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Diagnostic Accuracy of Diffusion-Weighted Imaging and PSA for Prostate Carcinoma Using Histopathology as the Gold Standard: A Cross-Sectional Study

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ABSTRACT

Background: Accurate non-invasive detection of Prostate Cancer (PCa) prior to biopsy remains a clinical challenge. This study evaluated the diagnostic performance of Diffusion-Weighted Imaging (DWI) and serum Prostate-Specific Antigen (PSA) and identified independent predictors of histopathologically confirmed PCa.

Methods: A cross-sectional diagnostic accuracy study was conducted among 209 male patients with clinically suspected PCa. All participants underwent serum PSA assessment, DWI evaluation, and histopathological examination, with histopathology serving as the gold standard. Statistical analysis was performed using SPSS version 26.0. Quantitative variables were expressed as mean ± SD or median (IQR), while categorical variables were presented as frequencies and percentages. Associations were assessed using the Mann–Whitney U test and Chi-square test. Diagnostic indices of DWI, including sensitivity, specificity, PPV, NPV and accuracy, were calculated, while agreement with histopathology was evaluated using Cohen's kappa. ROC analysis was performed for PSA, and binary logistic regression identified independent predictors of PCa. A p-value <0.05 was considered statistically significant.

Results: The mean age of participants was 60.28 ± 6.83 years, and the mean PSA level was 16.78 ± 5.05 ng/mL. Histopathology confirmed PCa in 111 patients (53.1%). DWI demonstrated a sensitivity of 84.7%, specificity of 81.6%, PPV of 83.9%, NPV of 82.5%, and overall diagnostic accuracy of 83.3%. Agreement between DWI and histopathology was substantial (κ=0.664, p<0.001). PSA levels were significantly higher among patients with PCa (p<0.001). ROC analysis showed excellent diagnostic performance of PSA with an area under the curve (AUC) of 0.909 (95% CI: 0.869–0.950). The optimal PSA cutoff value was 13.21 ng/mL, providing sensitivity of 96.4% and specificity of 50.0%. Binary logistic regression identified PSA (OR=1.529, 95% CI: 1.233–1.897, p<0.001), duration of symptoms (OR=2.012, 95% CI: 1.557–2.599, p<0.001), and DWI positivity (OR=0.077, 95% CI: 0.010–0.577, p=0.013) as significant independent predictors of PCa.

Conclusion: DWI demonstrated good diagnostic accuracy and substantial agreement with histopathology for the detection of PCa. Combined assessment using DWI and serum PSA may improve diagnostic precision and support early detection of prostate malignancy while potentially reducing unnecessary invasive procedures.

Keywords:

Prostate cancer, Diffusion-weighted imaging, Prostate-specific antigen, Diagnostic accuracy, Histopathology, Logistic regression.

Introduction

Prostate Cancer (PCa) ranks among the most prevalent malignancies affecting men worldwide and constitutes a leading contributor to cancer-related morbidity and mortality on a global scale [1,2]. According to Globocan 2022, PCa accounted for approximately 1,466,680 new cases and 396,792 deaths worldwide, representing 7.3% of all incident cancers and ranking as the 4th most frequently diagnosed cancer across both sexes and the 2nd most common malignancy in men globally [3]. These estimates, derived from the International Agency for Research on Cancer (IARC), underline the sustained and escalating public health burden imposed by this disease, which now affects men in virtually every geographic region [4,5].

The early and accurate detection of PCa is central to improving patient outcomes and reducing unnecessary treatment-related morbidity. Serum Prostate-Specific Antigen (PSA) has been the primary screening biomarker for several decades; however, it suffers from well-recognized limitations including poor specificity, as PSA elevations may arise from benign prostatic hyperplasia (BPH), prostatitis, or other non-malignant conditions [6]. Reliance on PSA alone to trigger biopsy has historically resulted in 40–65% of performed biopsies being redundant, exposing patients unnecessarily to the risks of bleeding, infection, pain, and psychological distress, while simultaneously leaving up to 30% of clinically significant PCa undetected due to the inherent sampling limitations of Transrectal Ultrasound (TRUS)-guided systematic biopsy [7]. These shortcomings have catalyzed the search for non-invasive functional imaging techniques capable of more precisely characterizing prostatic lesions before a histopathological decision is made [8].

Multiparametric Magnetic Resonance Imaging (mpMRI), integrating T2-Weighted Imaging (T2WI), Diffusion-Weighted Imaging (DWI), and Dynamic Contrast-Enhanced (DCE) sequences, has emerged as the cornerstone of the contemporary pre-biopsy diagnostic pathway and is now endorsed by the EAU, AUA, and PI-RADS v2.1 guidelines [9]. Within this framework, DWI is designated as the dominant sequence for lesion detection and characterization in the peripheral zone (the site of origin of approximately 70–75% of PCa) based on its ability to quantify restriction of water molecule diffusion imposed by hypercellular tumour tissue [10]. The quantitative parameter derived from DWI, the Apparent Diffusion Coefficient (ADC), reflects cellular packing and membrane integrity; malignant foci characteristically exhibit significantly lower ADC values compared to adjacent benign prostatic tissue [11].

DWI exploits thermally induced Brownian motion of water molecules using paired diffusion-sensitising gradients at varying b-values. In malignant tissue, the densely packed cellular architecture constitutes a barrier to water diffusion, yielding conspicuously low ADC values. Conversely, normal glandular epithelium and benign hyperplastic nodules exhibit relatively unrestricted diffusion. A meta-analysis of 26 studies comprising 1,633 lesions reported a pooled mean ADC of 0.86×10^{-3} mm²/s for clinically significant PCa (Gleason score ≥ 7) versus 1.1×10^{-3} mm²/s for clinically insignificant disease, with an inverse correlation coefficient of r=−0.45 between ADC and Gleason score, stronger in the peripheral zone (r=−0.48) [12].

Despite its established utility in the peripheral zone, the diagnostic performance of DWI for transition zone tumours is comparatively limited due to heterogeneous BPH architecture confounding ADC interpretation [7]. Furthermore, inter-reader variability, absence of consensus on optimal b-value selection, and dependency of ADC values on field strength and acquisition protocol have hampered cross-study reproducibility [13]. These challenges highlight the need for rigorous, prospective studies with histopathological validation to establish clinically actionable ADC thresholds specific to different patient populations and settings.

Histopathological analysis of prostate biopsy cores remains the definitive gold standard for PCa diagnosis and grading. Correlation of DWI/ADC findings with biopsy-confirmed histopathology enables rigorous evaluation of sensitivity, specificity, PPV, NPV, and AUC-ROC essential for determining whether DWI can reliably stratify patients as candidates for biopsy, active surveillance, or deferral [14]. The present study therefore aimed to determine the diagnostic accuracy of diffusion-weighted imaging in the diagnosis of prostate carcinoma, taking histopathology as the gold standard.

Methodology

This cross-sectional study was conducted in the Department of Radiology, Liaquat National Hospital, Karachi, over a period of one year following ethical approval from the Institutional Ethical Review Committee (Ref #). Written informed consent was obtained from all participants. A sample of 209 patients was calculated based on a reported sensitivity of 86.7% and specificity of 87.8% for DWI-MRI, disease prevalence of 79.82%, 95% confidence interval (CI), and desired precision of 10%, using non-probability consecutive sampling.

Male patients aged 20–70 years referred from Urology with clinical suspicion of PCa, borderline PSA of 4.0–10.0 ng/mL, heterogeneous areas on transrectal ultrasound, or hard/nodular prostate on digital rectal examination were included. Patients with a prior diagnosis of PCa, previous hormonal, radiation or surgical treatment, external institution imaging, or those who declined consent were excluded.

Magnetic resonance imaging was performed using a 1.5-Tesla Magnetom Harmony scanner (Siemens, Germany) with a dedicated prostate surface coil. High-resolution T2-weighted images were acquired in axial, sagittal, and coronal planes (TR 5000–7000 ms, TE 100 ms, FOV 20 cm, slice thickness 3 mm, matrix 256 × 256). This was followed by diffusion-weighted imaging using single-shot echo-planar imaging (TR 4000–5000 ms, TE 84 ms, FOV 30 cm, slice thickness 4 mm, b-values 50–800 s/mm²) with corresponding apparent diffusion coefficient (ADC) map generation. All imaging studies were interpreted by a radiologist, blinded to histopathological results. DWI findings were categorized as positive or negative for malignancy based on the presence of diffusion restriction with corresponding low ADC values.

Statistical analyses were performed using IBM SPSS v26.0. Normality was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests, with normally distributed variables expressed as mean ± SD and non-normal variables as median (IQR). PSA differences between groups were assessed using the Mann-Whitney U test, and categorical associations using the Pearson chi-square test. Sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy were derived from a 2×2 contingency table. Inter-method agreement was quantified using Cohen's kappa (κ). ROC curve analysis evaluated PSA discriminative ability, with the optimal cutoff determined by Youden's Index. Binary logistic regression identified independent predictors of malignancy. A p-value of less than 0.05 was considered statistically significant.

Results

The study enrolled 209 male participants with a mean age of 60.28 ± 6.83 years (range: 45–79 years). The mean serum PSA level was 16.78 ± 5.05 ng/mL (range: 4.17–27.35 ng/mL) and the mean BMI was 27.55 ± 5.19 kg/m² (range: 16.5–42.3 kg/m²). The median duration of symptoms was 9 months, with an interquartile range (IQR) of 11 months.

With respect to comorbidities, DM was present in 88 participants (42.1%) and absent in the remaining 121 (57.9%). HTN was recorded in 101 participants (48.3%), while 108 participants (51.7%) were normotensive. On histopathological examination, which served as the diagnostic reference standard, PCa was confirmed in 111 participants (53.1%), while without PCa was identified in the remaining 98 participants (46.9%). DWI, evaluated as the index test, returned a positive result in 112 participants (53.6%) and a negative result in 97 participants (46.4%) (Figure 1).

PSA levels were significantly higher in patients with histopathologically confirmed PCa compared to those without PC (mean rank: 145.13 vs. 59.55; U=985.0, Z=−10.208, p < .001. No significant association was observed between DM

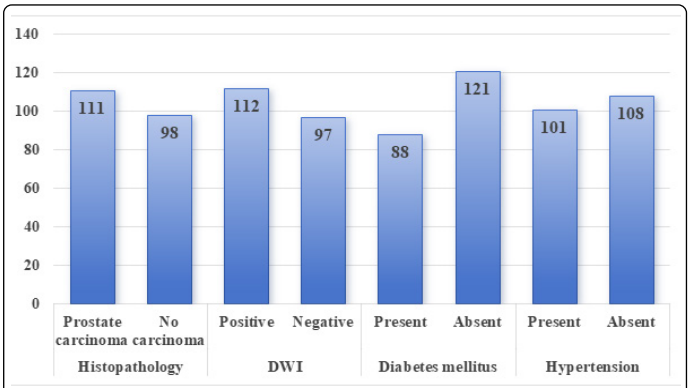


Figure 1: Clinical and imaging characteristics of the study population.

and histopathologically confirmed PC (p=0.184). In the non-cancer group, 52 (53.1%) were non-diabetic and 46 (46.9%) were diabetic, while in the PCa group, 69 (62.2%) were non-diabetic and 42 (37.8%) were diabetic. Similarly, HTN was not significantly associated with PCa (p=0.313). Among non-cancer patients, 47 (48.0%) were non-hypertensive and 51 (52.0%) were hypertensive, compared to 61 (55.0%) and 50 (45.0%) respectively in the PCa group (Table 1).

DWI demonstrated good diagnostic performance for the detection of PCa, with a sensitivity of 84.7%, specificity of 81.6%, Positive Predictive Value (PPV) of 83.9%, negative predictive value (NPV) of 82.5%, and an overall diagnostic accuracy of 83.3%, taking histopathology as the reference standard. Among

Table 1: Association of clinical variables with histopathological diagnosis.

		Histopathology Negative n (%)	Histopathology Positive n (%)	P-value
PSA (ng/mL)	Mean Rank	59.55	145.13	0.000*
DM history	No	52 (53.1%)	69 (62.2%)	0.184#
	Yes	46 (46.9%)	42(37.8%)	
HTN history	No	47 (48.0%)	61 (55.0%)	0.313#
		51 (52.0%)	50 (45.0%)	

*Mann-Whitney U test; #Chi-Square Test; PSA: Prostate-Specific Antigen; DM: Diabetes Mellitus; HTN: Hypertension.

patients without cancer, 82.5% of DWI-negative cases were confirmed on histopathology. In contrast, among patients with cancer, 83.9% of DWI-positive cases were histopathologically confirmed as PCa. Agreement between DWI and histopathological diagnosis showed substantial concordance, with a Cohen's kappa value of κ=0.664 (SE=0.052, p<0.001), indicating good agreement beyond chance.

ROC curve analysis demonstrated excellent discriminative ability of serum PSA for detecting PCa, with an AUC of 0.909 (95% CI: 0.869–0.950, p<0.001). The optimal cutoff was identified at 13.21 ng/mL, yielding a sensitivity of 96.4% and specificity of 50.0% (Figure 2).

Binary logistic regression analysis identified PSA, duration of symptoms, and DWI findings as significant independent predictors of PC. Patients with higher PSA levels were more likely to have PCa (OR=1.529, 95% CI: 1.233–1.897, p<0.001). Similarly, patients with longer duration of symptoms were more likely to have malignancy, with the odds increasing approximately twofold for each unit increase in duration (OR=2.012, 95% CI: 1.557–2.599, p<0.001). In contrast, patients with positive DWI findings were less likely to be free of carcinoma, indicating a strong association between DWI positivity and the presence of PC (OR=0.077, 95% CI: 0.010–0.577, p=0.013). Age, BMI, DM, and HTN were not significantly associated with PC, indicating that patients with these characteristics were neither more nor less likely to have cancer.

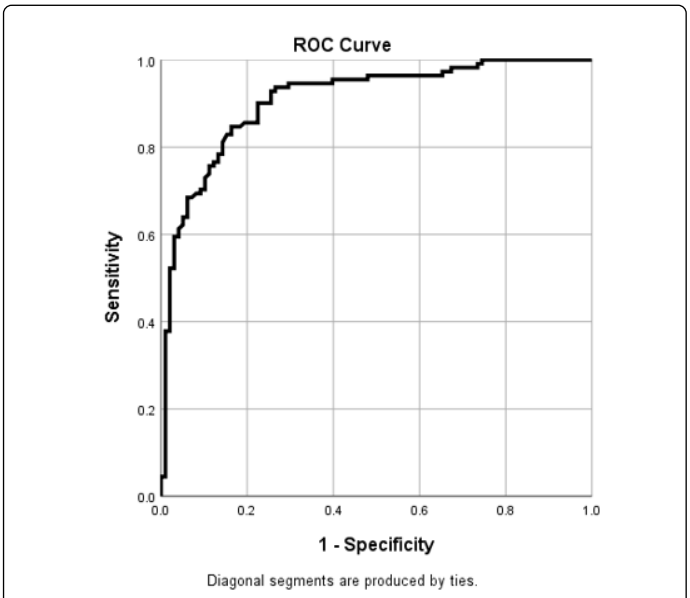


Figure 2: ROC curve for serum PSA in the diagnosis of PCa. The diagonal reference line represents a test with no discriminative ability (AUC=0.5)

Discussion

The present study evaluated the diagnostic performance of Diffusion-Weighted Imaging (DWI) for the detection of Prostate Cancer (PCa) using histopathology as the reference standard. Our findings demonstrated good diagnostic performance, with a sensitivity of 84.7%, specificity of 81.6%, PPV of 83.9%, NPV of 82.5%, and overall diagnostic accuracy of 83.3%. Furthermore, DWI showed substantial agreement with histopathology (κ=0.664, p<0.001), indicating reliable concordance beyond chance. These findings support the increasing role of DWI as a noninvasive and clinically valuable imaging modality for PCa detection.

Our findings are highly consistent with both international and regional studies evaluating the diagnostic performance of Diffusion-Weighted Imaging (DWI) in Prostate Cancer (PCa). A systematic meta-analysis of 24 studies assessing high b-value DWI demonstrated pooled sensitivity and specificity of 84% and 87%, respectively, with a diagnostic odds ratio of 34 and an area

Table 2: Binary logistic regression analysis of predictors of PCa.

Variable	B	Odds Ratio (OR)	95% CI	p-value
Age	-0.055	0.946	0.855 – 1.047	0.284
PSA	0.425	1.529	1.233 – 1.897	0.000
BMI	0.042	1.043	0.923 – 1.178	0.502
Duration of symptoms	0.699	2.012	1.557 – 2.599	0.000
DM	-0.089	0.915	0.267 – 3.140	0.888
HTN	-1.135	0.321	0.091 – 1.130	0.077
DWI positivity	-2.559	0.077	0.010 – 0.577	0.013
PSA: Prostate-Specific Antigen; BMI: Body Mass Index; DM: Diabetes Mellitus; HTN: Hypertension; DWI: Diffusion-Weighted Imaging				

under the Summary Receiver Operating Characteristic (sROC) curve of 0.91, reflecting excellent overall diagnostic accuracy [15]. Further supporting the role of DWI within a multiparametric MRI framework, a meta-analysis of 33 studies involving 2,949 patients evaluating combined DWI and T2-weighted imaging reported pooled sensitivity and specificity values of 0.69 and 0.84, respectively, with an sROC AUC of 0.84. The study also demonstrated that the use of high b-values (>1000 s/mm²) significantly improved sensitivity while maintaining specificity [16]. Our results also align with evidence from larger systematic reviews evaluating biparametric MRI approaches that rely heavily on DWI sequences. Bass et al., in a systematic review and meta-analysis published in Prostate Cancer and Prostatic Diseases, demonstrated pooled sensitivity and specificity values of approximately 84% and 75%, respectively, for biparametric MRI in detecting clinically significant PCa [17].

Recent evidence has further highlighted the diagnostic value of DWI-derived Apparent Diffusion Coefficient (ADC) parameters in combination with clinical indices. A 2024 study from China reported that ADC values together with PSA significantly improved the prediction of PCa, with PSA showing an AUC of 0.914 [18]. Likewise, Feng et al. demonstrated that biparametric and multiparametric MRI parameters combined with PSA density significantly improved the detection of clinically significant PCa [19].

Comparable results have also been reported in regional studies. A 2024 study by Samad et al. [20] reported sensitivity, specificity, and diagnostic accuracy values of 84.2%, 83.3%, and 83.6%, respectively, for DWI in diagnosing PCa using histopathology as the gold standard, closely paralleling our findings. Similarly, Kamran et al. [21] reported sensitivity of 86.7%, specificity of 87.8%, and diagnostic accuracy of 87.5% among patients with suspected PCa undergoing DWI evaluation. Minor variations in diagnostic indices across studies may be attributable to differences in MRI acquisition protocols, magnetic field strength, patient demographics, lesion size, reader expertise, and interpretation criteria.

In agreement with previously published evidence regarding inter-reader reliability in prostate MRI, studies assessing agreement among radiologists have demonstrated moderate-to-good Cohen's kappa values for DWI interpretation (κ=0.64), highlighting the inherent variability associated with subjective image assessment and emphasizing the importance of standardized reporting systems such as PI-RADS [22]. The Cohen's kappa value of 0.664 observed in our study indicates substantial agreement between DWI findings and histopathological diagnosis, supporting the acceptable reproducibility and reliability of DWI in the detection of PCa [23].

In the present study, PSA levels were significantly higher in histopathologically confirmed PCa patients, and ROC analysis demonstrated excellent discriminative ability with an AUC of 0.909. The optimal PSA cutoff of 13.21 ng/mL yielded very high sensitivity (96.4%) but relatively modest specificity (50.0%). Similar findings have been consistently reported in the literature, where PSA demonstrates excellent sensitivity but limited specificity because elevated PSA may also occur in benign prostatic hyperplasia, prostatitis, and other nonmalignant conditions. Recent clinical evidence continues to support the complementary use of MRI and PSA to improve risk stratification and reduce unnecessary biopsies [19]. A systematic review and meta-analysis of PSA diagnostic accuracy in symptomatic patients reported a combined sensitivity of 0.93 but a combined specificity of only 0.20 for a PSA threshold of ≥4 ng/mL, with a hierarchical summary ROC AUC of 0.72, highlighting the inherently limited specificity of PSA in symptomatic populations [24]. Regarding the optimal PSA threshold, cutoff values vary substantially across populations and clinical contexts. A 2024 study employing ROC-based cutoff determination identified an optimal PSA level for biopsy referral of 19.71 ng/mL, with a sensitivity of 69.23% and specificity of 72.5%, in a cohort where the AUC was 0.798 [25].

Binary logistic regression identified PSA level (OR=1.529), duration of symptoms (OR=2.012), and DWI positivity (OR=0.077) as significant independent predictors of PCa, while age, BMI, DM, and HTN were not significantly associated with the outcome. The role of PSA as an independent predictor is well established and consistent across multiple prediction models. A recent risk prediction model development study in patients with elevated PSA (>4 ng/mL) undergoing biopsy confirmed PSA as a central independent predictor of malignancy on multivariable logistic regression, and highlighted the need to integrate PSA with peripheral blood biomarkers and MRI findings to achieve clinically meaningful discrimination [26].

The finding that longer symptom duration independently predicts PCa with OR approximately doubling per unit increase is consistent with the indolent natural history of the disease and the progressive nature of lower urinary tract symptoms in men

with undiagnosed malignancy. In a logistic regression analysis of clinical predictors of prostate pathology, urinary symptoms including hesitancy, incomplete voiding, and frequency were significantly associated with adenocarcinoma diagnosis, alongside bone pain and abnormal digital rectal examination findings, reinforcing the importance of integrating symptom profiles into pre-biopsy risk assessment [27]. Taken together, these data suggest that the duration and character of urinary symptoms represent underutilized clinical predictors that, when combined with PSA and imaging, could meaningfully refine patient selection for biopsy.

Regarding age and BMI, neither was a significant predictor of PCa on multivariate analysis in the present study. This is not entirely unexpected, as the confounding effects of PSA which exhibits age- and BMI-related variation may attenuate the apparent independent contribution of these variables once PSA is included in the model. A large Italian biopsy cohort study similarly found that BMI was not significantly associated with increased prostate cancer risk on multivariate analysis (p=0.19), though among men diagnosed with cancer, higher BMI was independently associated with high-grade disease (Gleason ≥ 7; p=0.005) [28]. This suggests that while BMI may not independently predict cancer detection at biopsy, it may modulate tumour aggressiveness, a nuance not captured by the binary outcome used in the our study.

No significant association was observed between DM and histopathologically confirmed PCa in this cohort (p=0.184). This aligns with a robust body of meta-analytic evidence suggesting an inverse or null relationship between diabetes and PCa risk. A 2024 systematic review and meta-analysis including 41 articles and over 3.7 million patients found that diabetes mellitus was associated with a significantly reduced risk of PCa, with pooled odds ratios of 0.68 in case-control studies and a pooled relative risk of 0.71 in cohort studies, suggesting a potentially protective effect [29]. A concurrent meta-analysis incorporating 72 articles and Mendelian randomization analyses confirmed that diabetes mellitus is associated with a reduced risk of prostate cancer, with the magnitude of the protective effect varying by geographic region and BMI stratum, and Mendelian randomization providing genetic-level evidence supporting a causal relationship in European and Asian populations [30].

Similarly, HTN was not significantly associated with PCa in this cohort (p=0.313). The epidemiological literature on this relationship is notably inconsistent. A meta-analysis of 21 published studies found a modest but statistically significant increase in PCa risk among hypertensive individuals (RR 1.08, 95% CI 1.02–1.15), although substantial heterogeneity was observed across included studies (I^2=72.1%), limiting the interpretability of pooled estimates [31]. In contrast, a large pooled cohort study of 430,472 men from five Swedish prospective cohorts found that increasing combined systolic and diastolic blood pressure was associated with a slightly lower prostate cancer risk (HR 0.98 per standard deviation of mid-blood pressure; 95% CI 0.97–0.99), with authors concluding that pre-diagnostic blood pressure is unlikely to constitute an important independent risk factor for prostate cancer development, and that reduced PSA testing frequency among hypertensive men may partly explain their apparently lower cancer incidence in population studies [32].

Several limitations warrant consideration. This was a single-institution study, which may limit the generalizability of findings to other settings with different patient demographics, imaging platforms, or operator expertise. The absence of PI-RADS scoring represents a significant constraint, as standardized multiparametric MRI reporting has become the clinical norm and the primary reference framework in contemporary literature, precluding direct comparison with PI-RADS-based studies. DWI parameters including b-values and ADC thresholds were not standardized or reported, potentially introducing inter-reader variability. The cross-sectional design precludes causal inference.

Conclusion

Our findings demonstrate that DWI possesses good diagnostic accuracy and substantial agreement with histopathology for the detection of PCa. When integrated with serum PSA assessment, DWI may improve diagnostic precision, facilitate early cancer detection, and potentially reduce unnecessary invasive biopsies, particularly in resource-limited settings.

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None.

Conflict of Interests

The authors declare no conflict of interest.

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