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Pictorial Review

Similarities and differences between Likert and PIRADS v2.1 scores of prostate multiparametric MRI: a pictorial review of histology-validated cases

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The UK National Institute for Health and Care Excellence (NICE) 2019 "Prostate cancer: diagnosis and management" guidelines have recommended that all patients suspected of prostate cancer undergo multiparametric magnetic resonance imaging (mpMRI) prior to biopsy. The Likert scoring system is advocated for mpMRI reporting based on multicentre studies that have demonstrated its effectiveness within the National Health Service (NHS). In recent years, there has been considerable drive towards standardised prostate reporting, which led to the development of "Prostate Imaging-Reporting And Data System" (PI-RADS). The PI-RADS system has been adopted by the majority of European countries and within the US. This paper reviews these systems indicating the similarities and specific differences that exist between PI-RADS and Likert assessment through a series of histologically proven clinical cases.

Introduction

Multiparametric magnetic resonance imaging (mpMRI) is being increasingly used for detection and characterisation of prostate cancer as well as risk stratification of clinically significant prostate cancer.[1–3] Prostate mpMRI incorporates multiple imaging sequences including T2-weighted imaging (T2W), diffusion-weighted imaging (DWI), and dynamic contrast-enhanced imaging (DCE-MRI).[4,5] The sensitivity of prostate mpMRI as a diagnostic test for significant cancer has been shown to be 93% (88–96%) with negative predictive values of 89% (83–94%).[6] Use of prostate mpMRI prior to biopsy can also result in the lower detection rate of insignificant cancers, i.e., cancers that are unlikely to result in morbidity/mortality.[7]

To disseminate the benefits of prostate mpMRI outside of a handful of specialist centres, there has been considerable drive towards standardised prostate mpMRI acquisition and reporting. The outcomes from the first European consensus

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meeting[8] materialised into the European Society of Urogenital Radiology (ESUR) guidelines describing a standardised prostate mpMRI reporting structure, retrospectively referred to as version 1 of the Prostate Imaging-Reporting And Data System (PI-RADS).[9] It described a scoring system based on levels of suspicion for the presence of clinically significant prostate cancer on mpMRI. Subsequently, the American College of Radiology collaborated with the ESUR to develop a revision of the version of PI-RADS (PI-RADS v2), where MRI terminology was standardised and risk assessment score categories updated. Several studies have subsequently validated the first[10–13] and second versions of the PI-RADS[14–17]; however, some studies have highlighted inconsistencies and limitations in the system, for instance, interobserver agreement is reported as being only good-to-moderate, and there are difficulties in the assessment of the transition zone (TZ) and the separation of the central zone (CZ) and the anterior fibromascular stroma (AFMS).[18,19] To address these issues, the PI-RADS Steering Committee recently released PI-RADS v2.1, which has recommended several minor modifications to the scoring system, whilst maintaining the framework of assigning scores to individual sequences and using these scores to derive an overall assessment category.[19]

In recognising the limitations of PIRADS v2, the latest prostate mpMRI UK consensus guidelines recommended the use of a Likert assessment scoring system.[5] Like PI-RADS, Likert assessment uses a five-point score to rate cancer probability on mpMRI, and although it is based on similar features as highlighted in the PIRADS scoring system, the Likert score takes clinical parameters into account and does not require specific sequential review of MRI sequences. Like PIRADS, the diagnostic accuracy of the Likert assessment has also been proven in large prospective multicentre trials.[6,20]

In the UK, the recently revised National Institute for Health and Care Excellence (NICE) guidelines have recommended the use of Likert scoring of prostate mpMRI.[21] The aim of this review is to illustrate the main similarities and differences between these two scoring systems, the Likert scale and PI-RADS v2.1, using histology-validated example cases.

Table 1
Comparison of Likert assessment and PI-RADS.

	Likert assessment	PI-RADS
What is it?	Scaled likelihood of disease, using imaging features, clinical data and reader's experience	Categorisation scale based on pre-specified imaging-only features, evaluated in a set order
Flexibility and adaptability for usage	Yes	No: detection only
Level of analysis	Prostate/zonal and lesion based	Lesion based
Detection and Characterisation of clinically significant prostate cancer	Applicable	Applicable
Adds to multivariate models for biopsy avoidance	Not well investigated	Yes
Adds to risk models for risk stratification of diagnosed cancer	Not well investigated	Yes
Investigated pathological/genomic underpinning	Yes extensive/no	Yes extensive/early work
Active surveillance	Applicable	No
Recurrence	Applicable	No
Application after gland-sparing therapy	Applicable	No
Risk stratification	Applicable	No
Prognostication	Applicable	No
Treatment planning applications	Applicable	No

Courtesy of Prof. Anwar R Padhani, Paul Strickland Scanner Centre, Mount Vernon Hospital, Northwood, UK.

Table 2
Main differences in Likert assessment versus PI-RADS scoring systems.

	Likert assessment	PI-RADS
Clinical information is used for final scoring	Considered	Explicitly disregarded
PSA density	Considered	Not considered
Family history/genetic	Considered	Not considered
Anatomical site of lesion	Considered	Not considered
Distinct AFMS lesion	Yes	No (categorised as PZ or TZ origin)
Dominant sequence for PZ–TZ	No	Yes
Presence of micro cysts in TZ (likely benign)	Considered	Not considered
DCE	Can be used as the primary sequence on which a lesion is detected in PZ and TZ	Only used as secondary sequence for further characterisation of score 3 lesions evident on DWI in PZ
Unencapsulated sheet-like confluent TZ enhancement (likely cancer)	Considered	Not considered

AFMS, Anterior fibromascular stroma; DCE, dynamic contrast enhanced; PSA, prostate specific antigen; PZ, peripheral zone; TZ, transition zone.

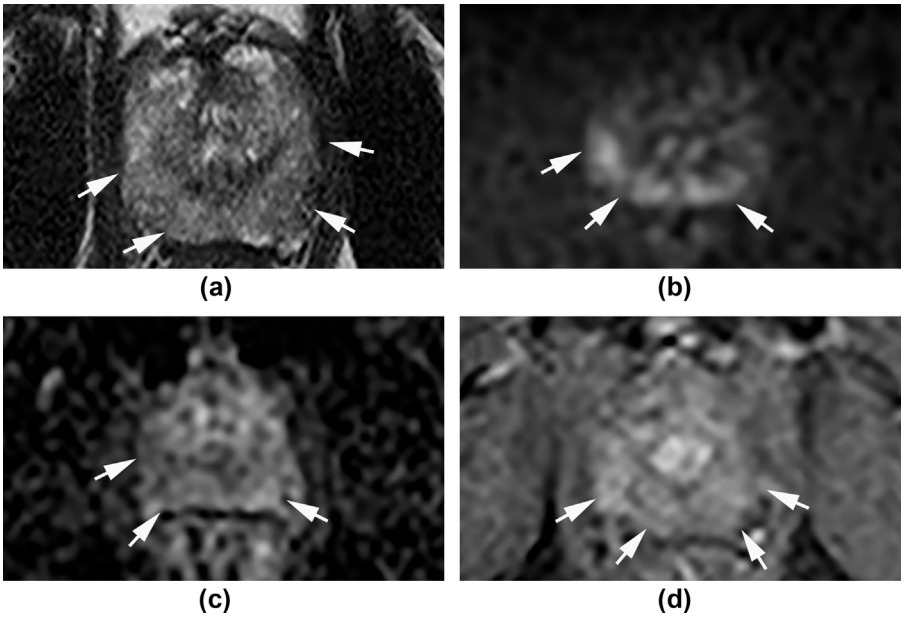

Figure 1 mpMRI description: (a) axial T2W MRI shows diffuse low signal intensity (arrows) within the left and right PZ from 1 o'clock to 11 o'clock at the apex. (b) On axial b=2,000 s/mm^2 DWI, there is diffuse high signal intensities (arrows) predominantly in the right PZ from 4 o'clock to 10 o'clock. (c) There is no focal lesion that is moderate or markedly hypo-intense on axial ADC map with diffuse changes shown (arrows). (d) Early post-contrast DCE-MRI shows diffuse enhancement of the right and left PZ (arrows). PI-RADS v2.1 interpretation: with ADC/DWI as dominant sequence, no focal hypo-intense lesion is found on ADC/DWI and therefore this mpMRI would score a 2. Likert assessment: this mpMRI was scored a Likert assessment score 3 because of the b=2,000 s/mm^2 DWI signal intensities mostly in the right PZ showing corresponding early and diffuse enhancement on DCE-MRI. These diffuse signal changes show low T2W MRI signal intensity, which are not linear or stranded. Histology: adenocarcinoma Gleason 3+4 (10% Gleason 4 pattern) was found in the left medial posterior base and in the right medial posterior apex. MRI targeted right posterior apex also revealed adenocarcinoma Gleason 3+4 (10% Gleason 4 pattern).

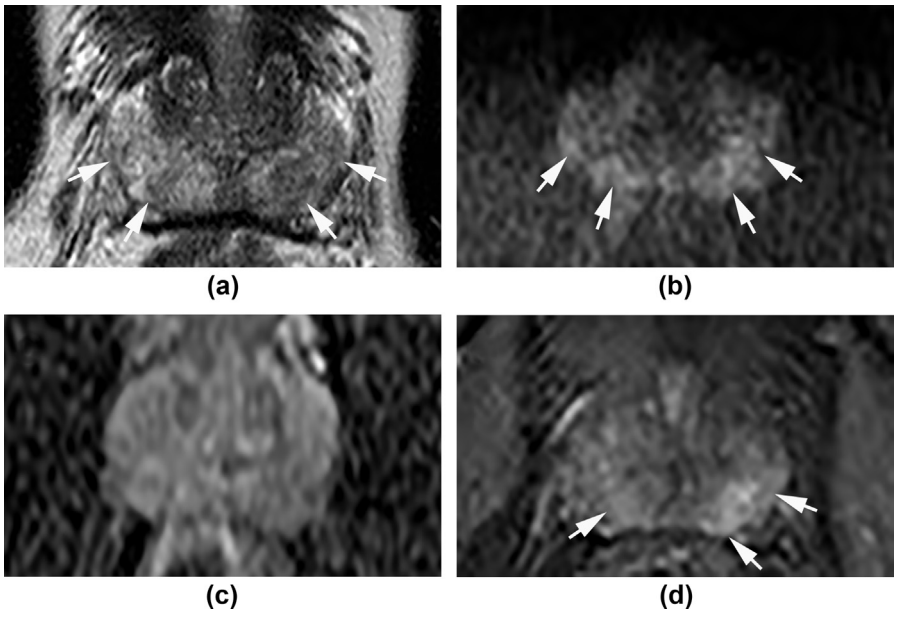

Figure 2 mpMRI description: (a) axial T2W MRI shows patchy areas of low signal intensity throughout the right and left PZ at the base (arrows). (b) Axial b=2,000 s/mm^2 DWI shows diffuse high signal intensities (arrows) in both the left and right PZ; no definite focus of markedly low ADC (c) is clearly apparent. (d) Early post-contrast DCE-MRI show bilateral enhancement (arrows) with a relatively more prominent focus of early enhancement in the left posteromedial to posterolateral PZ (from 3–5 o'clock). PI-RADS v2.1 interpretation: diffuse mild hyper-intensities on DWI and no focal restricted diffusion on this mpMRI are attributed to a PI-RADS score of 2. Likert assessment: this mpMRI is scored 3 on Likert assessment due to the bilateral and diffuse hyper-intensities relating to early enhancement on DCE-MRI and high signal intensities on b=2,000 s/mm^2 DWI. The suspicion that this prostate could harbour significant cancer is raised especially within the left posteromedial PZ showing moderately higher signal intensity on DCE-MRI with mild corresponding restricted diffusion; however, as bilateral signal changes are present, it is unknown where exactly significant cancer could lie within the PZ and so a score of 3 is given throughout the PZ. Histology: adenocarcinoma Gleason 3+4 (20% Gleason 4 pattern) in the left para-posterior base and in the right medial posterior apex.

PI-RADS

In the first version of PI-RADS, qualitative imaging patterns pertaining to benign findings and abnormalities in the prostate were described and defined for each score category on each pulse sequence (T2W, DWI, DCE-MRI and optional magnetic resonance spectroscopy)[9]; however, no recommendation was elaborated as to how to arrive at an overall score for a lesion. PI-RADS v2 described how to arrive at an overall assessment category score and introduced several changes to PI-RADS v1.[4] First, the notion of a dominant sequence for overall score classification was introduced separately for the peripheral zone (PZ) and for the TZ. The dominant parameters being DWI in the PZ and T2WI for the TZ. Second, DCE-MRI was relegated to a secondary role and with the five-point scale being replaced by a binary score of "positive" and "negative" enhancement in the PZ. Positive enhancement on DCE-MRI would only help in upgrading an indeterminate PI-RADS score of 3 to PI-RADS category 4 in the PZ. Third, DWI was recommended in the TZ as the secondary parameter; equivocal PI-RADS 3 TZ lesion on the primary pulse sequence T2W MRI would be upgraded to PI-RADS 4 only if it was scored 5 on DWI. Fourth, a size criteria of $\geq$1.5 cm was introduced to differentiate between a score

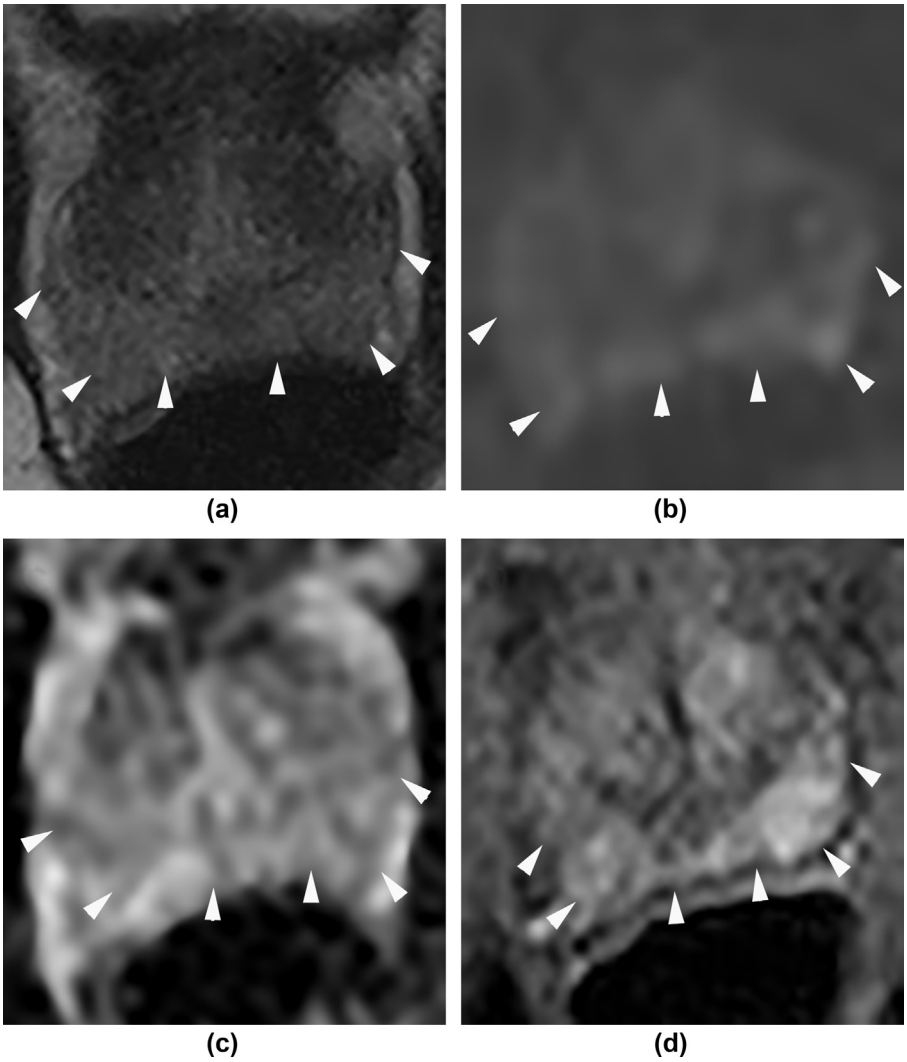

Figure 3 mpMRI description: (a) axial T2W MRI shows stranded diffuse low signal intensity throughout the left and right PZ in the mid-gland (arrowheads). (b) On axial b=2,000 s/mm^2 DWI, no convincing focal area of increased signal intensity can be seen and no focal lesion that is moderately or markedly hypo-intense on axial ADC map (c) is apparent. A mild patchy diffuse increased signal intensity on DWI (arrowheads) and corresponding mild stranded hypo-intensity on ADC map (arrowheads) is seen throughout the left and right PZ. (d) Axial DCE-MRI shows prominent bilateral diffuse early enhancement of the left and right PZ (arrowheads). PI-RADS v2.1 interpretation: the assessment of ADC map shows indistinct bilateral hypo-intensities without any convincing focal area of markedly decreased ADC and no focal hyper-intensity on b=2,000 s/mm^2 DWI is seen. In keeping with PI-RADS v2.1 category assessment recommendations, this scores a DWI and overall PI-RADS score of 2. Likert assessment: as these diffuse low T2W MRI signal changes in the PZ show bilateral early enhancement on DCE-MRI, it suggests that clinically significant cancer within these changes could be present even in the absence of any clear focal abnormality; and therefore the mpMRI is scored 3. A score of 2 is not given as significant cancer cannot be confidently excluded. Histology: 48 prostatic biopsies from 21 sites showed neither high-grade prostate intraepithelial neoplasia (PIN) nor prostate carcinoma.

4 and 5 on T2W MRI in both the PZ and TZ and on DWI in the PZ. The recently updated version 2.1 of PI-RADS v2 incorporates a modification for detection and scoring of CZ, AFMS, as well as an update on evaluation and scoring of TZ and a revision of criteria for DWI scores 2 and 3.[20] The criteria for assessment of PZ and TZ on T2W, DWI and DCE MRI as well as PI-RADS v2.1 scoring for PZ and TZ is tabulated in Electronic Supplementary Material Tables S1–5.

Likert assessment

In Likert assessment, the same reporting lexicons and qualitative descriptions of prostate mpMRI as elaborated in PI-RADS v2.1 are used for detection and staging purposes; however, Likert assessment differs from PI-RADS v2.1 in several ways. Firstly, Likert assessment takes into consideration clinical information such as age, prostate-specific antigen (PSA), gland volume, PSA density, family history alongside the radiologist's experience to report overall prostate probability scoring on mpMRI. Secondly, Likert assessment does not strictly adhere to the use of DWI as a dominant pulse sequence for PZ cancer detection or T2W MRI for the TZ cancer detection. Although DWI has been recently proven to be the dominant sequence in the PZ, the dominance of T2W MRI in the TZ was less convincing.[22] Likert assessment acknowledges DWI as the pulse sequence most associated with prostate cancer aggressiveness not only in the PZ but also in the TZ.[23–26] The non-adherence to a dominant sequence allows for more flexibility towards the modification of the overall score when highly suspicious signs on other pulse sequences are present. Thirdly, although "positive DCE" in PI-RADS v2.1 is limited to focal lesions only, in Likert assessment diffuse signal changes demonstrating enhancement on DCE-MRI images are also recognised as positive enhancement as together with diffuse T2 and ADC signal changes, non-focal background signal change may mask significant tumour.[27] Fourth, there is no use of $\geq$1.5 cm size criteria to differentiate between a score 4 and 5 in the Likert assessment unlike PI-RADS. What differentiates a score 4 and a score 5 in Likert assessment is how confident the reader is in their assessment for the presence of significant cancer on mpMRI, regardless of lesion size or gland confinement. Fifth, although PI-RADS is a lesion-based-only scoring system, Likert advocates the scoring of the whole prostate or sections of the prostate (background signal) as this can increase the risk of tumour being masked, particularly when combined with a high PSA density.[5,28] Finally, PI-RADS has been developed for the pre-biopsy setting only and does not cover any follow-up, or post-treatment setting, whereas Likert evaluation can be applied to any clinical scenario, albeit with a modification of the imaging features associated with malignancy.[29–31]

An often raised criticism of Likert has been the potential for poor reproducibility when compared with PI-RADS; however, studies have reported good interobserver agreement, which is on a par with PI-RADS.[5,32,33]

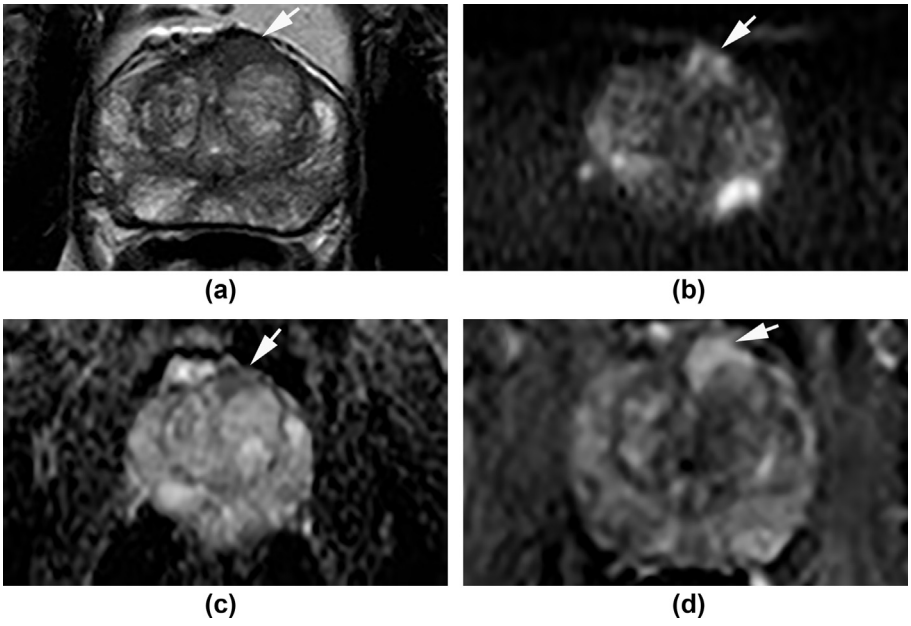

Figure 4 mpMRI description: (a) axial T2W MR image shows a 12 mm lenticular area of low signal intensity centred in the left para-sagittal TZ mid-gland to apex (arrow). It presents an anterior bulge displacing the AFMS. The lesion shows high signal intensity on axial b=2,000 s/mm^2 DWI image (b), and hypo-intensity on ADC map (c), representing restricted diffusion (arrows). (d) It shows clear early enhancement on axial DCE-MRI image (arrow). PI-RADS v2.1 interpretation: With PI-RADS v2.1, looking at T2W MRI as the dominant sequence, this lesion is suspicious due to the lenticular and homogeneous T2W MRI hypo-intensity and corresponds to PI-RADS category 4 description but because of the invasive tumour involvement of the pseudo-capsule the overall PI-RADS v2.1 score is 5. Likert assessment: the lesion shows a well-defined focus of high signal intensity on both b=2,000 s/mm^2 DWI and hypo-intensity on ADC map images along with a concordant early enhancement. It is suspicious on all of the sequences and because the tumour shows a bulge of the anterior capsule on T2W MRI, the likelihood that this lesion represents significant tumour is very high, it scores a 5 on Likert assessment. Histology: adenocarcinoma Gleason 3+3 and a maximum cancer core length of 7 mm anteriorly.

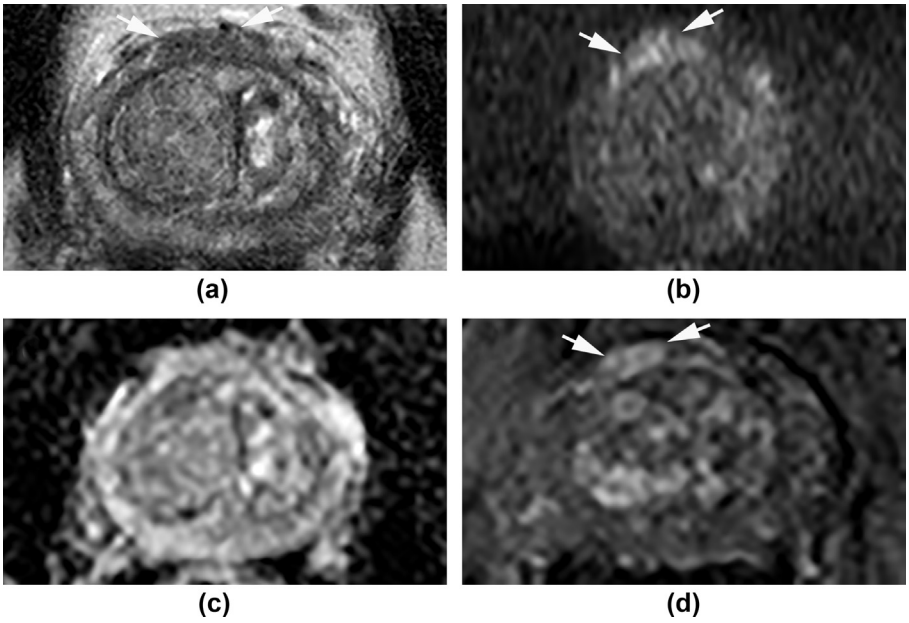

Figure 5 mpMRI description: (a) axial T2W MRI shows an area of low signal intensity in anterior prostate gland (arrow), likely the AFMS, extending from left para-sagittal to predominantly the right hemi mid-gland, and measuring 17 mm. (b) There is also corresponding high signal intensity on axial b=2,000 s/mm^2 DWI (arrow) but no convincing area of hypo-intensity on axial ADC map (c). (d) This lesion shows early enhancement on axial DCE-MRI from 11–12 o'clock (arrow). PI-RADS v2.1 interpretation: according to PI-RADS v2.1, a suspicious lesion in the AFMS should be assessed using either the criteria for PZ or TZ. Were this lesion to be assessed like a TZ lesion, then using the predominant T2W MRI pulse sequence, this would be interpreted as a homogeneous focus, which is moderately hypo-intense and measuring >1.5 cm and therefore would be scored a 5. Alternatively, were this lesion to be assessed like a PZ lesion, using the predominant DWI sequence, this would be interpreted as a homogeneous focus of moderate hyper-intensity on b=2,000 s/mm^2 DWI measuring >1.5 cm, and therefore, would be scored a 5. Likert assessment: using the Likert assessment, not only the T2W MRI or DWI sequences are looked at, but all the sequences altogether. The fact that all the pulse sequences are suspicious: the low T2 signal intensity with restricted diffusion and positive DCE-MRI enhancement and additionally the size of the lesion in this case, comfort the scoring of 5/5 on Likert assessment. Histology: histology results confirmed adenocarcinoma 4+3 with a maximum cancer core length of 4 mm.

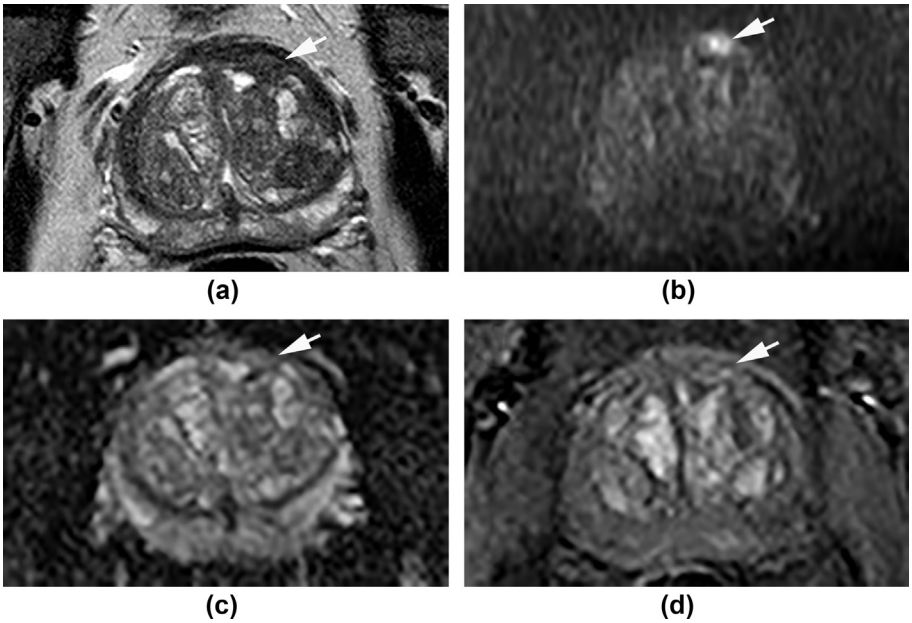

Figure 6 mpMRI description: (a) axial T2W MRI demonstrates a low T2 signal intensity in the left anterior TZ from 12–1 o'clock in the mid-gland (arrow) with a corresponding focus of increased signal intensity on axial high b=2,000 s/mm^2 DWI (b) and hypo-intense focus on axial ADC map (c) (arrows). Axial DCE-MRI is equivocal for this lesion (arrows). PI-RADS v2.1 interpretation: using PI-RADS v2.1, looking at the T2W MRI image only as this is the dominant sequence, this lesion may be described as a circumscribed encapsulated hypo-intensity scoring a 2. Likert assessment: the restricted diffusion on b=2,000 s/mm^2 DWI would raise the suspicion of this lesion and thus upgrade it to a score of 3. Histology: histology results following biopsy revealed Gleason 3+4 tumour with a cancer core length of 4 mm.

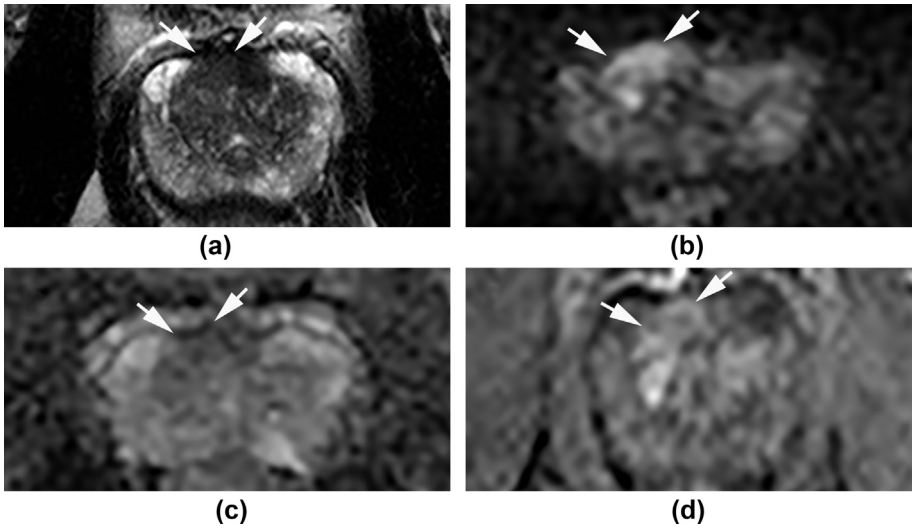

Figure 7 mpMRI description: (a) axial T2W MRI shows a heterogeneous TZ signal. An area of markedly low signal intensity on T2W MRI at the base is seen (arrows) with a corresponding increased signal intensity focus on axial b=2,000 s/mm^2 DWI (b) (arrows) mainly from 11–12 o'clock corresponding to hypo-intense focus on axial ADC map (c) (arrows). (d) There is a corresponding focus of early enhancement present on axial DCE-MRI (arrows). PI-RADS v2.1 interpretation: this lesion is difficult to categorise as per the PI-RADS description based solely on T2W MRI as it could be considered as a hypo-intense circumscribed area scoring a 2, or the posterior margins may be considered as blurred and the lesion therefore score higher. The final score may be highly subjective. Likert assessment: the signal from DWI and ADC and the corresponding early enhancement of the lesion on DCE-MRI raises significant suspicion of tumour and the lesion would score a consistently score 4. Histology: this lesion harboured Gleason 3+4, a maximum cancer core length of 3 mm was found.

Electronic Supplementary Material Tables S6–9 describe the morphological and signal characteristics on T2W, DWI, and DCE-MRI that are used to derive the Likert score for PZ and TZ as well as extra-prostatic disease. Tables 1 and 2 highlight the key differences between Likert assessment and PI-RADS scoring system.

Case-based illustrations

Pre-biopsy setting

The following cases refer to men who have not undergone any prostatic biopsy prior to their mpMRI examinations. All

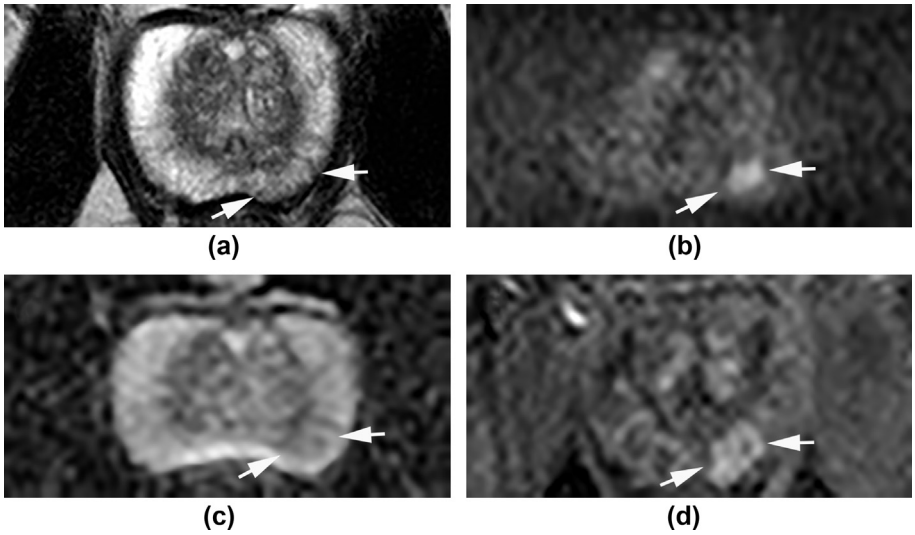

Figure 8 mpMRI description: (a) axial T2W MRI demonstrates linear hypo-intensities in the left posteromedial and posterolateral PZ in the mid-gland from 4–6 o'clock (arrows). (b) There is also a corresponding high intensity signal on axial b=2,000 s/mm^2 DWI (arrows) with corresponding focus of moderate hypo-intensity on axial ADC map (c) from 4–5 o'clock (arrows). (d) The lesion presents an early enhancement on axial DCE-MRI and adjacent sub-capsular enhancement is noted but no evidence of macroscopic extra-prostatic disease is seen. PI-RADS v2.1 interpretation: With PI-RADS v2.1, this lesion scores a 3 on DWI due to the moderate hypo-intensity on ADC and is then upgraded to a final overall score of 4 because of the positive focal enhancement on DCE-MRI. Likert assessment: as sub-capsular enhancement is seen, this lesion would score a 4. Histology: histologically, adenocarcinoma Gleason 3+4 with a cancer core length of 6 mm was found.

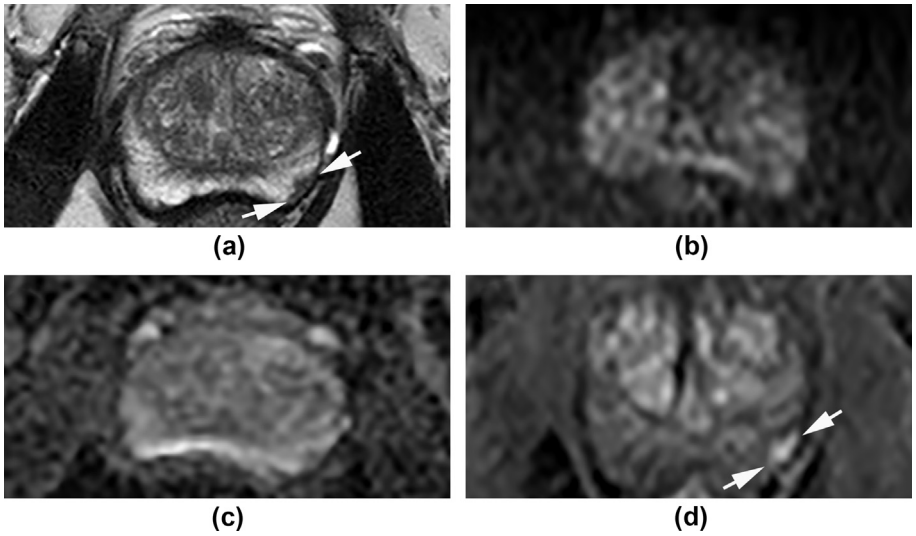

Figure 9 mpMRI description: (a) axial T2W MRI demonstrates streaks of T2W MRI signal hypo-intensities in PZ of the mid-gland (arrows). (b) There is no high signal intensity on axial b=2,000 s/mm^2 DWI and no hypo-intensity on axial ADC map (c). (d) Axial DCE-MRI shows a small focus of early capsular enhancement seen at the posteromedial PZ at ~5 o'clock (arrows). PI-RADS v2 interpretation: DWI being the dominant sequence in the PZ, the absence of restricted diffusion would entail in this examination to be scored a PI-RADS 2. Likert assessment: however, this lesion scored 4 due to the presence of a focal sub-capsular enhancement demonstrated on DCE-MRI, corresponding to a low T2W MRI signal focus. Histology: histology results confirmed adenocarcinoma Gleason 3+4 and a cancer core length of 2 mm.

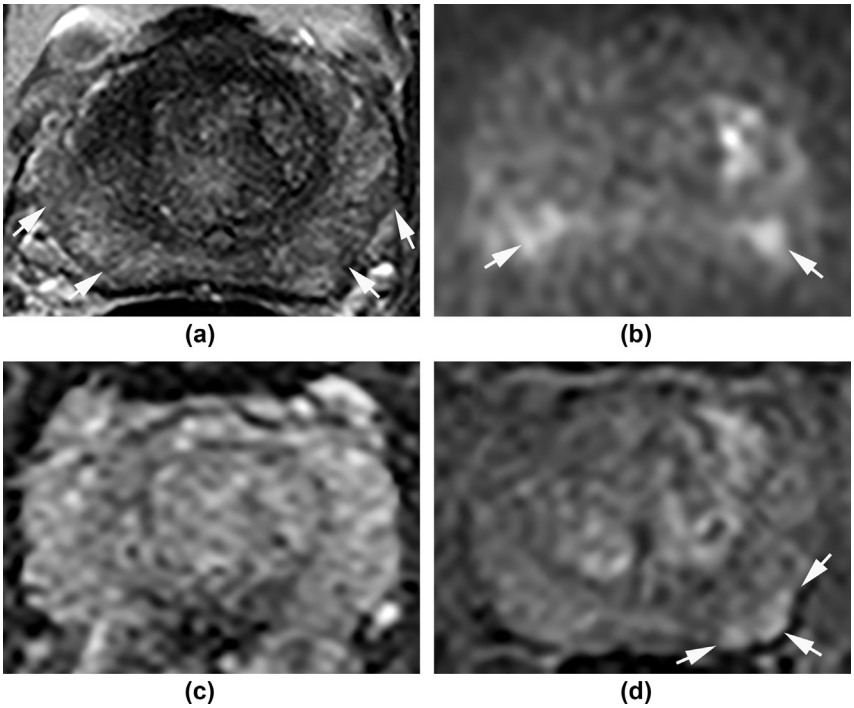

Figure 10 mpMRI description: (a) axial T2W MRI demonstrates diffuse patchy T2 signal hypo-intensities in PZ of the mid-gland (arrows). (b) Moderate hyper-intense areas on axial b=2,000 s/mm^2 DWI are observed at the posterolateral PZ bilaterally (arrows). (c) No convincing area of hypo-intense focus on axial ADC map is observed considering some distortion artefact. (d) On axial DCE-MRI, there is early sub-capsular enhancement in left PZ at ~5 o'clock (arrows). PI-RADS v2.1 interpretation: as there is no suspicious focal hypo-intensity on ADC and corresponding hyper-intensity on b=2,000 s/mm^2 DWI, this mpMRI scores a PI-RADS 2. Likert assessment: however, this lesion scored 4 due to the presence of focal early enhancement and adjacent sub-capsular enhancement at 5 o'clock on DCE-MRI. Histology: adenocarcinoma Gleason 3+4 and a cancer core length of 8 mm in the left the posteromedial PZ.

histology results following mpMRI were obtained from trans-perineal prostate mapping (TPM) biopsy.

Diffuse PZ signal changes

Diffuse PZ signal changes are only described under PI-RADS category 2, particularly when they form a linear, wedge-shape or diffuse mild hypo-intensity on T2W MRI.[4,20] Recent studies have found that PI-RADS score 2 can harbour significant cancer in up to 13% of cases.[34–37] With Likert assessment, not all the PZ diffuse signal changes on T2W MRI are scored 2; these changes would be upgraded in the Likert assessment to a score of 3 (indeterminate), when they are accompanied by corresponding DWI or DCE-MRI abnormalities.

Morphologically, signal changes which are geographical (versus round) in shape, with ill-defined (versus well-defined) borders, radial (versus parallel) orientation to the capsule, hyper-intense to the bladder wall, homogeneously spread (versus stranded) would more likely be upgraded to a Likert assessment score 3, even though none of these, are perfect discriminators for significant cancer.[27,38] It has been shown that DWI can discriminate significant cancer within indeterminate lesions[38] but the contribution of DCE-MRI is yet to be determined.

Although there may be a consequential increase in the number of indeterminate scans in Likert assessment as opposed to a misclassification of all diffuse signal changes under a PI-RADS score category 2, PSA density at a threshold of >0.15 ng/ml^2 was found to be useful in determining which of these equivocal lesions would require a biopsy in clinical practice.[5,27] The following three cases illustrate diffuse PZ signal changes.

Case 1

Clinical information: a 62-year-old man with a presenting PSA of 5.18 ng/ml, prostate volume of 25 cm^3, and a PSA density of 0.21 ng/ml^2. Fig 1 shows axial images of his prostate mpMRI.

Case 2

Clinical information: a 57-year-old man with a PSA of 9.9 ng/ml at presentation, prostate volume of 22 cm^3, and a PSA density of 0.45 ng/ml^2. Fig 2 shows axial images of his prostate mpMRI.

Case 3

Clinical information: a 46-year-old man with a PSA of 4.01 ng/ml, prostate volume of 26 cm^3, and a PSA density of 0.15 ng/ml^2. Fig 3 shows axial mpMRI images of the patient.

AFMS and the TZ

The assessment of the normal AFMS has been recently added in the PI-RADS v2.1, but without a separate scoring system for lesions within this region. According to PI-RADS

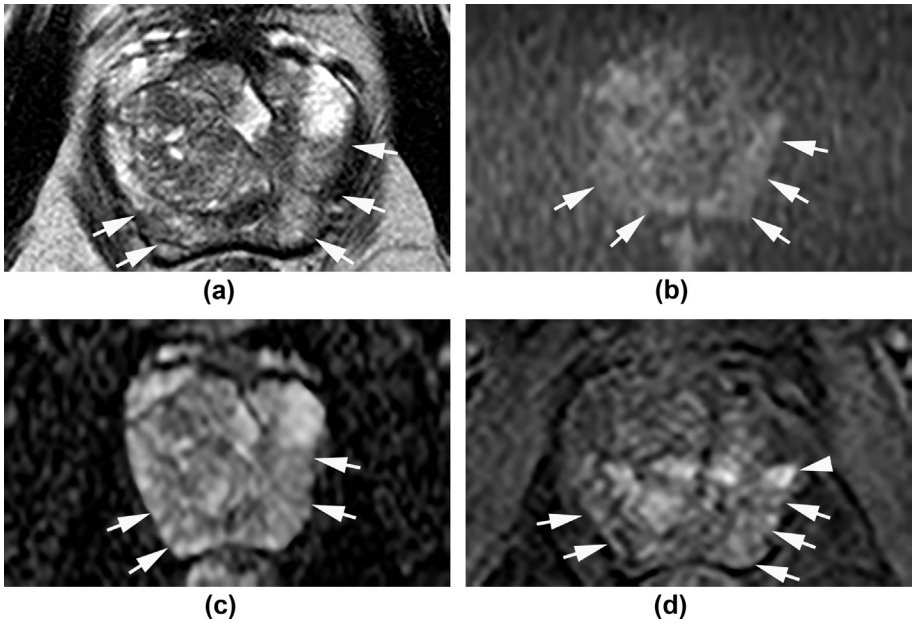

Figure 11 mpMRI description: (a) axial T2W MRI demonstrates diffuse and patchy T2 signal hypo-intensities in basal PZ (arrows). (b) These corresponds to diffuse signal hyper-intensities on axial b=2,000 s/mm^2 DWI bilaterally (arrows) and indistinct hypo-intensities on axial ADC map (c) bilaterally in the PZ (arrows). (d) On axial DCE-MRI, the low T2 signal abnormalities in the PZ are showing diffuse early enhancement (arrows); bilateral sub-capsular enhancement is observed with a more focal area of enhancement at 3 o'clock in the PZ (arrowhead). PI-RADS v2.1 interpretation: using PI-RADS v2.1, there is no distinct area that is markedly hypo-intense on the dominant ADC map and no corresponding hyper-intensity on b=2,000 s/mm^2 DWI; this corresponds to a PI-RADS 2 score category description. Likert assessment: this mpMRI, in particular the PZ, scored Likert score of 3 due to the diffuse bilateral signal changes with accompanying bilateral early capsular enhancement on DCE-MRI. A small volume of significant cancer could be present anywhere in the PZ. Histology: histology results confirmed the presence of Gleason 3+4 and a cancer core length of 3 mm at the 3 o'clock site of focal enhancement.

v2.1, a suspicious lesion in the AFMS should be assessed using either the criteria for PZ or TZ, depending on the zone where the lesion is most likely to be originating from [20]; however, it is also acknowledged that differentiating the origin of a suspicious lesion in the AFMS is not always certain, which can act to limit the PI-RADS evaluation of the AFMS.

In the TZ, the Likert assessment will be concordant with PI-RADS v2.1 scoring system for a T3a stage lesion, i.e. when bulging lesions or lesions with capsular invasion or any extra-prostatic disease are present. Cancer foci scoring PI-RADS 5 will almost certainly be high enough probability to correspond to a Likert assessment score 5 (allowing for a strong clinical suspicion of a confounding differential such as granulomatous prostatitis); however, high probability Likert 5 lesions less than 1.5 cm in size and with no invasive features will correspond to PI-RADS category 4. The following cases aim to illustrate the above.

Case 4

Clinical information: Fig 4 shows axial prostate mpMRI images of a 52-year-old man with presenting PSA of 5.2 ng/ml, prostate volume of 34 cm^3, and PSA density of 0.15 ng/ml^2.

Case 5

Clinical information: a 70-year-old man with a presenting PSA of 3.9 ng/ml, prostate volume of 67 cm^3, and a PSA density of 0.06 ng/ml^2. Fig 5 shows axial images of his prostate mpMRI.

Case 6

Clinical information: Fig 6 shows axial prostate mpMRI images of a 68-year-old man with presenting PSA of 10.5 ng/ml, prostate volume of 90 cm^3, and a PSA density of 0.12 ng/ml^2.

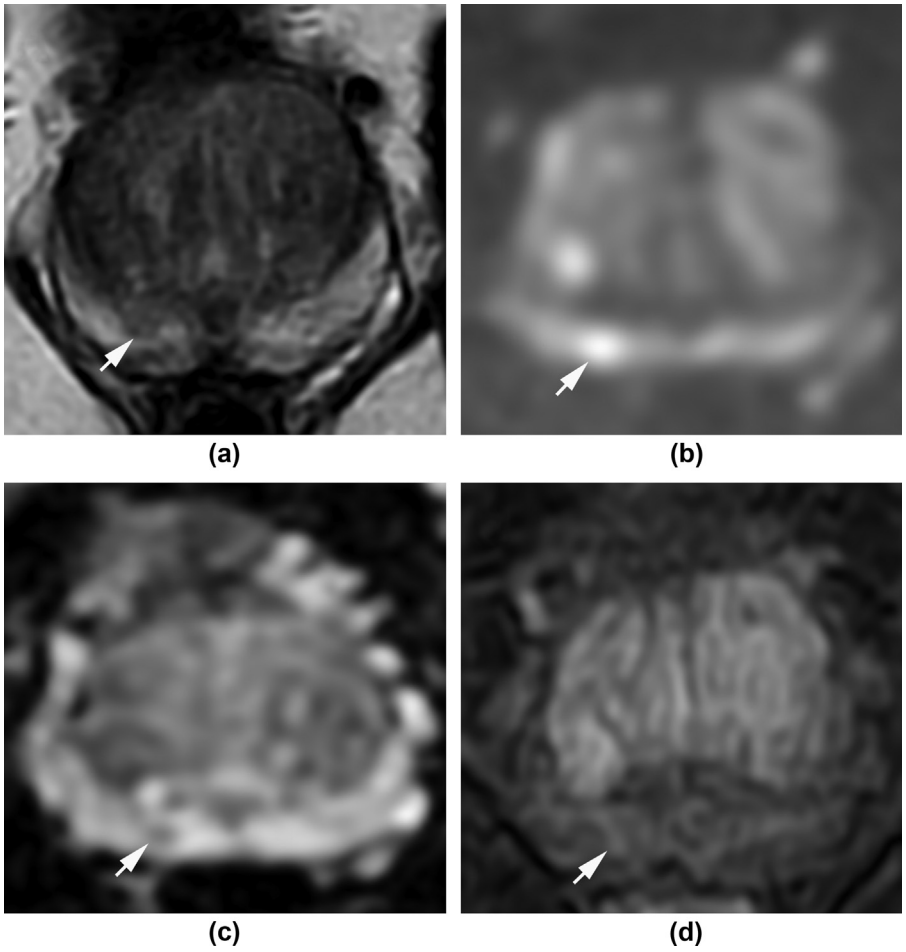

Figure 12 mpMRI description: (a) axial T2W MRI depicts a nodular low signal intensity (arrow) and a corresponding increased b=2,000 s/mm^2 DWI signal intensity (b) and hypo-intensity on ADC map (c) in the mid-gland (arrows). The lesion shows minimal enhancement on axial DCE-MRI (d) (arrow). PI-RADS v2.1 interpretation: this lesion scored either a 3 or 4 on PI-RADS v2.1. Although the lesion shows markedly increased signal intensity on DWI, whether the ADC reduction is markedly hypo-intense is subject to opinion. If markedly hypo-intense, a score of 4 would be appropriate, or if not markedly (moderate/mild hypo-intensity only), then without contrast enhancement a score of 3 would be correct. Likert assessment: this lesion was attributed a score of 2 upon Likert assessment because of its heterogeneous T2 signal and position at the TZ/PZ border. Histology: the TPM biopsy did not demonstrate any sites positive for prostate carcinoma.

Case 7

Clinical information: a 55-year-old man with presenting PSA of 6.3 ng/ml, prostate volume of 26 cm^3, and a PSA density of 0.24 ng/ml^2 whose axial prostate mpMRI images are shown in Fig 7.

Focal enhancement

Focal early enhancement within the PZ can be indicative of tumour presence, even with mild changes on other accompanying sequences.[39–41] The following cases illustrate examples where focal enhancement has been helpful in demonstrating the presence of tumour.

Case 8

Clinical information: a 60-year-old man with presenting PSA of 5.6 ng/ml, prostate volume of 44 cm^3, and PSA density of 0.13 ng/ml^2 whose axial prostate mpMRI images are shown in Fig 8.

Case 9

Clinical information: a 62-year-old man with presenting PSA of 6.5 ng/ml, prostate volume of 37 cm^3, and PSA density of 0.18 ng/ml^2 whose axial prostate mpMRI images are shown in Fig 9.

Case 10

Clinical information: a 61-year-old man with presenting PSA of 6.8 ng/ml, prostate volume of 36 cm^3, and PSA density of 0.19 ng/ml^2 whose axial prostate mpMRI images are shown in Fig 10.

Case 11

Clinical information: Fig 11 shows axial prostate mpMRI images of a 60-year-old man with presenting PSA of 6.8 ng/ml, prostate volume of 30 cm^3, and a PSA density of 0.23 ng/ml^2.

Case 12

Clinical information: a 69-year-old man with presenting PSA of 3.8 ng/ml, prostate volume of 38 cm^3, and PSA density of 0.10 ng/ml^2. Fig. 12 shows his axial prostate mpMRI images.

Post-treatment

The following cases will discuss patients in the post-treatment setting. In PI-RADS v2.1, no recommendation is made on how to categorise lesions post-therapy. Below we discuss two cases post-radiotherapy and post-high-intensity focused ultrasound (HIFU) therapy.

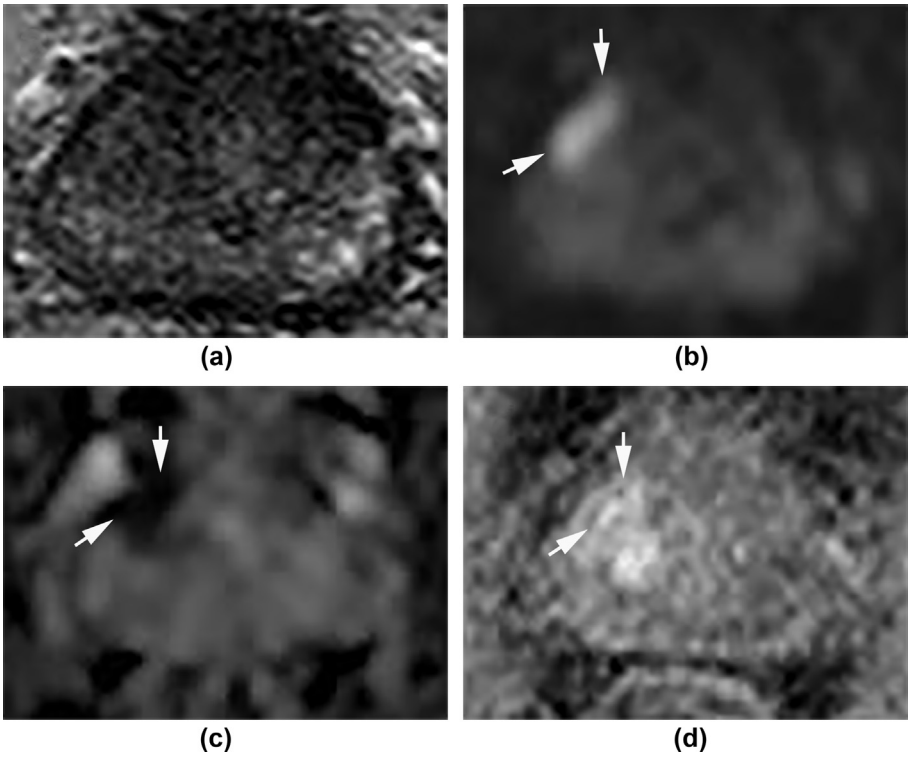

Figure 13 Post-radiotherapy mpMRI description: (a) there is generalised low signal intensity on axial T2W MRI throughout the gland in keeping with treatment effect. (b) Axial b=2,000 s/mm^2 DWI shows an area of increased signal intensity within the PZ at the right apex between 6 and 7 o'clock (arrows) with corresponding hypo-intense focus on axial ADC map (c) (arrows). (d) There is also a probable focal area of early enhancement on axial DCE-MRI, associated with elevated signal intensity on b=2,000 s/mm^2 DWI and reduced signal intensity on ADC map (arrows). PI-RADS v2.1 interpretation: PI-RADS v2.1 is not applicable in post-treatment settings so a PI-RADS score cannot be given. Likert assessment: given the appearance of DWI, DCE and T2W MRI in right apical PZ, this was scored as Likert score 4 and was targeted at biopsy. Histology: targeted biopsy confirmed the presence of Gleason 3+4 prostate adenocarcinoma with maximum core length of 6 mm.

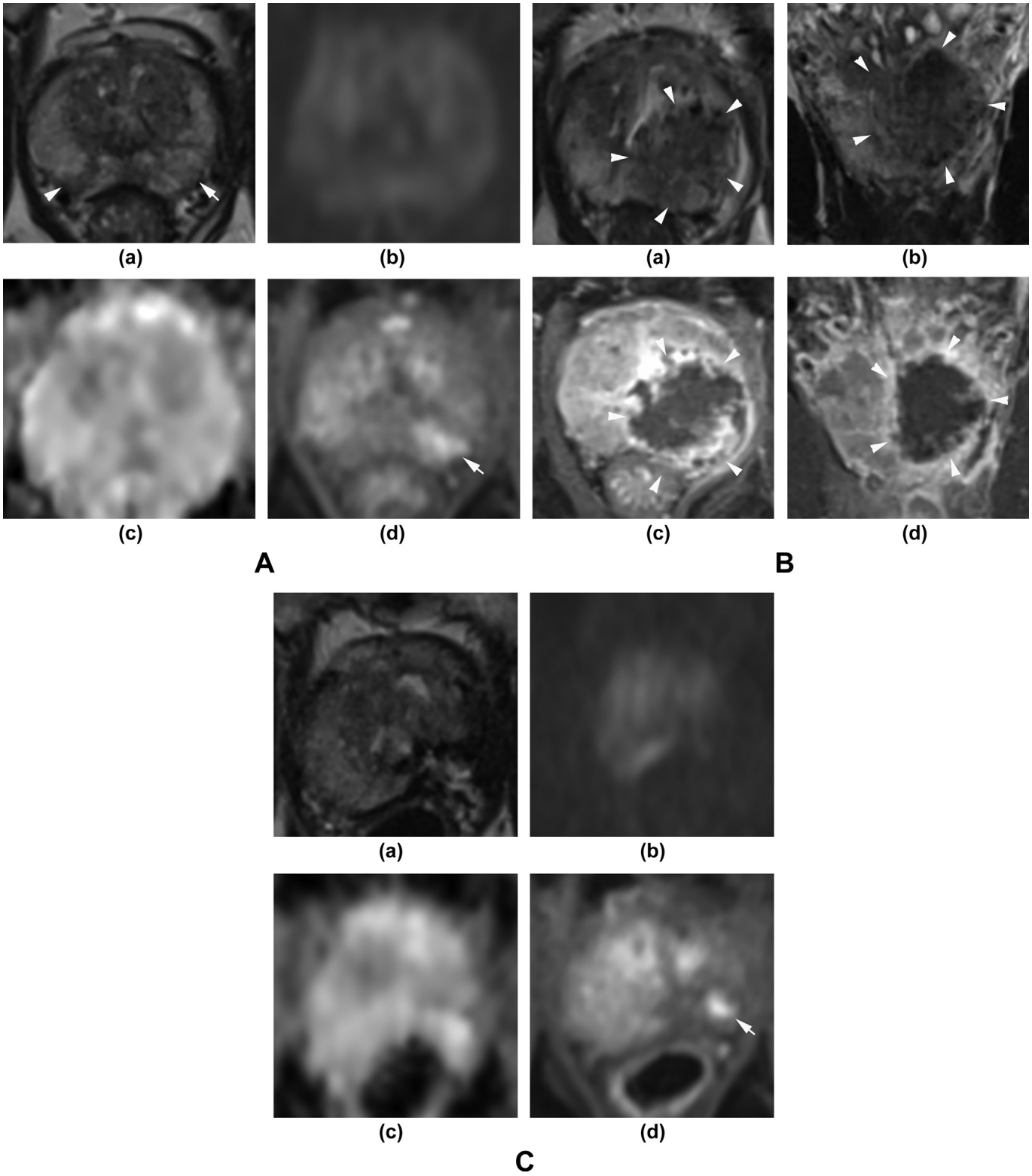

Figure 14 (A) mpMRI description: (a) There is a patchy low T2 signal intensity in the right and left posterior medial PZ at the mid-gland level, more prominent on the right. There are no corresponding changes on axial b=2,000 s/mm^2 DWI (b) and ADC map (c). (d) Axial DCE-MRI shows an area of early enhancement in the left posterior medial PZ at the mid-gland level between 4 and 5 o'clock (arrow). PI-RADS v2.1 interpretation: the left PZ in the pre-treatment setting corresponds to a DWI score of 1 as no abnormal b=2,000 s/mm^2 DWI and ADC map lesion were noticed. This corresponds to an overall score of 1 regardless of T2W and DCE-MRI findings. Likert assessment: given the patchy hypo-intensities on T2W MRI and corresponding earl enhancement on DCE-MRI in the left posterior medial PZ, the presence of significant cancer cannot be ruled out and the scan score a 3 on Likert assessment. Histology: Gleason 4+3 on the left posterior medial PZ, 2 mm maximum cancer core length. (B) mpMRI description: coronal (a, b) T2W and (c, d) DCE MRI demonstrate an ablation zone measuring 2.5×2.9×3.2 cm, which covers the posterior

Post-radiotherapy

Case 13

Clinical information: a 62-year-old man with presenting PSA of 5.2 ng/ml, prostate volume of 32 cm^3, and PSA density of 0.16 ng/ml^2. Initial results from biopsy and scan showed T2c N0 Mx prostate carcinoma Gleason 4+3. Treatment: Patient went onto receive radical prostate radiotherapy with 60 Gy delivered in 20 fractions over 4 weeks. Following his treatment, his PSA gradually went up and reached 6.5 ng/ml and a follow-up MRI (Fig 13) scan scheduled nearly 10 years following his EBRT.

Post-HIFU therapy

Case 14

Clinical information: a 62-year-old patient with PSA of 4.6 ng/ml, prostate volume of 26 cm^3, and PSA density of 0.18 ng/ml^2. Fig 14a–c show pre-treatment, early post-treatment and late post-treatment scans, respectively. Fig 14b shows prostate mpMRI axial images of the patient 6 months post-HIFU treatment. Fig 14c shows prostate mpMRI axial images of the patient 18 months post-HIFU treatment.

Histology

Both PI-RADS and Likert assessment systems are applied with the intention of detecting "clinically significant" prostate cancer. As such, both systems have a low sensitivity for detection of low-volume Gleason 3+3 disease (low-risk prostate cancer).[18] For PI-RADS v2.1, clinically significant cancer is defined on pathology/histology as Gleason score $\geq$7 (including 3+4 with prominent but not predominant Gleason 4 component), and/or volume $\geq$0.5 ml, and/or extra prostatic extension (EPE). Likert assessment is usually scored for the presence of any Gleason pattern 4 tumour, and/or a volume disease $>$ 0.2 ml. The differences in threshold may account for some of the discrepancies between lesion scores. In addition, scoring of background signal changes is recommended by Likert as these may act to mask small volume Gleason pattern 4 tumour.[27]

Discussion

This review of case-based examples illustrates the differences in the interpretation of prostate mpMRI with PI-RADS v2.1 and Likert assessment. Both scoring systems use similar lexicons and descriptive terms relating to mpMRI interpretation for diagnosis and staging, as described in PI-RADS v2.1; however, Likert assessment differs from PI-RADS v2.1 scoring mainly because no dominant sequence rule is used to arrive at an overall score (all pulse sequences are used equally in combination), clinical parameters influence the final radiological Likert score, and Likert assessment is applicable in some instances where PI-RADS v2.1 is not, for instance in active surveillance follow-up, in post-treatment settings, and when a lesion's zone of origin is uncertain, e.g., at the TZ–PZ interface. Although previous studies have compared the Likert assessment to PI-RADS v1[33,42] or summed score of PI-RADS v1,[32] no study has yet compared Likert assessment and PI-RADS v2.1.

The final Likert assessment and PI-RADS v2 scores do not always correspond. This may be explained by some unmet challenges identified with PI-RADS v2.1. Firstly, in PI-RADS v2.1, a DWI score of 5 is required in the TZ to upgrade a lesion scored equivocal (score 3) to a score 4. The reason why a DWI score of 4 is not used is questionable. Furthermore, recent evidence demonstrating the discriminative power of DWI in detecting clinically significant cancer in the TZ[19,43–47] disputes its secondary role in PI-RADS v2.1. Secondly, in the PZ if DWI fails for technical reasons, morphological T2W MRI is promoted to be the dominant sequence, bypassing the designated secondary sequence of DCE-MRI. Although this may be purely semantic, in order to derive a five-point score, a combination of T2W and DCE-MRI has been shown to increase diagnostic accuracy in these cases.[47,48] Thirdly, an empirical size criterion of 15 mm is used to differentiate between a PI-RADS score of 4 and 5, although lesion diameter only shown a modest correlation with Gleason grade and significant cancer detection.[44,49] Furthermore, the assessment of post-treatment mpMRI examinations is lacking in PI-RADS v2.1 and so these will always default to being scored with Likert assessment.

The secondary role of DCE-MRI in PI-RADS v2.1 may account for some of the discrepancy of PI-RADS scoring with the overall Likert-scoring. Although DCE-MRI is increasingly being questioned,[16,50–55] some authors still maintain its importance.[5,39,56,57] Studies analysing DCE-MRI show disparity in their technical conduct and protocol with variable temporal and spatial resolutions making comparison amongst them difficult.[58,59] As functional wash-out curve characteristics on DCE-MRI are no longer recommended,[4] DCE-MRI with high temporal resolution (of $<$7 seconds) may not be necessary.[19] Instead, DCE-MRI with higher spatial resolution can be acquired in order to improve lesion conspicuity, better visualisation of the prostatic capsule, urethra, and PZ–TZ boundary, and further helping in overall gland staging. In addition, many studies examining the use of DCE-MRI have been scored using PI-RADS v2 whereby DCE-MRI already holds a secondary role, therefore introducing a reader bias in the evaluation of the distinct

two-thirds of the left hemi gland. (C) mpMRI description: (a) axial T2W MRI, (b) axial b=2,000 s/mm^2 DWI and (c) ADC map demonstrating no discernible abnormality. (d) There is a 0.12 ml focus of early enhancement in left PZ at the treatment site at apex to mid-gland between 3–4 o'clock on DCE-MRI (arrow). PI-RADS v2.1 interpretation: no recommendation is available for post-treatment assessment of prostate mpMRI in PI-RADS v2.1 and so this mpMRI can only be scored with Likert assessment. Likert assessment: the early enhancement at the site of previous treatment is suspicious for residual/recurrent tumour and scores 4 on Likert assessment. Histology: biopsy of the left PZ focus of enhancement shows prostate adenocarcinoma Gleason 4+3 with maximum core length of 7 mm.

contribution of DCE-MRI. The fact that cancer detection rate of DCE-MRI on its own is approximately only approximately 10% limits the statistical power to demonstrate its added benefit, although DCE-MRI was found to add value to cancer detection in up to 30% overall in the prostate, including 25% of cases in the PZ, and 77% in TZ.[57] Dismissing DCE-MRI would compromise the role of mpMRI as an accurate diagnostic tool.

Lastly, unless the reader who uses PI-RADS makes an explicit effort to avoid all clinical information (such as age, PSA, PSA-density, etc.), then the score risks being influenced by these and deviates from PI-RADS reporting framework.

Conclusions

Reporting prostate mpMRI is complex. Translating the expertise of radiologists from a Likert assessment into a simple standardised scoring system is challenging, but important. PI-RADS represents a promising scoring system to unify practice in reporting the likelihood of prostate cancer on mpMRI. Highlighting differences between Likert assessment and PI-RADS should prompt further scientific evidence to build upon future improved versions of the PI-RADS.

Conflict of interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crad.2019.08.020.

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