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RESEARCH

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Interobserver agreement for the Vesical Imaging-Reporting and Data System (VI-RADS) in differentiating non-muscle-invasive and muscle-invasive urinary bladder tumors

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Abstract

Background Bladder cancer is the most common tumor of the genitourinary tract. Transitional cell carcinoma is divided into two categories: non-muscle-invasive bladder cancer (NMIBC) and muscle-invasive bladder cancer (MIBC). In spite of the high recurrence rate, NMIBC has good prognosis, while MIBC has poor prognosis due to local organ invasion and metastases. Mp-MRI shows better tumor detection and staging. The aim of this study is to validate VI-RADS in detecting MIBC and assessing interobserver agreement and impact of reader's experience.

Results At cutoff value of VI-RADS score ≥ 3, the VI-RADS showed sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of 96.8%,83.3%, 93.8%, 90.9%, and 93%, respectively, for reader 1, 93.5%, 91.7%, 84.6%, and 93% for reader 2, and 96.8%,83.3%, 93.8%, 90.9%, and 93% for reader 3. The interobserver agreement between individual readers was excellent among the three readers.

Conclusions Vesical imaging-reporting and data system (VI-RADS) is a good method showing satisfactory sensitivity, specificity, and diagnostic value for detecting detrusor muscle invasion.

Keywords NMIBC, MIBC, Mp-MRI, VI-RADS

Background

Transitional cell carcinoma (TCC) is divided into two categories: non-muscle-invasive bladder cancer (NMIBC) and muscle-invasive bladder cancer (MIBC) [1]. In spite of the high recurrence rate, NMIBC has good prognosis, while MIBC has poor prognosis due to local organ invasion and metastases [2].

Previously, excretory urography was used to investigate gross hematuria and suspected urothelial tumor. Now, imaging was shifted to ultrasonography (US) and cross-sectional modalities such as computed tomography (CT) and magnetic resonance (MR) imaging. Cystoscopy and biopsy are the gold standard for diagnosis of urothelial tumor. Imaging is mandatory for proper staging and treatment planning [3].

Multiparametric MRI (mp-MRI) is recently introduced and it combines functional sequences as diffusion-weighted imaging (DWI) and dynamic contrast-enhanced MRI (DCE-MR) with anatomic T2-weighted images (T2-WI). This improves tumor detection, staging, assessment of treatment response, and detects recurrence [4].

The interpretation of the presence of muscle invasion may vary between radiologists. Therefore, standardized and systematic reporting increases interobserver agreement, and improves communication between different specialists. Panebianco et al. proposed the

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vesical imaging-reporting and data system (VI-RADS). It is a standardized mp-MRI protocol to evaluate the risk of muscle invasion by bladder cancer using T2-WI structural categorization, DWI, and DCE-MRI [5, 6].

Methods

Patients

Thirty-eight patient, with a mean age of 62.26 ± 8.18 years, were included in this study. Patients were recruited from urology clinics in our hospitals from April 2021 to January 2022.

Inclusion criteria were patients diagnosed with urinary bladder cancer by cystoscopy or by any previous radiologic investigations with no age or sex predilection. Exclusion criteria were any contraindications to intravenous MRI contrast administration, e.g., allergy to IV contrast, high serum creatinine, low GFR or severe renal impairment; patients who were unfit for transurethral resection of bladder tumor (TURBT), e.g., as those unfit for anesthesia or with urethral stricture; patients who underwent recent biopsy within 1–2 days before MRI; and pathology was non-TCC bladder cancer. The study was done after the approval of our ethical committee which waived the requirement for written consent.

Technique of Multiparametric-MRI examination

The MRI examination was done using 1.5 T MRI (Philips Achieva scanner, Healthcare, Netherlands) with an eight-channel phased-array coil. A respiratory belt was placed around patient abdomen for synchronization of patient breath. T2-weighted turbo spin-echo images were acquired in three orthogonal planes (axial, sagittal, and coronal). Axial DWI with ADC was done. Axial dynamic contrast-enhanced imaging (DCE) axial T1 fat suppressed three-dimensional-gradient echo sequence (THRIVE) before and after IV injection of 0.1 mmol/kg of body weight of gadolinium-based contrast agent (gadoteric acid) at a rate of 2 ml/sec. followed by saline flush. An initial post-contrast acquisition was done 15 s after contrast injection, followed by five consecutive sequences taken every 15 s (Table 1).

Analysis of data

Mp-MRI analysis and interpretation

- The MR images were interpreted independently by three radiologists from the same institution with different levels of expertise: two consultants of more than 5 and more than 10 years (readers 1 and 3) and a resident of 2.5 years (reader 2). All readers were blinded to histopathology results. The assessments for T2-WI structural category (SC), diffusion-weighted imaging category (DW), dynamic contrast-enhanced imaging category (DCE), and VI-RADS scores were assigned to each lesion as follows: (Panebianco et al. [4]).
- *VI-RADS 1 (muscle invasion is highly unlikely)* SC, CE, and DW category 1.
- *VI-RADS 2 (muscle invasion is unlikely to be present)* SC, CE, and DW category 2; both CE and DW category 2 with SC category 3.
- *VI-RADS 3 (the presence of muscle invasion is equivocal)* SC, CE, and DW category 3; SC category 3, CE or DW category 3, the remaining sequence category 2.
- *VI-RADS 4 (muscle invasion is likely)* at least SC and/or DW and CE category 4; the remaining category 3 or 4; SC category 3 plus DW and/or CE category 4; SC category 5 plus DW and/or CE category 4.
- *VI-RADS 5 (invasion of muscle and beyond the bladder is very likely)* at least SC plus DW and/or CE category 5; the remaining category 4 or 5.

Table 1 Multiparametric MRI protocol

	Axial T2-WI	Coronal T2-WI	Sagittal T2-WI	Axial DWI
TR	4385	7645	3000	2200
TE	100–115	100–115	100–115	63
FOV	27–32 cm	28–32 cm	16 cm	28–32 cm
Matrix	272 × 272	232 × 135	160 × 160	96 × 96
Slice thickness	3–4 mm	3–4 mm	3–4 mm	3 mm
Gap	0–0.5 mm	0–0.5 mm	0–0.5 mm	0.5–1 mm
Flip angle	90	90	90	90
Acquisition time	180 s	30 s	48 s	4:35 min
B value				0,400,800 s/mm^2

Statistical analysis

- Data were collected, revised, coded, and entered to the Statistical Package for Social Science (IBM SPSS) version 23. The quantitative data with parametric distribution were presented as mean, standard deviations, and ranges. Also, qualitative variables were presented as numbers and percentages.

The following tests were done:

- Student *t* test was applied to compare parametric quantitative variables between two groups.
- Mann–Whitney test was applied for comparison of nonparametric quantitative variables between two groups
- Independent-samples *t* test of significance was used when comparing between two means.
- Chi-square (X2) test of significance was used in order to compare proportions between two qualitative parameters.
- Pearson's correlation coefficient (*r*) test was used for correlating data.
- Probability (*P* value)
  - *P* value < 0.05 was considered significant.
  - *P* value < 0.001 was considered as highly significant.
  - *P* value > 0.05 was considered insignificant.

- Kappa agreement was used to assess the agreement between each reader and the histopathological results and the readers with each other.
- Kappa result is interpreted as follows: values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as excellent or almost perfect agreement.

Results

The current study was conducted upon 38 patients; 31 males and seven females. The mean age was 62.26 ± 8.18 years (range, 47–83 years).

The study included patients with pathologically proven urothelial carcinoma who previously underwent mp-MRI of the pelvis. In the studied cases, the total number of lesions was 43. The histologic assessment revealed that 12 of them (27.9%) were non-muscle-invasive urothelial carcinoma (Figs. 1 and 2) and 31 (72.1%) were muscle invasive (Figs. 3 and 4). Thirteen lesions were low grade and 30 lesions were high grade .

Most of the studied lesions were found in the lateral bladder wall, greater than 3 cm in size and showed no stalk.

Highly significant correlation was obtained regarding the tumor contact length (TCL) and the presence of stalk with the presence or absence of muscle invasion. Significant correlation was obtained regarding the tumor size and pathologic result at cutoff value ≥ 3 cm. The ADC value was statistically nonsignificant in this studied group (Table 2).

All parameters individually and collectively showed highly significant correlation with the histopathological results for all readers.

At cutoff value of VI-RADS score ≥ 3, VI-RADS showed sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of 96.8%,83.3%, 93.8%, 90.9%, and 93%, respectively, for reader 1, 93.5%, 91.7%, 84.6%, and 93% for reader 2 and 96.8%,83.3%, 93.8%, 90.9%, and 93% for reader 3 (Table 3).

The interobserver agreement between individual readers was excellent among all three readers (0.81–1.00) (Tables 4, 5, 6 and 7).

Discussion

Evaluation of muscle invasion is essential in staging and treatment planning for urinary bladder (UB) cancer [7]. For NMIBC, transurethral resection with or without intravesical Bacillus Calmette–Guerin (BCG) instillations is recommended while patients with MIBC instead undergo radical cystectomy with or without neoadjuvant chemotherapy [8].

Panebianco et al. [4] developed the VI-RADS to standardize MRI acquisition and interpretation for UB cancer.

Our preliminary results indicate that the performance of the VI-RADS is satisfactory regarding sensitivity, specificity, and overall accuracy was high.

In this study, all tumors scored as VI-RADS 4 and 5 were proved to be muscle-invasive cancer based on pathologic examination ($n = 29$, 67.4%).

For tumors scored as VI-RADS 2 by the more experienced readers (reader 1 and 3) ($n = 11$, 25.6%) all of them were correctly staged except one and verified as non-muscle invasive (90.9%).

For tumors scored as VI-RADS 2 by the less experienced reader (reader 2) ($n = 13$, 30.2%), 3 of them were incorrectly staged and were proven to be muscle invasive (23.07%).

For tumors scored as VI-RADS 3 (equivocal for muscle invasion) by the more experienced readers ($n = 3$, 7%), all were confirmed to be muscle-invasive cancer.

The less experienced reader scored three lesions as VI-RADS 3, two of them were confirmed to be

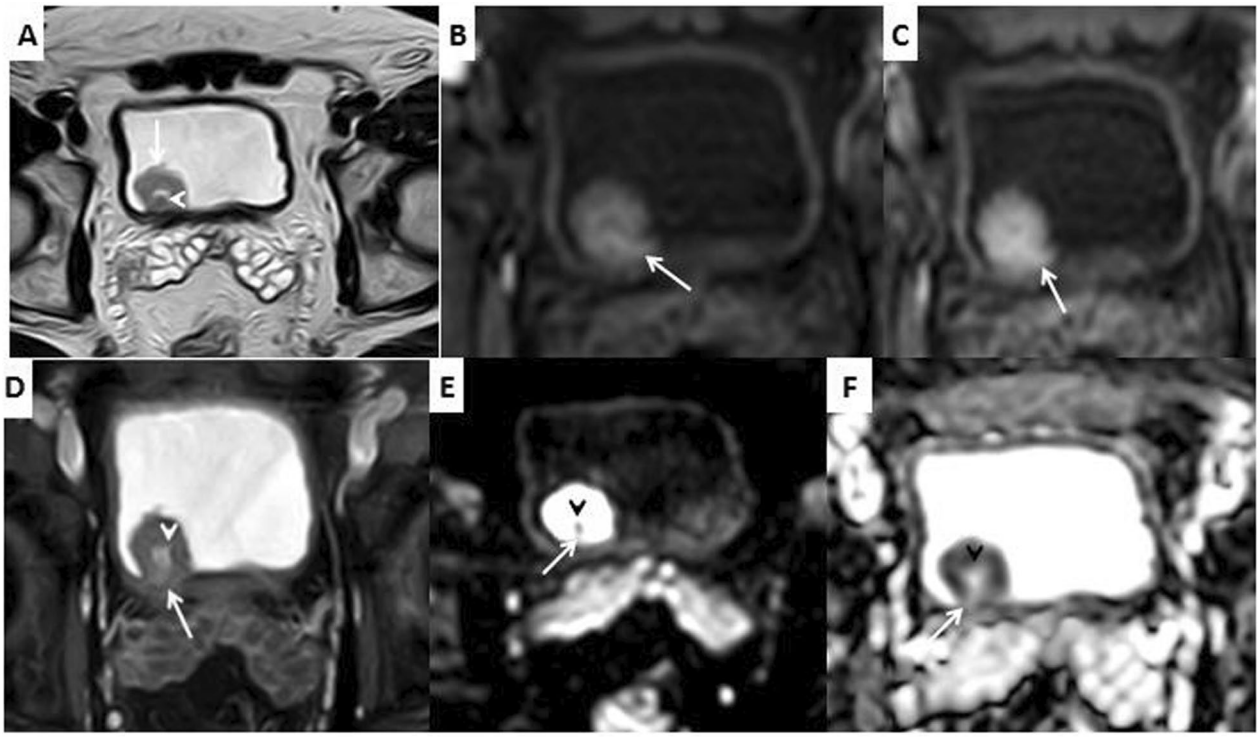

Fig. 1 **A** T2-WI shows a tumor at right posterior urinary bladder wall (arrow) with a stalk (arrowhead). The VI-RADS score for SC category was 2. **B**–**D** Axial DCE with early and delayed phases shows early enhancement of the submucosa and uninterrupted muscle layer (arrows) and enhancing stalk (arrow heads). The VI-RADS score for CE category was 2. **E**, **F** Axial DWI and ADC map show restricted diffusion of the tumor with ADC value 0.994×10^{-3} mm^2/s with a stalk connecting to the posterior bladder wall (arrows). The VI-RADS score for DW category was 2. Final VI-RADS score is 2, denoting that muscle invasion is unlikely to be present. Pathology proved low-grade papillary TCC with no invasion of the muscularis propria

muscle-invasive bladder cancer and one was confirmed to be non-muscle invasive.

No lesions were scored as VI-RADS 1 attributed to the late presentation of most of the patients in our institute.

Our study tested quantitative indicators for predicting muscle layer invasion of bladder cancer including the tumor size at cutoff ≥ 3 cm, tumor contact length (TCL), and ADC values.

Tumor size quantification showed statistically significant results, indicating that bigger tumors are more likely to be muscle invasive, same as a previous study done by Wang et al. [9].

TCL has been previously used to enhance the prediction of a tumor invasion depth in other multiple organs as in prostate cancer and lung cancer [10]. For bladder cancer, Ahn et al. [11] showed that the tumor contact length (TCL) can be used as a complementary to VI-RADS in predicting MIBC at a threshold of 3 cm. Wang et al. [10] reported that the integration of the TCL with the VI-RADS score can improve the diagnostic efficacy in distinguishing MIBC from NMIBC.

TCL quantification in our study showed highly significant results for detection of MIBC, yet further studies are needed with more equivocal lesions, because most of the lesions included in our study were of large size and consequently large TCL.

Measurements of ADC values were statistically nonsignificant in our study to assess muscle invasion to predict the tumor grade, likely attributed to the small number of studied lesions and high grades of most of the lesions.

Our study suggests that most of the lesions with fibrovascular stalk (10 out of 12 lesions) were proved to be NMIBC. This was studied previously by Takeuchi et al. [12] as the characteristic "inchworm sign" diffusion-weighted magnetic resonance imaging (DW-MRI) proposed as a criterion NMIBC.

Our results showed that for tumors scored as VI-RADS 4 and 5, the VI-RADS system achieved an accuracy of 100% in predicting muscle invasion, same as a previous study done by Wang et al. [9].

For tumors scored with VI-RADS 2, approximately 90% were NMIBC suggesting a good predictive performance for the absence of muscle invasion with comparable results as Wang et al. [9] and Ueno et al. [13].

Only three tumors were scored as VI-RADS 3, all were proven to be MIBC.

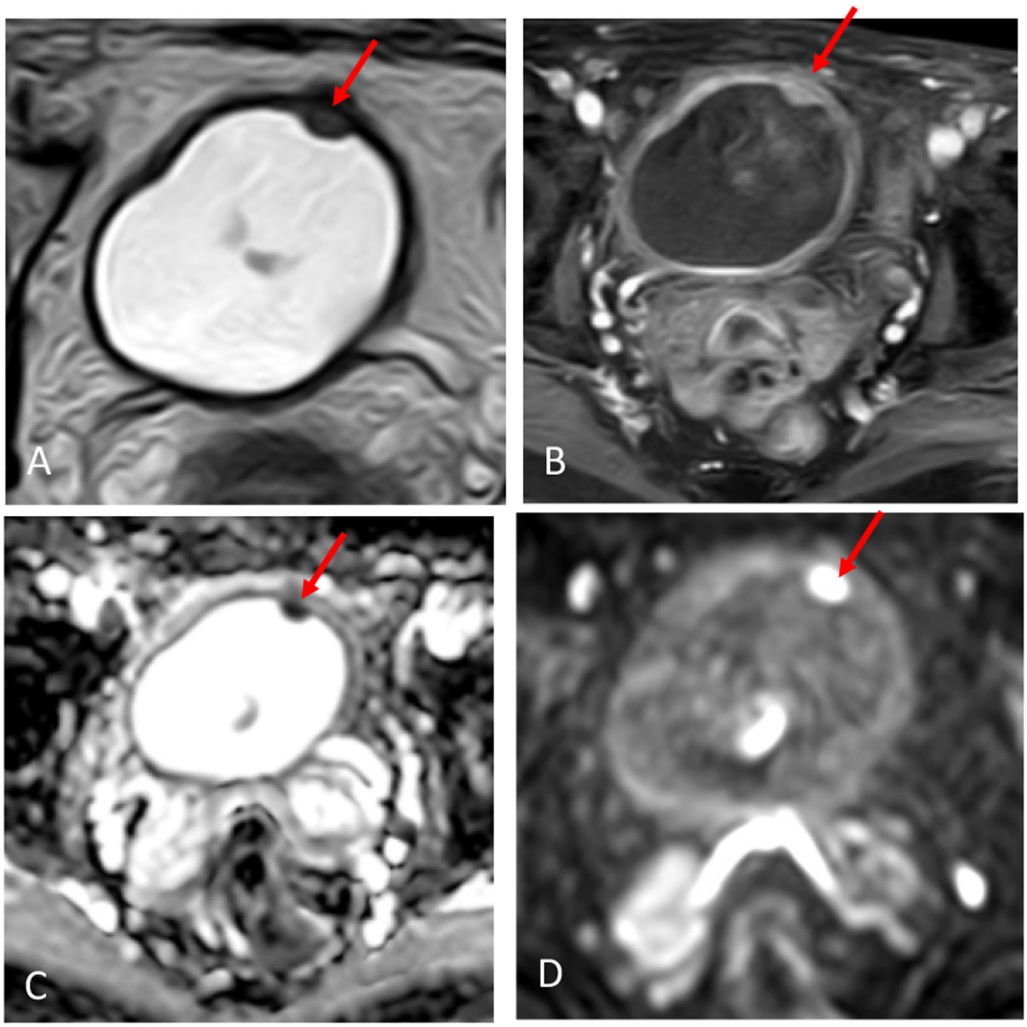

Fig. 2 **A** T2-WI shows a tumor in the anterior wall of the urinary bladder with uninterrupted muscle layer. The VI-RADS score for SC category was 2. **B** Axial DCE shows enhancing tumor in the anterior bladder wall with uninterrupted muscle layer (arrows). The VI-RADS score for CE category was 2. **C**, **D** Axial DW image and ADC map show restricted diffusion of the tumor with ADC value 0.89×10^{-3} mm^2/s. The VI-RADS score for DW category was 2. Final VI-RADS score is 2, denoting that muscle invasion is unlikely to be present. Pathology proved low-grade papillary TCC with no invasion of the muscularis propria

At cutoff value of VI-RADS 3 or greater, the accuracy of VI-RADS was 93%, with sensitivity of 96.8% and specificity 83.3% for the experienced readers and sensitivity of 93.5%, specificity of 91.7% and accuracy of 93% for the less experienced one. So, VI-RADS can detect muscle invasion when the VI-RADS score is 3 or greater. This is consistent with the results of recent meta-analysis by Huang et al. [14] which reported that multiparametric MRI has a good diagnostic performance for predicting MIBC.

The optimal VI-RADS cutoff value that predicted muscle invasion was debatable among different literature. Wang et al. [9] used cutoff value above VI-RADS 3 with sensitivity, specificity, and accuracy of 82.3%, 95.3%, and 88.64%, respectively.

Barchetti et al. [5] found sensitivity, specificity, and accuracy of 85–91%, 89–94%, and 77–82%, respectively, for predicting muscle invasion for ≥ VI-RADS 3.

Other literature by Del Giudice [15] and Makboul et al. [16] establishes VI-RADS ≥ 2 as a highly prognostic cutoff value for muscle invasion with sensitivity, specificity, and accuracy ranged between 78 and 91.9%, 88 and 96.5%, and 84 and 87.9%, respectively.

Experienced readers in the study of Ueno [13] pinpointed sensitivity, specificity, accuracy, PPV, and NPV of 74.1%, 94.1%, 83.7%, 93.1%, and 78.7%, respectively,

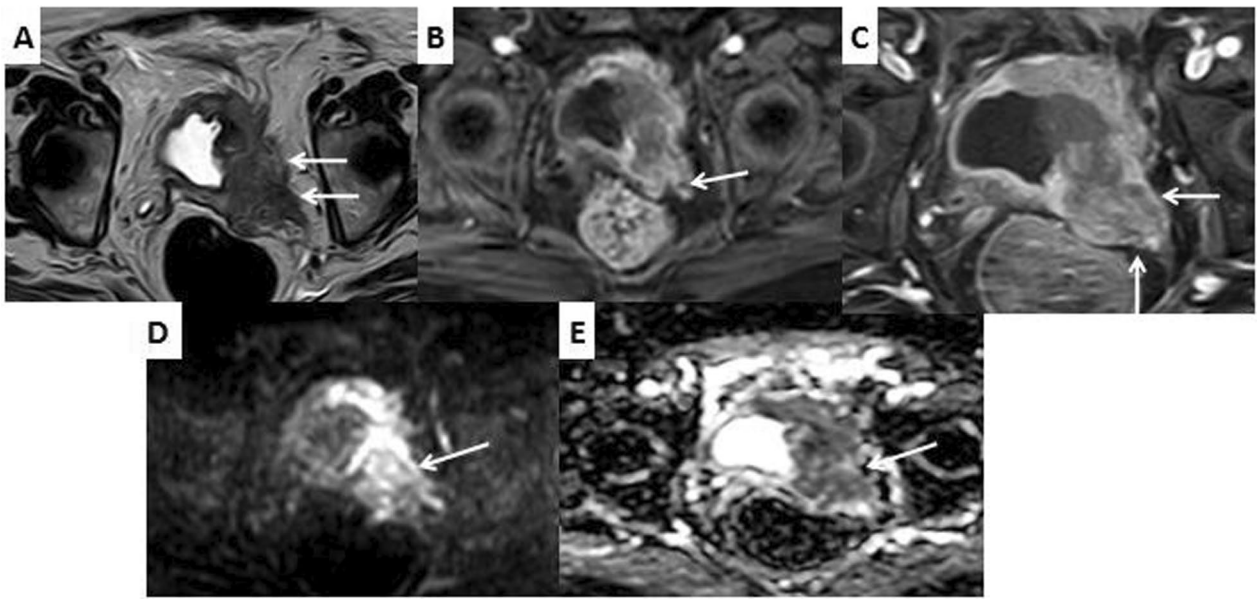

Fig. 3 **A** T2-WI shows tumor at the anterior and left posterolateral sides of the bladder with extravesical tumor mass (arrows), SC category 5. **B**, **C** Axial DCE with early and delayed phases shows enhancement of the tumor at the anterior and left posterolateral walls with extravesical mass (arrows), CE category 5. **D**, **E** Axial DWI and ADC map show restricted diffusion of the tumor with ADC value 0.694×10^{-3} mm^2/s at the anterior and left posterolateral walls with extravesical mass (arrow), DW category 5. Final VI-RADS score is 5, meaning that invasion of muscle and beyond the bladder is very likely. Pathology proved high-grade TCC with invasion of the muscularis propria

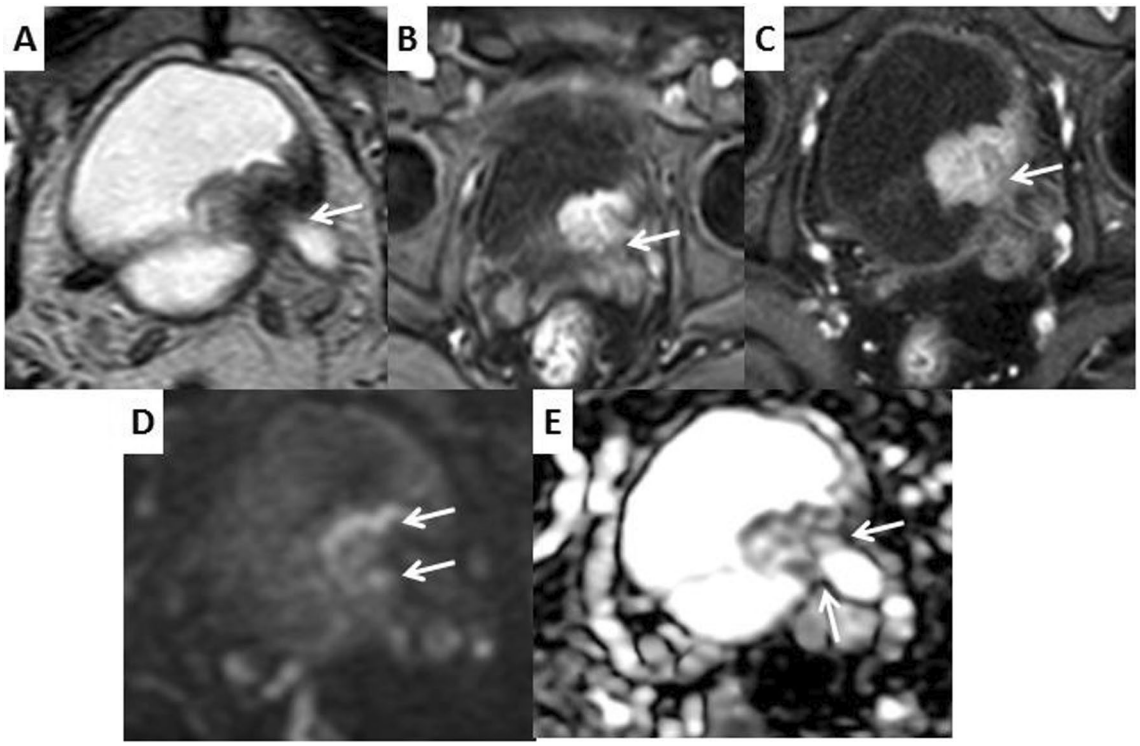

Fig. 4 **A** T2-WI shows a tumor at the left lateral wall of the bladder near the vesicoureteric junction with interruption of the low SI muscularis propria and mild ureteric dilatation (arrow). The VI-RADS score for SC category was 4. **B**, **C** Axial DCE with early and delayed phases shows tumor at left lateral wall with no early enhancement of the muscularis propria (arrow). The VI-RADS score for CE category was 3. **D**, **E** Axial DW image and ADC map show minimal restricted diffusion, no clear interruption of the muscle layer (arrows). The VI-RADS score for DW category was 3. Final VI-RADS score is 3, denoting that the presence of muscle invasion is equivocal. Pathology proved high TCC with invasion of the muscularis propria

Table 2 Relation between pathology with lesions' characteristics

	Pathology		Test value	*P* value	Sig.
	Non-muscle invasive	Muscle invasive			
	No. = 12	No. = 31			
Location of lesions					
Neck	0 (0.0%)	2 (6.5%)	0.812*	0.368	NS
Trigone	1 (8.3%)	3 (9.7%)	0.019*	0.892	NS
Dome	1 (8.3%)	5 (16.1%)	0.438*	0.508	NS
Anterior wall	1 (8.3%)	4 (12.9%)	0.176*	0.675	NS
Posterior wall	3 (25.0%)	1 (3.2%)	4.862*	0.027	S
Lateral walls	4 (33.3%)	16 (51.6%)	1.162*	0.281	NS
Circumferential	0 (0.0%)	5 (16.1%)	2.190*	0.139	NS
Ureteral orifice	1 (8.3%)	3 (9.7%)	0.019*	0.892	NS
Size					
< 3 cm	6 (50.0%)	5 (16.1%)	5.213*	0.022	S
≥ 3 cm	6 (50.0%)	26 (83.9%)			
Tumor contact length (TCL) (cm)					
Median (IQR)	2.9 (1.65–3.75)	5 (3.8–7.6)	− 2.682 ≠	0.007	HS
Range	1.4–8.2	1.1–16			
Stalk					
No	2 (16.7%)	30 (96.8%)	29.162*	0.000	HS
Yes	10 (83.3%)	1 (3.2%)			
ADC value ($\times 10^{-3}$ mm^2/s)					
Mean ± SD	1.03 ± 0.28	1.03 ± 0.23	0.028•	0.978	NS
Range	0.68–1.7	0.59–1.5			
T stage					
< T3	12 (100.0%)	1 (3.2%)	38.412*	0.000	HS
≥ T3	0 (0.0%)	30 (96.8%)			

P value > 0.05: Nonsignificant; *P* value < 0.05: Significant; *P* value < 0.01: Highly significant

*Chi-square test; •: Independent t test; ≠: Mann–Whitney test

for ≥ VI-RADS 3, and 83.4%, 77.3%, 80.4%, 80.3%, and 79.7%, respectively, for ≥ VI-RADS 2.

A recent meta-analysis published by Luo et al. [17] ascertained that VI-RADS score provides a good predictive ability for detecting MIBC with VI-RADS 3 or 4 as the cutoff value.

A study done by Metwally et al. [18] found that the optimal cutoff value for predicting MIBC after the first TURBT was VI-RADS 3 or more with 84.1% sensitivity, 92.3% specificity, and 87.9% accuracy. However, after the second TURBT, the cutoff value was VI-RADS 2 or more with 89.9% sensitivity, 90.1% specificity, and 90% accuracy.

In our study, we compared the predictive ability between each image sequence. T2-WI sequences revealed four over-staged lesions by reader 1, five over-staged lesions by reader 2, and six over-staged lesions by reader 3. This was consistent with literature, mentioning that over-staging occurred more often on T2-WI and DCE images, due to the inflammatory change or fibrosis/edema surrounding the tumor and simulating MIBC [19]. T2-WI can provide an anatomic details of the bladder and DCE imaging can depict lesions smaller than 0.5 mm [20]. DWI can reduce the over-staging ratio [21].

Due to the absence of reliable method to avoid or measure reactive change in the bladder wall after TURBT, bladder biopsy, or intravesical treatment, MRI examination is best performed before or at least 2 weeks post to intervention. Air in the bladder, from cystoscopy or indwelling catheter, can cause distortion of DWI due to susceptibility artifact. MRI examination is recommended to be performed after 2–3-day interval between cystoscopy and removal of Foley catheter [4].

Our study results also suggest that the consistency between the three readers in VI-RADS scoring was excellent (kappa 0.81–1.00) supporting the previously reported high reproducibility of VI-RADS (Table 7).

Table 3 Diagnostic performance of each reader for T2-WI, DWI, DCE, and overall VI-RADS score at cutoff value ≥ 3

Cutoff ≥ 3	Pathology		Test value	*P* value	Sig.
	Non-muscle invasive	Muscle invasive			
	No. = 12	No. = 31			
SC category					
Reader 1					
Negative (< 3)	8 (66.7%)	0 (0.0%)	25.390*	0.000 or < 0.001	HS
Positive (≥ 3)	4 (33.3%)	31 (100.0%)			
Reader 2					
Negative	7 (58.3%)	1 (3.2%)	17.349*	0.000	HS
Positive	5 (41.7%)	30 (96.8%)			
Reader 3					
Negative	6 (50.0%)	0 (0.0%)	18.014*	0.000	HS
Positive	6 (50.0%)	31 (100.0%)			
DWI category					
Reader 1					
Negative	10 (83.3%)	1 (3.2%)	29.162*	0.000	HS
Positive	2 (16.7%)	30 (96.8%)			
Reader 2					
Negative	11 (91.7%)	2 (6.5%)	29.784*	0.000	HS
Positive	1 (8.3%)	29 (93.5%)			
Reader 3					
Negative	10 (83.3%)	1 (3.2%)	29.162*	0.000	HS
Positive	2 (16.7%)	30 (96.8%)			
CE category					
Reader 1					
Negative	10 (83.3%)	1 (3.2%)	29.162*	0.000	HS
Positive	2 (16.7%)	30 (96.8%)			
Reader 2					
Negative	11 (91.7%)	2 (6.5%)	29.784*	0.000	HS
Positive	1 (8.3%)	29 (93.5%)			
Reader 3					
Negative	10 (83.3%)	1 (3.2%)	29.162*	0.000	HS
Positive	2 (16.7%)	30 (96.8%)			
Overall VI-RADS score					
Reader 1					
Negative	10 (83.3%)	1 (3.2%)	29.162*	0.000	HS
Positive	2 (16.7%)	30 (96.8%)			
Reader 2					
Negative	11 (91.7%)	2 (6.5%)	29.784*	0.000	HS
Positive	1 (8.3%)	29 (93.5%)			
Reader 3					
Negative	10 (83.3%)	1 (3.2%)	29.162*	0.000	HS
Positive	2 (16.7%)	30 (96.8%)			

P value > 0.05: Nonsignificant; *P* value < 0.05: Significant; *P* value < 0.01: Highly significant

*Chi-square test

Limitation

Most of the cases were MIBC due to their late presentation which might have caused a bias in the resulting statistics.

Also, the VI-RADS is still unfamiliar to many physicians and is still under modification. Therefore, further

Table 4 Agreement between reader 1 and pathology at cutoff value ≥ 3

	Pathology No. = 43	Reader 1 No. = 43	Test value	*P* value	Kappa agreement (95% CI)
SC					
Negative	12 (27.9%)	8 (18.6%)	1.042	0.307	0.743 (0.510–0.975)
Positive	31 (72.1%)	35 (81.4%)			
DWI					
Negative	12 (27.9%)	11 (25.6%)	0.059	0.808	0.822 (0.629–1.000)
Positive	31 (72.1%)	32 (74.4%)			
CE					
Negative	12 (27.9%)	11 (25.6%)	0.059	0.808	0.822 (0.629–1.000)
Positive	31 (72.1%)	32 (74.4%)			
Overall VI-RADS					
Negative	12 (27.9%)	11 (25.6%)	0.059	0.808	0.822 (0.629–1.000)
Positive	31 (72.1%)	32 (74.4%)			

Table 5 Agreement between reader 2 and pathology at cutoff value ≥ 3

	Pathology No. = 43	Reader 2 No. = 43	Test value	*P* value	Kappa agreement (95% CI)
SC					
Negative	12 (27.9%)	8 (18.6%)	1.042	0.307	0.614 (0.341–0.887)
Positive	31 (72.1%)	35 (81.4%)			
DWI					
Negative	12 (27.9%)	13 (30.2%)	0.056	0.813	0.831 (0.647–1.000)
Positive	31 (72.1%)	30 (69.8%)			
CE					
Negative	12 (27.9%)	13 (30.2%)	0.056	0.813	0.831 (0.647–1.000)
Positive	31 (72.1%)	30 (69.8%)			
Overall VI-RADS					
Negative	12 (27.9%)	13 (30.2%)	0.056	0.813	0.831 (0.647–1.000)
Positive	31 (72.1%)	30 (69.8%)			

Table 6 Agreement between reader 3 and pathology at cutoff value ≥ 3

	Pathology No. = 43	Reader 3 No. = 43	Test value	*P* value	Kappa agreement (95% CI)
SC					
Negative	12 (27.9%)	6 (14.0%)	2.529	0.112	0.590 (0.313–0.868)
Positive	31 (72.1%)	37 (86.0%)			
DWI					
Negative	12 (27.9%)	11 (25.6%)	0.059	0.808	0.822 (0.629–1.000)
Positive	31 (72.1%)	32 (74.4%)			
CE					
Negative	12 (27.9%)	11 (25.6%)	0.059	0.808	0.822 (0.629–1.000)
Positive	31 (72.1%)	32 (74.4%)			
Overall VI-RADS					
Negative	12 (27.9%)	11 (25.6%)	0.059	0.808	0.822 (0.629–1.000)
Positive	31 (72.1%)	32 (74.4%)			

Table 7 Agreement between all three readers (cutoff ≥ 3)

	Reader 1	Reader 2
Reader 2	0.885 (0.730–1.000)	–
Reader 3	0.878 (0.713–1.000)	0.885 (0.730–1.000)

studies, possibly including multiple institutions and more readers, shall represent the next step for future standardization.

Conclusions

VI-RADS is an effective comprehensive method showing satisfactory sensitivity, specificity, and diagnostic value for detecting MIBC. VI-RADS shows excellent interobserver agreement regardless the reader's experience.

Abbreviations

TCC	Transitional cell carcinoma
ADC	Apparent diffusion coefficient
BCG	Bacillus Calmette–Guerin
CECT	Contrast-enhanced computerized tomography
DWI	Diffusion-weighted image
DCE-MRI	Dynamic contrast-enhanced magnetic resonance imaging
MIBC	Muscle-invasive bladder cancer
NPV	Negative predictive value
NMIBC	Non-muscle-invasive bladder cancer
PPV	Positive predictive value
SC	Structural category
T1 WIs	T1 weighted images
T2 WIs	T2-weighted images
TSE	Turbo spin-echo
VI-RADS	Vesical imaging-reporting and data system

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Author contributions

NM was involved in idea of the research, collecting cases, manuscript writing. SM helped in results and statistics. RS contributed to idea of the research, collecting cases, manuscript writing. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request**.**

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of the Faculty of Medicine at Ain shams University in Egypt (FWA 000017585); Reference Number of approval: M S 93/2021. The requirement for written consent was waived in this prospective study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interest.

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