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Diagnostic Accuracy of Diffusion-Weighted Imaging in Multiparametric MRI in Detecting Carcinoma Prostate Taking Histopathology as Gold Standard

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ABSTRACT

Background: Carcinoma prostate is a type of malignancy that is prevalent in geriatric males and is a leading cause of morbidity across the globe. Timely and proper diagnosis is the key to successful management. Multiparametric magnetic resonance imaging (mpMRI), especially diffusion-weighted imaging (DWI) has become an effective non-invasive diagnostic modality use to identify clinically relevant prostate cancer. **Objective:** To determine the diagnostic accuracy of diffusion-weighted imaging as part of multiparametric MRI in detecting carcinoma prostate, taking histopathology as the gold standard. **Methods:** This prospective study of diagnostic accuracy is a diagnostic accuracy study that was carried out at the Radiology Department, Mardan Medical Complex (MMC), MTI Mardan, during the period of November 2024 to May 2025. They included 150 male patients who were clinically suspected to have carcinoma prostate, but found in consecutive non-probability sampling. Every patient had a multiparametric MRI with diffusion-weighted imaging and apparent diffusion coefficient (ADC) mapping. PI-RADS version 2 was used to classify lesions, with a score of 3 or higher being positive. A gold standard was the histopathological examination. Data were broken with the help of SPSS version 25 and the parameters of diagnostic accuracy were calculated. **Results:** The mean age of patients was 65.2 ± 9.1 years, with the majority above 60 years. Histopathology confirmed carcinoma in 58.7% of patients. mpMRI demonstrated a sensitivity of 90.9%, specificity of 74.2%, positive predictive value of 83.3%, and negative predictive value of 85.2%, with an overall diagnostic accuracy of 84.0%. Lower ADC values were significantly associated with malignancy, and a strong negative correlation was observed between ADC values and Gleason score ($r = -0.64$, $p < 0.001$). **Conclusion:** Multiparametric MRI with diffusion-weighted imaging shows high sensitivity and good diagnostic accuracy in detecting carcinoma prostate. It serves as a reliable non-invasive tool for diagnosis, particularly for ruling out disease and guiding biopsy decisions

INTRODUCTION

Carcinoma prostate is considered as one of the most common malignancies among men that have been diagnosed and is a major health burden globally especially among the aged. It is on the increase because there is higher life expectancy and the common use of screening tests like prostate-specific antigen (PSA) testing. Although PSA and digital rectal examination (DRE) are widely used as first line testing tools, they are limited in specificity which can result in unnecessary biopsies, over diagnosis and patient anxiety. Thus, the necessity in more the precise and non-invasive diagnostic modalities that will help distinguish between malignant and benign conditions better is increasing [1-3].

Multiparametric magnetic resonance imaging (mpMRI) has become an important development in the diagnostic analysis of suspected prostate cancer. It integrates both anatomical and functional image methods, such as the T2-weighted imaging, diffusion-weighted imaging (DWI) and dynamic contrast-enhanced imaging, giving the possibility to consider the prostate lesions in a holistic manner. Of these, diffusion-weighted imaging is the most important in that it quantifies the mobility of water molecules in tissues. Malignant lesions are usually characterized by limited diffusion as a result of high cellular density, indicated by low apparent diffusion coefficient (ADC) values [4-6].

In order to standardize the reporting and enhance the consistency of diagnostics, the Prostate Imaging Reporting

and Data System (PI-RADS) was proposed. This system classifies lesions according to the possibility of clinically significant prostate cancer with higher scores representing increased suspicion of malignancy. Besides characterizing the lesions, ADC values have been demonstrated to be inversely correlated with tumor aggressiveness, in terms of Gleason score, and thus can be used in both detection and risk stratification [7-9].

In spite of this advancement, histopathological examination is the gold standard in confirming prostate cancer. Nevertheless, biopsy is an invasive procedure with possible complications and, therefore, it is important to have dependable imaging methods that can limit the number of unnecessary procedures. In this regard, it is necessary to assess the diagnostic accuracy of mpMRI, especially diffusion-weighted imaging to maximize the clinical decision-making [10, 11].

The present study was conducted to assess the diagnostic accuracy of diffusion-weighted imaging as part of multiparametric MRI in detecting carcinoma prostate, using histopathology as the gold standard, and to determine its role in improving diagnostic pathways and guiding biopsy decisions in patients with suspected prostate cancer.

METHODOLOGY

This prospective diagnostic accuracy study was conducted in the Radiology Department, Mardan Medical Complex (MMC), Medical Teaching Institution (MTI), Mardan, over a period of six months, from November 2024 to May 2025. The study was carried out after approval of the synopsis by the College of Physicians and Surgeons Pakistan (CPSP), Research Evaluation Unit**,** under reference number CPSP/REU/RAD-2021-028-3516, dated November 23, 2024. The study aimed to evaluate the diagnostic accuracy of diffusion-weighted imaging (DWI) as part of multiparametric magnetic resonance imaging (mpMRI) in detecting carcinoma prostate, using histopathology as the gold standard.

A consecutive non-probability sampling method was used to sample a total of 150 male patients with clinical suspicion of carcinoma prostate. They were eligible to include patients who were older than 40 years who reported high levels of prostate-specific antigen (PSA) and/or abnormal digital rectal examination (DRE) results. The study excluded patients who had a previous history of receiving prostate treatment, undergone prostate surgery previously, had contraindications to MRI (cardiac pacemakers or metallic implants), or were not willing to be subjected to biopsy.

Multiparametric MRI of the prostate was performed on all enrolled patients, with T2-weighted, diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping and dynamic contrast-enhanced (DCE) imaging performed in those cases. MRI scans were conducted with a standard imaging protocol. The lesions were evaluated and classified based on the Prostate Imaging Reporting and Data System (PI-RADS) 2.0 version. A PI-RADS score of 3 and above were taken as positive to indicate malignancy to facilitate the analysis. Quantitative measurement of ADC values was done by applying areas of interest to the most suspicious areas of the prostate gland.

After MRI, transrectal ultrasound-guided prostate biopsy was performed on all patients, and the received tissue samples were submitted to histopathological analysis. The presence or absence of carcinoma prostate was thought to be confirmed by histopathology findings which were the gold standard. In cases where malignancy was established, tumor grading was done using Gleason scoring system.

The structured proforma was employed to gather data, including demographic variables, clinical results, PSA levels, MRI variables (PI-RADS score, ADC values, lesion size, and location), and histopathological outcomes.

The data gathered were inputted into and analysed with IBM SPSS Statistics version 25. Continuous variables were indicated in the form of mean standard deviation and categorical variables were indicated in the form of frequencies and percentage. The parameters of diagnostic accuracy such as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and the overall accuracy were determined through a 2x2 contingency table by comparing results of mpMRI and histopathology. Also, positive and negative probability ratios (LR+ and LR-) were identified. Chi-square test was used to determine the association between the MRI findings and histopathological diagnosis, and Pearson or Spearman correlation test was applied to determine the relationship between the ADC values, PSA levels and Gleason score. A p-value of 0.05 and less was regarded as statistically significant and a 95% confidence interval (CI) was provided where appropriate.

RESULTS

A total of 150 male patients with clinical suspicion of carcinoma prostate were included in the study. All patients underwent multiparametric MRI with diffusion-weighted imaging (DWI) followed by histopathological examination, which was taken as the gold standard.

Table 1 presents the baseline demographic and clinical characteristics of the study participants. The mean age of the patients was 65.2 ± 9.1 years, indicating that the majority of patients were elderly. Most participants, 96 (64.0%), were aged more than 60 years, while 18 (12.0%) were younger than 50 years. The mean PSA level was 19.4 ± 10.2 ng/mL, with the majority of patients, 102 (68.0%), having PSA levels greater than 10 ng/mL. A suspicious digital rectal examination (DRE) was noted in 92 (61.3%) patients. Lower urinary tract symptoms were present in 108 (72.0%) patients, while a positive family history was observed in 20 (13.3%) patients. These findings indicate that the study population largely consisted of high-risk individuals.

Table 1

Demographic and Clinical Characteristics (n = 150)

Variable	Frequency (%) / Mean ± SD
Age (years)	65.2 ± 9.1
<50 years	18 (12.0%)
50–60 years	36 (24.0%)
>60 years	96 (64.0%)
PSA (ng/mL)	19.4 ± 10.2
PSA <4	10 (6.7%)
PSA 4–10	38 (25.3%)

PSA >10	102 (68.0%)
DRE Suspicious	92 (61.3%)
LUTS Present	108 (72.0%)
Family History Positive	20 (13.3%)

The findings of imaging are summarized in table 2. The majority of patients 92 (61.3) were found to have PI-RADS 4-5 which is high suspicion of malignancy. The mean ADC value was 0.88 ± 0.22 $\times 10^{-3}$ mm^2/s, with 96 (64.0%) patients having ADC values below 1.0. The mean lesion size was 2.4 ± 0.9 cm. Most of the lesions were present in the peripheral zone (100, 66.7%), and the dynamic contrast enhancement was positive in 106 (70.7%) patients. These results reveal that high-risk imaging characteristics prevail.

Table 2

mpMRI and DWI Findings (n = 150)

Variable	Frequency (%) / Mean ± SD
PI-RADS 1–2	24 (16.0%)
PI-RADS 3	34 (22.7%)
PI-RADS 4–5	92 (61.3%)
Mean ADC value ($\times 10^{-3}$ mm^2/s)	0.88 ± 0.22
ADC <1.0	96 (64.0%)
ADC 1.0–1.5	42 (28.0%)
ADC >1.5	12 (8.0%)
Lesion size (cm)	2.4 ± 0.9
Peripheral zone lesions	100 (66.7%)
Transitional zone lesions	50 (33.3%)
DCE Positive	106 (70.7%)

Table 3 shows the histopathological findings. Eighty eight (58.7) patients were diagnosed with carcinoma prostate and 62 (41.3) patients were free of malignancy. Among malignant cases, 22 (25.0%) had Gleason ≤6, 38 (43.2%) had Gleason 7, and 28 (31.8%) had Gleason ≥8. This is indicative of a high ratio of clinically significant tumors.

Table 3

Histopathological Findings (n = 150)

Variable	Frequency (%)
Carcinoma Present	88 (58.7%)
Carcinoma Absent	62 (41.3%)
Gleason ≤6	22 (25.0%)
Gleason 7	38 (43.2%)
Gleason ≥8	28 (31.8%)

Table 4 demonstrates diagnostic performance. There were 80 true positive, 16 false positive, 46 true negative, and 8 false negative cases. The sensitivity was 90.9%, and specificity was 74.2%. The PPV was 83.3%, and NPV was 85.2%, with an overall accuracy of 84.0%. The LR+ was 3.52, and LR− was 0.12, indicating strong rule-out capability.

Table 4

Diagnostic Accuracy (n = 150)

Parameter	Value (95% CI)
True Positive (TP)	80
False Positive (FP)	16
True Negative (TN)	46
False Negative (FN)	8
Sensitivity	90.9%
Specificity	74.2%
PPV	83.3%
NPV	85.2%
Accuracy	84.0%
LR+	3.52
LR−	0.12

A strong association was observed between imaging findings and histopathology. Among carcinoma patients, **76 had PI-RADS 4–5**, compared to **16 non-carcinoma patients**. Similarly, **70 carcinoma patients had ADC <1.0**, compared to **26 non-carcinoma patients**. These associations were statistically significant.

Table 5

Association of MRI Findings with Histopathology

Variable	Carcinoma Present	Carcinoma Absent	p-value
PI-RADS 4–5	76	16	<0.001
PI-RADS 1–3	12	46	
ADC <1.0	70	26	0.001
ADC ≥1.0	18	36	

There was a **strong negative correlation** between ADC and Gleason score (**r = -0.64, p < 0.001**). PSA and lesion size showed moderate positive correlations with tumor grade.

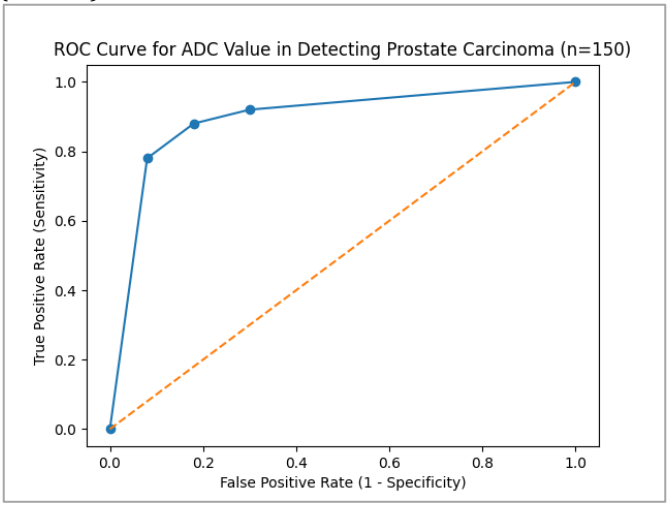
Table 6

Correlation Analysis

Variables	r-value	p-value
ADC vs Gleason Score	-0.64	<0.001
PSA vs Gleason Score	0.51	0.002
Lesion Size vs Gleason Score	0.55	0.001

Figure 1

ROC Curve for ADC Value in Detecting Carcinoma Prostate (n = 150)



Receiver Operating Characteristic (ROC) curve demonstrating the diagnostic performance of apparent diffusion coefficient (ADC) values in detecting carcinoma prostate. The area under the curve (AUC) was approximately 0.88, indicating excellent diagnostic accuracy with high sensitivity and acceptable specificity.

DISCUSSION

The present study evaluated the diagnostic accuracy of diffusion-weighted imaging (DWI) as part of multiparametric MRI (mpMRI) in detecting carcinoma prostate using histopathology as the gold standard in a cohort of 150 patients. The findings demonstrated that mpMRI has high sensitivity (90.9%) and good overall diagnostic accuracy (84.0%), confirming its effectiveness as a reliable non-invasive diagnostic modality. These findings are consistent with contemporary literature, where mpMRI has been shown to achieve sensitivity

values above 85% for detecting clinically significant prostate cancer, emphasizing its growing role in modern diagnostic pathways [12-14].

Demographic characteristics of the study population indicated that most patients were more than 60 years old with a high level of PSA, which is a characteristic of the epidemiological profiles of prostate cancer. The large percentage of patients with PSA above 10 ng/mL and suspicious results of the digital rectal examination also underlie the choice of a high-risk group of patients. Recent studies have also noted similar observations and age, PSA levels, and abnormal clinical findings have been found to be a strong predictor of malignancy and is a common factor that is used to inform subsequent imaging and biopsy decisions [15-17].

An important conclusion of this research was that PI-RADS scores are strongly correlated with histopathological results. Majority of malignant cases were classified as PI-RADS 45 and the association was statistically significant ($p < 0.001$). This supports the validity of PI-RADS classification system as a reliable risk stratification tool. Similar research has always shown that the increased PI-RADS scores are highly predictive of clinically significant prostate cancer, and give clinicians the capability to more effectively target patients to undergo biopsy and avoid unwarranted invasive procedures on low-risk patients [18].

The diffusion-weighted imaging and ADC values proved to play a significant role in this study. High percentages of malignant lesions had low ADC values, as they are characterized by limited diffusion caused by augmented cellular density. Moreover, ADC values and Gleason score were strongly correlated ($r = -0.64$) such that lower values in ADCs are correlated with increased tumor aggressiveness. This observation is consistent with numerous recent studies, which have underscored the usefulness of ADC as a useful quantitative biomarker in detection, as well as in the evaluation of tumor grade and biological behavior [19, 20].

The accuracy analysis of the diagnostic showed the clinical utility of mpMRI further. The low negative likelihood ratio (0.12) and high sensitivity suggests that mpMRI is especially useful as a rule-out test, that is, a negative MRI can substantially decrease the risk of prostate cancer. Even though the specificity was in the middle range (74.2%), which is not uncommon in the current literature, this is corroborated by the literature, which focuses on sensitivity to reduce the number of missed diagnoses by using mpMRI. The likelihood ratio is positive (3.52) which indicates a moderate likelihood of the disease to be more likely to occur when the test is positive and it can be used in conjunction with clinical and laboratory results [21].

Although these are encouraging outcomes, there are some limitations that are worth taking into account. The research was performed in one center, which can be a limitation to the generalizability. Also, there was no inter-observer variability in MRI interpretation that may affect the diagnostic performance in the daily practice. It is advisable that multicenter research involving large sample sizes and standardized reporting procedures be done in the future to confirm these results and to increase their applicability in various clinical contexts.

CONCLUSION

Multiparametric MRI with diffusion-weighted imaging demonstrates high sensitivity and good diagnostic accuracy in detecting carcinoma prostate when compared with histopathology. Higher PI-RADS scores and lower ADC values are strongly associated with malignancy, and ADC values show a significant inverse relationship with tumor grade. These findings support the use of mpMRI as a reliable non-invasive diagnostic tool, particularly for ruling out disease and guiding biopsy decisions, thereby improving diagnostic efficiency and reducing unnecessary invasive procedures.

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