# MR Imaging of the Urinary Bladder

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**KEYWORDS**

• Bladder cancer • Magnetic resonance imaging • Bladder imaging • Staging

**KEY POINTS**

- Bladder cancer continues to cause significant mortality and morbidity worldwide.
- MR imaging is the imaging modality of choice for accurate local staging, which is fundamental in determining further clinical management, particularly for those with T2 or greater disease.
- Novel MR imaging techniques, such as lymphotropic nanoparticle-enhanced MR imaging and the expanded use of diffusion-weighted imaging, may help further in local and nodal staging of disease.

Bladder cancer continues to remain a cause of more than 100,000 deaths annually worldwide. It is estimated that in the United States alone, 72,570 men and women were diagnosed with bladder cancer in 2013, with an estimated annual death rate of 15,210.

Accurate preoperative staging of bladder cancer is of paramount importance in determining the further management pathway. Radiologic and pathologic staging at initial presentation determines this, and prognosis also depends on this initial staging.

Despite involvement of ionizing radiation, computed tomography (CT) has been shown to be a valuable imaging modality in staging bladder cancer. However, MR imaging is more useful in the local staging of bladder cancer because of its inherent soft tissue resolution, soft tissue contrast, and multiplanar capabilities.[1–5] Because of these combined parameters, clear differentiation between bladder wall layers is possible, therefore allowing for more accurate local staging by differentiating muscle invasive from non–muscle invasive disease, and also extramural invasion. These factors all affect further management and prognosis.

## BIOLOGY OF BLADDER CARCINOMA

More than 90% of bladder carcinomas are transitional cell carcinomas derived from the urothelium. About 6% to 8% are squamous cell carcinomas, and 2% are adenocarcinomas.[6] Adenocarcinomas may be either of urachal origin or of nonurachal origin; the latter type is generally thought to arise from metaplasia of chronically irritated transitional epithelium.[7] Pathologic grade, which is based on cellular atypia, nuclear abnormalities, and the number of mitotic figures, is of great prognostic importance.

Several etiologic factors are associated with the development of bladder cancer, but in industrialized countries, cigarette smoking is the most important. Specific chemicals have also been identified as causing bladder cancer, as have several occupational exposures to less well-defined agents including aniline dyes.[8] Treatment with cytostatic drugs, especially cyclophosphamide, is associated with increased risk of bladder cancer, as is treatment with radiotherapy for uterine cancer. In developing countries, especially in the Middle East and parts of Africa, infections with members of the genus *Schistosoma* are

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responsible for a high incidence of bladder cancer, 75% of which are squamous cell carcinomas. Other risk factors for squamous cell carcinomas include long-term catheterization, nonfunctioning bladder (urinary stasis), and urinary tract calculi.[9]

Muscle-invasive bladder tumors are characterized by defects in the p53 and retinoblastoma tumor suppressor genes, whereas non–muscle-invasive bladder tumors are characterized by activating mutations in the HRAS gene and fibroblast growth factor.[10]

## ANATOMY OF THE URINARY BLADDER

The urinary bladder is a musculomembranous sac, predominantly extraperitoneal, its size position and relations varying according to the amount of fluid it contains. Peritoneum covers the superior surface, or dome of the bladder. The bladder receives both ureters posterolaterally, whereas inferiorly, the bladder neck is continuous with the urethra. The orifices of the ureters at the ureterovesical junction are joined by an elevated ridge covered by mucosa (the interureteric ridge). The trigone describes a triangular region on the internal face of the bladder on the inferior wall, marked at its corners by the ureterovesical junction and the urethra.

The bladder is composed of four layers from inside out: (1) the urothelium (mucosa), (2) the lamina propria (submucosa), (3) the muscularis propria, (4) and the serosa (derived from peritoneum). The tunica mucosa is thin and smooth, continuous, above through the ureters with the lining membrane of the renal tubules, and below with that of the urethra. The thickness of the highly vascular lamina propria varies with the degree of distention of the bladder. The muscularis propria, also known as the detrusor, consists of three layers of unstriated muscular fibers: an external, middle, and an internal layer, although radiologically these are not

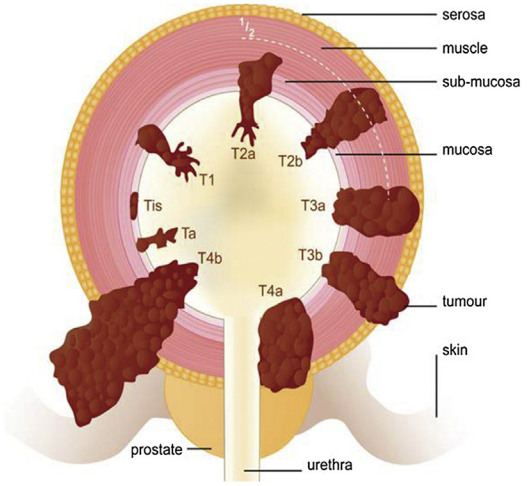


Fig. 1. Diagram illustrating the layers of the bladder wall and tumor staging based on depth of invasion. Also, see Table 1.

**Table 1**
**TNM staging of urinary bladder cancer**

| TNM Guidelines for the Staging of Urinary Bladder Cancer | |
|---|---|
| **Descriptor** | **Definition** |
| *Tumor* | |
| Tx | Primary tumor cannot be evaluated |
| T0 | No primary tumor |
| Ta | Noninvasive papillary carcinoma |
| Tis | Carcinoma in situ |
| T1 | Tumor invades connective tissue under the epithelium (surface layer) |
| T2 | Tumor invades muscle |
| T2a | Superficial muscle affected (inner half) |
| T2b | Deep muscle affected (outer half) |
| T3 | Tumor invades perivesical fat |
| T3a | Tumor is detected microscopically |
| T3b | Extravesical tumor is visible macroscopically |
| T4 | Tumor invades the prostate gland, uterus, vagina, pelvic wall, or abdominal wall |
| *Node* | |
| Nx | Regional lymph nodes cannot be evaluated |
| N0 | No regional lymph node metastasis |
| N1 | Metastasis in a single lymph node <2 cm in size |
| N2 | Metastasis in a single lymph node >2 cm but <5 cm in size, or multiple lymph nodes <5 cm in size |
| N3 | Metastasis in a lymph node >5 cm in size |
| *Metastasis* | |
| Mx | Distant metastasis cannot be evaluated |
| M0 | No distant metastasis |
| M1 | Distant metastasis |

*From* Greene FL, Page DL, Fleming ID, et al. Urinary bladder. In: AJCC cancer staging manual. 6th edition. New York: Springer-Verlag; 2002. p. 335–40.

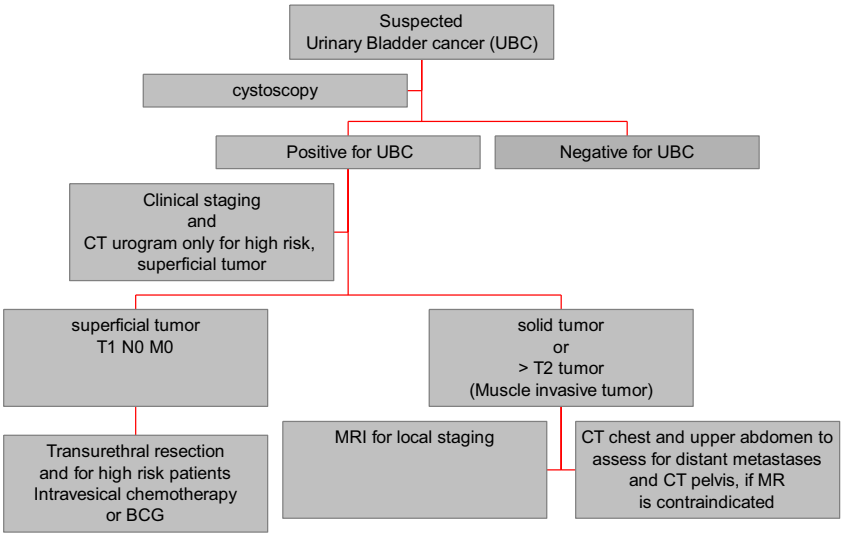


Fig. 2. Algorithm demonstrating the imaging pathway for suspected urinary bladder lesion in our institution. BCG, Bacillus Calmette-Guérin; CT, computed tomography.

differentiated. The serosa invests the superior surface and the upper parts of the lateral surfaces. It is reflected from these onto the abdominal and pelvic walls.

## STAGING OF BLADDER CANCER

Staging of bladder cancer is based on the TNM (tumor-node-metastasis) staging system, with T stage representing the degree of bladder wall invasion (**Fig. 1**, **Table 1**). Transurethral resection of bladder tumor is often used for T1 disease, whereas partial or total cystectomy or adjuvant therapies are used for stage T2 and beyond, because an adverse side effect of transurethral resection of invasive bladder tumors is local tumor recurrence. Preoperative radiologic distinction between T1 and T2 (or greater) staging of tumors is therefore fundamental to guiding management decisions (**Fig. 2**).

## MR IMAGING TECHNIQUE

The MR imaging protocols used in the figures shown in this article were performed using a Siemens 1.5-T MR imaging scanner (Magnetom Symphony; Siemens Medical Solutions, Erlangen, Germany) (**Table 2**). A six-channel phased array body coil was used with thin sections and a large matrix. Preliminary localizer sequences are used to evaluate for appropriate coil placement and bladder distention. T1-weighted images (T1WI) are obtained in the axial or coronal plane to give an overview of the pelvis. In particular, the perivesical fat plane for extravesical involvement, pelvic lymph nodes, and bone metastases can be assessed. On T1WI, urine has low signal intensity (SI), bladder wall intermediate SI, and perivesical fat a high SI. T2-weighted images (T2WI) are obtained in all three orthogonal planes to demonstrate the detrusor muscle well. The detrusor muscle is depicted as a T2 hypointense line and is interrupted in the case of muscle-invasive tumors. Urine has a high SI on T2WI.

Optimal bladder distention is of fundamental importance for accurate diagnosis. Overdistention can result in flat or plaquelike lesions being missed, and underdistention can result in smaller lesions being missed because of detrusor muscle thickening. Some centers advocate use of antiperistaltic agents to prevent artifact from bowel peristalsis; however, we do not routinely use them.

The use of dynamic gadolinium-enhanced sequences as part of a standard protocol varies

**Table 2**
**MR imaging protocol for bladder cancer: adequate patient positioning**

| MR Imaging Acquisition Parameters[a] | TR | TE | FOV |
|---|---|---|---|
| T2 sagittal | 230 | 100 | 230 |
| T2 coronal | 4700 | 107 | 160 |
| T1 axial | 499 | 12 | 400 |
| T2 axial | 2600 | 100 | 200 |

[a] MR imaging acquisition parameters at our institute.

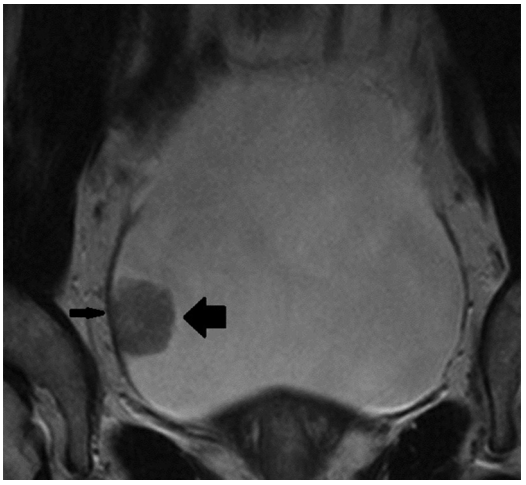

Fig. 3. T2-weighted axial image. The *thick arrow* indicates the tumor. The low signal (*thin arrow*) of the detrusor muscle is uninterrupted in keeping with T1 stage.

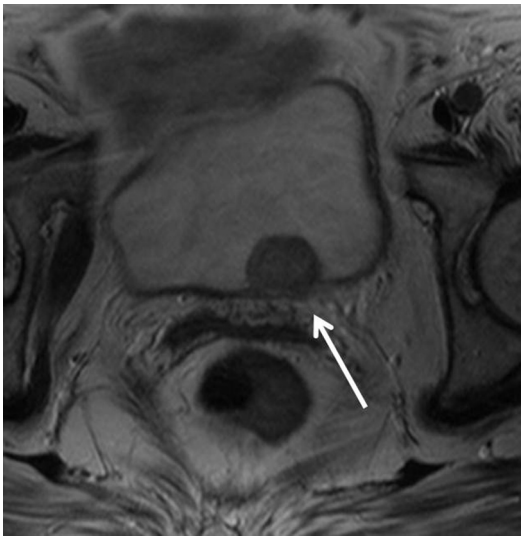

Fig. 4. T2-weighted axial image. There is interruption of low signal muscular wall of the bladder (*arrow*) in keeping with T2 tumor.

between institutions. Some studies advocate its use, whereas others have shown no significant advantage.[3,11,12,13]

## MR IMAGING STAGING

### *T Staging*

The most important role of MR imaging in bladder cancer in terms of clinical management is to determine the presence of muscle invasion. T1 disease does not involve the detrusor muscle (**Fig. 3**). Conversely, depth of mural invasion can also be assessed and subdivided on MR imaging into T2a and T2b disease (**Fig. 4**). T2WI can demonstrate macroscopic perivesical spread, seen as a direct extension of the lesion into the perivesical fat tissue and indicating T3b disease (**Fig. 5**). It is important to interpret this in the clinical context, however, because postcystoscopic biopsy imaging can lead to perivesical stranding, which should not be interpreted as disease extension. Such imaging should be delayed until about 4 to 6 weeks postintervention. Conversely, microscopic perivesical spread indicating T3a disease cannot readily be appreciated on CT or MR imaging. Although T1 lesions can be differentiated from T2 lesions or higher with the use of

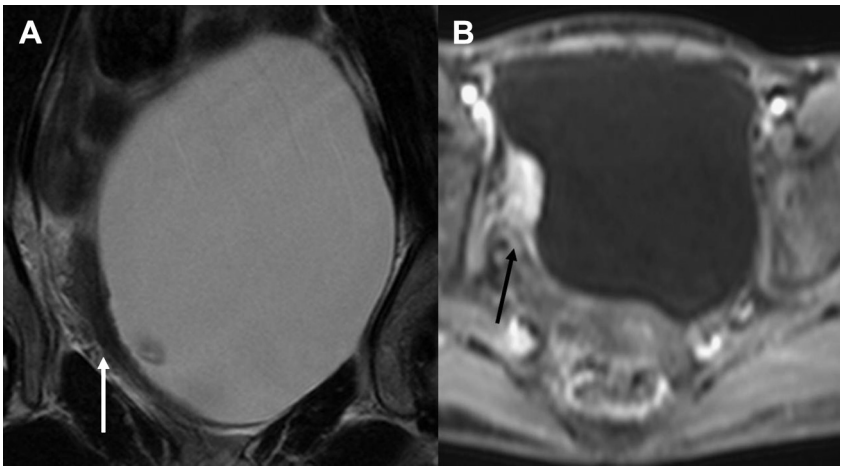


Fig. 5. T2-weighted (*A*) and T1 fat saturated postcontrast (*B*) axial images. The *arrows* indicate bladder wall invasion and perivesicle extension in keeping with a T3b tumor.

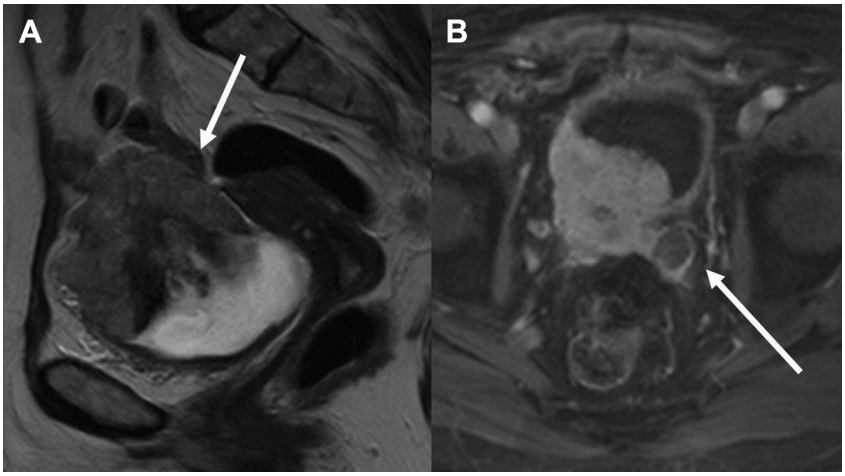


Fig. 6. T2-weighted (*A*) and T1 FS postcontrast (*B*) axial images. The *arrows* indicate small bowel involvement in keeping with T4a tumor.

contrast enhancement, the need for this is usually precluded by histologic confirmation. Invasion of local structures indicating T4 disease is usually well appreciated on MR imaging (**Figs. 6–8**). The overall sensitivity of detecting and staging the primary tumor ranges from 62% to 87.5%.[11,12]

### *N Staging*

The inherent challenge faced with recognition of nodal disease is that it is primarily based on size criteria. Large nodes can be hyperplastic and reactive, and malignant nodes are not always enlarged. These lead to false-positive and false-negative results. Bladder cancer spreads to the paravesical, lateral sacral and presacral nodes, then to the obturator, hypogastric, external iliac and common iliac nodes. Obturator nodes are involved in 75% of those with nodal disease.[14] The overall sensitivity of detecting nodal metastases based on node size ranges from 64% to 92%.[13,15]

## DEVELOPING MR IMAGING TECHNIQUES

The role of diffusion-weighted imaging (DWI) is still being established. DWI can be beneficial in the differentiation of benign and malignant bladder lesions, and of high- and low-grade urinary carcinomas, using quantitative apparent diffusion coefficient measurements. DWI has also been evaluated in terms of staging and efficacy of induction chemotherapy.[16–19] Ultrasmall superparamagnetic iron-oxide–enhanced MR imaging has been reported to improved lymph node staging in several studies, and in patients with bladder and/or prostate cancer, a diagnostic accuracy of

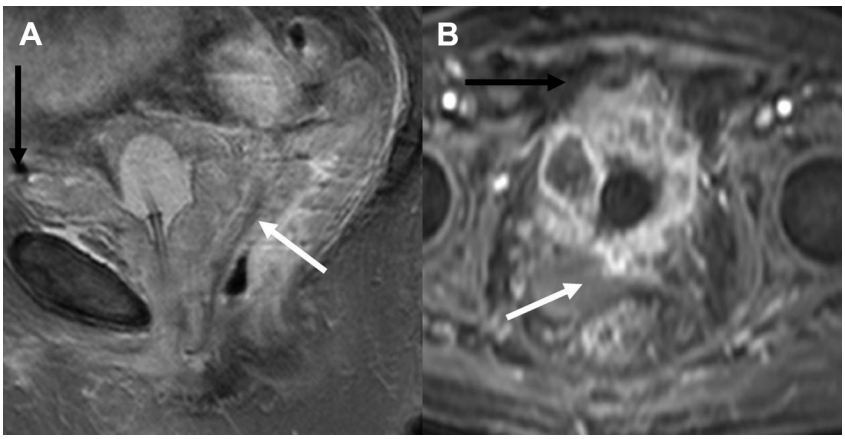


Fig. 7. T2-weighted (*A*) sagittal and T1 FS postcontrast (*B*) axial images. *White arrow* indicates rectal invasion, *black arrow* indicates abdominal wall invasion, both in keeping with stage T4b.

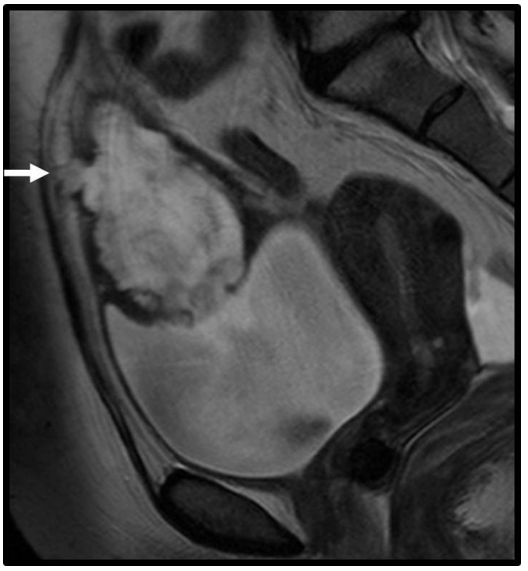

**Fig. 8.** Sagittal T2-weighted image showing mixed signal intensity mass in the dome extending into the urachal remnant and anterior abdominal wall (*arrow*).

up to 90% has been achieved for detecting metastatic lymph nodes.[20]

## SUMMARY

MR imaging is the modality of choice for accurate local staging of bladder cancer. In addition, bladder MR imaging helps detect lymph node involvement, and in conjunction with CT, provides complete staging. Familiarity with optimal imaging protocols, normal urinary bladder anatomy, and pathologic MR imaging appearances is essential for the radiologist. Evolving techniques, such as use of DWI and lymphotropic nanoparticle-enhanced MR imaging, may further enhance the ability of MR imaging in local and nodal staging.

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