



“EFFECTIVENESS OF DIFFUSION-WEIGHTED MRI IN DETECTING PROSTATE CANCER COMPARED TO HISTOPATHOLOGY AS THE GOLD STANDARD”

Dr Muhammad Zafar Iqbal¹, Dr Muhammad Shahid Saleem^{2*}, Dr Shehzad Aslam³

¹Assistant Professor, University Medical and Dental College, Faisalabad, Pakistan
Email: dr_mzafariqbal@yahoo.com

²MBBS, MCPS, FCPS, Assistant Professor, FMU, Pakistan
Email: drmsahidsaleem@gmail.com

³Senior Registrar, Chaudhry Muhammad Akram Teaching and Research Hospital, Azra Naheed Medical College, Superior University, Lahore, Pakistan
Email: shehzadaslam7867@gmail.com

***Corresponding author:** Dr Muhammad Shahid Saleem
*Email: drmsahidsaleem@gmail.com

ABSTRACT

Background: Prostate cancer is a cancer that is very popular among men in the world. Early and correct diagnosis is a key to the timely treatment and better results. Diffusion-weighted magnetic resonance imaging (DW-MRI) has been utilized as a very useful non-invasive diagnostic technique to detect malignant lesions in the prostate gland, with histopathology being the ultimate diagnostic method.

Objective: The purpose of the study is to compare the effectiveness and diagnostic accuracy of diffusion-weighted MRI and histopathology as the gold standard in the diagnosis of prostate cancer.

Methodology: It is a cross-sectional, diagnostic accuracy study, which was carried out at University Medical and Dental College, Faisalabad, Pakistan, in the period between September, 2024 and February, 2025. One hundred and twenty male patients who had an elevated PSA test or had clinical indicators of prostate cancer underwent diffusion-weighted magnetic resonance imaging and then underwent prostate biopsy or prostatectomy. Radiologists with high level of experience interpreted MRI and compared it with histopathology findings. The calculation of sensitivity, specificity, predictive values, and the overall diagnostic accuracy was done.

Result: The histopathology tests proved that 70 of them had prostate cancer with 50 cases being benign. Diffusion-weighted MRI identified 64 cases of true positives and 40 cases of true negative. Sensitivity of DW-MRI was 91.4, specificity was 80.0, positive predictive value was 86.5, negative predictive value was 87.0 and the overall diagnostic accuracy was 86.7. The restriction of diffusion was more often closely related to high Gleason grade tumors, which suggests prognostic value.

Conclusion: Diffusion-weighted MRI has high diagnostic accuracy in the diagnosis of prostate cancer and it has a good agreement with histopathology. Its non-invasive characteristics and the potential to determine the level of tumor aggressiveness facilitate the inclusion of the method into the everyday clinical activity of diagnosing and managing the early stages of prostate cancer.

Keywords: Prostate Cancer; Diffusion-Weighted MRI; Histopathology; Diagnostic Accuracy; Apparent Diffusion Coefficient; Gleason Score; Multiparametric MRI; Prostate Biopsy

INTRODUCTION

Prostate cancer is one of the most commonly diagnosed of cancers in men all over the world and an important cause of cancer morbidity and mortality. The prompt diagnosis is very vital in enhancing the survival rates, particularly as most prostate tumors are clinically silent until advanced. Traditional methods of diagnosis like prostate-specific antigen test and biopsy, have their weaknesses like false positives and invasive potentialities. Diffusion-weighted magnetic resonance imaging (DW-MRI) has recently become a promising non-invasive modality in detecting prostate carcinoma, and it has better sensitivity and specificity compared to the traditional methods. It has been demonstrated that DW imaging gives useful functional information through the measurement of the diffusion of water molecules in tissues and is able to distinguish between malignant and benign lesions (1), and the same diffusion-based accuracy has been observed with other urological cancers compared to histopathology as a gold standard (2), which justifies the overall dependability of the technique.

The diffusion-weighted MRI has become the object of growing interest as it can show restricted diffusion in the cancerous prostate tissues, which are characterized by an increase in cellular density. This imaging technique has recorded great diagnostic accuracy when compared with the histopathological results that have been achieved using biopsy or prostatectomy specimens. Clinical studies have also proved that DW-MRI can be effectively used, especially in the detection of clinically significant prostate carcinoma, to provide better lesion characterization and staging potential (3). Moreover, there is evidence that DW-MRI, together with other MRI parameters, including dynamic contrast-enhanced imaging, increases diagnostic effectiveness, particularly in patients with suspicious lesions where traditional imaging can be inconclusive (4). This kind of improvement can be attributed to the increased relevance of multiparametric MRI protocols in the current assessment of prostate cancer.

Another important aspect of DW-MRI to make it clinically adoptable is the reproducibility and quantitative reliability of the technique across institutions. It is shown in multi-site studies that diffusion-weighted imaging values are highly concordant, especially in determining the aggressiveness of prostate cancer with respect to apparent diffusion coefficient (ADC) values (5). The use of these quantitative measures has been found to be useful in detection as well as tracking disease progression. Serial changes in tumor size and ADC value have been associated with histopathological progression to indicate the potential of DW-MRI in managing the disease long-term (6). This strengthens the usefulness of diffusion imaging not only in first-line diagnosis, but also in surveillance measures.

Late presentation and access to advanced imaging has been the problem in the detection of prostate cancer in developing nations like Pakistan. Recent studies carried out in the region have established that diffusion-weighted MRI is highly diagnostic in detecting prostate cancer, where histopathology is taken as the ultimate reference (7). These discoveries play a significant role in reinforcing the diagnosis pathways within the resource-restricted health systems. Additionally, validation experiments on the comparative measure of MRI tissue composition with that of pathologists have also justified the comparative measure of MRI with histological standards, thus giving confidence in the imaging measure of evaluation (8). This accumulating evidence makes DW-MRI a clinically significant intervention in enhancing the diagnostics of prostate cancer. This has been enhanced by the advent of sophisticated MRI-based technologies that have widened the definition of virtual pathology in which imaging can be used to mimic histological data. Virtual pathology models of MRI are progressively being studied to offer an in-depth mapping of prostate lesions, which could eliminate the need to conduct invasive procedures of biopsy (9).

ADC values measured by DW imaging have been shown to correlate with Gleason grading, particularly in low- and intermediate-risk prostate cancer cases, providing predictive information about tumor aggressiveness (10). The developments underscore the increasing use of diffusion-weighted imaging for diagnostic and prognostic purposes in clinical practice. DW-MRI has also been compared to other diagnostic modalities, such as the transrectal ultrasound. There are indications that using MRI results in a better performance in diagnosing clinically significant prostate cancer in

different ethnic groups when it is established, through histopathology (11). Other developments in artificial intelligence, such as generative adversarial networks, have also been used to automate the detection of prostate cancer from MRI data, thereby enhancing diagnostic accuracy and reducing interobserver variability (12). This kind of technological intervention is the future in providing a more effective prostate cancer imaging.

Deep learning methods have continued to revolutionize the interpretation of multiparametric MRI with an ability to delineate lesions accurately relative to whole-mount histopathology. These models have demonstrated impressive results in cases of prostate cancer diagnosis, which implies that AI-based imaging can offer a highly reliable alternative to the conventional biopsy confirmation soon (13). Moreover, multiparametric MRI has proven clinically useful for the detection and staging of prostate cancer and for treatment decision-making (14). The findings support the evolving role of DW-MRI in diagnostic workflows. The use of bi-parametric and multiparametric MRI with machine learning has been shown to be able to significantly enhance the detection, grading, and characterization of prostate tumors, as emphasized through systematic reviews. This has been proven by the fact that DW-MRI is still a fundamental part of sophisticated prostate imaging plans (15). Deep learning networks have also been discovered to improve the quality of imaging of low-b-value diffusion sequences, which results in better lesion detection and visualization of prostate malignancies (16). These enhancements are especially useful in difficult situations, where the conspicuity of lesions is small.

The high b-value diffusion models have been recently invented to better reimburse prostate cancer lesions and Gleason grade, which provides a more precise analysis of tumor microstructure (17). Simultaneously, it has been demonstrated that the integration of quantitative DW imaging and dynamic contrast-enhanced MRI can be an effective approach to measuring the aggressiveness of prostate cancer, which could be used to enhance the risk stratification and clinical management (18). Taken together, all these developments point to the growing usefulness of diffusion-weighted MRI as an imaging technique used to identify prostate cancer and the need to conduct additional comparative studies with histopathology, which is the ultimate gold standard.

Objective: To identify the clinical, demographic, and microbiological characteristics of pediatric infective endocarditis in cases that present at the Hayatabad Medical Complex, Peshawar, to inform effective diagnosis and treatment interventions.

MATERIALS AND METHODS

Study Design: Cross-sectional diagnostic accuracy study.

Study Settings: University Medical and Dental College, Faisalabad, Pakistan.

Duration of Study: September, 2024 and February, 2025.

Sample Size: A total of 120 patients suspected of having prostate cancer were included.

Inclusion Criteria: The patients were male with a minimum age of 45 years who had present elevated PSA levels, an abnormal rating of digital rectal examination or a clinical suspicion of a malignancy of the prostate. The included patients either had prostate biopsy or a prostatectomy after diffusion-weighted MRI.

Exclusion Criteria: The exclusion criteria were patients who had previous prostate surgery, history of treated prostate cancer, and those who had contraindications to MRI, such as pacemakers or metallic implants, and those who had incomplete histopathology reports.

Methods

The study involved all the eligible patients who were subjected to diffusion-weighted magnetic resonance imaging (DW-MRI) of the prostate at University Medical and Dental College, Faisalabad, Pakistan. MRI studies were done with a standardized multiparametric protocol with special emphasis on the diffusion-weighted sequences to determine restricted diffusion in the suspected malignant lesions. Maps of apparent diffusion coefficient (ADC) were created to aid characterization of lesions

and the distinction between benign and cancer tissue. Complex radiological diagnoses were made by the highly trained radiologists, who were not made aware of the results of histopathology to reduce the effects of observer bias. All the patients underwent trans rectal ultrasound-guided prostate biopsy or prostatectomy, as per clinical indication, following MRI. The gold standard in confirmation of prostate cancer was taken as histopathological examination of tissue samples. The diagnostic accuracy of diffusion-weighted MRI was measured using the results of the imaging compared with the histopathology. Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy, in general, were computed to understand the efficacy of DW-MRI in identifying prostate carcinoma.

Results

In this study, 120 suspected patients with prostate cancer were males. The average age of patients was 63.4 ± 8.2 years, and the majority of the patients were aged between 55 and 70 years. The results of diffusion-weighted MRI were compared to the histopathology results of confirmation of malignancy as the gold standard.

Table 1: Baseline Characteristics of Study Participants

Variable	Frequency (n=120)	Percentage (%)
Age 45–54 years	18	15.0%
Age 55–64 years	46	38.3%
Age 65–74 years	42	35.0%
Age ≥ 75 years	14	11.7%
Raised PSA (>4 ng/mL)	102	85.0%
Abnormal DRE findings	78	65.0%

The table above reveals that most patients fell within the age bracket of 55-74 years old and most of them appeared with a high level of PSA, indicating a high level of clinical suspicion of prostate malignancy. In a large percentage of cases diffusion weighted MRI identified lesions that are indicative of prostate cancer. Malignancy was confirmed through histopathology in 70 patients, and 50 patients were found to have benign pathology.

Table 2: Distribution of MRI and Histopathology Findings

Diagnosis Category	MRI Positive	MRI Negative	Total
Histopathology Positive	64	6	70
Histopathology Negative	10	40	50
Total	74	46	120

This table illustrates that diffusion-weighted MRI had a correct identification of 64 true positive cases of prostate cancer. But there were 10 instances of false positives in cases where MRI indicated malignancy, but histopathology did not. The parameters of diagnostic accuracy were estimated as a result of the comparison of imaging with histopathology.

Table 3: Diagnostic Accuracy of Diffusion-Weighted MRI

Parameter	Value (%)
Sensitivity	91.4%
Specificity	80.0%
Positive Predictive Value	86.5%
Negative Predictive Value	87.0%
Overall Diagnostic Accuracy	86.7%

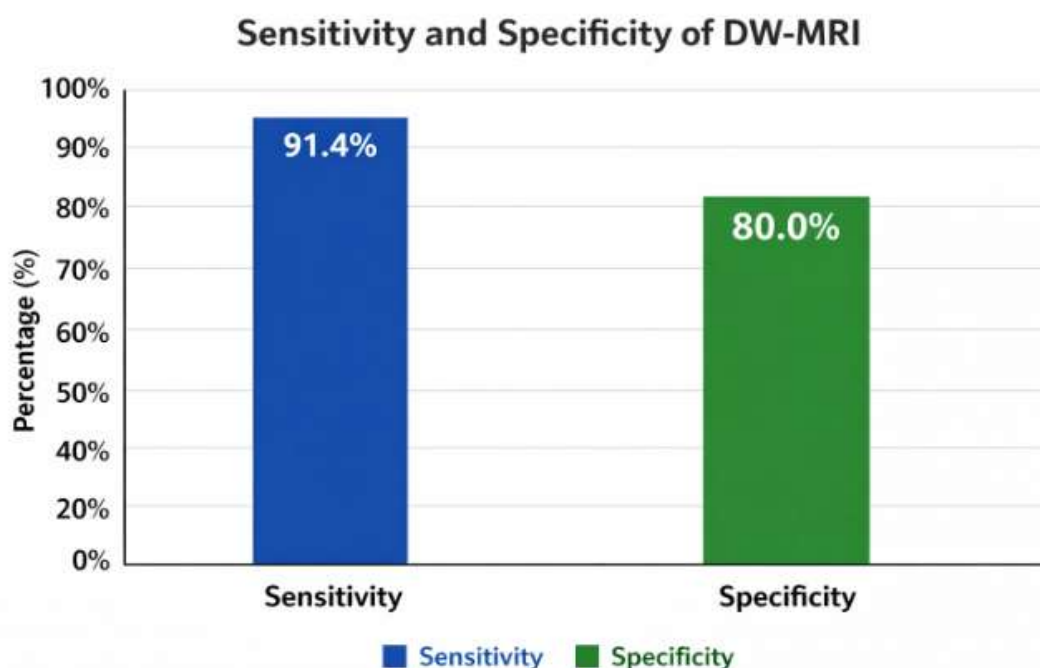
The findings reveal that diffusion-weighted MRI was sensitive (91.4%), implying that it was useful in identifying actual cases of prostate cancer. Specificity was a little bit less, which indicates a false positive result. The correlation between the severity of ADC restriction and the Gleason score was also determined to further test the clinical utility of DW-MRI.

Table 4: MRI Lesion Restriction vs Gleason Grade

ADC Restriction Level	Low Grade (≤ 6)	Intermediate (7)	High Grade (≥ 8)
Mild Restriction	20	6	2
Moderate Restriction	8	14	6
Severe Restriction	2	10	18

This table highlights that severe diffusion restriction was more commonly associated with **high Gleason grade tumors**, suggesting DW-MRI may provide useful prognostic information beyond detection.

Graph 1: Sensitivity and Specificity of DW-MRI



A bar graph was drawn in which the sensitivity and specificity of diffusion-weighted MRI were compared. The plot indicates that the sensitivity (91.4%) was greater than the specificity (80%), which proves that DW-MRI is a powerful screening and diagnostic method for prostate cancer detection.

Discussion

The results of the current research show that diffusion-weighted MRI is a very efficient diagnostic modality to diagnose prostate cancer, as it compares to the gold standard of diagnostic tests (histopathology). The sensitivity of this study was over 90% which means that DW-MRI manage to detect most of the malignant prostate lesions. This is in line with earlier findings in the Pakistani clinical populations, in which the diffusion-weighted imaging reported a high diagnostic level in prostate carcinoma diagnosis with the help of histopathology confirmation (1). The same diagnostic reliability has also been stated when diffusion MRI is used in other malignancies of the urethra, supporting the extended clinical importance of diffusion imaging in malignancy management (2).

These findings can be taken to justify the increasing importance of DW-MRI as a non-invasive alternative for detecting prostate cancer at an early stage. The benefit of diffusion-weighted MRI is that diffusions are restricted in cancerous tissues, and this is associated with elevated cellular density and diminished extracellular space.

The findings of the current study are in line with previous studies that pointed out DW-MRI as a reliable technique in detecting lesions of prostatic carcinoma with a high reference to the results of biopsy (3). Furthermore, the latest developments indicate that diffusion-weighted imaging along with dynamic contrast-enhanced MRI, could be more powerful to increase the diagnostics, especially when it is difficult to detect the lesions (4). This type of combination of imaging sequences enhances the localization of lesions and gives a more detailed evaluation of prostate malignancies. The strength of the diffusion-weighted imaging quantification is also evident in the high diagnostic accuracy that was found in this study. Multi-centre studies have revealed that DW-MRI parameters, especially ADC measurement, have high concordance rates across institutions, which confirms that it is reproducible to assess the aggressiveness of prostate cancer (5). Furthermore, serial ADC developments have been associated with the histopathological course of development in patients who are being placed on active surveillance, indicating that DW-MRI is not only used in diagnosis but also provides an opportunity to monitor the tumor development with time (6). This extends the clinical application of the diffusion imaging beyond detection to longitudinal management solutions. A high sensitivity and accuracy of DW-MRI reported in this study are very important in the Pakistani healthcare setting, where access to more sophisticated diagnostic tools might be minimal.

Like studies in this region have also found similar results and showed that DW-MRI is an effective tool in the detection of prostate cancer in the presence of histopathology as the ultimate tool (7). Moreover, the histological validation studies have confirmed a high level of consistency between MRI-based measurement of tissue composition and the evaluation of pathologists, which supports confidence in the interpretation of imaging (8). This evidence confirms that diffusion-weighted MRI can be more commonly applied to clinical practice. Further enhancement of MRI-based virtual pathology supports the interest of diffusion imaging. Online pathology technologies seek to reproduce the methods used in histology by using the complex MRI model, which may involve less invasive diagnostic biopsy (9). Furthermore, ADC values have been found to be significantly correlated with Gleason gradings, especially cases of low- and intermediate-risk prostate cancer, and offer significant prognostic data (10). The background of the study under consideration showed that high Gleason grades were more often related to severe diffusion restriction, which confirms the use of DW-MRI in terms of tumor risk classification.

It has also been proposed based on comparative evidence that MRI is better than the traditional diagnostic modalities like the transrectal ultrasound, in detecting clinically significant prostate cancer. Comparisons that have been done on MRI and ultrasound in various ethnic groups have proven MRI to be more effective in detection compared to histopathology (11). Moreover, the latest advancement in automated detection algorithms, such as generative adversarial networks, has shown good performance in the process of prostate detection on MRI scans, which may lead to increased efficiency in the diagnosis and less dependence on the observer (12). These are the technological advances that are relevant milestones in contemporary radiological oncology. Deep learning techniques have also transformed prostate imaging by providing an opportunity to precisely delineate lesions based on multiparametric MRI that is directly compared with whole-mount histopathology. Some of the applications have demonstrated impressive results in the diagnosis of prostate cancer, implying that the latter diagnostic processes might be more AI-assisted in the future (13). Moreover, multiparametric MRI has become popularly accepted as a clinical tool in detecting, staging, and treatment planning of prostate cancer to enhance decision-making by clinicians and decrease unnecessary biopsies (14). This clinical significance is supported in the current study because it shows high diagnostic efficacy of diffusion-weighted MRI.

Systematic reviews have highlighted that the bi-parametric and multiparametric MRI, together with machine learning and deep learning approaches, can substantially enhance the prostate cancer

detection, grading, and characterization (15). Besides, the enhancement of deep learning on low-b-value diffusion imaging has been demonstrated to boost image quality and lesion conspicuity, resulting in increased diagnostic confidence in the evaluation of prostate cancer (16). These enhancements can be used to overcome existing weaknesses of diffusion imaging, especially small or low-contrast lesions. Recent high b-value diffusion models have also yielded a better understanding of the microstructure of prostate tumors and allowed for the characterization of lesions and the assessment of Gleason grade better (17). Other research that has incorporated quantitative diffusion-weighted imaging, together with dynamic contrast-enhanced MRI, has been found to be highly effective in determining the aggressiveness of tumors and risk-based clinical management.

These results correspond to the current research findings, as it is stressed that DW-MRI is not only efficient in identifying prostate cancer but is also useful in establishing tumor severity. In general, the discussion shows that diffusion-weighted MRI is a valid, precise, and clinically significant diagnostic method of detecting prostate cancer compared to histopathology (18). This high sensitivity and close correlation with Gleason grading make it potentially useful in early diagnosis, prognostic assessment, and monitoring. DW-MRI could potentially become a mandatory addition to the diagnostic pathways of prostate cancer with further development of imaging procedures and AI utilization, particularly in a resource-constrained country like Pakistan.

Conclusion

This research finds that diffusion-weighted MRI is a powerful and dependable imaging method that can be used to identify prostate cancer as compared to histopathology as the gold standard imaging method. The sensitivity and the overall diagnostic accuracy is very high, therefore showing that DW-MRI can effectively detect the presence of malignant prostate lesions in most suspected cases. Moreover, diffusion restriction patterns and ADC values add valuable data to the information about tumor aggressiveness and Gleason grading, which makes it a prognostic value. Diffusion-weighted MRI is a non-invasive methodology that could potentially decrease unnecessary biopsies and enhance the detection of the disease at an early stage, especially where the patient has a high PSA level or other signs of abnormalities. The results support the increasing importance of DW-MRI as a constituent of multiparametric prostate imaging. Therefore, diffusion-weighted MRI should be introduced into the clinical routine in order to increase diagnostic confidence, better patient management, and lead to improved results due to the earlier diagnosis and proper characterization of prostate carcinoma.

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