

Role of MRI in Detection and Staging of Urinary Bladder Malignancy

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Abstract

Background: The Vesical Imaging Reporting and Data System (VI-RADS) is a novel MRI-based scoring system that has been proposed to standardize the interpretation of bladder MRI and improve its diagnostic accuracy. **This study aimed to** evaluate the role of MRI using Multiparametric and DWI in detection, evaluation and staging of urinary bladder malignancy using various MRI sequences that play an important role in post-treatment surveillance. **Methods:** This cross-sectional observational study included 30 patients with suspected urinary bladder masses who met the inclusion criteria and did not meet the exclusion criteria. All patients underwent complete history taking, general clinical examination, pelvi-abdominal ultrasound and/or CT, and MRI using a 1.5T machine. The newly developed Vesical Imaging Reporting and Data System (VI-RADS) score was used to analyze and classify the MRI images. The final histopathological results were achieved by surgical specimen or cystoscopy-guided biopsy and served as the gold standard. **Results:** ROC curve analysis revealed that MRI could be excellent test of diagnosis of Malignancy of bladder mass with 96.2% sensitivity and 100% specificity (AUC, 0.98 and 95% CI, 0.93-1). There was Strong agreement between VIRAD and Cystoscopic-Biopsy In detection of stage 1 tumor grading, stage 2, stage 3, stage 4 and stage 5 (Kappa= 0.89, 1, 0.65, 0.81, 0.92, respectively with p-value <0.001). **Conclusion:** VI-RAD scoring system using Dynamic MRI protocol is a safe and confident method in detection, differentiating benign from malignant urinary bladder masses and in grading of urinary bladder carcinoma.

Keywords: MRI; Detection; Staging; Urinary Bladder; Malignancy.

Introduction

Bladder carcinoma (BC) is the most common neoplasm of the urinary system. Urothelial carcinoma (UC) is the most common histologic type of BC

(approximately 90%). The definition of UC is the invasion of the basement membrane or lamina propria or deeper by neoplastic cells of urothelial origin. The World Health Organization (2016) classifies bladder

cancers based on differentiation as low grade (grade 1 and 2) or high grade (grade 3). The distinction between low-grade and high-grade urothelial disease has implications related to risk stratification and management of patients (1).

Magnetic resonance imaging gives an excellent insight into the anatomy and pathology of urinary bladder as it provides high fluid-tissue contrast resolution and clearly delineates urinary bladder musculature. Its multi planar capacity allows depiction of complex pelvic anatomic relationships (2). This gives improved characterization of urinary bladder abnormalities and more accurate demonstration of the extent of luminal, mural and perivesical pathology. Although transabdominal and transvaginal ultrasound are the techniques employed for the initial investigation of pelvic pathology and are usually sufficient for evaluation of benign disease, with MRI being used for problem-solving; MRI has become invaluable in the evaluation and staging of urinary bladder malignancy (3).

Multiparametric MRI and the VI-RADS score have been consistently validated across several different institutions as appropriate tools for local staging of bladder cancer and have been proven to contribute to the diagnostic workup and management of urinary bladder cancer. Local and regional disease spread is the strongest predictors of treatment success (4).

MDCT is considered the imaging technique of choice for detecting metastases in bladder cancer. MRI is considered superior to CT

for local staging because of its high soft-tissue contrast resolution and multiplanar imaging capabilities. In addition, MRI clearly differentiates the layers of the bladder wall and enables accurate assessment of the depth of tumor invasion in the bladder wall and extravesical extension. The differentiation between muscle-invasive and non-muscle-invasive disease is essential for treatment planning (5).

This study aimed to evaluate the role of MRI using Multiparametric and DWI in detection, evaluation and staging of urinary bladder malignancy using various MRI sequences that play an important role in post-treatment surveillance. Besides, to ensure a proper evaluation of bladder cancer using MRI with appropriate use of VI-RADS to aid communication among radiologists, urologists, and other medical staff.

Patients and methods

This cross-sectional observational study included 30 patients with suspected urinary bladder masses on the basis of clinical symptoms, U/S results and/or CT results, who were admitted to Benha University hospitals & other private institutions over a period of two years from January 2021 to January 2023.

The study was done after being approved by the institutional Ethical Committee, Faculty of Medicine-Benha University. Informed consent was obtained from all participants included.

Inclusions criteria were patients of both sexes over > 18 years old with history of recurrent attacks of hematuria, Patients with agreement to give written consent.

Exclusion criteria were overweight, non-cooperative and claustrophobic patients, patients with metallic prosthesis and cardiac pacemakers, contraindication to MRI and history of urinary tract trauma.

All patients were subjected to complete history taking (Onset, course, duration and relation of the disease to stress is documented, history of any systemic diseases eg; liver diseases, diabetes mellitus hyperlipidemia or hypertension, history of drug intake, previous hospital admission, also family history of a similar condition, were taken into consideration. **General clinical examination** including assessment of vital signs. **Pelvi-abdominal U/S and/or CT abdomen and pelvis:** were done as part of previous routine investigations for detection of the possible cause of hematuria.

Magnetic Resonance Imaging (MRI): Using a 1.5T MRI machine the entire pelvis was imaged from the aortic bifurcation to the inferior margin of the pubic symphysis. Axial T1-weighted and T2-weighted imaging and high-spatial-resolution fat-suppressed T2-weighted imaging in three orthogonal planes were performed with three excitations averaged. DWI imaging was performed during free breathing with a water-excited single-shot spin-echo echo-planar sequence in axial and oblique sagittal planes perpendicular to the tumor base. Images from dynamic contrast enhanced MRI were acquired with an axial or sagittal

fat-suppressed three-dimensional volumetric spoiled gradient-echo sequence before and after intravenous injection of 0.2 mL/kg of Magnevist at 2 mL/sec up to a total volume of 20 mL. Five sets of CE images were obtained 20–131 seconds after injection of contrast material. Subsequently, all the MRI images will be analyzed and classified using the newly developed Vesical Imaging Reporting and Data System (VI-RADS) score.

Assessment for T2-WI with structural category (SC): **SC1-category:** uninterrupted low signal line representing the integrity of muscularis propria, lesion <1 cm, exophytic tumor with stalk and/or high signal thickened inner layer. **SC2-category:** uninterrupted low signal line representing the integrity of muscularis propria, lesion >1 cm, exophytic tumor with stalk and/or high signal thickened inner layer or sessile/broad-based tumor with high signal thickened inner layer. **SC3-category:** lack of category 2 findings with associated presence of an exophytic tumor without stalk or sessile/broad-based tumor without high signal thickened inner layer but with no clear disruption of low signal muscularis propria. **SC4-category:** interruption of low signal line suggesting extension of the intermediate signal tumor tissue to muscularis propria. **SC5-category:** extension of intermediate signal tumor to extravesical fat, representing the invasion of the entire bladder wall and extravesical tissues.

Assessment for DCE with contrast-enhanced category (CE): **CE1-category:** no early enhancement of the muscularis

propria, lesions corresponding to SC1 findings. **CE2-category:** no early enhancement of muscularis propria with early enhancement of inner layer, lesions corresponding to SC2 findings. **CE3-category:** lack of category 2 findings but with no clear disruption of low signal muscularis propria, lesions corresponding to SC3 findings. **CE4-category:** tumor early enhancement extends focally to muscularis propria. **CE5-category:** tumor early enhancement extends to the entire bladder wall and to extravesical fat.

Assessment for DWI/ADC with DW category (DW): **DW1-category:** muscularis propria with intermediate continuous signal on DWI, lesion <1 cm, hyperintense on DWI and hypointense on ADC, with or without stalk and/ or low signal thickened inner layer on DWI. **DW2-category:** muscularis propria with continuous intermediate signal on DWI, lesion >1 cm, hyperintense on DWI and hypointense on ADC, with low signal stalk and/or low signal thickened inner layer on DWI or broad-based/sessile tumor with low/intermediate signal thickened inner layer on DWI. **DW3-category:** lack of category 2 findings (lesions corresponding to T2 category 3 findings) but with no clear disruption of low signal muscularis propria. **DW4-category:** high signal tumor on DWI and low signal tumor on ADC extending focally to muscularis propria. **DW5-category:** high signal tumor on DWI and low signal tumor on ADC extending to the entire bladder wall and extravesical fat.

Standard for reference: The operative, cystoscopic findings and pathologic

specimen were the gold standard. The final histo-pathological results were achieved by surgical specimen or cystoscopy-guided biopsy.

Statistical analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Armonk, NY, USA). Quantitative variables were presented as mean and standard deviation (SD). Qualitative variables were presented as frequency and percentage (%). Evaluation of Diagnostic Performance was performed using diagnostic sensitivity, specificity, PPV and NPV. Receiver Operating Characteristic curve (ROC-curve) analysis were performed: Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of VIRADS system for assessment bladder masses. A two tailed P value < 0.05 was considered statistically significant.

Research ethics committee:Ms.22.7.2022

Results

Demographic characters of studied groups were shown in **Table 1**.

Receiver Operating Characteristic (ROC) curve analysis of MRI for diagnosis of Malignancy of bladder mass: ROC curve analysis revealed that MRI could be excellent test of diagnosis of Malignancy of bladder mass with 96.2% sensitivity and 100% specificity (AUC, 0.98 and 95% CI, 0.93-1). **Figure 1**

There was Strong agreement between VIRAD and Cystoscopic-Biopsy In detection of stage 1 tumor grading, stage 2,

stage 3, stage 4 and stage 5 (Kappa= 0.89, 1, 0.65, 0.81, 0.92, respectively with p-value <0.001). **Table 2**

Cases

Case 1: 63 years old male patient presented with recurrent attacks of hematuria and left loin pain. Computed tomography revealed soft tissue mass arising from the urinary bladder base & left lateral wall. Axial & Sagittal T2W1s show fungating soft tissue masses arising from the left lateral wall of the urinary bladder. The mass displays relatively low signal intensity on T2Ws with disruption of normal low signal intensity line of the bladder wall and evidence of perivesical extension.

On DWIs the masses show restricted diffusion evident by high signal intensity on diffusion weighted images. The mean ADC value (image d & e) measures 0.59×10^{-3} mm²/sec. Dynamic study shows postcontrast heterogenous enhancement. This Value denotes malignant urinary bladder tumor VIRAD V.

The patient underwent radical cystectomy, and the mass was proved to be high grade squamous cell carcinoma. **Figure 2**

Case 2: 60 years old female patient presented with recurrent attacks of hematuria. Ultrasound revealed a polypoidal soft tissue mass arising from anterior wall of the urinary bladder. Axial T2W1 shows a polypoidal soft tissue mass lesion seen arising from anterior wall of the urinary bladder. The mass displays intermediate signal intensity on T2Ws with intact normal low signal intensity line of the bladder wall. No evidence of extra-vesical extension. A catheter is noted within the urinary bladder. On DWIs the mass shows restricted diffusion evident by high signal intensity on diffusion weighted images. The mean ADC value measures 1.09×10^{-3} mm²/sec denoting low grade tumor. This Value denotes urinary bladder tumor VIRAD II. Cystoscopic transurethral resection of bladder tumor was performed, and pathological finding was low grade Transitional cell carcinoma. **Figure 3**

Table 1: Demographic characters of studied groups:

Age (mean ± SD) yrs		53.8 ± 13.5	
Sex	Female	8	26.7
No. & %	Male	22	73.3
Marital status	Not married	7	23.3
No. & %	Married	23	76.7

Table 2: Agreement between VIRAD and Cystoscopic-Biopsy in stage 1

Stage 1		Cystoscopic-Biopsy		Kappa	p-value
		Positive	Negative		
VIRAD	Positive	24	1	0.89	<0.001
	Negative	0	5		
Stage 2					
VIRAD	Positive	27	0	1	<0.001
	Negative	0	3		
Stage 3					
VIRAD	Positive	28	0	0.65	<0.001
	Negative	1	1		
Stage 4					
VIRAD	Positive	22	1	0.81	<0.001
	Negative	1	6		
Stage 5					
VIRAD	Positive	21	1	0.92	<0.001
	Negative	0	8		

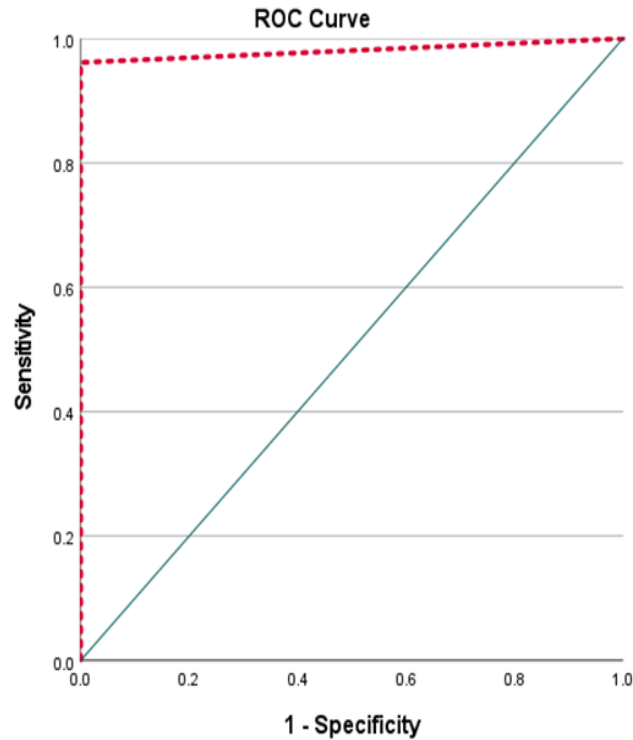


Figure 1: Receiver Operating Characteristic (ROC) curve analysis of MRI for diagnosis of Malignancy of bladder mass

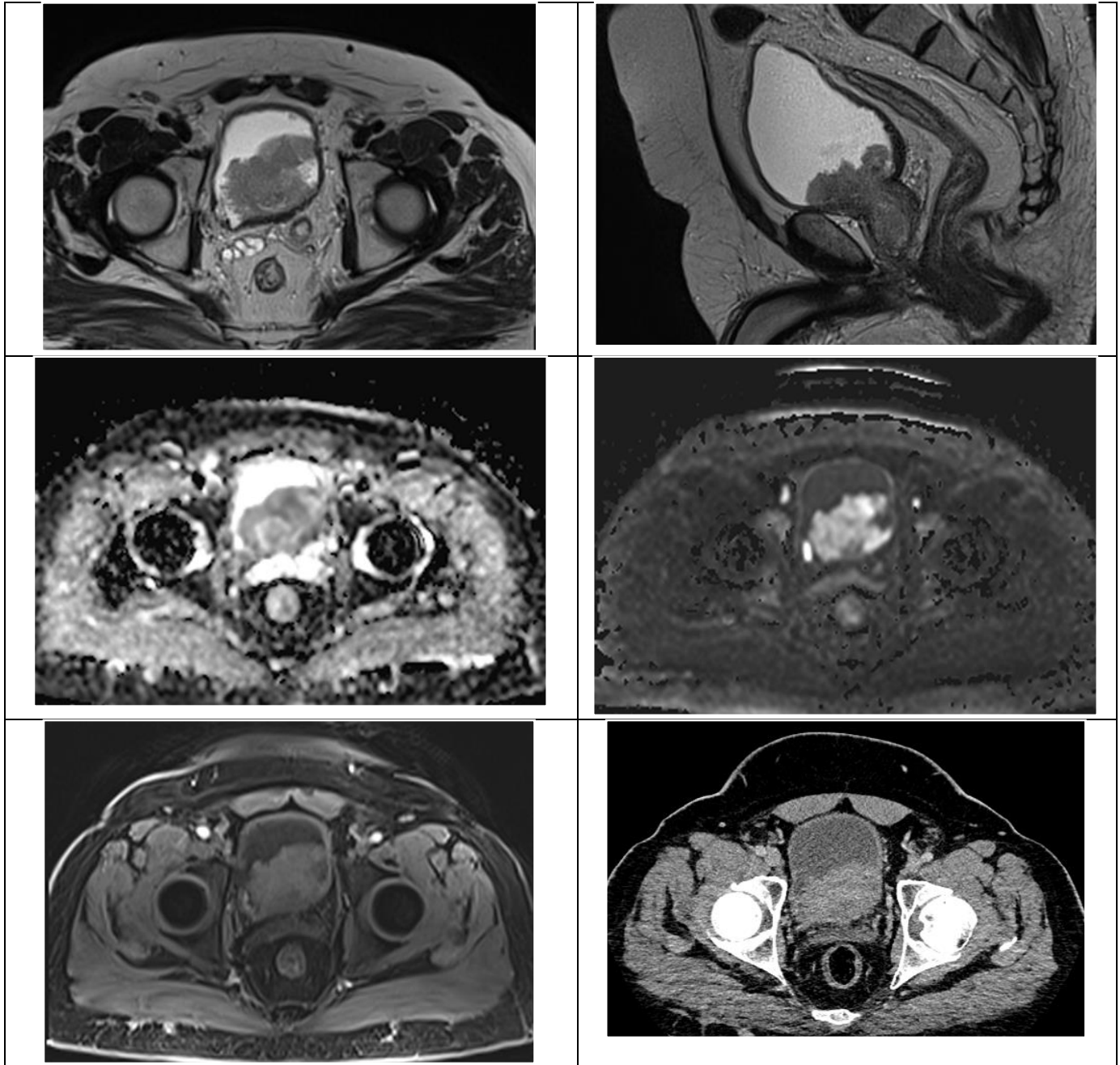


Figure 2: 63 years old male patient presented with recurrent attacks of hematuria and left loin pain. Computed tomography revealed soft tissue mass arising from the urinary bladder base & left lateral wall. Axial & Sagittal T2WIs show fungating soft tissue masses arising from the left lateral wall of the urinary bladder. The mass displays relatively low signal intensity on T2Ws with disruption of normal low signal intensity line of the bladder wall and evidence of perivesical extension. On DWIs the masses show restricted diffusion evident by high signal intensity on diffusion weighted images. The mean ADC value (image d & e) measures 0.59×10^{-3} mm²/sec. Dynamic study shows postcontrast heterogenous enhancement. This Value denotes malignant urinary bladder tumor VIRAD V. The patient underwent radical cystectomy, and the mass was proved to be high grade squamous cell carcinoma.

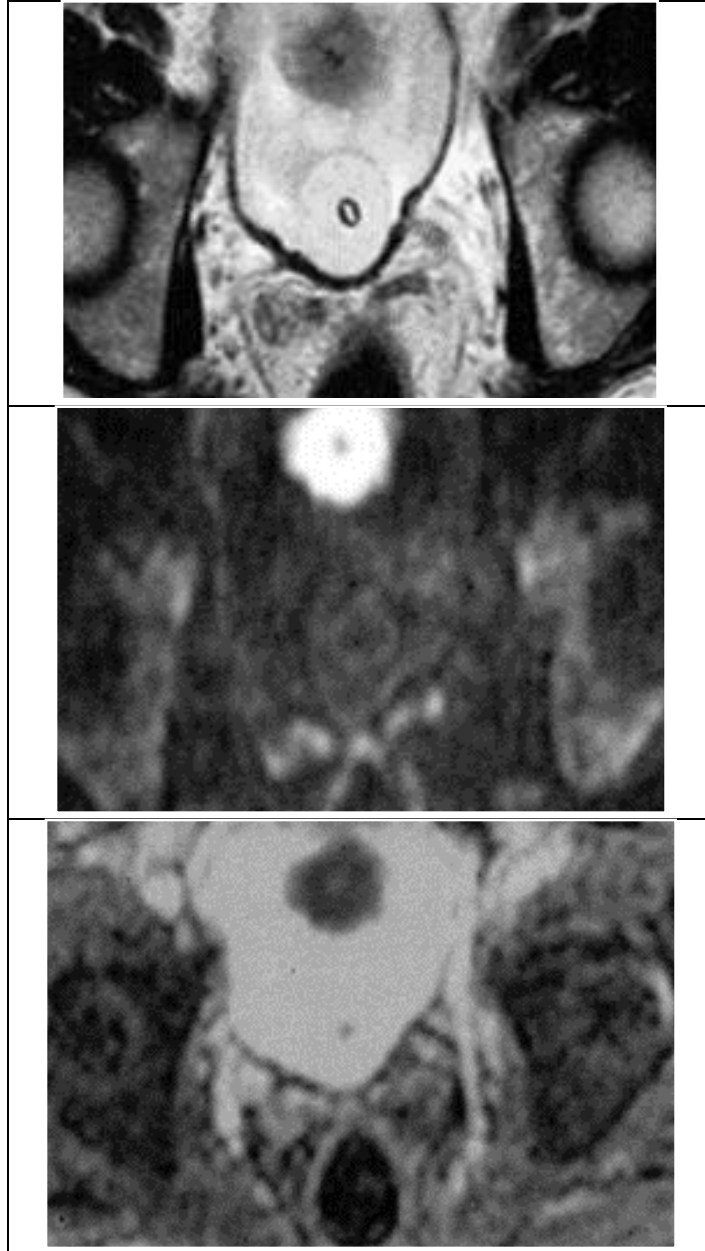


Figure 3: 60 years old female patient presented with recurrent attacks of hematuria. Ultrasound revealed a polypoidal soft tissue mass arising from anterior wall of the urinary bladder. Axial T2W1 shows a polypoidal soft tissue mass lesion seen arising from anterior wall of the urinary bladder. The mass displays intermediate signal intensity on T2Ws with intact normal low signal intensity line of the bladder wall. No evidence of extra-vesical extension. A catheter is noted within the urinary bladder. On DWIs the mass shows restricted diffusion evident by high signal intensity on diffusion weighted images. The mean ADC value measures 1.09×10^{-3} mm²/sec denoting low grade tumor. This Value denotes urinary bladder tumor VIRAD II. Cystoscopic transurethral resection of bladder tumor was performed, and pathological finding was low grade Transitional cell carcinoma.

Discussion

Bladder cancer is a common disease with significant associated morbidity and mortality. Globally it is the ninth most common cause of cancer related death in men (6).

In patients with hematuria who have normal upper urinary system examinations, bladder tumor is considered among the foremost possible diagnoses. More than half of urinary system tumors are in the bladder. More than 90% of bladder tumors, 80-90% of which are macroscopically of polypoid origin, are considered to be carcinomas with mutating epithelial cells (7). Cystoscopy is accepted as the most reliable examination method in the detection of bladder tumors and is considered to be the gold standard. However, radiological examinations are also needed in order to detect tumors and in the follow-up process of the disease. Imaging techniques such as intravenous pyelography, ultrasonography, CT and Dynamic MRI are used either alone or together (8).

Patients who die from bladder cancer almost always have disease that has metastasized from the bladder to other organs. Low-grade bladder cancers rarely grow into the muscular wall of the bladder and rarely metastasize, so patients with low-grade bladder cancers very rarely die from their cancer. Nonetheless, they may experience multiple relapses that need to be resected. Almost all deaths from bladder cancer are among patients with high-grade disease, which has a much

greater potential to invade deeply into the bladder's muscular wall and spread to other organs (9). Approximately 70% to 80% of patients with newly diagnosed bladder cancer will present with superficial bladder tumors. The prognosis of these patients depends largely on the grade of the tumor. Patients with high-grade tumors have a significant risk of dying of their cancer even if it is not muscle-invasive. Among patients with high-grade tumors, those who present with superficial, nonmuscle-invasive bladder cancer can usually be cured, and those with muscle-invasive disease can sometimes be cured (10).

As known, MRI has multiple advantages such as, no ionizing radiation, high spatial resolution and high soft tissue contrast, DWI was first applied in the brain and became the 'gold standard' imaging for the diagnosis of acute stroke. After technical advances such as fast sequences, DWI has been applied in the abdomen and pelvis including urinary tract tumors (11).

DWI has a high level of diagnostic performance in detecting bladder cancer and is comparable to T2WI but with better inter-observer agreement, this may be due to the clear contrast visible in DWI; signals of bladder cancer are very bright while images of surrounding tissues appear muted (12).

Recently, new technique called vesical imaging and reporting data system (VI-RADS) has been introduced by combining the results from T2WI, DWI & dynamic

contrast images to classify urinary bladder carcinomas (13).

The final pathological results in our study revealed that 16 patients (53.3 %) were T4 group, 1 patient (3.3 %) were classified as T3 group, 3 patient (10 %) were classified as T2 group and 6 patients (20 %) were classified as T1 group. Whereas benign bladder mass lesions were representing 13.3 % of the examined patients.

In a study on 80 patients; the sensitivity of VI-RAD IV was 76% and the sensitivity of VI-RAD III was 88% (14).

Another study on 50 patients with bladder masses, the sensitivity of VI-RADS scoring system 78% (15).

The results of our and previously published studies suggest a high reliability of MRI imaging for the diagnosis of bladder lesions in patients with gross hematuria. In addition, VI-RAD scoring system can provide information regarding lesion grade to surgeons who perform conventional cystoscopy.

Conclusion

Our study concluded that VI-RAD scoring system using Dynamic MRI protocol is a safe and confident method in detection, differentiating benign from malignant urinary bladder masses and in grading of urinary bladder carcinoma. Hence DCE-MRI, T2WI, DWI & ADC map may be added to imaging protocols of urinary bladder tumors.

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