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RESEARCH

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# Diagnostic accuracy of the different pulse sequences of multi-parametric prostate MRI in the diagnosis of prostate cancer in the peripheral and transitional zones

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## Abstract

**Background** One of the most prevalent malignancies among males is prostate carcinoma (PCa). For the diagnosis of PCa, multiparametric magnetic resonance imaging (mpMRI) constitutes by far the most accurate imaging technique. The PI-RADS v2.1 indications for dynamic contrast enhanced (DCE) sequence include identifying PI-RADS score 3 lesions, as clinically significant prostate carcinoma, aiding evaluation of examinations having poor quality of T2 as well as diffusion weighted imaging (DWI), and helping readers having relatively reduced expertise. Most articles don't provide outcomes pertaining to these indications, which weakens their conclusions. All MRI scans, even those with low quality T2 or DWI, were included in our study. Additionally, special emphasis on assessing peripheral zone lesions was made. Our objective was to assess the diagnostic accuracy of the various mpMRI pulse sequences, including the T2 sequence, diffusion and apparent diffusion coefficient (ADC) sequences, both T2 and diffusion sequences (biparametric (bp) MRI), DCE sequence, and the entire examination (mpMRI), in the diagnosis of PCa in the peripheral as well as the transitional zone using PI-RADS version 2.1 scoring system, once when malignant lesions are considered as those having PI-RADS scores 4 and 5 and once when PI-RADS categories 3, 4 and 5 were regarded as malignant.

**Results** In the assessment of peripheral zone lesions, when PI-RADS categories 3, 4, and 5 were considered malignant, both bpMRI and mpMRI showed similar sensitivity (94.29%) and diagnostic accuracy (77.78%) while when considering scores 4 and 5 malignant, mpMRI demonstrated increased diagnostic accuracy and sensitivity but lower specificity (sensitivity was 82.86%/60%, specificity was 80%/100%, and diagnostic accuracy was 82.22%/68.89% for mpMRI/bpMRI test comparaison). Both bpMRI and mpMRI had similar sensitivity (95.83%) and diagnostic accuracy (71.05%) when PI-RADS categories 3, 4, and 5 were regarded as malignant; however, mpMRI demonstrated better diagnostic accuracy and sensitivity considering scores 4 and 5 malignant (sensitivity was 77.08% for mpMRI compared to 60.42% for bpMRI and diagnostic accuracy was 82.89% for mpMRI compared to 75% for bpMRI).

**Conclusions** Both bpMRI and mpMRI demonstrated similar diagnostic accuracy when PI-RADS categories 3, 4, and 5 were taken into account as malignant while mpMRI had higher diagnostic accuracy considering categories 4 and 5 malignant.

**Keywords** Prostate carcinoma, Multiparametric MRI, Biparametric MRI, Contrast media

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## Background

One of the most prevalent solid organ tumors in males is prostate carcinoma (PCa). Digital rectal examination, prostate-specific antigen (PSA) test, and a subsequent transrectal, ultrasound-guided (TRUS) prostate biopsy were formerly done to detect prostate cancer [1]. This biopsy approach has a high probability of false-negative results for significant cancer as well as an overreporting of insignificant cancer. As a result, men with low-risk disease were overtreated, with effects that were projected to be as high as 10% for radical prostatectomy and 45% for radical radiotherapy [2]. In individuals with increased PSA, magnetic resonance imaging (MRI) is now increasingly being done prior to biopsy. By directing biopsies to worrisome lesions, multiparametric (mp) MRI, which incorporates T2, diffusion-weighted (DWI), and dynamic contrast-enhanced (DCE) sequences, boosts reliability while lowering the chance of pointless procedures or false-negative results [3]. The Prostate Imaging—Reporting and Data System (PI-RADS) version 2.1 standards are now used to assess and report prostate MRI examinations. It states that DCE is only used to evaluate suspicious lesions in the peripheral zone (PZ), however it has no place in the assessment of the transitional zone (TZ) [4]. DCE may therefore, in the vast majority of situations, be inessential in the setting of high quality T2 and DW imaging. Omitting DCE could have a number of benefits, such as avoiding the side effects of gadolinium agents and cutting down on examination time and expense, which could promote more widespread prostate MRI use [3]. The PI-RADS v2.1 indications for DCE include: (a) identifying PI-RADS category 3 lesions as clinically significant prostate carcinoma; (b) aiding reading of examinations having poor quality of T2 as well as DWI sequences; and (c) helping readers having relatively little expertise reading prostate MRIs. Those indicators received support as new quality criteria for prostate MRI, and they became crucial when talking about the usefulness of DCE. The majority of studies that attempt to address the main research issue ignore results or comments pertaining to these indications, which weakens their conclusions when considered separately and when combined in systematic reviews [5]. All MRI scans, even those with poor quality T2 or DWI, were included in the study. Additionally, special emphasis on assessing peripheral zone lesions was made.

The objective of our work was to assess the diagnostic accuracy of the various pulse sequences used in multiparametric prostate MRI, including the T2 sequence, diffusion and apparent diffusion coefficient (ADC) sequences, both T2 and diffusion sequences (biparametric (bp) MRI), DCE sequence, and the entire examination (mpMRI), in identifying prostate cancer in the peripheral as well as the transitional zones depending on PI-RADS version 2.1 scoring system, once when malignant lesions are considered as those having PI-RADS scores 4 and 5 and once when PI-RADS categories 3, 4 and 5 are regarded as malignant.

## Methods

Our study was accepted by the local research Ethical Committee (code: MD-95–2021). An informed consent was acquired from each patient. This prospective analytical observational study was carried on a convenient sample of 63 adult male subjects with suspected diagnosis of prostatic carcinoma (raised PSA > 4 ng/ml and/or abnormal digital rectal examination) and those formerly treated for prostatic carcinoma now presenting with biochemical recurrence (BCR) (Based on the Phoenix criterion, BCR is defined as an absolute rise in PSA value of 2 ng/ml above nadir (i.e., the lowest after-treatment PSA level) following radiation therapy) during the time from April 2021 till October 2022.

### Exclusion criteria

- o Patients having absolute contraindications to MRI as patients with pacemakers.
- o Patients having contraindications to contrast injection as patients suffering from impaired renal function with eGFR‹30 ml.

All patients were subjected to medical history taking; data was obtained by reviewing medical records whenever feasible in addition to direct patient interviewing (age and PSA level were recorded) as well as complete physical examination; full physical examination was carried out by the clinician (W.A.E) for all subjects.

### Magnetic resonance imaging

All patients had prostate MRI in Radiology department using a Philips Achieva, Netherland (1.5 Tesla) superconducting magnet. All subjects were examined in the supine position, head first and an abdominal eight-channel surface phased array coil was applied. The following sequences were acquired: (1) T2-weighted images of the prostate in the axial, sagittal and coronal planes (repetition time (TR) 3000–5000 msec, echo time (TE) 120 msec, slice thickness 4 mm, interslice gap 0.5 mm, field of view (FOV) 200 mm, and matrix 200 × 200). (2) Diffusion-weighted images (TR 2700 msec, TE 85 msec, slice thickness 4 mm, interslice gap 0.5 mm, FOV 280 mm,

and matrix 92 × 92) and apparent diffusion coefficient maps (the following b-values were acquired: b0, b500 and b1000 s/mm$^2$. High b value (b 1400) as well as apparent diffusion coefficient maps were automatically calculated). and (3) Axial dynamic contrast enhanced images following gadolinium injection at a dose of 0.1 mmol/kg (TR 19 msec, TE 1.93 msec, slice thickness 4 mm, no interslice gap, FOV 310 mm, and matrix 280 × 176).

#### Image interpretation

Different pulse sequences were reviewed by 2 radiologists (M.A.S and A.A.H) having 5 and 14 years experience in radiology blinded to the clinical and pathological data. The two radiologists analyzed each sequence separately, and then, subsequently on the same setting, the biparametric and multiparametric MR images were analyzed. The two readers viewed the cases separately, the inter-reader agreement was calculated and in the cases where differences in scoring were found, the two readers viewed the cases together and a consensus was reached. Prostate volume was calculated by multiplying the transverse, anterior-to-posterior, and cranio-caudal dimensions x 0.52 and recorded in cm$^3$. Site of lesion was determined whether within the peripheral or the transitional zone as well as at the base, apex or mid gland level either on the right or left side. Each lesion was given a score according to PI-RADS version 2.1 [4]. Neurovascular bundle affection was assessed. Seminal vesicle infiltration was determined as low signal onT2WI within the seminal vesicle, lesion position at the prostate base, loss of normal tubular architecture of the seminal vesicle and related diffusion restriction. Capsular invasion best evaluated on T2WI as wide contact of the lesion with the prostatic capsule, bulging of the capsule beyond the anticipated borders of the gland, obliteration of the rectoprostatic angle and asymmetry of the neurovascular bundles.

#### Final diagnosis

Results of MRI were compared to biopsy results which was performed following the MRI study by a specialized urologist (standard 12-core random systematic biopsy as well as biopsy from detected MRI lesions (having PIRADS score ≥ 3)). Based on PI-RADS v2.1, clinically significant prostate carcinoma (csPCa) is determined by histopathology when the lesion is of Gleason score ≥ 7.

#### Statistical methods

The statistical package for the social sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA) was used to code and enter the data. Quantitative data were analysed using the mean, standard deviation, median, minimum, and maximum; categorical data were analysed using frequency (count) and relative frequency (%). To compare quantitative variables, the non-parametric Mann-Whitney test was used [6]. To compare categorical data, the chi square ($\chi 2$) test was used. The exact test was used in its place when the expected frequency was less than 5 [7]. Standard diagnostic indices like sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic efficacy were calculated [8], as stated by (Galen, 1980). Receiver operating characteristic curves were visually inspected and the area under the curve was reported.

## Results

Our study involved 63 male patients having a mean age ± SD of 66.67 ± 12.17 years. The patients had a mean PSA level ± SD of 36.04 ± 17.01 ng/ml. The patients had a mean prostate volume ± SD of 77.19 ± 52.13 cm$^3$ as calculated by MRI. Of the 63 patients, only one case had recurrent prostate carcinoma following radiotherapy. A total number of 76 lesions were identified by MRI (average 1.2 lesion/patient); 39 lesions (51.3%) were found

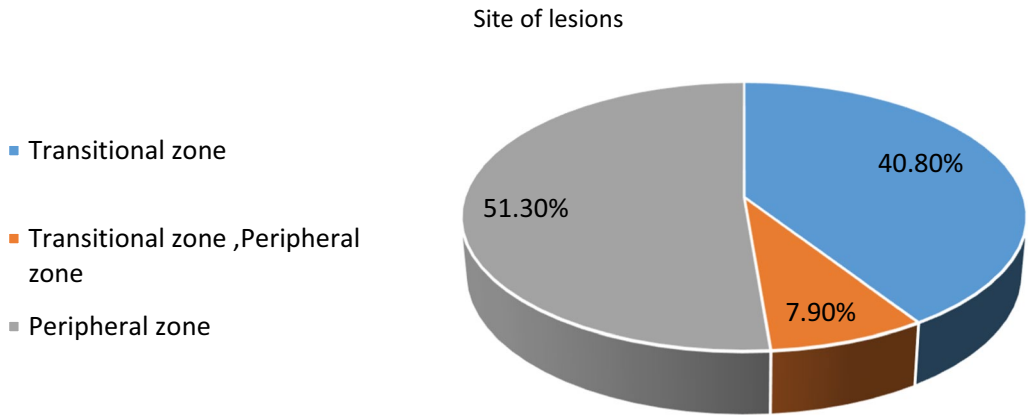


**Fig. 1** Site of lesions

in the peripheral zone, 31 lesions (40.8%) in the transitional zone and 6 lesions (7.9%) were occupying both the peripheral and transitional zones as shown in Figure 1. Fourteen lesions (18.4%) were situated in the right prostate apex, 27 (35.5%) in the right mid prostate and 19 (25%) in the right prostate base. Twenty two lesions (28.9%) were found in the left prostate apex, 45 (59.2%) in the left mid prostate and 26 (34.2%) in the left prostate base. Fourteen lesions (18.4%) showed affection of the neurovascular bundle, 13 lesions (17.1%) showed seminal vesicle infiltration and 17 lesions (22.4%) showed capsular invasion. Prostate cancer was pathologically proved in 48 lesions (63.2%) with all of these cancers being adenocarcinoma; 29 lesions (38.2%) were clinically significant prostate carcinoma having a Gleason Score ≥ 7 as shown in Figure 2. In the other 28 lesions with no PCa, pathological analysis of 27 of them proved to be benign in nature (18 having benign prostatic hyperplasia and 9 having prostatitis), the last patient was completely free of any pathologies.

The cases were viewed by two radiologists with calculated inter-reader agreement of about 94.7 % agreement. In the cases where differences in scoring were found, the two readers viewed the cases together and a consensus was reached.

Based on the assessment of bpMRI, 10 lesions were classified as having PI-RADs 1 and 2, only 2 had PCa, this PCa was pathologically proved to be of Gleason score 6 (insignificant prostate cancer), 37 lesions as PI-RADs 3, 17 were PCa, 7 of them were csPCa. Biopsies of the other 20 lesions pathologically revealed hyperplasia (13 lesions) and prostatitis (7 lesions). All 10 lesions with PI-RADs 4 were PCa, 7 of them were csPCa. All 19 lesions with PI-RADs 5 were PCa, 15 of them were csPCa (Figs. 3, 4 and 5). Based on the assessment of mpMRI, 10 lesions were classified as having PI-RADs 1 and 2, only 2 had PCa, this PCa was pathologically proved to be of Gleason score 6 (insignificant prostate cancer), 27 lesions as PI-RADs 3, 9 were PCa, 4 of them were csPCa. Biopsies of the other 18 lesions pathologically revealed hyperplasia (13 lesions) and prostatitis (5 lesions), 20 lesions as PI-RADs 4, 18 were PCa, 10 of them were csPCa. Biopsy of the other 2 lesions pathologically revealed prostatitis. All 19 lesions with PI-RADs 5 were PCa, 15 of them were csPCa (Figs. 3, 4 and 5) as shown in Table 1.

Considering PI-RADS scores 3, 4, and 5 malignant, biparametric and multiparametric MRI demonstrated comparable sensitivity and diagnostic accuracy. Both had 95.83% sensitivity, 28.57% specificity, 69.7% PPV, 80% NPV, and 71.05% diagnostic accuracy. When malignant lesions were regarded as those having categories 4 and 5 only, mpMRI had higher sensitivity and diagnostic accuracy. Multiparametric MRI had 77.08% sensitivity, 92.86% specificity, 94.87% PPV, 70.27% NPV, and 82.89% diagnostic accuracy while biparametric MRI had 60.42% sensitivity, 100% specificity, 100% PPV, 59.57% NPV, and 75% diagnostic accuracy as shown in Table 2. The area under the curve (AUC) was higher for mpMRI compared to bpMRI (0.875 versus 0.836, $p < 0.001$) as shown in Figure 6.

**For lesions located at the peripheral zone**, when PI-RADS categories 3, 4, and 5 were considered malignant, both bpMRI and mpMRI showed similar sensitivity (94.29%) and diagnostic accuracy (77.78%) while when considering scores 4 and 5 malignant, mpMRI demonstrated increased diagnostic accuracy and sensitivity but lower specificity (sensitivity was 82.86% for mpMRI compared to 60% for bpMRI, specificity was 80% for mpMRI

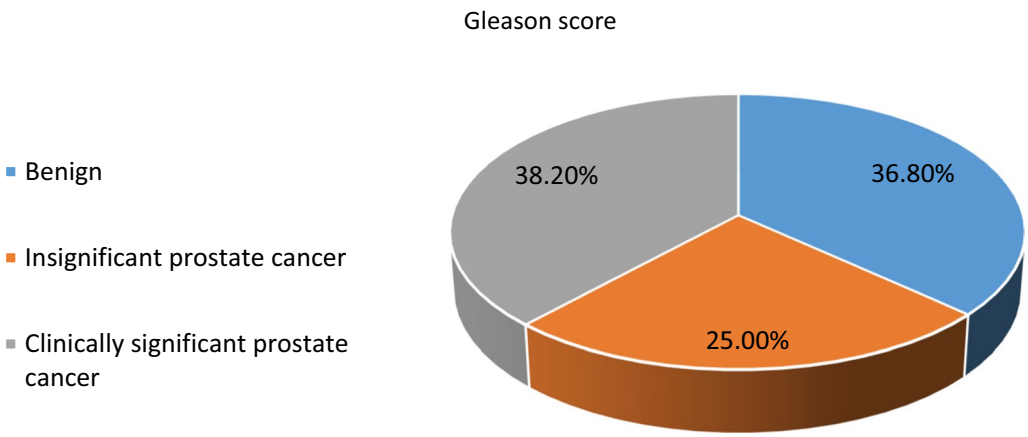


**Fig. 2** Gleason score in the study population

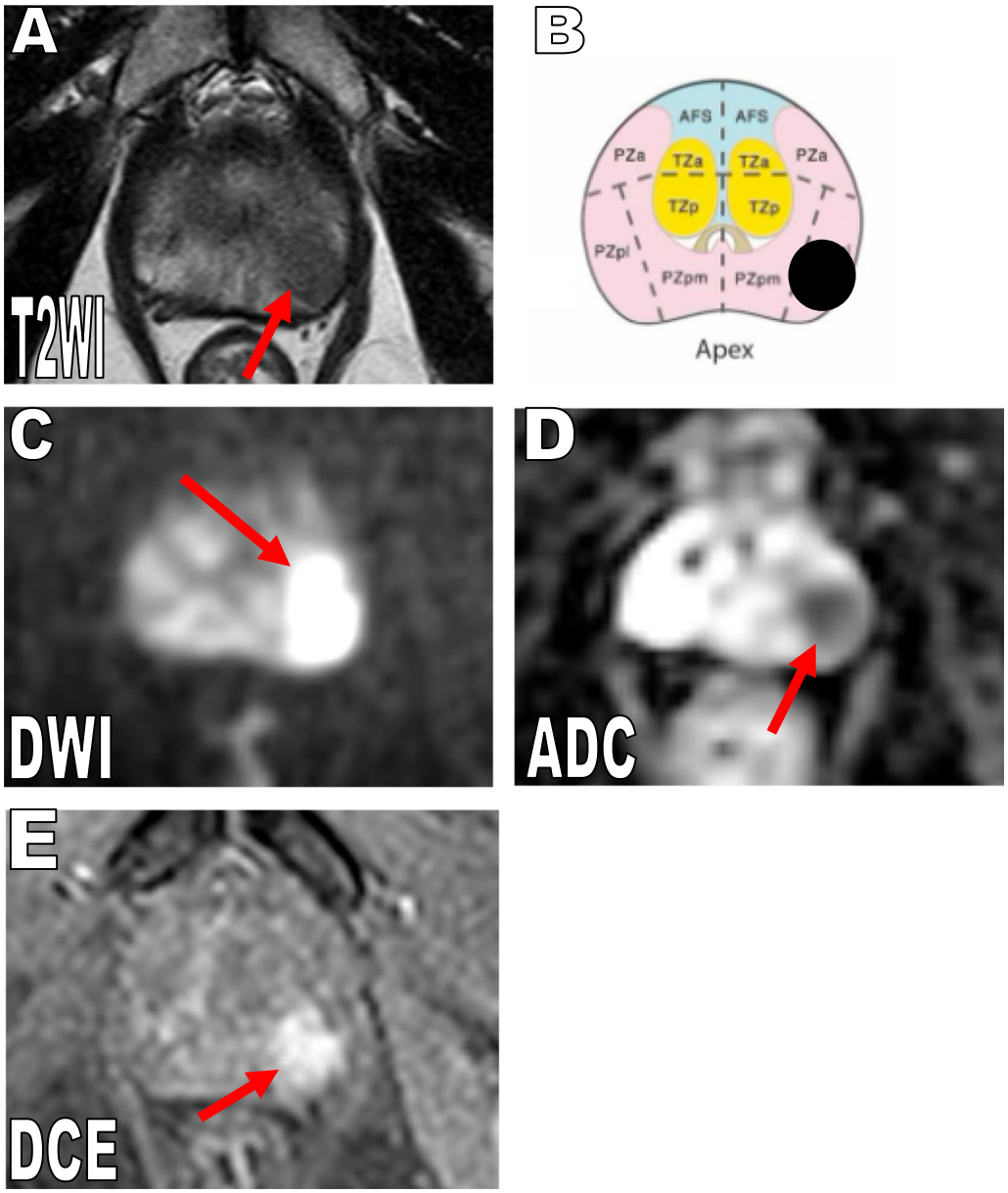


**Fig. 3** A 73 year old male patient having serum PSA level of 56 ng/ml and gland volume of 59.1 cm3. **A** Axial T2WI demonstrates a focal lesion of moderate hypointensity (arrow) involving the peripheral zone at the left prostate apex and mid gland levels measuring about 1.7 × 1.2 cm along its maximum axial dimensions (score 5). **B** showing diagramatic representation of the lesion. **C** and **D** Axial high b value DWI and axial ADC demonstrate marked high DWI and mild to moderate low ADC value (score 5), (According to bpMRI, the final PI-RADS category was 5). **E** Axial DCE demonstrates positive contrast enhancement (According to mpMRI, the final PI-RADS category was 5). Histopathology revealed prostatic adenocarcinoma of Gleason score 7 (3 + 4) at the left prostate apex and mid gland levels

compared to 100% for bpMRI, and diagnostic accuracy was 82.22% for mpMRI versus 68.89% for bpMRI). The diagnosis of prostate cancer by DWI was highly specific (specificity was 100% for DWI compared to 70% for T2) when scores 4 and 5 were taken into account as malignant. In comparison to the transitional zone, the DCE sequence demonstrated higher sensitivity in the identification of PCa in the peripheral zone (60% sensitivity in the peripheral zone compared to 47.37% in the transitional zone) as shown in Table 3.

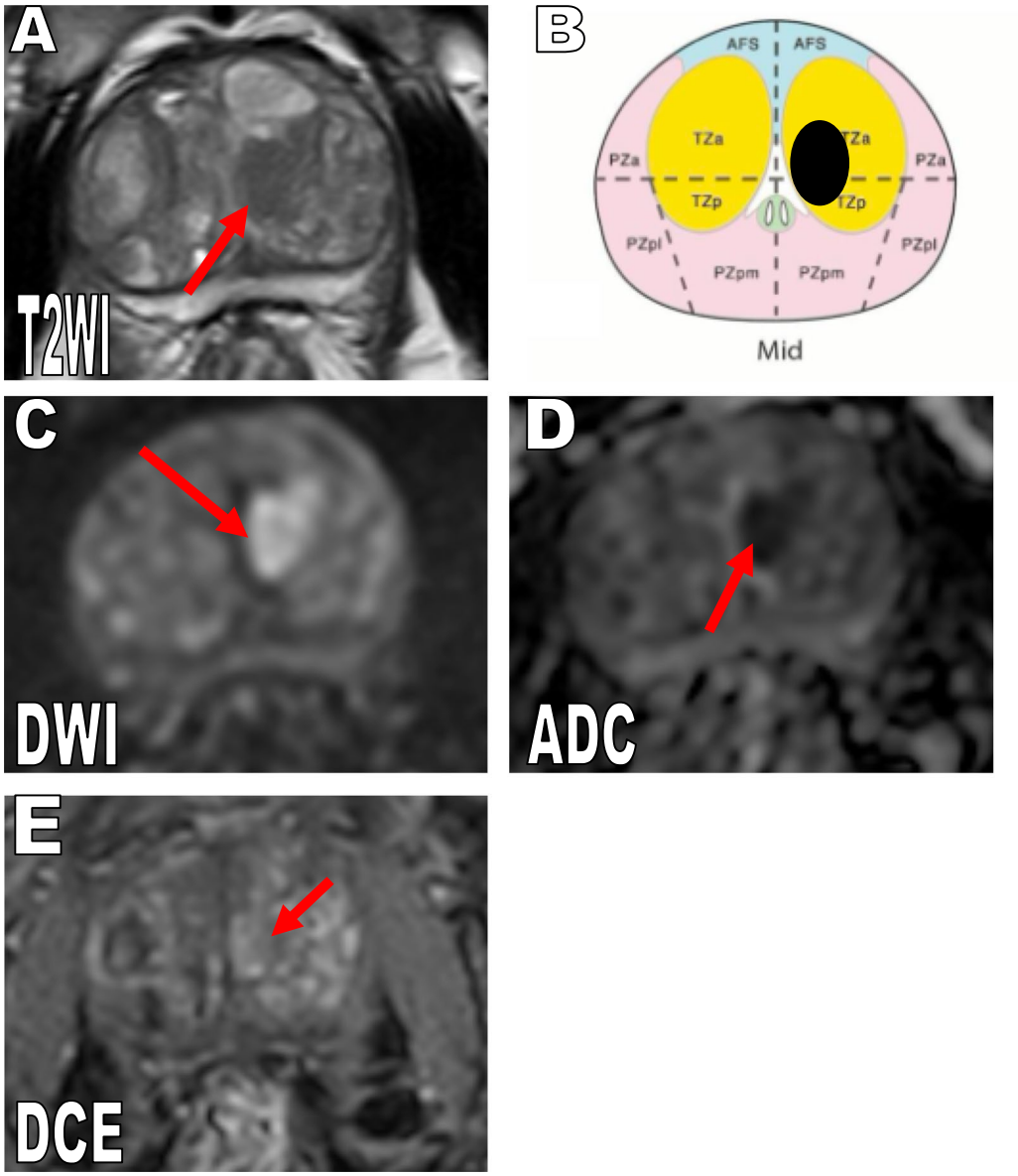


**Fig. 4** A 74 year old male patient having serum PSA level of 59 ng/ml and gland volume of 130 cm3. **A** Axial T2WI demonstrates a fairly-defined nodule of low signal with obscured margins (arrow) measuring about 1.8 × 1.2 cm along its maximum axial dimensions involving the transitional zone at the left mid gland level (score 3). **B** showing diagramatic representation of the lesion. **C** and **D** Axial high b value DWI and axial ADC demonstrate marked high DWI and marked low ADC value (score 5), (According to bpMRI, the final PI-RADS category was 4). **E** Axial DCE demonstrates positive contrast enhancement (According to mpMRI, the final PI-RADS category was 4). Histopathology showed prostatic adenocarcinoma of Gleason score 7 (4 + 3) at the left mid gland level

**For lesions located at the transitional zone**, T2 was highly specific in the detection of PCa considering PI-RADS categories 4 and 5 malignant (specificity was 100% for T2 compared to 94.44% for DWI). T2 was highly sensitive in the diagnosis of PCa regarding categories 3, 4 and 5 malignant (sensitivity was 100% for T2 compared to 94.74% for DWI) as shown in Table 4.

## Discussion

In our study, in the assessment of peripheral zone lesions, both mpMRI and bpMRI demonstrated comparable sensitivity and diagnostic accuracy considering categories 3, 4, and 5 malignant while when malignant lesions were regarded as scores 4 and 5, mpMRI showed increased

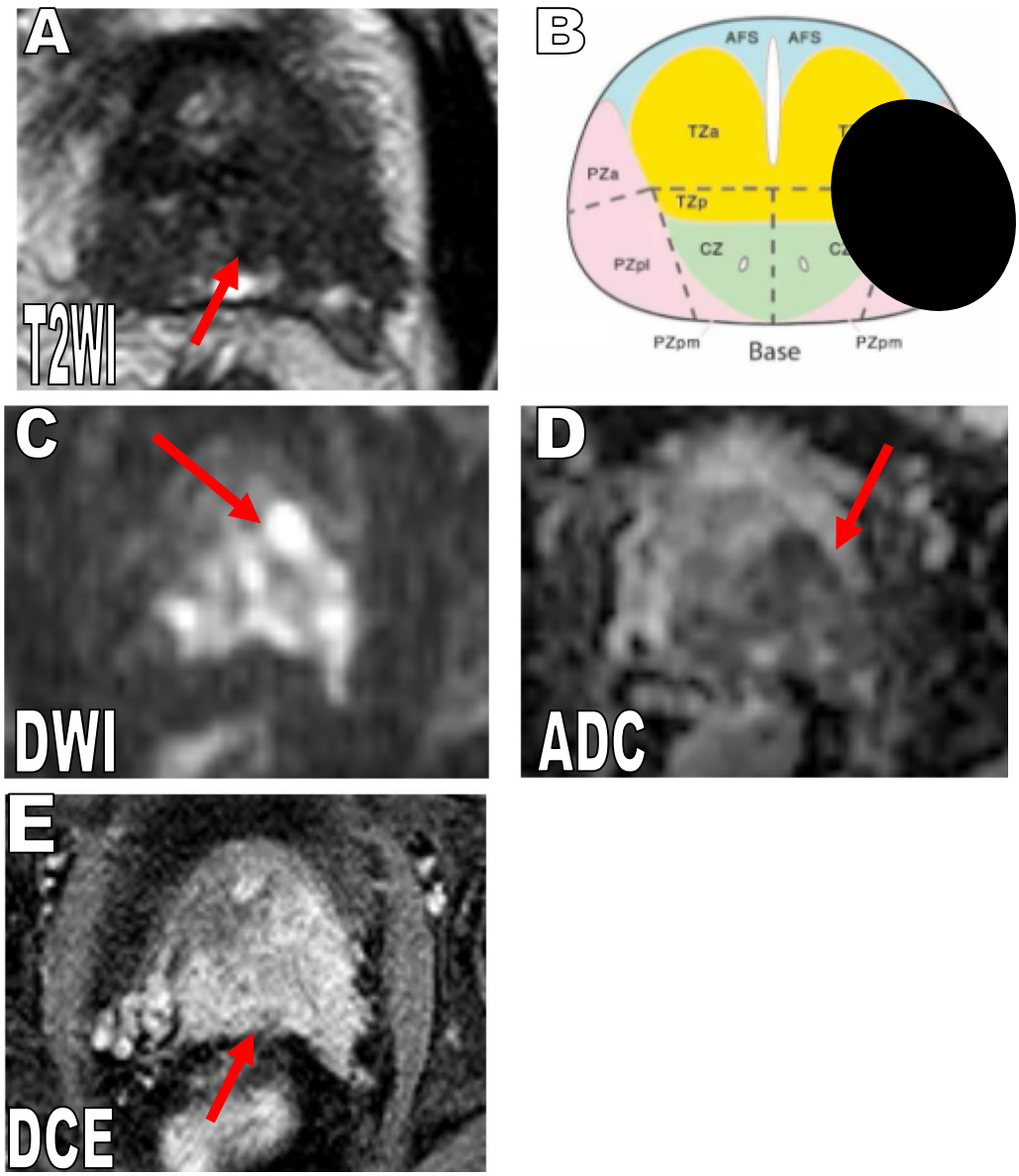


**Fig. 5** A 55 year old male patient having serum PSA level of 53 ng/ml and gland volume of 40.8 cm3. **A** Axial T2WI demonstrates ill defined focal lesions of abnormal hypointensity (arrow) involving the peripheral and transitional zones at the prostate base, mid gland and apex levels bilaterally associated with exophytic disruption of the prostatic capsule more on the left side and infiltration of the seminal vesicles and neurovascular bundles (score 5). **B** showing diagramatic representation of the lesion. **C** and **D** Axial high b value DWI and axial ADC demonstrate high DWI and low ADC value (score 5), (According to bpMRI, the final PI-RADS category was 5). **E** Axial DCE demonstrates positive contrast enhancement (According to mpMRI, the final PI-RADS category was 5). Histopathology showed prostatic adenocarcinoma of Gleason score 7 (4 + 3)

diagnostic accuracy and sensitivity but lower specificity. This conforms to the results of Zhang et al. who stated that mpMRI and bpMRI applying PI-RADS v2.1 showed comparable diagnostic effectiveness in pzPCa (specificities 54.2% versus 64.8%; sensitivities 89.1% versus 81.8%, respectively) [9].

Our study compares the diagnostic performance of the various pulse sequences of multiparametric prostate MRI using the 2019 updated PI-RADS version 2.1 in the peripheral as well as the transitional zones. We found that the diagnosis of prostate cancer in the

**Table 1** Correlation between PIRADS score and Gleason score

| | | Gleason score | | | | | |
|---|---|---|---|---|---|---|---|
| | | Benign | | Insignificant prostate cancer | | Clinically significant prostate cancer | |
| | | Count | % | Count | % | Count | % |
| PIRADS score based on T2 and diffusion sequences only (biparametric) | 1 + 2 | 8 | 80.0 | 2 | 20.0 | 0 | 0.0 |
| | 3 | 20 | 54.1 | 10 | 27.0 | 7 | 18.9 |
| | 4 | 0 | 0.0 | 3 | 30.0 | 7 | 70.0 |
| | 5 | 0 | 0.0 | 4 | 21.1 | 15 | 78.9 |
| PIRADS score (multiparametric) | 1 + 2 | 8 | 80.0 | 2 | 20.0 | 0 | 0.0 |
| | 3 | 18 | 66.7 | 5 | 18.5 | 4 | 14.8 |
| | 4 | 2 | 10.0 | 8 | 40.0 | 10 | 50.0 |
| | 5 | 0 | 0.0 | 4 | 21.1 | 15 | 78.9 |

peripheral zone by DWI was very specific when scores 4 and 5 were taken into account as malignant. In the transitional zone, T2 was highly specific in the detection of PCa considering categories 4 and 5 malignant and highly sensitive regarding categories 3, 4 and 5 malignant. In comparison to the transitional zone, the DCE sequence demonstrated higher sensitivity in the identification of PCa in the peripheral zone. Similarly Greer et al. performed validation of the PI-RADS version 2 dominant sequence and the function of dynamic contrast-enhanced imaging, DWI performed better than T2-weighted imaging in the PZ (odds ratio (OR), 3.49 vs. 2.45; $P = 0.008$). In the TZ, T2-weighted imaging performed somewhat better than DWI imaging (OR, 4.79 vs. 3.77; $P = 0.494$), but not significantly better. For PI-RADS score 2, 3, and 4 lesions, the chance of cancer diagnosis increased by 15.7%, 16.0%, and 9.2%, respectively, when adding DCE imaging to DWI imaging in the PZ (OR, 2.0; $P = 0.027$) [10].

There was a debate over the role of DCE in a number of earlier studies that assessed the added benefit of DCE to T2WI and DWI in PCa diagnosis using PI-RADS v. 2. We found that both bpMRI and mpMRI demonstrated similar sensitivity and diagnostic accuracy when malignant lesions were considered as those having PI-RADS categories 3, 4 and 5 similar to many previous studies. According to Greenberg et al., bpMRI detects prostate cancer at comparable rates to mpMRI [11]. According to Thaiss et al., bpMRI is sufficient for planning and performance of targeted biopsy in patients with suspected PCa. Sensitivity was 99.0%/97.1% ($p < 0.001$), specificity was 47.5%/61.2% ($p < 0.001$), PPV was 69.5%/75.1% ($p < 0.001$), and NPV was 97.6%/94.6% (non significant) for the mpMRI/bpMRI test comparison [12]. According to EL-Adalany et al., both bpMRI and mpMRI had similar sensitivity and diagnostic accuracy (sensitivity was 94.3% and diagnostic accuracy was 86.7% for both) considering PI-RADS categories 3, 4 and 5 malignant [13]. Brancato et al. stated the PI-RADS scoring in bpMRI protocol was similar to that given in the mpMRI protocol, according to the overall findings regarding diagnostic accuracy [14]. In their meta-analysis, Alabousi et al. observed no remarkable difference between mpMRI and bpMRI. In terms of sensitivity (mpMRI: 86%, bpMRI: 90%) and specificity (mpMRI: 73%, bpMRI: 70%), pooled summary data showed no significant differences. The mpMRI (0.87) and bpMRI (0.90) summary receiver operating characteristic curves were similar [15].

However, in PI-RADS version 2.1, the PI-RADS committee continued to advise the addition of DCE to the protocol of mpMRI applied in prostate cancer detection especially when T2WI or DWI demonstrated decreased image quality. According to EL-Adalany et al., mpMRI demonstrated better sensitivity and diagnostic accuracy regarding PI-RADS scores 4 and 5 malignant (sensitivity was 88.6% for mpMRI compared to 60% for bpMRI and diagnostic accuracy was 91.7% for mpMRI versus 75% for bpMRI) [13]. According to Xu et al., DCE was reported

**Table 2** Diagnostic indices of biparametric and multiparametric prostate MRI

| All | | Pathology | | | | Sensitivity | Specificity | PPV | NPV | Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Benign | | Malignant | | | | | | |
| | | N | % | N | % | | | | | |
| PIRADS score based on T2 and diffusion sequences only (biparametric) (3, 4 and 5 only as malignant) | Benign | 8 | 28.6 | 2 | 4.2 | 95.83% | 28.57% | 69.70% | 80.00% | 71.05% |
| | Malignant | 20 | 71.4 | 46 | 95.8 | | | | | |
| PIRADS score (multiparametric) (3, 4 and 5 only as malignant) | Benign | 8 | 28.6 | 2 | 4.2 | 95.83% | 28.57% | 69.70% | 80.00% | 71.05% |
| | Malignant | 20 | 71.4 | 46 | 95.8 | | | | | |
| PIRADS score based on T2 and diffusion sequences only (biparametric) (4 and 5 only as malignant) | Benign | 28 | 100.0 | 19 | 39.6 | 60.42% | 100.00% | 100.00% | 59.57% | 75.00% |
| | Malignant | 0 | 0.0 | 29 | 60.4 | | | | | |
| PIRADS score (multiparametric) (4 and 5 only as malignant) | Benign | 26 | 92.9 | 11 | 22.9 | 77.08% | 92.86% | 94.87% | 70.27% | 82.89% |
| | Malignant | 2 | 7.1 | 37 | 77.1 | | | | | |

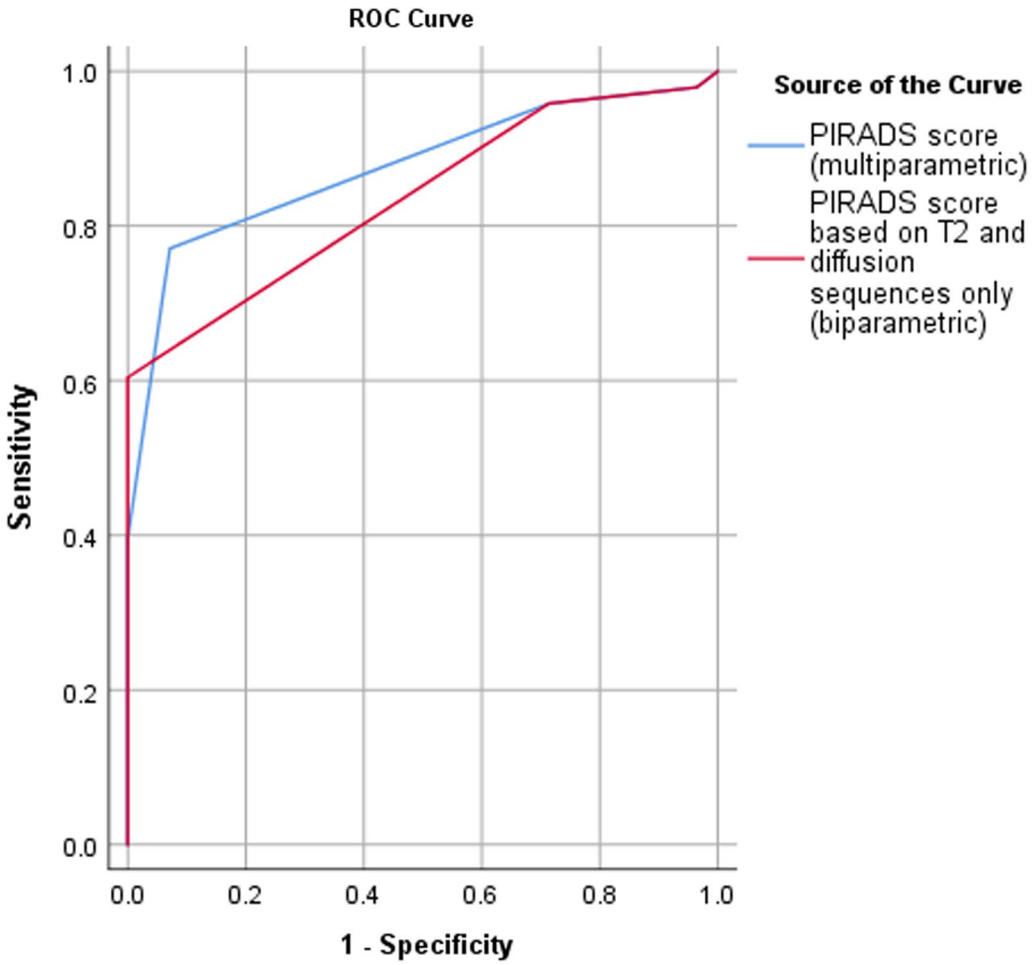


**Fig. 6** Receiver operating characteristic curves for bpMRI and mpMRI considering PI-RADS categories 4 and 5 malignant. MpMRI resulted in a higher AUC 87.5% versus 83.6 for bpMRI (*p* value ‹ 0.001)

to be statistically significant in the detection of PCa for lesions having a score more than or equal to 3 on bpMRI [16]. Greer et al. also reported that DCE may raise the tumor detection rate for category 3 PZ lesions on DWI by about 16% [10]. In our study, mpMRI demonstrated better sensitivity and diagnostic accuracy when malignant lesions were considered as those having PI-RADS scores 4 and 5.

Our study has the following limitations: a small number of patients were evaluated. It is advised that multicenter studies be conducted.

## Conclusions

Both bpMRI and mpMRI had similar diagnostic accuracy considering categories 3, 4, and 5 malignant; however, mpMRI showed better diagnostic accuracy and sensitivity when scores 4 and 5 were considered malignant.

**Table 3** Diagnostic indices of various sequences of multiparametric prostate MRI for lesions located at the peripheral zone

| Peripheral zone | | Pathology | | | | Sensitivity | Specificity | PPV | NPV | Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Benign | | malignant | | | | | | |
| | | N | % | N | % | | | | | |
| PIRADS score based on T2 sequence only (4 and 5 only as malignant) | Benign | 7 | 70.0 | 8 | 22.9 | 77.14% | 70.00% | 90.00% | 46.67% | 75.56% |
| | malignant | 3 | 30.0 | 27 | 77.1 | | | | | |
| PIRADS score based on T2 sequence only (3, 4 and 5 only as malignant) | Benign | 3 | 30.0 | 2 | 5.7 | 94.29% | 30.00% | 82.50% | 60.00% | 80.00% |
| | Malignant | 7 | 70.0 | 33 | 94.3 | | | | | |
| PIRADS score based on diffusion sequence only (4 and 5 only as malignant) | Benign | 10 | 100.0 | 14 | 40.0 | 60.00% | 100.00% | 100.00% | 41.67% | 68.89% |
| | Malignant | 0 | 0.0 | 21 | 60.0 | | | | | |
| PIRADS score based on diffusion sequence only (3, 4 and 5 only as malignant) | Benign | 2 | 20.0 | 2 | 5.7 | 94.29% | 20.00% | 80.49% | 50.00% | 77.78% |
| | Malignant | 8 | 80.0 | 33 | 94.3 | | | | | |
| PIRADS score based on T2 and diffusion sequences only (biparametric) (4 and 5 only as malignant) | Benign | 10 | 100.0 | 14 | 40.0 | 60.00% | 100.00% | 100.00% | 41.67% | 68.89% |
| | Malignant | 0 | 0.0 | 21 | 60.0 | | | | | |
| PIRADS score based on T2 and diffusion sequences only (biparametric) (3, 4 and 5 only as malignant) | Benign | 2 | 20.0 | 2 | 5.7 | 94.29% | 20.00% | 80.49% | 50.00% | 77.78% |
| | Malignant | 8 | 80.0 | 33 | 94.3 | | | | | |
| PIRADS score based on contrast enhanced sequence only | Benign | 8 | 80.0 | 14 | 40.0 | 60.00% | 80.00% | 91.30% | 36.36% | 64.44% |
| | Malignant | 2 | 20.0 | 21 | 60.0 | | | | | |
| PIRADS score (multiparametric) (4 and 5 only as malignant) | Benign | 8 | 80.0 | 6 | 17.1 | 82.86 | 80.00% | 93.55 | 57.14% | 82.22% |
| | Malignant | 2 | 20.0 | 29 | 82.9 | | | | | |
| PIRADS score (multiparametric) (3, 4 and 5 only as malignant) | Benign | 2 | 20.0 | 2 | 5.7 | 94.29% | 20.00% | 80.49 | 50.00% | 77.78% |
| | Malignant | 8 | 80.0 | 33 | 94.3 | | | | | |

**Table 4** Diagnostic indices of various sequences of multiparametric prostate MRI for lesions located at the transitional zone

| Transitional zone | | Pathology | | | | Sensitivity | Specificity | PPV | NPV | Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Benign | | malignant | | | | | | |
| | | N | % | N | % | | | | | |
| PIRADS score based on T2 sequence only (4 and 5 only as malignant) | Benign | 18 | 100.0 | 7 | 36.8 | 63.16% | 100.00% | 100.00% | 72.00% | 81.08% |
| | Malignant | 0 | 0.0 | 12 | 63.2 | | | | | |
| PIRADS score based on T2 sequence only (3, 4 and 5 only as malignant) | Benign | 6 | 33.3 | 0 | 0.0 | 100.00% | 33.33% | 61.29% | 100.00% | 67.57% |
| | Malignant | 12 | 66.7 | 19 | 100.0 | | | | | |
| PIRADS score based on diffusion sequence only (4 and 5 only as malignant) | Benign | 17 | 94.4 | 10 | 52.6 | 47.37% | 94.44% | 90.00% | 62.96% | 70.27% |
| | Malignant | 1 | 5.6 | 9 | 47.4 | | | | | |
| PIRADS score based on diffusion sequence only (3, 4 and 5 only as malignant) | Benign | 5 | 27.8 | 1 | 5.3 | 94.74% | 27.78% | 58.06% | 83.33% | 62.16% |
| | Malignant | 13 | 72.2 | 18 | 94.7 | | | | | |
| PIRADS score based on T2 and diffusion sequences only (biparametric) (4 and 5 only as malignant) | Benign | 18 | 100.0 | 5 | 26.3 | 73.68% | 100.00% | 100.00% | 78.26% | 86.49% |
| | Malignant | 0 | 0.0 | 14 | 73.7 | | | | | |
| PIRADS score based on T2 and diffusion sequences only (biparametric) (3, 4 and 5 only as malignant) | Benign | 6 | 33.3 | 0 | 0.0 | 100.00% | 33.33% | 61.29% | 100.00% | 67.57% |
| | Malignant | 12 | 66.7 | 19 | 100.0 | | | | | |
| PIRADS score based on contrast enhanced sequence only | Benign | 15 | 83.3 | 10 | 52.6 | 47.37% | 83.33% | 75.00% | 60.00% | 64.86% |
| | Malignant | 3 | 16.7 | 9 | 47.4 | | | | | |
| PIRADS score (multiparametric) (4 and 5 only as malignant) | Benign | 18 | 100.0 | 5 | 26.3 | 73.68% | 100.00% | 100.00% | 78.26% | 86.49% |
| | Malignant | 0 | 0.0 | 14 | 73.7 | | | | | |
| PIRADS score (multiparametric) (3, 4 and 5 only as malignant) | Benign | 6 | 33.3 | 0 | 0.0 | 100.00% | 33.33% | 61.29% | 100.00% | 67.57% |
| | malignant | 12 | 66.7 | 19 | 100.0 | | | | | |

**Abbreviations**

| | |
|---|---|
| PCa | Prostate carcinoma |
| PSA | Prostate specific antigen |
| TRUS | Transrectal ultrasound-guided |
| MRI | Magnetic resonance imaging |
| mp | Multiparametric |
| DWI | Diffusion weighted |
| DCE | Dynamic contrast enhanced |
| PI-RADS | Prostate Imaging—Reporting and Data System |
| TZ | Transition zone |
| PZ | Peripheral zone |
| ADC | Apparent diffusion coefficient |
| bp | Biparametric |
| BCR | Biochemical recurrence |
| FOV | Field of view |
| TR | Repetition time |
| TE | Echo time |
| csPCa | Clinically significant prostate carcinoma |
| SPSS | Statistical package for the social sciences |
| PPV | Positive predictive value |
| NPV | Negative predictive value |
| AUC | Area under the curve |
| OR | Odds ratio |

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**Author contributions**
A.A.H put the idea of the study, participated in the study design, and MRI assessment. M.A.S: participation in the study design, MRI assessment, data collection, and performed statistical analysis. Editor of the manuscript. W.A.E: data collection, and clinical assessment of the patients. M.H.W: data collection, and participation in the study design, and statistical analysis. S.M.A: data collection, and participation in the study design, and statistical analysis. All authors read and approved the final manuscript.

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**Availability of data and materials**
All the datasets used and analyzed in this study are available with the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
Written informed consent was signed by all patients before the examination. The study was approved by the research committee of Faculty of Medicine, Kasr Alainy Hospitals. Cairo University 2021. The reference number provided by the committee was MD-95–2021.

**Consent for publication**
All patients included in this research were fully conscious and gave written informed consent to publish the data contained within this study.

**Competing interests**
The authors declare that they have no competing interests.

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