR imaging that uses compartmental pharmacokinetic modeling (most commonly, Tofts modeling) (39), which allows calculation of time constants for the rate of contrast wash-in and

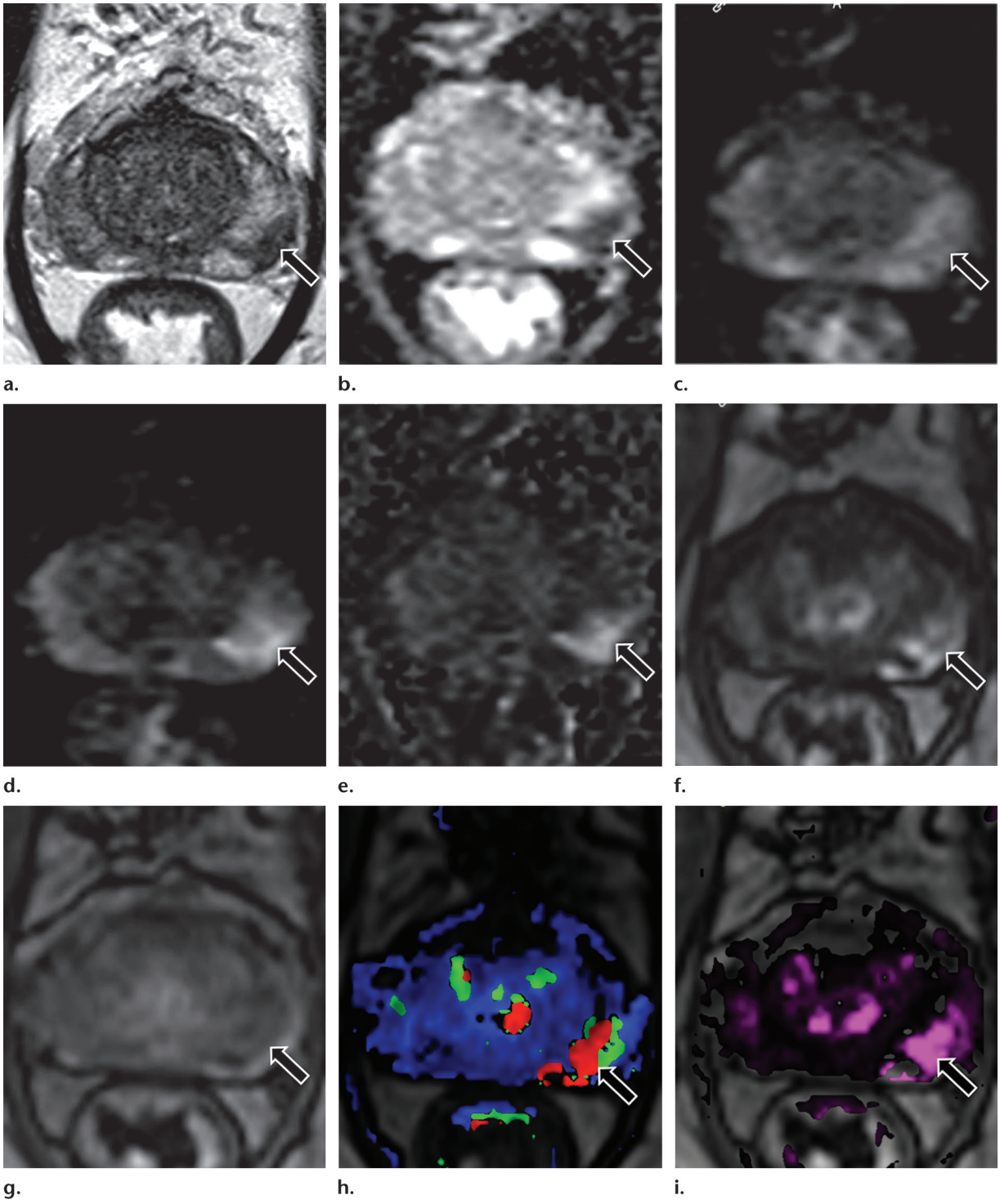


Figure 12. Images of a 72-year-old man with prostate cancer (Gleason score, 3 + 4) detected at systematic transrectal US–guided biopsy, who was referred for multiparametric MR imaging for staging. **(a)** Axial T2-weighted MR image shows a hypointense focal lesion (arrow) in the left posterolateral peripheral zone at the base, abutting the capsule but without definite extraprostatic extension (T2-weighted imaging score: 4). **(b)** ADC map shows a 1.3-cm markedly hypointense lesion (arrow). **(c–e)** Diffusion-weighted MR images obtained with progressive increases in *b* value (**c**, 400 sec/mm^2; **d**, 900 sec/mm^2; **e**, 1500 sec/mm^2) show that the focal lesion (arrow) progressively increases in signal intensity and conspicuity (DWI-ADC score: 4). **(f, g)** Axial dynamic contrast-enhanced T1-weighted MR images obtained in the early **(f)** and later **(g)** phases show early and intense enhancement (arrow on **f**), followed by a decrease in signal intensity (arrow on **g**) in the area corresponding to the abnormality identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). **(h)** Color-coded parametric map shows that the lesion (arrow) has red areas, which represent rapid wash-in and washout of contrast material, and green areas, which represent rapid wash-in followed by persistent contrast enhancement or "plateau." The areas coded in blue represent tissue with normal progressive enhancement. **(i)** The K^{trans} (forward volume transfer constant) map shows increased tissue permeability (coded in magenta) in the corresponding region (arrow), a feature associated with angiogenesis, which can be present not only in some cancers but also in inflammatory conditions, a fact that limits its diagnostic value at multiparametric MR imaging.

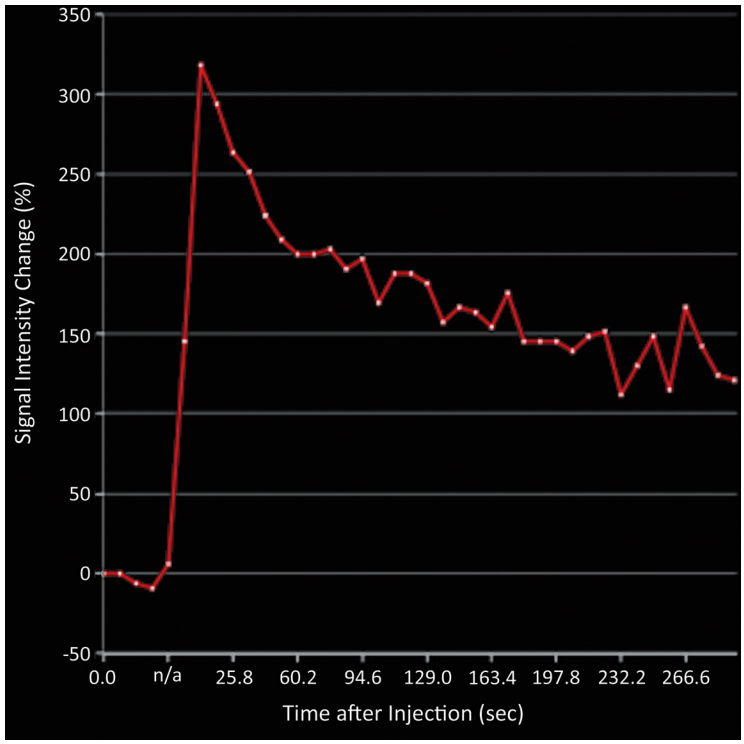


Figure 13. Semiquantitative time–signal intensity curve of a region of interest drawn in the lesion of a 72-year-old man (same patient as in Fig 12) displays the rapid wash-in and washout enhancement pattern of the lesion, a pattern corresponding to a type 3 curve. *n/a* = not available.

washout from the tumor, was considered to have insufficient evidence to support its widespread use and is therefore not included in the guidelines.

Caveats

The PI-RADS version 2 criteria for evaluating individual pulse sequences, as well as for deriving overall assessment categories, are expected to work well for the interpretation of most lesions. However, for PI-RADS version 2, there are a number of caveats with regard to pitfalls that may result if the scheme is applied in an overly dogmatic fashion. These points emphasize the importance of a lesion's shape and texture, along with the signal intensity on multiple image sets, in assigning scores. Symmetric bilateral findings are considered to usually represent normal anatomic structures or a benign process. For instance, the central zone is an anatomic region located at the base of the prostate gland, with a symmetric appearance on either side of the ejaculatory ducts (Fig 14). Because of its rich stromal component, the central zone demonstrates low signal intensity on T2-weighted MR images and restricted diffusion and thus may be confused with cancer (40). In addition, because prostatitis can show abnormal signal intensity with all pulse sequences, it should be emphasized that findings that are indistinct, linear, lobar, or diffuse in nature, rather than having discrete margins, usually are also benign (Fig 15). In the transition zone, it is noted that round circumscribed encapsulated nodules usually represent benign prostatic hyperplasia and rarely represent clinically significant cancer, despite occasionally showing pronounced changes at DWI-ADC and dynamic contrast-enhanced MR imaging. Therefore, these lesions do not need to be assigned a PI-RADS assessment category. In the peripheral zone, a round circumscribed encapsulated lesion likely represents extruded benign prostatic hyperplasia and warrants an overall assessment category of 2, regardless of the presence of reduced ADC. Users of PI-RADS version 2 are encouraged to carefully review and become familiar with all of the caveats within the guidelines to avoid these and other pitfalls.

Prostate Sector Map

For anatomic localization of prostatic lesions, PI-RADS version 2 recommends the use of a standardized sector map that defines regions of the prostate (Fig 16) (41). This sector map is based on the zonal anatomy of the prostate initially described by McNeal (42) and defines 36 sectors corresponding with the prostate, two corresponding with the seminal vesicles, and one corresponding with the external urethral sphincter. Each traditional prostate sextant (right base, right midgland, right apex, left base, left midgland, and left apex) is further subdivided into six sectors: anterior fibromuscular stroma, anterior transition zone, posterior transition zone, anterior peripheral zone, posteromedial peripheral zone, and posterolateral peripheral zone. Anterior and

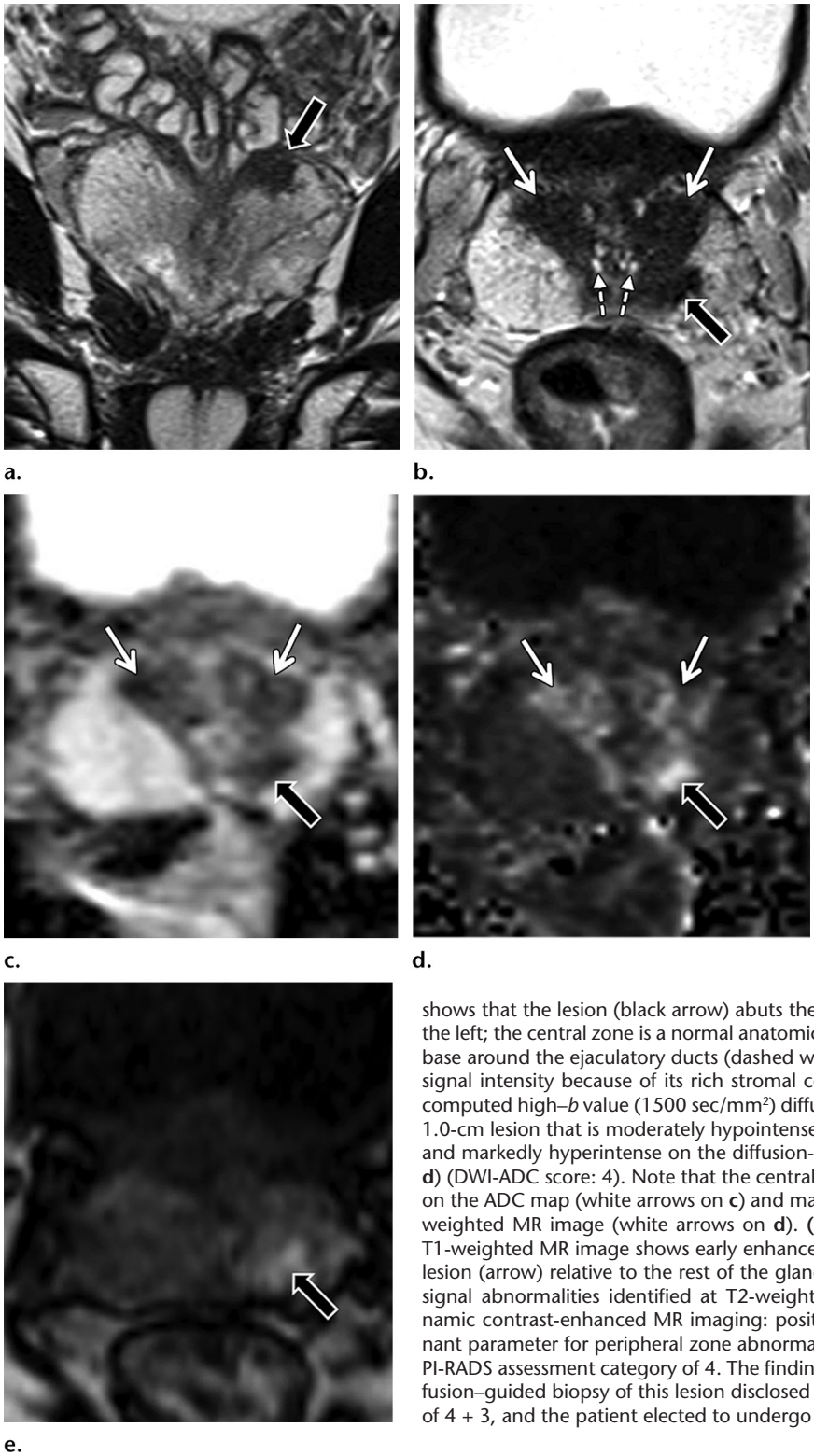


Figure 14. Images of a 70-year-old man with prostate cancer (Gleason score, 3 + 3) detected at systematic transrectal US–guided biopsy, who was referred for multiparametric MR imaging before entering a program of active surveillance of the cancer. **(a)** Coronal T2-weighted MR image shows a hypointense focal nodular lesion (arrow) in the left posteromedial peripheral zone at the base (T2-weighted imaging score: 4). **(b)** Axial T2-weighted MR image shows that the lesion (black arrow) abuts the central zone (solid white arrows) on the left; the central zone is a normal anatomic region of the prostate located at the base around the ejaculatory ducts (dashed white arrows) that also displays low T2 signal intensity because of its rich stromal component. **(c, d)** ADC map **(c)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(d)** show a 1.0-cm lesion that is moderately hypointense on the ADC map (black arrow on **c**) and markedly hyperintense on the diffusion-weighted MR image (black arrow on **d**) (DWI-ADC score: 4). Note that the central zone is also moderately hypointense on the ADC map (white arrows on **c**) and markedly hyperintense on the diffusion-weighted MR image (white arrows on **d**). **(e)** Axial dynamic contrast-enhanced T1-weighted MR image shows early enhancement (or early phase wash-in) of the lesion (arrow) relative to the rest of the gland, a finding that matches the area of signal abnormalities identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because DWI-ADC is the dominant parameter for peripheral zone abnormalities, this focal lesion was assigned a PI-RADS assessment category of 4. The findings at software-based MR imaging/US fusion–guided biopsy of this lesion disclosed prostate cancer with a Gleason score of 4 + 3, and the patient elected to undergo radical prostatectomy.

posterior sectors are defined by a line bisecting the prostate into anterior and posterior halves. Medial and lateral sectors are defined by a line extending along the junction of the peripheral and transition zones in the anterior-posterior direction. Primarily for the purpose of targeting during interventions, abnormalities identified at multiparametric MR imaging of the prostate should be reported in relation to one or more of these sectors, along with their assigned PI-RADS assessment categories.

Conclusion

PI-RADS version 2 is the result of a collaborative effort and constitutes a comprehensive yet practical

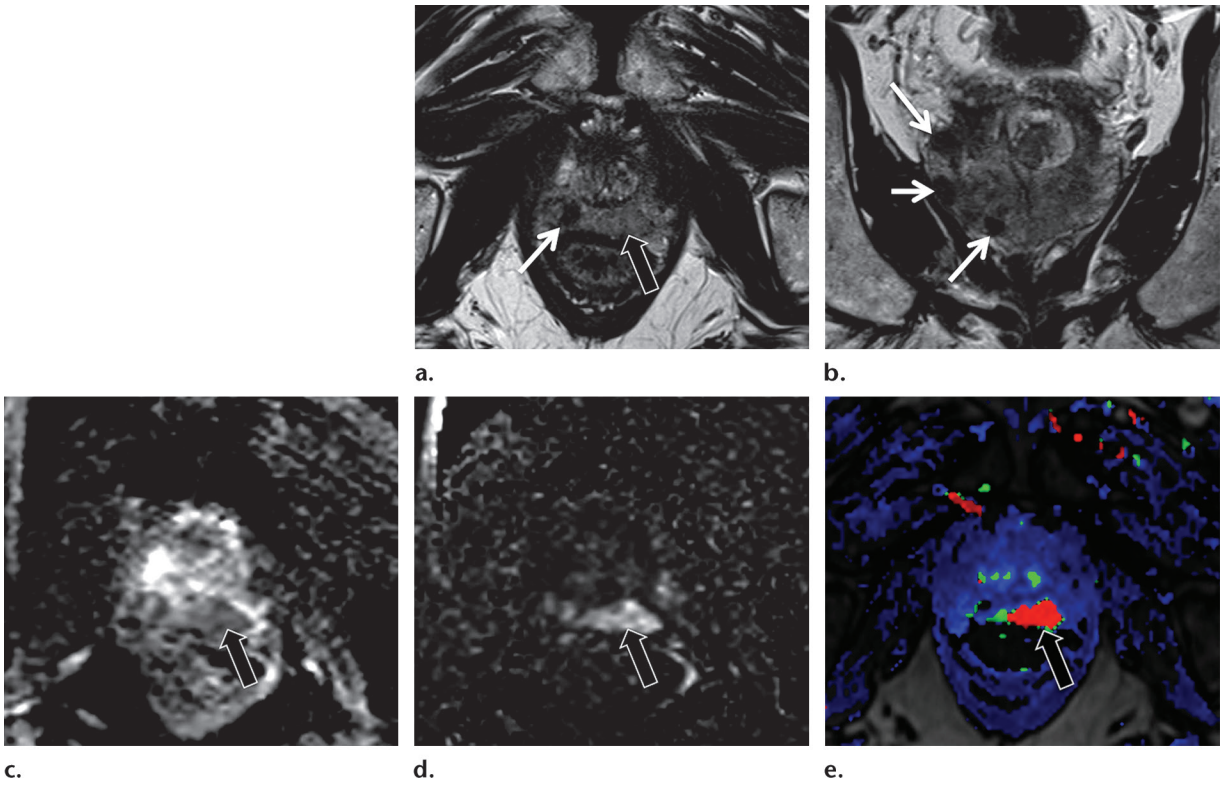


Figure 15. Images of a 65-year-old man with an elevated PSA level (5.8 ng/mL) and a history of noninvasive bladder cancer treated with intravesical injection of BCG, who was referred for MR imaging before possible MR imaging/US fusion–guided biopsy. **(a, b)** Axial **(a)** and coronal **(b)** T2-weighted MR images show several 0.5–0.7-cm markedly hypointense focal nodular lesions (white arrows) scattered in the peripheral zone, which, in a patient with previous BCG therapy, are suggestive of small granulomas. In addition, an ill-defined moderately hypointense lesion (black arrow on **a**) is depicted in the posteromedial peripheral zone at the apex (T2-weighted imaging score: 3). **(c, d)** ADC map **(c)** and computed high–*b* value (1500 sec/mm^2) diffusion-weighted MR image **(d)** show that the largest lesion, a 1.4-cm lesion at the posteromedial apex, is markedly hypointense on the ADC map (arrow on **c**) and markedly hyperintense on the diffusion-weighted MR image (arrow on **d**) (DWI-ADC score: 4). **(e)** Axial dynamic contrast-enhanced T1-weighted MR image shows early enhancement (or early phase wash-in) of the dominant lesion at the apex (arrow) relative to the rest of the gland, a finding that matches the area of signal abnormalities identified at T2-weighted MR imaging and DWI-ADC (dynamic contrast-enhanced MR imaging: positive). Because DWI-ADC is the dominant parameter for peripheral zone abnormalities, the dominant lesion at the apex was assigned a PI-RADS assessment category of 4. The findings from MR imaging/US fusion–guided biopsy of this lesion and systematic sextant biopsy of the prostate disclosed acute and chronic inflammation but no cancer. This case illustrates how prostatitis may produce changes that mimic cancer with all multiparametric MR imaging pulse sequences. In such cases, targeted biopsy may be necessary to exclude cancer.

set of guidelines to further enhance the use and interpretation of multiparametric MR imaging. The creation of explicit recommendations to assign the level of suspicion for clinically significant prostate cancer will likely improve the accuracy of multiparametric MR imaging and help triage patients to appropriate management. The system is expected to evolve with time, with updated versions of the system released as the prostate MR imaging community gains experience in the clinical application of the current PI-RADS version and as new scientific evidence and technologies emerge.

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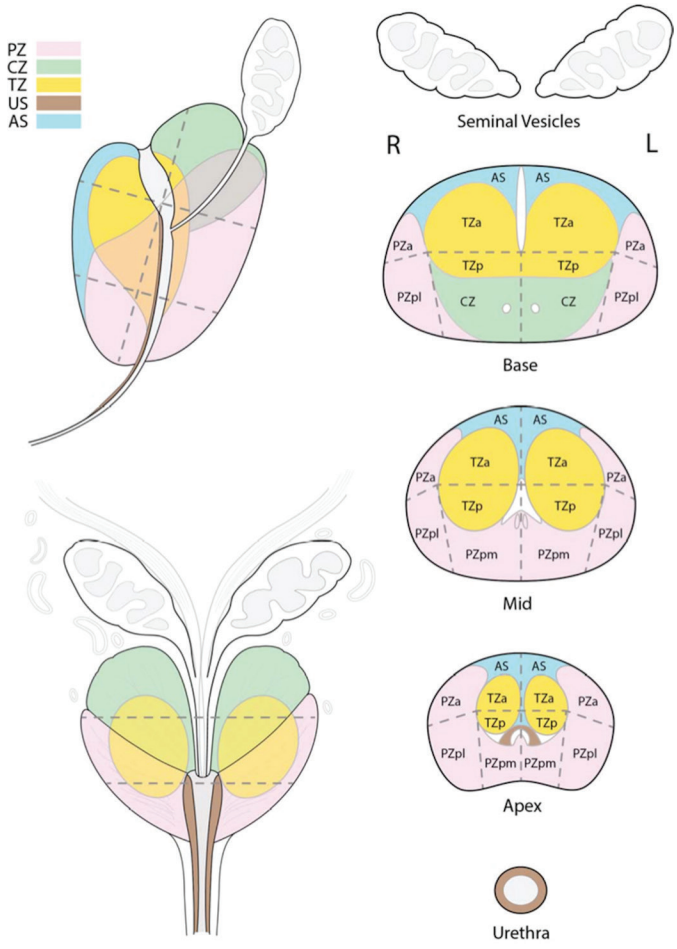

Figure 16. Prostate sector map. *AS* = anterior fibromuscular stroma, *CZ* = central zone, *PZ* = peripheral zone, *TZ* = transition zone, *US* = urethral sphincter. (Reprinted under a CC BY-NC-ND 4.0 license from the American College of Radiology Web site.)

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