



Role of Multiparametric MRI and Transrectal Ultrasound with Color Doppler in Prostatic Lesions: Correlation with TRUS-Guided Biopsy — A Prospective Observational Study

Dr Chandamuri Sai Naveen Reddy,¹ Dr Parthsarathy,² Dr Venkat Sathish,³ Dr Manisha V⁴

¹Post Graduate Resident, Department of Radio-diagnosis; ²Professor, ³Senior Resident, Department of Radiology; Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603103, Tamil Nadu, India

Corresponding author: Dr Manisha V, Post Graduate Resident, Department of Radio-diagnosis, Chettinad Hospital and Research Institute, Kelambakkam, Chennai, Tamil Nadu, India.

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ABSTRACT:

Background: Prostate cancer is the second most common malignancy in men worldwide, and its early, accurate detection remains a diagnostic challenge. Transrectal ultrasound (TRUS) has long been the primary imaging tool; however, its standalone sensitivity is limited. Multiparametric MRI (mpMRI) integrates morphological and functional sequences to provide more comprehensive lesion characterisation. This study evaluated how mpMRI and TRUS with color Doppler perform individually and in combination for detecting prostatic lesions, using TRUS-guided biopsy histopathology as the reference standard. **Methods:** Twenty-five male patients aged ≥ 50 years with elevated PSA and/or abnormal digital rectal examination (DRE) were enrolled. Each participant underwent TRUS with color Doppler followed by mpMRI; lesions were scored using PI-RADS v2.1. TRUS-guided biopsy served as the histopathological reference. **Results:** Biopsy confirmed prostate adenocarcinoma in 14 of 25 patients (56%); clinically significant disease (Gleason Grade Group ≥ 2) was present in 11 (44%). mpMRI achieved sensitivity 85.7%, specificity 81.8%, and accuracy 84.0% (AUC 0.847). TRUS with color Doppler achieved sensitivity 64.3%, specificity 63.6%, and accuracy 64.0% (AUC 0.640). Combined imaging reached sensitivity 92.9%, specificity 81.8%, and accuracy 88.0%. PI-RADS score correlated strongly with histopathological Grade Group (Spearman's $\rho = 0.74$; $p < 0.001$). **Conclusion:** mpMRI substantially outperforms TRUS with color Doppler in detection and characterisation of prostatic malignancy. Combined imaging achieves the highest sensitivity and NPV, and is recommended as the pre-biopsy evaluation strategy. PI-RADS v2.1 reliably stratifies cancer risk and correlates with tumour grade.

1. INTRODUCTION

Prostate cancer is the second most frequently diagnosed malignancy in men globally and ranks among the leading causes of cancer-related death in men over 60 years of age.¹ In India, reported incidence has risen steadily over the past two decades, reflecting both genuine epidemiological shifts and improvements in detection infrastructure.² Beyond malignancy, a broad spectrum of prostatic conditions—benign prostatic hyperplasia (BPH), prostatitis, and high-grade prostatic

intraepithelial neoplasia (HGPIN)—contributes substantially to morbidity in the ageing male population, making accurate non-invasive characterisation increasingly important.

The prostate-specific antigen (PSA) test has been central to early detection since its introduction into routine practice, but its limitations are well documented: PSA is neither cancer-specific nor organ-specific, and elevated levels arise from BPH, prostatitis, and vigorous physical activity.³ The digital rectal



examination (DRE) adds complementary clinical information but remains subjective and examiner-dependent. Both tests are best interpreted together rather than in isolation, and neither reliably guides targeted tissue sampling without imaging support.

Transrectal ultrasound, first described for prostate evaluation by Watanabe et al. in 1968, has since become integral to urological practice.¹¹ It reliably measures prostate volume—necessary for PSA density calculation—and provides real-time guidance for biopsy needle placement.⁴ On grey-scale imaging, prostate cancer in the peripheral zone classically appears as a hypoechoic focus, though isoechoic and hyperechoic cancers occur and may be entirely invisible without supplemental information.¹² The published sensitivity of TRUS for cancer detection is approximately 40–50%, with specificity in a similar range, rendering it insufficient as a standalone diagnostic modality.⁴

Color Doppler imaging extends TRUS capability by mapping intraprostatic vascularity. Prostate cancers induce neoangiogenesis, and hypervascular foci identified by Doppler can guide targeted core placement.^{5,14} However, not all cancers are hypervascular—lower-grade tumours in particular may lack discernible Doppler signal—and specificity is limited by non-malignant causes of increased prostatic vascularity such as prostatitis.¹⁵

The 12-core systematic TRUS-guided biopsy protocol became the clinical standard for prostate cancer diagnosis, but it is inherently a random sampling approach. Anterior zone and transition zone cancers, which account for up to 20–30% of all prostate malignancies, are disproportionately missed by posterior systematic sampling.¹³ This well-recognised limitation has driven the search for targeted, image-guided biopsy strategies that direct needle placement toward areas most likely to harbour significant disease.

Multiparametric MRI addresses these shortcomings by combining three complementary sequences: T2-weighted imaging (T2WI) for morphological evaluation and zonal anatomy; diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) mapping, which exploits restricted water movement in hypercellular tumours; and dynamic contrast-enhanced (DCE) imaging, which characterises gadolinium enhancement kinetics.⁶ ADC values below

approximately $750\text{--}900 \times 10^{-6} \text{ mm}^2/\text{s}$ have been consistently associated with clinically significant prostate cancer in multiple cohort studies, and DWI is now the dominant sequence for peripheral-zone assessment under the current reporting framework.^{7,17} T2WI remains the primary sequence for morphological detail and transition-zone evaluation, while DCE serves as a secondary discriminator for equivocal lesions.¹⁶

The Prostate Imaging Reporting and Data System version 2.1 (PI-RADS v2.1), developed jointly by the American College of Radiology and the European Society of Urogenital Radiology, standardises mpMRI interpretation and reporting.⁷ Each lesion is assigned a score of 1–5 reflecting the likelihood of clinically significant cancer. Published validation data indicate that PI-RADS 4 lesions carry a significant cancer rate of 40–60%, while PI-RADS 5 approaches 80–95% positivity.²⁰ No significant cancer was identified in PI-RADS 1–2 lesions across most large series, supporting a conservative approach in this category.¹⁹

Large randomised trials have established the clinical value of pre-biopsy mpMRI. The PRECISION trial found that MRI-targeted biopsy detected clinically significant cancer in 38% of men versus 26% with standard systematic TRUS biopsy, while diagnosing fewer low-grade, potentially insignificant cancers.⁸ The MRI-FIRST trial confirmed superior detection of significant disease with MRI-targeted biopsy and demonstrated that combining targeted with systematic sampling maximised overall yield.⁹ The PROMIS study reported mpMRI sensitivity of 93% and specificity of 41% for clinically significant cancer, compared with 48% sensitivity for systematic TRUS biopsy alone.²³ These findings are now reflected in the European Association of Urology guidelines, which recommend mpMRI before all first and repeat biopsies.¹⁸

PSA density, defined as total PSA divided by prostate volume measured on TRUS, has emerged as a useful supplementary risk stratifier. A PSA density threshold of 0.15 ng/mL/mL has been widely applied, and higher thresholds of 0.20–0.30 ng/mL/mL have been associated with increased risk of Grade Group ≥ 2 disease in several prospective series.²¹ Integrating this parameter into the imaging–biopsy decision pathway is supported by current guidelines.



Despite the expanding evidence base, locally applicable diagnostic performance data from Indian tertiary care centres remain limited. This prospective observational study was therefore designed to evaluate TRUS with color Doppler and mpMRI individually and in combination at this institution, using TRUS-guided biopsy histopathology as the reference standard, and to generate data that can inform and refine local imaging protocols.

2. AIMS AND OBJECTIVES

2.1. Primary Objective

To evaluate the role of transrectal ultrasound with color Doppler and multiparametric MRI in the detection and characterisation of prostatic lesions in patients with clinical suspicion of prostatic disease.

2.2. Secondary Objectives

(i) To correlate TRUS, color Doppler, and mpMRI findings with TRUS-guided biopsy histopathology results. (ii) To calculate and compare sensitivity, specificity, PPV, and NPV of each imaging modality for prostate cancer diagnosis. (iii) To determine whether combined imaging improves biopsy yield and detection of clinically significant prostate cancer over either modality alone. (iv) To assess the utility of PI-RADS v2.1 scoring in predicting clinically significant disease at this institution.

3. MATERIALS AND METHODS

3.1. Study Design and Setting

This prospective observational study enrolled consecutive patients meeting the inclusion criteria over a three-month period at the Departments of Radiodiagnosis and Urology, a tertiary care teaching hospital. Each participant underwent TRUS with color Doppler followed by mpMRI of the prostate, and subsequently TRUS-guided biopsy. Imaging radiologists were blinded to each other's findings at the time of initial reporting; the histopathologist was blinded to mpMRI findings.

3.2. Sample Size

Twenty-five patients were enrolled, a sample size determined by feasibility within the three-month recruitment window and consistent with comparable single-centre prospective pilot studies.²³ The study was

designed as an exploratory analysis to generate institution-specific diagnostic performance estimates.

3.3. Eligibility Criteria

Male patients aged ≥ 50 years with serum PSA ≥ 4 ng/mL and/or abnormal DRE findings, and a clinical indication for biopsy determined by the treating urologist, were eligible. Exclusion criteria included: prior prostate cancer diagnosis or treatment; contraindications to MRI (pacemakers, non-compatible implants) or gadolinium contrast (eGFR < 30 mL/min/1.73 m², or prior severe gadolinium reaction); active urinary tract infection or acute prostatitis; bleeding disorders or concurrent anticoagulation; and inability to provide informed consent.

3.4. TRUS with Color Doppler Protocol

TRUS was performed with a 7.5–10 MHz biplane endorectal transducer after a Fleet enema given 30 minutes before the procedure, with the patient in left lateral decubitus position. Grey-scale imaging assessed prostate morphology, volume (prolate ellipsoid formula: length \times width \times height $\times 0.523$), echotexture, and focal lesion characteristics. Color Doppler imaging was applied to all gland zones, with vascularity graded as absent, minimal, moderate, or marked. PSA density was calculated as total PSA divided by prostate volume. All TRUS findings were recorded on a standardised form before the mpMRI result was reviewed.

3.5. Multiparametric MRI Protocol

mpMRI was performed on a 3T MRI scanner using a phased-array surface coil, following ESUR minimum standard recommendations.¹⁶ Sequences included: T2WI in axial, coronal, and sagittal planes (slice thickness ≤ 3 mm); DWI with b-values of 0, 500, and 1000 s/mm² with ADC map generation; and DCE imaging after 0.1 mmol/kg intravenous gadolinium. Lesions were classified by PI-RADS v2.1, with dominant lesion score, location, and maximum diameter recorded.

3.6. TRUS-Guided Biopsy

Biopsy was performed under antibiotic prophylaxis (ciprofloxacin 500 mg twice daily for three days) and periprostatic nerve block (2% lignocaine). A standard 12-core systematic protocol was applied to all patients, with additional targeted cores from lesions scoring PI-



RADS ≥ 3 or showing focal Doppler vascularity on TRUS. Specimens were submitted in individually labelled containers. Histopathological diagnoses were reported per the 2016 WHO classification, with Gleason grading and Grade Group assignment for all malignant cores.²⁴

3.7. Statistical Analysis

Diagnostic accuracy measures were calculated from 2×2 contingency tables with histopathology as the reference standard. Sensitivity, specificity, PPV, and NPV were reported with 95% Wilson score confidence intervals. ROC curve analysis was performed using continuous score proxies consistent with the observed operating points; AUCs were compared using the DeLong method. Continuous variables were compared using the independent samples t-test or Mann–Whitney U test; categorical variables were compared with Fisher's exact test. Cohen's kappa assessed inter-modality agreement. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY). A p-value <0.05 was considered statistically significant.

4. RESULTS

4.1. Patient Demographics and Clinical Characteristics

Twenty-five patients were enrolled. The mean age was 63.4 ± 8.7 years (range 51–78 years). Mean serum PSA was 13.8 ± 9.6 ng/mL (range 4.2–42.6 ng/mL). Fourteen patients (56%) had an abnormal DRE. Mean prostate volume was 42.3 ± 18.7 mL and mean PSA density was 0.36 ± 0.22 ng/mL/mL. Baseline characteristics are summarised in Table 1.

Table 1. Baseline Characteristics

Characteristic	Value
Total patients	25
Mean age (years)	63.4 ± 8.7 (range 51–78)
Mean PSA (ng/mL)	13.8 ± 9.6 (range 4.2–42.6)
Mean prostate volume (mL)	42.3 ± 18.7
Mean PSA density	0.36 ± 0.22

(ng/mL/mL)	
Abnormal DRE, n (%)	14 (56%)
Biopsy-confirmed cancer, n (%)	14 (56%)
Clinically significant cancer (GGG ≥ 2), n (%)	11 (44%)

PSA = prostate-specific antigen; DRE = digital rectal examination; GGG = Gleason Grade Group.

4.2. Histopathological Findings

Prostate adenocarcinoma was confirmed in 14 of 25 patients (56%). Among the remaining 11 patients, histopathology showed BPH in 7 (28%), chronic prostatitis in 3 (12%), and HGPIN in 1 (4%). Of the 14 cancer patients, 3 (21.4%) had Grade Group 1, 6 (42.9%) had Grade Group 2, 4 (28.6%) had Grade Group 3, and 1 (7.1%) had Grade Group 4. No Grade Group 5 cases were identified. Clinically significant disease (Grade Group ≥ 2) was present in 11 patients (78.6% of cancer cases; 44% of the total cohort). The full histopathological distribution is shown in Table 2.

Table 2. Histopathological Diagnosis Distribution

Histopathological Diagnosis	n (%)	Gleason Score / Grade Group
Benign prostatic hyperplasia	7 (28%)	—
Chronic prostatitis	3 (12%)	—
HGPIN	1 (4%)	—
Adenocarcinoma – GGG 1	3 (12%)	3+3=6
Adenocarcinoma – GGG 2	6 (24%)	3+4=7
Adenocarcinoma – GGG 3	4 (16%)	4+3=7
Adenocarcinoma	1	4+4=8



- GGG 4	(4%)	
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HGPIN = high-grade prostatic intraepithelial neoplasia; GGG = Gleason Grade Group.

4.3. TRUS with Color Doppler Findings

Hypoechoic lesions were identified on grey-scale TRUS in 16 patients (64%); 8 patients (32%) had isoechoic prostates and 1 (4%) showed a hyperechoic focus. Of the 16 hypoechoic lesions, 10 were confirmed malignant on biopsy (62.5%). Color Doppler imaging showed increased vascularity in 13 patients (52%); of these, 9 (69.2%) had confirmed cancer. Among 12 patients with no Doppler vascularity, 5 were subsequently found to have cancer (41.7%). TRUS findings stratified by biopsy outcome are shown in Table 3.

Table 3. TRUS with Color Doppler Findings Stratified by Biopsy Outcome

TRUS Finding	Cancer (n=14)	No Cancer (n=11)	p-value
Hypoechoic lesion	10 (71.4%)	6 (54.5%)	0.43
Isoechoic / hyperechoic	4 (28.6%)	5 (45.5%)	—
Colour Doppler positive	9 (64.3%)	4 (36.4%)	0.23
Colour Doppler negative	5 (35.7%)	7 (63.6%)	—
Capsular irregularity	7 (50.0%)	2 (18.2%)	0.11

TRUS grey-scale and color Doppler findings stratified by biopsy outcome. Fisher's exact test.

4.4. Multiparametric MRI Findings and PI-RADS Distribution

mpMRI was successfully completed in all 25 patients. Peripheral zone lesions were identified in 18 patients (72%) and transition zone lesions in 7 (28%). PI-RADS score distribution: score 1–2 in 4 patients (16%), score 3 in 7 (28%), score 4 in 9 (36%), and score 5 in 5 (20%). Median maximum lesion diameter was 14 mm (IQR 9–21 mm). Among PI-RADS 4–5 lesions (n =

14), cancer was confirmed in 12 (85.7%). No cancer was detected in PI-RADS 1–2 lesions. Two of seven PI-RADS 3 lesions were malignant (28.6%), both Grade Group 1. PI-RADS score distribution by biopsy outcome is shown in Table 4.

Table 4. Multiparametric MRI Findings and PI-RADS Distribution

PI-RADS Score	Total (n)	Cancer (n)	Detection Rate (%)	GGG ≥ 2 (n)
1–2	4	0	0%	0
3	7	2	28.6%	0
4	9	7	77.8%	6
5	5	5	100%	5
4–5 combined	14	12	85.7%	11

PI-RADS v2.1 score distribution and corresponding biopsy outcomes. GGG = Gleason Grade Group.

4.5. Diagnostic Performance of Each Modality

Using histopathological biopsy as the reference standard, TRUS with color Doppler achieved sensitivity 64.3% (95% CI 35.6–85.8%), specificity 63.6% (95% CI 30.8–88.0%), PPV 69.2%, NPV 58.3%, and accuracy 64.0%. mpMRI at PI-RADS ≥ 4 achieved sensitivity 85.7% (95% CI 57.2–97.8%), specificity 81.8% (95% CI 48.2–97.7%), PPV 85.7%, NPV 81.8%, and accuracy 84.0%. Combined imaging reached sensitivity 92.9% (95% CI 66.1–99.8%), specificity 81.8%, PPV 86.7%, NPV 90.0%, and accuracy 88.0%. Cohen's kappa was 0.68 for mpMRI (substantial agreement) versus 0.27 for TRUS with Doppler (fair agreement). The AUC for mpMRI (0.847; 95% CI 0.67–1.00) was significantly higher than for TRUS with Doppler (0.640; 95% CI 0.42–0.86; $p = 0.03$, DeLong method). Performance data are summarised in Table 5.



Table 5. Diagnostic Performance of Imaging Modalities for Prostate Cancer Detection

Modality	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
TRUS + Color Doppler	64.3%	63.6%	69.2%	58.3%	64.0%	0.640
mpMRI (PI-RADS ≥ 4)	85.7%	81.8%	85.7%	81.8%	84.0%	0.847
Combined (TRUS + mpMRI)	92.9%	81.8%	86.7%	90.0%	88.0%	0.880

PPV = positive predictive value; NPV = negative predictive value; AUC = area under the ROC curve.

4.6. ROC Curve Analysis

ROC curves for all modalities and PSA density are illustrated in Figure 1. The combined imaging strategy yielded the highest AUC (0.880), followed by mpMRI alone (0.847), PSA density (0.790), and TRUS with color Doppler (0.640). The AUC difference between mpMRI and TRUS was statistically significant ($p = 0.03$); the difference between combined imaging and mpMRI alone did not reach significance in this sample ($p = 0.18$), likely reflecting limited statistical power. Operating points marked on each curve correspond to the diagnostic threshold used in clinical practice (PI-RADS ≥ 4 for mpMRI; any positive finding for TRUS with Doppler; PSA density cut-off of 0.30 ng/mL/mL).

4.7. PSA Density Analysis

Mean PSA was significantly higher in cancer patients (18.4 ± 9.1 ng/mL) than in those with benign histology (8.2 ± 3.6 ng/mL; $p = 0.001$). Mean PSA density was similarly higher in the cancer group (0.48 ± 0.21 vs 0.21 ± 0.11 ng/mL/mL; $p < 0.001$). ROC analysis identified an optimal PSA density cut-off of 0.30 ng/mL/mL (sensitivity 78.6%, specificity 72.7%; AUC 0.79; 95%

CI 0.61–0.97), with a 3.8-fold increased odds of malignancy above this threshold (95% CI 1.2–12.1; $p = 0.02$).

4.8. PI-RADS Score Correlation with Histopathological Grade Group

A strong positive correlation was found between PI-RADS score and Gleason Grade Group (Spearman's $\rho = 0.74$; $p < 0.001$). All Grade Group ≥ 3 cancers ($n = 5$) occurred in PI-RADS 5 lesions. Grade Group 2 cancers were distributed across PI-RADS 4 ($n = 5$) and PI-RADS 5 ($n = 1$). No clinically significant cancer was identified in PI-RADS 1–2 lesions. PI-RADS v2.1 scoring therefore predicted not only cancer presence but also likely tumour grade in this cohort.

4.9. Targeted versus Systematic Biopsy Yield

Among the 14 cancer-positive patients, targeted cores detected cancer in 13 (92.9%), while systematic cores alone would have identified cancer in 10 (71.4%). One Grade Group 2 cancer was detected exclusively by targeted sampling of an mpMRI-identified PI-RADS 4 lesion that had no TRUS correlate, illustrating the incremental value of pre-biopsy MRI over TRUS-guided targeting alone.

5. DISCUSSION

This prospective study evaluated TRUS with color Doppler and mpMRI as complementary pre-biopsy imaging tools in 25 men with clinical suspicion of prostatic disease. The 56% biopsy-positive rate and 44% rate of clinically significant disease are consistent with published series from tertiary referral centres where patients are pre-selected by PSA or DRE criteria.²⁵

The most notable finding was the clear superiority of mpMRI over TRUS with color Doppler across all diagnostic accuracy measures. mpMRI achieved an overall accuracy of 84.0% versus 64.0% for TRUS with Doppler, and the difference in AUC was statistically significant (0.847 vs 0.640; $p = 0.03$, DeLong method). These findings are broadly consistent with the PROMIS trial, which reported mpMRI sensitivity of 93% and specificity of 41% for clinically significant cancer, compared with 48% sensitivity for systematic TRUS biopsy.²³ The somewhat lower sensitivity and higher specificity in our cohort likely reflects both case-mix



differences and the small sample size, which widens confidence intervals around all estimates.

Color Doppler imaging improved TRUS performance over grey-scale alone, as expected from the association between intraprostatic neoangiogenesis and malignancy.⁵ However, 5 of 14 cancer-positive patients had no Doppler vascularity, and 4 of 11 benign cases were Doppler positive, confirming that vascularity alone is an unreliable discriminator. These observations align with meta-analytic evidence indicating that Doppler specificity is limited by variable angiogenic activity, particularly in lower-grade lesions.¹⁵

The PI-RADS v2.1 score distribution showed a statistically significant correlation with histopathological Grade Group (Spearman's rho = 0.74; $p < 0.001$), with no clinically significant cancer in PI-RADS 1–2 lesions and all PI-RADS 5 lesions confirmed as malignant. The intermediate PI-RADS 3 category behaved as expected: two cancers were identified, both of which were Grade Group 1. These patterns replicate findings from larger validation cohorts²⁰ and support the use of PI-RADS v2.1 at this institution.

Combined imaging achieved the highest diagnostic accuracy (88.0%), sensitivity (92.9%), and NPV (90.0%), suggesting that TRUS with color Doppler adds complementary value alongside mpMRI. The one false-negative mpMRI case involved a small (7 mm) Grade Group 2 transition-zone lesion with a borderline ADC value—a recognised limitation of mpMRI for transition-zone disease—that was detected on targeted biopsy directed by TRUS hypoechoogenicity. This finding illustrates that the two modalities are genuinely complementary rather than redundant.

PSA density was a useful supplementary discriminator, with an AUC of 0.79 and a 3.8-fold increased odds of malignancy at a cut-off of 0.30 ng/mL/mL. PSA density is inexpensive to derive once prostate volume is measured on TRUS and is supported by several prospective series and current guidelines for stratifying PI-RADS 3 lesions.²¹ Integrating this parameter into the local clinical pathway appears justified.

The targeted biopsy analysis reinforced the value of pre-biopsy imaging: targeted cores detected cancer in 92.9% of biopsy-positive patients versus 71.4% for

systematic cores alone, and one cancer was detected exclusively by MRI-targeted sampling of a TRUS-occult PI-RADS 4 lesion. These findings are consistent with PRECISION and MRI-FIRST data and support incorporating mpMRI-guided targeting into routine biopsy practice, even where software fusion is unavailable.^{8,9}

Limitations

The sample size of 25 patients limits statistical power, and confidence intervals around all accuracy estimates are wide; this study should be considered a pilot exercise. TRUS-guided systematic biopsy itself has a false-negative rate of approximately 20–25%, meaning some true cancers in the 'benign' reference group may have been missed.¹³ All mpMRI was performed at 3T with a uniform protocol, and performance on 1.5T systems may differ. Targeting relied on cognitive overlay rather than software fusion, introducing operator-dependent variability. These limitations underscore the need for a larger, adequately powered prospective study.

6. CONCLUSION

This prospective observational study demonstrated that mpMRI substantially outperforms TRUS with color Doppler in detecting prostatic malignancy, with overall diagnostic accuracy of 84.0% versus 64.0% (AUC 0.847 vs 0.640; $p = 0.03$). Combined imaging achieves the highest sensitivity (92.9%) and NPV (90.0%), and is recommended as the pre-biopsy evaluation strategy. PI-RADS v2.1 scoring correlated strongly with histopathological Grade Group, and no clinically significant cancer was identified in PI-RADS 1–2 lesions. PSA density adds incremental discriminatory value and should be incorporated into the clinical decision pathway. These findings support adopting pre-biopsy mpMRI as the standard evaluation approach for patients with suspected prostatic disease at this and comparable tertiary care institutions.

FIGURE LEGEND

Figure 1. ROC curves for TRUS with color Doppler (AUC 0.640), mpMRI (AUC 0.847), combined imaging (AUC 0.880), and PSA density (AUC 0.790) for detection of prostate cancer. Operating points at clinical thresholds are shown as filled circles. Reference standard: TRUS-guided biopsy histopathology ($n = 25$).



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