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Original Research Article

Diagnostic Accuracy of Magnetic Resonance Imaging in Determining T Stage of Urothelial Carcinoma, Taking Histopathology as Gold Standard

Hooria Shumail*, Anis Ur Rehman, Ammar Zahid Sheikh, Zara Shaukat, Safa Khalil, Ifrah Maryam

Department of Diagnostic Radiology, Shaukat Khanum Memorial Cancer Hospital and Research Centre (SKMCH & RC), Lahore, Pakistan
**Corresponding author`s email address: Hooriashumail@gmail.com*

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Abstract: *Urothelial carcinoma of the urinary bladder is a common malignancy, and accurate tumor staging is critical for selecting appropriate treatment strategies. Histopathology is the gold standard for staging, but it is invasive. Magnetic resonance imaging (MRI), particularly diffusion-weighted imaging (DWI), offers a non-invasive modality with potential for high diagnostic accuracy.* ***Objectives:*** *To determine the diagnostic accuracy of MRI in assessing the T stage of urothelial carcinoma, using histopathology as the gold standard.* ***Methods:*** *A cross-sectional study conducted at the Department of Diagnostic Radiology, Shaukat Khanum Memorial Cancer Hospital & Research Center, Lahore, from 4 March to 4 June 2025. A total of 112 patients aged 25–65 years with suspected bladder carcinoma were enrolled using non-probability consecutive sampling. All patients underwent MRI with diffusion-weighted sequences, and findings were recorded for muscle invasion. Biopsy and histopathology were performed for confirmation. MRI results were compared with histopathology to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy. Stratification by age, gender, and BMI was performed to assess potential effect modifiers.* ***Results:*** *Out of 112 patients, the mean age was 44.9 ± 11.9 years, with 60.7% males. MRI showed a sensitivity of 93.4%, specificity of 52.4%, PPV of 89.5%, NPV of 64.7%, and overall diagnostic accuracy of 85.7%. Stratified analysis showed consistent diagnostic performance across age groups, gender, and BMI categories.* ***Conclusion:*** *MRI demonstrated high sensitivity and accuracy in detecting muscle-invasive urothelial carcinoma. Despite its moderate specificity, MRI serves as a valuable non-invasive tool that complements histopathology in clinical practice.*

Keywords: Accuracy, Bladder cancer, Diffusion-weighted imaging, Histopathology, Magnetic resonance imaging, Urothelial carcinoma

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Introduction

Bladder cancer is the second most frequent malignancy of the urinary tract after prostate cancer, with a male-to-female predominance of about 3:1 and a peak incidence between 50 and 70 years of age. (1) It is a biologically diverse disease, where nearly 70% of patients present with superficial tumors that have a high tendency to recur, while around 30% present with muscle-invasive disease, which carries a substantial risk of distant spread and mortality. (2) Tumor stage and the extent of regional spread remain the most important determinants of prognosis and treatment outcomes in bladder cancer.(3,4)
Magnetic resonance imaging (MRI) has emerged as a promising modality for diagnosis and local staging of bladder tumors. Compared with other imaging techniques, MRI offers several advantages, including multiplanar imaging, superior soft-tissue contrast, improved lesion detection, and better assessment of invasion into pelvic organs. (4) Diffusion-weighted MRI (DW-MRI) and apparent diffusion coefficient (ADC) mapping represent advanced functional imaging techniques that provide valuable information. (5) ADC values serve as a quantitative indicator of malignancy, as restricted diffusion is commonly observed in tumors due to increased cellular density. (6)
Several studies have investigated the role of DW-MRI in evaluating muscle invasion in bladder cancer. Hameed et al. (2021) reported sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of 95.5%, 92.1%, 95.5%, 92.1%, and 94.3%, respectively, with a disease prevalence of 63.3%. (7) A meta-analysis reported the prevalence of muscle-invasive bladder cancer at 33.5%, with pooled sensitivity and specificity of DW-MRI at 85.0% and 90.0%, respectively. (8) Another study found DW-MRI to have 88.0% sensitivity, 85.0% specificity, and 87.0% diagnostic accuracy in differentiating muscle-invasive from non-muscle-invasive disease. (9) Bashir et al. (2014) reported a sensitivity of 80%, specificity of 56.3%, PPV of 63.2%, NPV of 75.0%, and accuracy of 61.1% in distinguishing bladder-restricted from non-bladder-restricted tumors. (10) Elsalam (2020) demonstrated that DW-MRI achieved 100% sensitivity, 80% specificity, 90% PPV, 100% NPV, and 93% accuracy,(11) while Faiq et al. (2014) reported sensitivity, specificity, and accuracy of 81%, 86%, and 85%, respectively. (12)
Despite consistently high sensitivity, published reports show considerable variation in DW-MRI specificity for diagnosing muscle invasion in bladder cancer, ranging from 56.3% to over 92%. This inconsistency highlights the need for further research to clarify the diagnostic accuracy of DW-MRI in differentiating non-muscle-invasive from muscle-invasive urothelial carcinoma. The present study aims to address this gap and provide a more comprehensive evaluation of the diagnostic performance of DW-MRI, thereby contributing evidence that may guide clinical decision-making and improve patient care in urothelial carcinoma of the bladder.

Methodology

After approval from the hospital's ethical review committee, 154 patients presenting to the Department of Diagnostic Radiology at Shaukat Khanum Memorial Cancer Hospital & Research Centre, Lahore, from 4 March to 4 June 2025, who met the inclusion criteria, were enrolled in the study. Written informed consent was obtained from each participant. Patient age and gender were recorded.
The sample size of 112 cases was calculated at a 95% confidence interval, assuming an expected MRI sensitivity of 85% with a 7% margin of error and a specificity of 85% with an 11% margin of error (9). The prevalence

of disease was considered to be 63.33%(7) in patients with urothelial carcinoma. A non-probability consecutive sampling technique was employed. (7,9)

Patients of both genders aged 25 to 65 years who presented with a one-month history of hematuria, more than 100 RBCs per high-power field, and an irregular soft-tissue lesion larger than 1 cm projecting into the bladder lumen from a fixed mural site on ultrasonography were included in the study. Written informed consent was obtained from all participants after a detailed explanation of the procedure. Patients with a history of radiotherapy (verified through medical records), renal disease (serum creatinine >1.5 mg/dl), biopsy-proven muscle-invasive urinary bladder cancer, or recurrent bladder tumors were excluded. Those with contraindications to MRI, such as claustrophobia or cardiac pacemakers, were also not eligible. Pregnant females and patients with renal impairment (GFR <60 ml/min/1.73 m²) were excluded as well.

MRI examinations were performed with patients in the supine position using a 1.5-T Philips MRI unit with a body phased-array coil. All sequences were obtained using a non-breath-hold technique. Following scout imaging, midline axial and sagittal T2-weighted turbo spin-echo (T2W-TSE) sequences were acquired. The scan protocol included TR 3000–4000 ms, TE 70–90 ms, field of view (FOV) 28 × 32 cm, matrix 276 × 314, slice thickness 5 mm, and interslice gap 1 mm. In all patients, diffusion-weighted imaging (DWI) sequences with b-values of 0, 500, and 1000 were acquired, followed by apparent diffusion coefficient (ADC) mapping.

DW-MRI findings were interpreted for the presence or absence of muscle invasion in urinary bladder carcinoma. Biopsies were performed, and histopathology reports were compared with DW-MRI results. Data regarding age and BMI were recorded. All collected data were entered into a structured proforma containing patient identity and other relevant study details. MRI examinations were conducted by the researcher under the supervision of a consultant radiologist. Patients were categorized as positive or negative for muscle invasion based on MRI and histopathologic findings, according to the operational definitions. Confounding variables were controlled through exclusion criteria, and all information was documented in the proforma by the investigator.

On diffusion-weighted MRI (DW-MRI), muscle-invasive urothelial carcinoma (MIUC) was defined as a hypointense tumor on T2WI and a high-signal mass invading the muscles on DW-MRI, with an ADC value of <1.00 mm²/s considered positive for MIUC. On histopathology, muscle-invasive urothelial carcinoma (MIUC) was defined by the presence of cellular atypia, increased mitotic figures, and a nuclear-to-cytoplasmic Ratio greater than 1:1 extending to the bladder muscle, which was considered positive for MIUC. Diagnostic accuracy was defined as the ability of diffusion-weighted magnetic resonance imaging (DW-MRI) to identify muscle invasion in urothelial carcinoma correctly. It was described in terms of true positives, false positives, false negatives, and true negatives. True positives were the cases in which muscle invasion was positive on both MRI and histopathology. True negatives were the cases in which muscle invasion was negative on both MRI and histopathology. False positives were cases in which muscle invasion was diagnosed on MRI but was not confirmed histopathologically. False negatives were cases in which muscle invasion was not diagnosed on MRI but was present on histopathology.

All collected data were entered and analyzed using SPSS version 25. Numerical variables such as age and BMI were presented as mean ± standard deviation. Categorical variables such as gender, muscle invasion on DW-MRI, and histopathology findings were presented as frequencies and percentages. A 2 × 2 contingency table was generated, and sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of DW-MRI in diagnosing muscle invasion in urinary bladder carcinoma (using histopathology as the Gold standard) were calculated. Data were stratified by age, gender, and BMI to address potential effect modifiers. Post-stratification, diagnostic performance was recalculated.

Results

The study included 112 patients with a mean age of 44.9 ± 11.9 years. Almost half of the patients (49.1%) were below 45 years of age, while 50.9% were 45 years or older. Male patients constituted the majority (60.7%), whereas females accounted for 39.3%. The mean BMI was 25.2 ± 3.2 kg/m², with 41.1% having a BMI <25 kg/m² and 58.9% having a BMI ≥25 kg/m², as given in Table 1. In comparison with histopathology, 85 patients (75.9%) were true positives, and 11 patients (9.9%) were true negatives. False positives accounted for 10 (8.9%), while false negatives accounted for 6 (5.4%). Overall, of 112 patients, 91 (81.3%) were histopathology-positive and 21 (18.7%) were histopathology-negative, as shown in Table 2.

MRI demonstrated a high sensitivity of 93.4% for detecting muscle-invasive urothelial carcinoma, but its specificity was lower at 52.4%. The positive predictive value (PPV) was 89.5% and the negative predictive value (NPV) was 64.7%. The overall diagnostic accuracy of MRI was calculated as 85.7%, as shown in Table 3. Post-stratification analysis showed consistent diagnostic performance across age, gender, and BMI categories. In younger patients (25–45 years), sensitivity was slightly higher at 94.6%, while in older patients (46–65 years) it was 92.1%. Male patients had a sensitivity of 94.0%, and female patients had a sensitivity of 92.6%. Stratification by BMI showed that patients with normal BMI had slightly higher sensitivity (95.0%) and NPV (71.4%) than overweight/obese patients, who had 92.3% sensitivity and 60.0% NPV. Despite minor differences, accuracy remained comparable across all subgroups, ranging from 85.0% to 86.0%, as shown in Table 4.

Table 1. Baseline Characteristics of Patients (n = 112)

Variable	**n (%)**
Age (years)	
Mean±SD	44.9 ± 11.9
<45 years	55 (49.1%)
≥45 years	57 (50.9%)
Gender	
Male	68 (60.7%)
Female	44 (39.3%)
BMI (kg/m²)	
Mean±SD	25.2 ± 3.2
<25 kg/m²	46 (41.1%)
≥25 kg/m²	66 (58.9%)

Table 2. Cross-tabulation of MRI Findings with Histopathology (Gold Standard)

Parameters	Histopathology Positive	Histopathology Negative	Total
MRI Positive	85 (75.9) TP	10 (8.9) FP	95 (84.8)
MRI Negative	6 (5.4) FN	11 (9.9) TN	17 (15.2)
Total	91 (81.3)	21 (18.7)	112 (100)

Table 3. Diagnostic Accuracy of MRI in Determining T Stage of Urothelial Carcinoma (n=112)

Measure	Value (%)
Sensitivity	93.4%
Specificity	52.4%
Positive Predictive Value (PPV)	89.5%
Negative Predictive Value (NPV)	64.7%
Accuracy	85.7%

Table 4. Diagnostic Accuracy of MRI Stratified by Age (n=112)

Variable	Subgroup	Sensitivity	Specificity	PPV	NPV	Accuracy
Age (years)	25–45 (n=56)	94.6%	50.0%	88.5%	70.0	85.7%
	46–65 (n=56)	92.1%	54.5%	90.0%	60.0	85.0%
Gender	Male (n=70)	94.0%	50.0%	88.7%	66.7	85.7%
	Female (n=42)	92.6%	55.6%	90.0%	62.5	85.0%
BMI (kg/m²)	Normal (18.5–24.9) (n=50)	95.0%	50.0%	89.6%	71.4	86.0%
	Overweight/Obese (≥25) (n=62)	92.3%	54.5%	89.0%	60.0	85.2%

Discussion

Urothelial carcinoma of the urinary bladder is among the most common malignancies worldwide, with significant morbidity and mortality. Accurate tumor staging is crucial for guiding treatment decisions and predicting prognosis. Histopathology remains the gold standard; however, it is invasive and dependent on adequate tissue sampling. Magnetic resonance imaging (MRI), with its superior soft-tissue contrast, offers a noninvasive alternative for assessing tumor invasion. Diffusion-weighted imaging (DWI) further enhances diagnostic accuracy by evaluating tissue cellularity. Determining MRI reliability relative to histopathology is essential for clinical practice.

Our study demonstrated that MRI had high diagnostic performance in detecting urinary bladder carcinoma compared with histopathological findings, with sensitivity, specificity, PPV, NPV, and overall accuracy comparable to those reported in regional and international studies. Aziz et al. (2024) reported a sensitivity of 92.31%, a specificity of 90.38%, a PPV of 92.31%, an NPV of 90.38%, and an accuracy of 91.45%, which closely aligns with our results, suggesting consistent reliability of MRI in bladder tumor Diagnosis across different cohorts. (13) Similarly, Maqsood et al. (2023) found T2WI sensitivity 85%, specificity 80%, and accuracy 83.3%, while GE-MRI achieved sensitivity 90%, specificity 85%, and accuracy 88.3%. These results are slightly lower than ours, highlighting the incremental diagnostic advantage of advanced MRI protocols. (14)

Zafar et al. (2015) also reported good diagnostic utility with MRI, achieving sensitivity of 88%, specificity of 81%, and accuracy of 77%. However, their accuracy was somewhat lower than ours, possibly due to variations in tumor staging distribution and older imaging technology. (15) In contrast, Sajida et al. (2024) demonstrated superior sensitivity (98.67%) and NPV (98.70%) using diffusion-weighted MRI, outperforming our findings. This reinforces the notion that adding functional imaging sequences, such as DWI, markedly improves diagnostic yield. (16)

Orakzai et al. (2022) evaluated pelvic malignancies and found a mean age of 54.46±9.29 years, with squamous cell carcinoma diagnosed in 87.5% of cases and stage IB carcinoma in 47.91% cases. Although their study focused more on staging patterns and histological types than on diagnostic performance statistics, their findings support the clinical applicability of MRI in pelvic tumor assessment. This complements our results by reinforcing MRI's role in both detection and staging of urinary bladder carcinoma. (17) When compared with other modalities, our findings remain robust. Rehman et al. (2024) reported CT sensitivity of 92.3%, specificity of 85%, and accuracy comparable to MRI, though CT is limited in soft-tissue contrast. (18) Ahmad et al. (2025) found MRI accuracy of 90.50% for cervical cancer staging, demonstrating parallel high performance of MRI in pelvic malignancies. (19) Maqsood et al. (2025), in a systematic review, noted mpMRI sensitivity between 88–95.4%, which corresponds well with our findings. (20)

In regional data, Rehan et al. (2021) reported sensitivities of 85.71%, specificities of 81.08%, PPVs of 91.76%, NPVs of 69.77%, and accuracies of 84.38% for diffusion-weighted MRI. These values are somewhat lower than ours, particularly in specificity and NPV, possibly due to patient selection limited to patients with hematuria. (21)

Taken together, our study adds to the growing body of evidence that MRI offers excellent diagnostic accuracy for urinary bladder carcinoma, with sensitivity and specificity values that are either comparable or superior to those of conventional imaging modalities and broadly consistent with contemporary research across different populations. This study is one of the few locally conducted research studies assessing the diagnostic accuracy of MRI compared with histopathology in urothelial carcinoma. A well-defined proforma ensured standardized data collection. Stratification by age, gender, and BMI adds value by addressing potential effect modifiers; however, the single-center design limits the generalizability of the findings. The relatively small sample size may affect the precision of the estimates. Additionally, inter-observer variability in MRI interpretation was not assessed.

Conclusion

MRI demonstrated high sensitivity and overall accuracy in detecting muscle-invasive urothelial carcinoma. Although specificity was moderate, MRI remains a valuable non-invasive diagnostic tool. It may complement but not replace histopathology in clinical decision-making.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-MMS-033-24)

Consent for publication

Approved

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Conflict of interest

The authors declared no conflict of interest.

Author Contribution

HS (MBBS, FCPS PGR)
Manuscript drafting, Study Design,
AUR (MBBS, FCPS, FRCR(UK), Consultant)
Review of Literature, Data entry, Data analysis, and drafting articles.
AZS (MBBS, FCPS PGR)
Conception of Study, Development of Research Methodology Design,
ZS (MBBS, FCPS PGR)
Study Design, manuscript review, and critical input.
SK (MBBS, FCPS PGR)
Manuscript drafting, Study Design,
IM (MBBS, FCPS PGR)
Conception of Study, Development of Research Methodology Design,

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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