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COMPARATIVE STUDY OF MAGNETIC RESONANCE IMAGING AND TRANS-RECTAL ULTRASOUND IN IDENTIFYING CLINICALLY SIGNIFICANT PROSTATE CANCER AMONG DIVERSE ETHNIC GROUPS USING HISTOPATHOLOGY AS THE GOLD STANDARD

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Abstract

Background: *Prostate cancer is one of the leading malignancies affecting men globally. Early and accurate diagnosis is essential to reduce morbidity and mortality. Magnetic Resonance Imaging (MRI) and Trans-Rectal Ultrasound (TRUS) are widely used imaging techniques for prostate cancer detection, but their diagnostic accuracy varies. This study aimed to compare the effectiveness of MRI and TRUS in identifying clinically significant prostate cancer (csPCa), using histopathology as the gold standard, and to examine associations with PSA levels and ethnicity.*

Objective: *To Compare the Magnetic Resonance Imaging and Trans-Rectal Ultrasound in Identifying Clinically Significant Prostate Cancer Among Diverse Ethnic Groups Using Histopathology as the Gold Standard.*

Methods: *A total of 120 male patients underwent PSA testing, MRI (reported using PI-RADS scores), TRUS, and histopathological evaluation via biopsy. Diagnostic performance was assessed using sensitivity and specificity calculations. Statistical associations between imaging findings, PSA levels, ethnicity, and histopathological results were evaluated using Chi-square and likelihood ratio tests.*

Results: *MRI demonstrated a high sensitivity of 95.5% but low specificity of 6.45%. TRUS showed a sensitivity of 68.5% and specificity of 25.8%. A statistically significant association was found between PI-RADS scores and histopathological outcomes ($p = 0.017$), confirming its diagnostic utility. No significant associations were found between MRI findings ($p = 0.801$), TRUS findings ($p = 0.110$), PSA levels ($p = 0.348$), or ethnicity ($p = 0.529$) and histopathological results.*

Conclusion: *MRI is more sensitive than TRUS in detecting csPCa, but its low specificity limits its standalone use. The significant correlation between PI-RADS and histopathology ($p = 0.017$) supports its use in clinical decision-making. A multimodal diagnostic approach combining MRI, TRUS, PSA, and biopsy is recommended for accurate and reliable prostate cancer diagnosis.*

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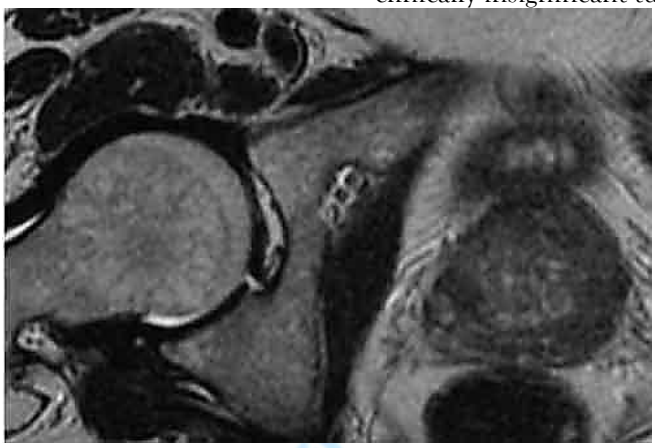
INTRODUCTION

Prostate cancer (PCa) remains a major public health concern and ranks as the second most commonly diagnosed malignancy and cause of cancer-related deaths among men worldwide, following lung cancer. It is a complex disease with a significant global burden, accounting for over 1.4 million new cases and approximately 375,000 deaths annually. The disease disproportionately affects individuals based on ethnic background, with non-Hispanic Black men exhibiting the highest incidence rate at 188.7 per 100,000, followed by non-Hispanic White men and non-Hispanic Asian/Pacific Islanders. The aging global population and widespread use of prostate-specific antigen (PSA) screening are expected to further increase the incidence of prostate cancer in the coming decades.

The variability in clinical behavior of prostate cancer—from indolent tumors that may not require immediate treatment to aggressive forms that metastasize rapidly—presents a challenge in urologic oncology. Clinically significant prostate cancer (csPCa) refers to tumors with a higher potential to grow, spread, and affect survival, thereby necessitating timely and accurate diagnosis. The goal of modern diagnostic approaches is to identify csPCa while avoiding overdiagnosis and overtreatment of clinically insignificant tumors.



Diffusion-Weighted Magnetic Resonance Imaging for Prostate Cancer Staging

The traditional diagnostic pathway involves PSA screening followed by digital rectal examination (DRE) and tissue biopsy if abnormalities are detected. Histopathological evaluation remains the gold standard for definitive diagnosis, providing essential information on tumor type, grade, and aggressiveness, commonly assessed using the Gleason scoring system. A Gleason score of 7 or higher typically indicates csPCa. Despite its diagnostic utility, biopsy is invasive and poses risks such as bleeding, infection, and sampling errors. Conventional trans-rectal ultrasound (TRUS)-guided biopsies can miss tumors, particularly in less accessible regions of the prostate.

Conversely, multiparametric magnetic resonance imaging (mpMRI) has emerged as a superior imaging technique. It combines anatomical and functional imaging—such as T2-weighted imaging, diffusion-weighted imaging (DWI), and dynamic contrast-enhanced (DCE) imaging—to enable better tissue characterization and localization of suspicious lesions. The adoption of the Prostate Imaging Reporting and Data System (PI-RADS) has standardized mpMRI interpretation, improving diagnostic accuracy and inter-observer reliability. Studies show that mpMRI significantly increases csPCa detection rates and reduces unnecessary biopsies by avoiding detection of indolent tumors. MRI-targeted biopsies based on mpMRI findings have demonstrated superior diagnostic accuracy compared to systematic TRUS-guided biopsies.

Nonetheless, mpMRI has limitations, including high costs, limited accessibility, longer procedure time, and dependence on radiologist expertise and equipment quality—factors especially relevant in low- and middle-income settings. This raises the need for comparative studies that evaluate the diagnostic

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performance of TRUS and mpMRI in identifying csPCa across diverse ethnic populations.

The diagnostic accuracy of mpMRI and TRUS in detecting clinically significant prostate cancer among men of varying ethnic backgrounds, using histopathology as the gold standard. By understanding the strengths and limitations of each modality across ethnic lines, this research seeks to contribute to the development of more personalized, effective diagnostic strategies for prostate cancer.

Methodology:

This research employed a comparative prospective study design, conducted over a six-month period in the Radiology Department of Aznostics – The Diagnostic Center, Lahore. A total of 120 participants were included, based on the sample size calculated using the formula $n = Z^2P(1-P)/d^2$. The sampling strategy used was the convenient sampling technique, which allowed for the inclusion of eligible individuals who presented during the study duration and met the inclusion criteria.

Participants were selected based on specific eligibility parameters. The inclusion criteria consisted of male individuals aged 40 years or older, those with elevated prostate-specific antigen (PSA) levels (e.g., PSA > 4 ng/mL), patients with clinically suspected or localized prostate cancer, and those who provided informed consent to participate in the study. On the other hand, the exclusion criteria ruled out individuals with a history of prior treatment for prostate cancer, patients suffering from severe comorbidities that could compromise the safety of imaging or biopsy, those with uncontrolled coagulopathies (posing a high risk of bleeding during biopsy), and patients with contraindications for MRI, such as metal implants, severe claustrophobia, or other related conditions.

The imaging modalities used in the study included a Siemens Magnetom C! MRI scanner with a field strength ranging from 0.35 to 1.5 Tesla, and a Toshiba Aplio 500 transrectal ultrasound probe, operating at a central frequency of 6 MHz, with native frequency options of 3.6 MHz, 5.8 MHz, and 8.8 MHz. These imaging systems were employed to evaluate and compare the diagnostic performance of multiparametric MRI and transrectal ultrasound in the detection of clinically significant prostate cancer, with histopathological findings serving as the gold standard reference.

Results:

The study included 120 male participants aged between 40 and 90 years, with a mean age of 65.96 years (SD = 9.87), highlighting an older adult population at higher risk for prostate cancer. The ethnic distribution was diverse, with Punjabis representing the largest subgroup (27.5%), followed by Urdu-speaking individuals (23.3%), Saraikis (15.8%), Baloch and Pashtuns (11.7% each), and Sindhis (10%). This diversity enhances the applicability of findings across ethnic communities.

Clinical histories revealed various presenting symptoms. The most common was urinary retention (28.3%), followed by hematuria (24.2%), prostatitis (20%), pelvic pain (14.2%), and weight loss (13.3%). These symptoms reflect typical urological conditions that often prompt further diagnostic evaluation.

All participants underwent MRI and TRUS procedures. Based on MRI results, 49.2% of participants were categorized as PI-RADS 4 (high risk), 36.7% as PI-RADS 5 (very high risk), and 14.2% as PI-RADS 3 (intermediate risk). Overall, 65.8% of participants were labeled "Suspicious" and 29.2% "Highly Suspicious", while only 5% had "Normal/Benign" MRI findings. These results suggest MRI's strong capacity to identify potentially malignant prostate lesions.

TRUS findings varied significantly. The most frequent observation was "no suspicious peripheral zone foci" (44.2%), followed by foci on either side (19.2%) and on the left side (17.5%). Fewer cases showed enlarged prostate with nodules (3.3%) or general suspicious findings (5.8%).

Histopathological analysis, considered the gold standard, confirmed prostatic acinar adenocarcinoma in 74.2% (n = 89) of cases, with the remaining 25.8% (n = 31) showing benign prostatic tissue. This high malignancy rate underscores the importance of accurate imaging in early detection.

PSA levels were also assessed. About 34.2% of participants had PSA >30, while others fell into the 10–20 (25.8%), 20–30 (24.2%), and <10 (15.8%) categories. Notably, cancer was also found in patients with lower PSA levels, indicating that PSA, while

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useful, is not fully reliable as a standalone marker for malignancy.

Cross-tabulation between MRI findings and histopathological results showed that most cancer cases were associated with abnormal MRI readings—60 of 79 "Suspicious" and 25 of 35 "Highly Suspicious" cases were confirmed malignant. However, the association was not statistically significant (χ^2 = 0.444, p = 0.801), suggesting MRI suspicion alone does not predict histopathological outcomes with certainty.

Category	Frequency	Percent (%)
TRUS: Enlarged prostate w/ nodules	4	3.3
TRUS: Suspicious right zone	12	10.0
TRUS: Suspicious left zone	21	17.5
TRUS: No suspicious zone	53	44.2
TRUS: Suspicious either side	23	19.2
TRUS: Suspicious unspecified	7	5.8
MRI: Normal/Benign	6	5.0
MRI: Suspicious	79	65.8
MRI: Highly Suspicious	35	29.2
PI-RADS 3 (Intermediate risk)	17	14.2
PI-RADS 4 (High risk)	59	49.2
PI-RADS 5 (Very high risk)	44	36.7

Modality	Sensitivity	Specificity	TP	FN	TN	FP
MRI	95.5	6.45	105	5	1	9
TRUS	68.5	25.8	75	35	3	7

In contrast, TRUS findings showed a stronger correlation with histopathology, particularly when peripheral zone foci were present on the left or both sides. Pearson's Chi-square test indicated statistical significance (χ^2 = 12.875, p = 0.025), supported by the Likelihood Ratio test (p = 0.015), though sparse data in some categories warrant cautious interpretation.

The PI-RADS scoring system showed a meaningful relationship with confirmed cancer diagnoses. Among PI-RADS 4 and 5 cases, 81.4% and 75% respectively were histologically malignant. Chi-square analysis confirmed this association (χ^2 = 8.128, p = 0.017), reinforcing PI-RADS as a useful tool in prostate cancer evaluation.

Ethnic group analysis revealed no statistically significant association with histopathological outcomes (χ^2 = 4.140, p = 0.529), although some differences in cancer prevalence were observed.

Likewise, PSA range was not significantly associated with histopathological outcomes (χ^2 = 3.297, p = 0.348), though higher PSA levels tended to align with more malignancy.

Diagnostic performance analysis revealed that MRI had high sensitivity (95.5%) but low specificity (6.45%), resulting in many false positives. TRUS exhibited moderate sensitivity (68.5%) and better specificity (25.8%), presented in the table 01 and chart 01. suggesting it was somewhat more accurate in ruling out benign cases. Therefore, while MRI is highly effective at identifying cancer, its low specificity limits its standalone value. The study supports a multimodal approach, combining MRI, TRUS, PSA levels, and histopathological evaluation,

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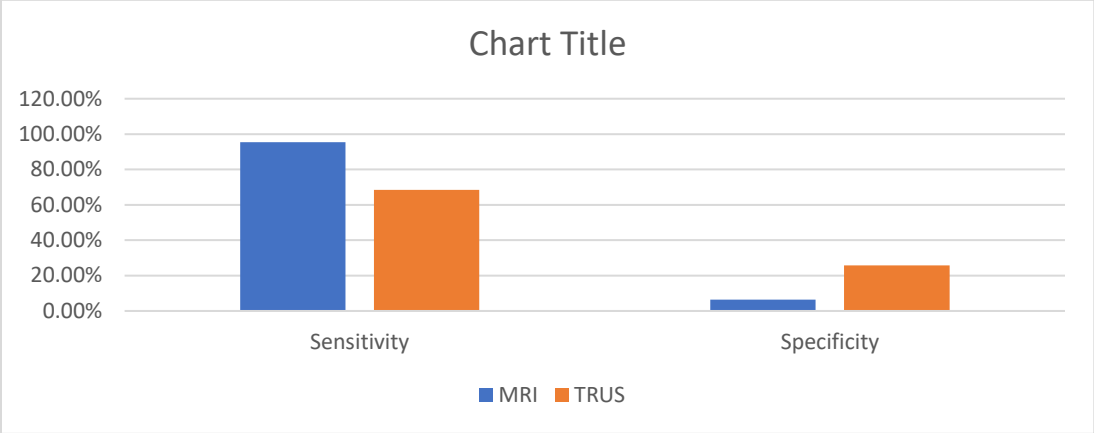
as the most reliable method for detecting clinically significant prostate cancer.



Discussion:

This research investigated and compared the sensitivity of Magnetic Resonance Imaging (MRI) and Trans-Rectal Ultrasound (TRUS) to diagnose clinically significant prostate cancer (csPCa) in relation to histopathology as the gold standard. It also checked whether ethnic background, PSA level or imaging scores (like PI-RADS) had effects on diagnosis. Having a heterogeneous sample of 120 participants, the results highlight the importance of the existing imaging methods in the prostate cancer diagnosis as well as their limitations and the necessity of using multiple methods.

MRI exhibited higher sensitivity (95.5%) than TRUS (68.5%), which means that it is more effective in identifying true positive cases of cancer. Its specificity, however, was very low (6.45%), and implied high false-positive rates and the low capability of distinguishing benign and malignant lesions. TRUS, however, demonstrated slightly higher specificity (25.8%) which is, nevertheless, not high, meaning that it also fails to eliminate the risk of malignancy in benign cases with confidence.

These findings are generally in line with those of Benelli et al. (2020) that found better cancer detection rates and high agreement of targeted MRI biopsy and post-surgery pathology. In their analysis, the detection of csPCa was strongly linked with higher PI-RADS scores (73.4% in PI-RADS 5), which is consistent with the current study since 75% of the PI-RADS 5 cases were revealed as histologically malignant. Furthermore, Boesen et al. (2018) concluded that mpMRI performed better compared to TRUS in identifying csPCa and correctly identified 78 percent of true positives compared to 58 percent of true positive results identified by TRUS, which closely matches our study result (33) , (35).

On the contrary, Ahetasham and Mathews (2019) found greater specificity of TRUS (95.4%) than MRI (76.9%) in characterizing the lesions, which contradicts our results. The difference can be related to differences in the quality of equipment, the experience of a radiologist, or a difference in the type of considered lesions. The extremely low specificity of MRI in this study may indicate either excessive dependence on suspicion without correlation to functional imaging or variation of interpretive criteria, even with PI-RADS (34)..

Our correlative analysis (cross- tabulation) of MRI results with histopathology results revealed that 85 patients of 114 patients with abnormal MRI results (either Suspicious or Highly Suspicious) results were found to have malignancy. Nevertheless, Chi-Square test by Pearson found no statistically significant relationship ($p = 0.801$). This might be explained by small population of patients (only 6) in the "Normal/ Benign" category MRI, which makes results skewed and power limited.

Conversely, Stabile et al. (2020) highlighted that mpMRI had the potential to decrease biopsies by a large margin, finding csPCa and preventing overdiagnosis of indolent tumors. Although our findings align with the high detection rate, it does question the assertion that MRI could confidently exclude benign disease on the basis of high false-positive rate in this group(4).

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In this study, the PI-RADS scoring system was a major predictor of prostate cancer (p = 0.017). Eighty-one and a half percent of PI-RADS 4 and 75 percent of PI-RADS 5 were found to have cancer. This statistically significant association proves the clinical utility of PI-RADS as a standardized MRI-based risk stratification measure.

The correlation between the PI-RADS scores and the detection of csPCa was considered strong by Benelli et al. (2020) and Ramacciotti et al. (2024) as well. According to Benelli, PI-RADS 3, 4 and 5 showed detection rates of 17.2%, 44.9% and 73.4%, respectively, which almost resembles our results of 47.1%, 81.4%, and 75%. This agreement facilitates the wider clinical use of PI-RADS in the imaging of prostate and biopsy targeting schemes.

The TRUS results were heterogeneous. Although cancer rates were higher with the presence of suspicious peripheral zone foci, the Pearson Chi-Square was not statistically significant (p = 0.110). Nevertheless, the Likelihood Ratio test was significant (p = 0.026) indicating a possible, yet complicated, relationship.

According to Luvhengo (2022), their experiments demonstrated that TRUS-guided biopsies were substantially more efficient than finger-guided ones in detecting cancer (62% vs. 53% detection rate), which once again proves the usefulness of TRUS, despite its limitations. We have also confirmed in our research the moderate diagnostic effectiveness of TRUS, in particular, the effectiveness of this test, when it is combined with other procedures (31).

In addition, a study by Zhu et al. (2019) indicated that TRUS could be superior to MRI in identifying non-clinically significant cancers, particularly in PI-RADS 3 instances- further adding context to the existing knowledge that TRUS could identify some low-grade lesions that MRI could either miss or under-rate (32)..

Although the higher PSA levels were associated with the greater malignancy in our study, it was also found that cancer was present in a large proportion of patients with low PSA levels (15 out of 19 patients with a PSA of 0.00 had cancer). This is supported by non-statistically significant association (p = 0.348) which concur with the study by Merriel et al. (2022) that found that PSA alone is insufficiently specific and sensitive to detect csPCa(41).

Therefore, PSA screening is a good but a limited tool, especially when used in isolation. The low rate of false negative at the low PSA levels also underscores the significance of complementing PSA testing with imaging and histopathology in order to achieve diagnosis.

The effect of ethnicity on the detection of prostate cancer was addressed through the comparison of histopathological results of 6 ethnic groups. Although there was some variability in the detection rates, such as in Saraiki (84.2%) and Baloch (85.7) where a higher rate of malignancy was noted, the association was not found to be significant (p = 0.529). This is consistent with the results of Nyame et al. (2022) and Mahal et al. (2022) that highlighted that racial and ethnic disparities in prostate cancer outcomes are usually multifactorial and include access to care, socioeconomic status, and biological differences.

In spite of the fact that our study did not provide significant differences in detection rates by ethnic groups, this may be because of small subgroup sizes. To make the stronger conclusions, even larger studies that stratify sampling by ethnicity are required to identify the slight but significant difference in imaging performance or disease burden.

The major conclusion of this study is that MRI is highly sensitive but cannot be used as the only tool to diagnose because it has very low specificity. TRUS, in its turn, will have complementary advantages, especially in characterising ambiguous or peripheral zone lesions and enhancing the cost-effective systematic of diagnostic processes in low-income countries.

The most effective clinical evidence includes multimodal diagnostic process (including PSA levels, MRI (with PI-RADS score), TRUS results and biopsy). This method gives a good mix of diagnostic sensitivity and cost, accessibility, and clinical accuracy, and eventually leads to better patient outcomes.

Consistent with recent research initiatives like the one by Wu et al. (2024) and Mehmood et al. (2025), combining mpMRI with DWI and ADC mapping has proven to be more sensitive and effective in

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characterizing lesions and, possibly, discriminating between aggressive cancer cases. This development provides an optimistic future to the centers with state-of-the-art MRI machines.

This research is limited in some ways. First, the small size of the sample (especially, in some ethnic and TRUS subgroups) decreased the statistical comparison power. Second, MRI specificity was not as high as anticipated, which could have been a result of reader variability, lack of experience or equipment limitations. Third, despite the use of the gold standard histopathology, the interobserver variability in the interpretation of biopsies was not considered. Finally, the single diagnostic center environment might impose a restricted transfer of the results to other populations.

In future, the studies need to be larger and multicentric with standardized imaging criteria and reader training to reduce interpretive bias. Furthermore, the introduction of machine learning and artificial intelligence (AI) to strengthen imaging analysis and increase specificity, especially in the case of MRI, might be an adequate solution to the false-positive issue.

Further studies should also examine genetic, environmental, and socioeconomic factors across ethnic groups, as they may influence both cancer risk and imaging accuracy. Finally, trials exploring MRI-TRUS fusion-guided biopsies may provide a balanced approach by combining the sensitivity of MRI with the accessibility of TRUS, as recommended by Antoinette Birs et al. (2016) and others.

Conclusion:

This study highlights the superior sensitivity of multiparametric MRI over TRUS in detecting clinically significant prostate cancer, especially when evaluated using PI-RADS scoring. Despite MRI's diagnostic strength, its low specificity and TRUS's moderate performance limit their standalone reliability. A multimodal approach—combining imaging, PSA levels, and histopathological confirmation—is essential for accurate diagnosis. Ethnicity did not show a significant association with cancer detection. The findings support integrated diagnostic strategies to enhance clinical accuracy. Such protocols can lead to earlier detection, reduced overtreatment, and better patient outcomes.

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