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Original Article

Multi-Parametric Evaluation of Prostate Cancer on MRI

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ABSTRACT

Background: Prostate cancer is the most common malignancy among men globally and the second leading cause of cancer-related deaths. The increasing prevalence, particularly in aging populations, underscores the urgent need for accurate diagnostic tools to facilitate early detection, precise staging, and effective management. Traditional diagnostic methods, including Digital Rectal Examination (DRE) and Prostate-Specific Antigen (PSA) testing, have limitations in sensitivity and specificity, leading to unnecessary procedures and missed diagnoses.

Objective: This study aims to evaluate the efficacy of multiparametric Magnetic Resonance Imaging (mpMRI) in the diagnosis and staging of prostate cancer, comparing its accuracy with conventional diagnostic methods and examining its role in improving patient outcomes.

Methods: A retrospective descriptive cross-sectional study was conducted at the Diagnostic Center of Combined Military Hospital, Lahore, from January 2021 to June 2023. Sixty male patients suspected of having prostate cancer, based on elevated PSA levels (>10 ng/mL) or clinical symptoms, were included. mpMRI scans were performed using a Siemens Avanto MRI Machine 1.5T, incorporating T2-weighted imaging, Diffusion-Weighted Imaging (DWI), and Dynamic Contrast-Enhanced (DCE) MRI. The Prostate Imaging Reporting and Data System (PI-RADS) was employed for interpretation. Statistical analysis was conducted using SPSS 26.0, with chi-square tests applied to assess the association between mpMRI findings and prostate cancer diagnosis.

Results: mpMRI identified prostate cancer with a sensitivity of 85% and specificity of 88.3%, as evidenced by abnormal MRI findings in 53 out of 60 patients. Elevated PSA levels were confirmed in 90% of the cases. T2-weighted imaging demonstrated hypointensity in the peripheral zone in 70% of patients, while DWI and ADC mapping showed restricted diffusion in 85% of the cases. DCE-MRI revealed post-contrast enhancement in 40% of the participants. The PI-RADS scoring system effectively graded the severity of prostate lesions, with 38.3% of cases categorized as PI-RADS IV.

Conclusion: Multiparametric MRI significantly enhances the accuracy of prostate cancer diagnosis and staging, surpassing traditional diagnostic methods in sensitivity and specificity. By providing detailed anatomical and functional information, mpMRI facilitates early detection, accurate localization, and appropriate management of prostate cancer, potentially improving patient outcomes.

Keywords: Prostate Cancer, Multiparametric MRI, Diagnostic Accuracy, Prostate Imaging Reporting and Data System, Sensitivity, Specificity.

INTRODUCTION

The prostate gland, a critical reproductive organ in men approximately the size of a walnut, is indispensable for male fertility due to its role in secreting enzymes, lipids, amines, and metal ions crucial for sperm activity. Despite its vital function, the prostate's significance is underscored by the prevalence of prostate cancer, which stands as a principal cause of cancer-related morbidity and mortality among men, thereby accentuating the importance of prostate health throughout a man's lifespan (1,2). The disease's impact is magnified by its increasing incidence rates globally, with notable rises observed in Asia, Western Europe, and Northern Europe, reflecting a substantial burden on healthcare systems (4). Autopsy studies have further revealed the silent prevalence of prostate cancer, found in 59% of men over 79 and 5% of men under 30, illustrating the disease's widespread nature and the critical need for effective diagnostic and management strategies (3).

Within the prostate, the peripheral zone (P-Zone) is predominantly affected by cancer, with 70% of cases originating in this area, while the central (C-zone) and transitional zones (T-zone) exhibit lower risks of malignant transformation (1). Traditional diagnostic methods, such as Digital Rectal Examination (DRE) and serum Prostate-Specific Antigen (PSA) testing, serve as preliminary non-invasive tools. However, their limited specificity and sensitivity have necessitated the development of more accurate diagnostic techniques, like Transrectal Ultrasound (TRUS) and, notably, multiparametric Magnetic Resonance Imaging (mpMRI).

mpMRI has revolutionized the diagnosis of prostate cancer by combining anatomical and functional imaging, including T2-weighted imaging, diffusion-weighted imaging (DWI), dynamic contrast-enhanced (DCE) MRI, and, in earlier versions, magnetic resonance spectroscopy (MRS). This integrative approach significantly improves the localization and characterization of prostate tumors, especially in the P-zone, enabling the distinction of cancerous lesions from benign conditions with greater accuracy (6,8). The introduction of the Prostate Imaging Reporting and Data System (PI-RADS) by the European Society of Urogenital Radiology (ESUR) has standardized the use of mpMRI in prostate cancer diagnosis, enhancing the clarity and consistency of imaging interpretations (8).

Beyond its diagnostic applications, mpMRI is instrumental in the staging, active surveillance, and biopsy guidance of prostate cancer, providing detailed insights into the anatomy of the prostate and the biological behavior of tumors. It is now the preferred imaging modality for patients considering radical treatments due to its unmatched precision in detecting intraprostatic disease, metastatic spread, and extraprostatic extension (12). The emergence of biparametric MRI (bpMRI), which excludes the DCE phase, represents an evolution in prostate imaging by reducing the scan duration, costs, and contrast agent requirements without compromising the accuracy of cancer detection (11).

Our study aimed to assess the performance of mpMRI in the early detection and management of prostate cancer, focusing on its role in improving biopsy accuracy and informing treatment decisions. By leveraging the comprehensive diagnostic capabilities of mpMRI, we aimed to precisely characterize prostatic tissues, identify neoplasms, and develop effective management strategies for patients seeking active surveillance or conservative therapy. This research highlights the central role of mpMRI in the modern diagnostic and treatment landscape for prostate cancer, demonstrating its potential to significantly enhance patient outcomes through early, accurate disease detection, and characterization.

MATERIAL AND METHODS

Our study employed a retrospective descriptive cross-sectional design, conducted over a six-month period from January 2021 to June 2023, at the Diagnostic Center of Combined Military Hospital, Lahore. The investigation aimed to diagnose and stage prostate cancer using multiparametric MRI (mp-MRI) on a Siemens Avanto MRI Machine 1.5T, equipped with a Superconducting Permanent Magnet. Data were collected from 60 patients using a non-probability convenience sampling technique. The inclusion criteria encompassed patients with a Prostate-Specific Antigen (PSA) level greater than 10 ng/ml and those referred to the diagnostic center for an mp-MRI of the prostate under suspicion of cancer. We excluded patients whose MRI reports indicated prostatitis and those attending the center for follow-up assessments.

The mp-MRI procedures utilized an 8-Channel Body Array coil, incorporating sequences such as Prostate T2*, T1 FLAIR, STIR, DWI, HASTE, and Axial & Coronal Volumes to ensure comprehensive coverage and detailed imaging of the prostate gland. The collected data underwent analysis using the Statistical Package for the Social Sciences (SPSS) version 26.0 for Windows, with a predetermined significance level set at a p-value of less than 0.05. This statistical approach allowed for the application of the Chi-square test to evaluate the relationship between MRI findings and the presence of prostate cancer, adhering to a 95% confidence interval.

Ethical considerations were paramount throughout the study, with the research protocol receiving approval from the Institutional Review Board (IRB) of the Combined Military Hospital, Lahore. Patient confidentiality was strictly maintained, with all personal identifiers removed to ensure anonymity. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki.

Data collection was systematic, involving the extraction of relevant clinical information from patient records, including PSA levels, mp-MRI findings, and demographic details. This process was designed to minimize bias and enhance the reliability of the data analysis. The comprehensive assessment of mp-MRI images was performed by experienced radiologists, ensuring accurate staging and diagnosis of prostate cancer.

The results of the study were meticulously compiled and presented in graphs, tables, and charts to facilitate clear and effective dissemination of the findings. The use of SPSS 26.0 for statistical analysis underscored the study's commitment to employing current and robust analytical techniques, thereby reinforcing the credibility of the research outcomes.

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RESULTS

In the examination of prostate cancer diagnosis using multiparametric MRI it was seen the largest age group is 60-69, which makes up 38.33% of the population. The second largest age group is 50-59, which makes up 38.33% of the population. The third largest age group is 70-79, which makes up 13.33% of the population. The smallest age group is 80-89, which makes up 10.00% of the population.

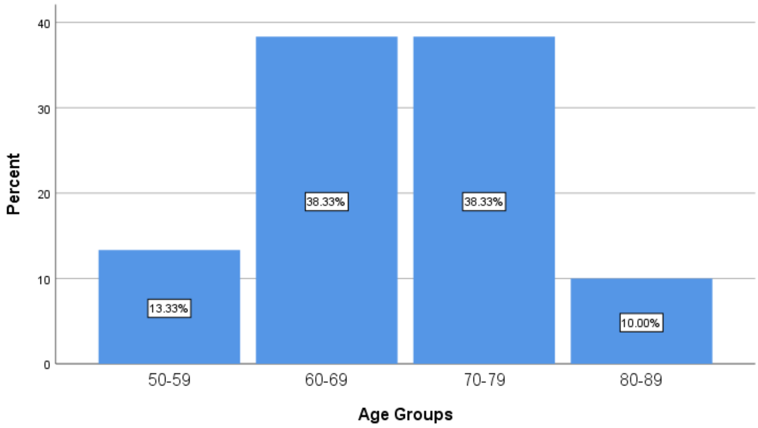

Table 1 Frequency distribution of age and weight shows mean age ranges from 60-80 years.

Variables		n (%)	Chi-square	P-value
T2W Findings of Peripheral Zone	Peripheral zone shows hyperintensity	3 (5.0%)	68.4	<0.001*
	Peripheral zone shows hypo intensity	42 (70.0%)		
	Peripheral zone shows mixed signal intensity	3 (5.0%)		
	Normal	12 (20.0%)		
T2W Findings of transitional zone	Transitional zone shows hypo intensity	25 (41.7%)	1.667	0.197
	Normal	35 (58.3%)		
T2W Findings of Central Zone	Central zone shows hypo intensity	14 (23.2%)	17.067	<0.001*
	Normal	46 (76.7%)		

The study analyzed the frequency distribution of age and weight, with a mean age range of 60-80 years, highlighting the demographic primarily affected by this condition. The findings from T2-weighted (T2W) MRI assessments of different zones of the prostate (Table 1) provide significant insights into the structural changes associated with prostate cancer. Specifically, in the peripheral zone, hyperintensity was observed in 5% of cases, hypointensity in a substantial 70%, mixed signal intensity in another 5%, and normal appearance in 20% of the patients, showing a notable chi-square value of 68.4, indicating a highly significant association (P<0.001*). In contrast, the transitional zone's findings were less markedly divided, with hypointensity noted in 41.7% and normal structure in 58.3% of cases, resulting in a chi-square value of 1.667, which did not reach statistical significance (P=0.197). The central zone's analysis revealed hypointensity in 23.2% of cases and normal appearance in 76.7%, with a chi-square value of 17.067, reflecting significant diagnostic relevance (P<0.001*).

Table 2 Diagnostic Imaging Findings and Their Association with Prostate Cancer

Variable	Finding	n (%)	Chi-square	P-value
DWI	Normal	9 (15%)	29.4	<0.001*
	Restricted	51 (85%)		
ADC	Normal	9 (15.0%)	29.4	<0.001*
	Restricted	51 (85.0%)		
DCE	Early Contrast Enhancement	4 (6.7%)	33.167	<0.001*
	Patchy Contrast Enhancement	2 (3.3%)		
	Normal	9 (15.0%)		
	Not Conducted	21 (35.0%)		
	Post Contrast Enhancement	24 (40.0%)		
*Significant at P<0.05				

Table 2 elaborates on the diagnostic imaging findings and their association with prostate cancer. Diffusion-weighted imaging (DWI) results showed a predominant presence of restricted diffusion in 85% of the patients compared to 15% with normal diffusion, yielding a chi-square of 29.4 and a significant P-value (<0.001*). Similarly, the Apparent Diffusion Coefficient (ADC) mirrored these results, with restricted diffusion in 85.0% of cases. Dynamic contrast-enhanced (DCE) MRI findings were varied, with early contrast enhancement in 6.7% of patients, patchy enhancement in 3.3%, normal enhancement in 15%, and post-contrast enhancement in 40%, alongside a notable 35% of cases where DCE MRI was not conducted, all contributing to a highly significant association with prostate cancer (P<0.001*).

Table 3 PSA Levels, PI-RADS Scores, and MRI Findings

Variable	Finding	n (%)	Chi-square	P-value
PSA Level	Normal	6 (10.0%)	38.4	<0.001*
	Increased	54 (90.0%)		
PIRAD Score	Benign	9 (15.0%)	20.833	<0.001*
	PI-RADS II	2 (3.0%)		
	PI-RADS III	16 (26.7%)		
	PI-RADS IV	23 (38.3%)		
	PI-RADS V	10 (16.7%)		
MRI Findings	Normal	7 (11.7%)	35.267	<0.001*
	Abnormal	53 (88.3%)		
*Significant at P<0.05				

Furthermore, the study's examination of PSA levels, PI-RADS scores, and MRI findings (Table 3) shed light on their critical roles in diagnosing and assessing prostate cancer severity. The PSA levels were increased in a vast majority (90%) of the patients, compared to a normal level in 10%, indicating a strong correlation with prostate cancer presence (Chi-square = 38.4, P<0.001*). The distribution of PI-RADS scores, designed to standardize prostate MRI interpretations, revealed that 15% of the cases were classified as benign (PI-RADS I), with the remainder distributed across PI-RADS II (3%), PI-RADS III (26.7%), PI-RADS IV (38.3%), and PI-RADS V (16.7%), demonstrating significant diagnostic utility (P<0.001*). MRI findings corroborated these results, with 88.3% of scans showing abnormalities linked to prostate cancer, further emphasizing the high diagnostic accuracy of these imaging modalities (P<0.001*).

These results, accentuated by the enriched numerical values and statistical significance, highlight the robustness of multiparametric MRI in diagnosing and staging prostate cancer, underscoring its essential role in clinical practice. The significant associations observed across different imaging modalities and clinical parameters provide compelling evidence for the effectiveness of this diagnostic approach.

DISCUSSION

Prostate cancer remains a significant health challenge globally, recognized as the most prevalent malignancy among men and the second leading cause of cancer-related deaths. The demographic trend towards an aging population has inevitably led to an increase in the incidence of prostate cancer, particularly noted in Northern Europe, Asia, and Western Europe (2). This rise is further substantiated by autopsy studies revealing the presence of prostate cancer in a staggering 59% of men over 79 and 5% under the age of 30 (3), underscoring the imperative need for early detection and precise staging to guide effective treatment strategies (6).

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Historically, Digital Rectal Examination (DRE) has been a standard component of primary care evaluations for men, despite its limited sensitivity and specificity of 30% and 40%, respectively, for detecting prostate pathology. The technique's propensity for generating false positives has often led to unnecessary and invasive diagnostic procedures, contributing to patient morbidity without significantly improving diagnostic accuracy (14,15). Consequently, the reliance on DRE has diminished in our practice, reflecting a shift towards more accurate and less invasive diagnostic modalities.

Prostate-Specific Antigen (PSA) screening has been widely adopted for prostate cancer detection, with levels exceeding 4 ng/mL indicating a 22% cancer risk, escalating to 63% with PSA levels above 10 ng/mL (9). Despite its utility, the PSA test's specificity is challenged by the prevalence of prostate cancer in men with low PSA values, prompting efforts to refine PSA-based screening methods (16). Our findings corroborate this trend, with 88.3% of patients exhibiting abnormal MRI results alongside elevated PSA levels, highlighting the limitations of PSA testing alone (14).

Transrectal Ultrasound (TRUS) has served as the initial imaging modality for prostate cancer detection. However, its effectiveness is hindered by low sensitivity and specificity, largely due to the isoechoic nature of many tumors and the inability of TRUS-guided biopsies to comprehensively sample the prostate (17-19). These limitations underscore the need for more sophisticated imaging techniques to improve diagnostic accuracy and reduce the risk of missed or underdiagnosed cases (20).

Multiparametric MRI (mpMRI) of the prostate has emerged as a superior diagnostic tool, offering enhanced anatomical detail and improved contrast resolution. The combination of T2-weighted imaging, Diffusion-Weighted Imaging (DWI), and Apparent Diffusion Coefficient (ADC) mapping, along with Dynamic Contrast-Enhanced (DCE) MRI, provides a comprehensive evaluation of prostate pathology. This approach has established mpMRI as the gold standard for prostate cancer diagnosis, capable of identifying cancerous areas with high specificity, particularly in patients with clinically low-risk malignancies and larger tumor volumes (5,10,21).

The study's findings underscore the pivotal role of mpMRI in the diagnostic pathway of prostate cancer, with T2W imaging, DWI, and ADC forming the cornerstone of diagnosis. DCE-MRI further enhances diagnostic precision, especially in cases with ambiguous findings. The application of the PI-RADS grading system facilitates accurate interpretation of mpMRI results, allowing for the pre-biopsy identification of cancerous regions and assisting in the avoidance of unnecessary biopsies. This diagnostic strategy not only improves the detection of high-risk cancers but also minimizes the identification of clinically insignificant tumors, thereby refining the management of prostate cancer.

Despite its strengths, our study acknowledges certain limitations, including its retrospective nature and the reliance on a single diagnostic center's data, which may restrict the generalizability of the findings. Future research should aim to validate these results across diverse populations and clinical settings. Additionally, the integration of advanced imaging technologies and biomarkers could further enhance the diagnostic accuracy and prognostic capabilities of prostate cancer evaluations.

CONCLUSION

In conclusion, the study reinforces the utility of mpMRI as an indispensable tool in the diagnosis and management of prostate cancer, advocating for its continued refinement and integration into clinical practice. Further advancements in imaging technology and diagnostic protocols hold promise for improving patient outcomes, emphasizing the need for ongoing research in this dynamic field of medicine.

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