European Journal of Radiology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Review

Lower tract neoplasm: Update of imaging evaluation

Robert Hartman[a,*], Akira Kawashima[b,**]

[a] Department of Radiology, Mayo Clinic, Rochester, MN, USA
[b] Department of Radiology, Mayo Clinic, Scottsdale, AZ, USA

ARTICLE INFO

Keywords:
Urothelial cancer
UCB
Urachal cancer
Urethral cancer
Computed tomography (CT)
Magnetic resonance imaging (MRI)

ABSTRACT

Cancers of the lower urinary tract can arise from the bladder, urachus or urethra. Urothelial carcinoma of the bladder (UCB) is the most common of these. The presentation of bladder, urachal and urethral cancers can differ but many result in hematuria as an initial indication. The diagnosis and staging of these cancers often necessitate radiologic imaging often in the form of cross-section CT urography or MR urography. The following article reviews the specific nature of lower tract cancers and their imaging.

1. Introduction

Tumors of the lower urinary tract can affect the bladder, urachus or urethra. Depending on the tumor type and location the imaging modality best suited for evaluation may differ. This article will discuss the different types of tumors, their epidemiology, diagnosis and staging with emphasis on the radiologic imaging often utilizing cross-sectional Computed tomography (CT) and/or MRI.

2. Urinary bladder cancer

2.1. Epidemiology

Urothelial carcinoma of the bladder (UCB) is the most common malignant neoplasm of the lower urinary tract with an age-standardized incident rate in the world of 9.0 for men and 2.2 for women (per 100,000 person years). However the incidence of UCB varies within regions of the world. The age-standardized incidence in the European Union for instance is 19.1 for men and 4.0 for women [1]. In the United States UCB is the 6th most common malignancy with an annual incidence of around 79,000 new cases per year [2]. UCB in the U.S. typically affects Caucasian patients older than 65 years [3–6]. The incidence is about 4 times higher in men then in women.

Multiplicity and a higher rate of recurrence are typical for urothelial carcinoma. In the United States it tends to be one of the most expensive cancers to treat due to frequent recurrence [7]. Given the fact that the tumors can arise anywhere throughout the urinary tract, all of the urothelium may be susceptible to malignancy which is known as the field defect theory [8]. Tobacco smoking is the most significant and common risk factor although additional causes of carcinogenesis have been implicated as well [9].

2.2. Diagnosis of bladder cancer

Patient signs and symptoms, most notably hematuria, are often the initiating event leading to the search for lower tract malignancy. Initial evaluation including physical examination, cytology and eventually cystoscopy with biopsy most often lead to the diagnosis of a lower tract malignancy, specifically UCB. Cystoscopy and biopsy are necessary to delineate non-muscle invasive bladder cancer (NMIBC) from muscle invasive bladder cancer (MIBC).

2.3. Histology

UCB accounts for 90% of bladder tumors and can exhibit different patterns of growth characterized as either papillary or infiltrative. The pattern of growth tends to correlate with grade ranging from well-differentiated grade 1 to poorly differentiated grade 3 [10]. At the time of diagnosis most patients have NMIBC. However many can recur and a significant portion can progress to higher stage disease over time. Approximately 25% of patients will present with MIBC [11]. The treatment and imaging related to NMIBC is markedly different from MIBC.

Abbreviations: AJCC, American Joint Committee on Cancer; AUA, American Urological Association; CTU, Computed tomography urography; DWI, diffusion-weighted imaging; MIBC, muscle invasive bladder cancer; NCCN, National Comprehensive Cancer Network; NMIBC, non-muscle invasive bladder cancer; PET/CT, positron emission tomography-computed tomography; TNM, Tumor, node, metastases staging system; TURBT, Transurethral resection of bladder tumor; UCB, Urothelial carcinoma of the bladder

* Corresponding author at: Department of Radiology, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA.
** Corresponding author at: Department of Radiology, Mayo Clinic, 13400 E. Shea Boulevard, Scottsdale, AZ 85259, USA.
E-mail addresses: Hartman.robert@mayo.edu (R. Hartman), kawashima.akira@mayo.edu (A. Kawashima).

http://dx.doi.org/10.1016/j.ejrad.2017.10.019
Received 23 October 2017; Accepted 24 October 2017

Table 1
Primary tumor (T).
Original source [1].

TX	Primary tumor cannot be assessed
T0	No evidence of primary tumor
Ta	Non-invasive papillary carcinoma
Tis	Carcinoma in situ: "flat tumor"
T1	Tumor invades subepithelial connective tissue
T2	Tumor invades muscularis propria
pT2a	Tumor invades superficial muscularis propria (inner half)
pT2b	Tumor invades deep muscularis propria (outer half)
T3	Tumor invades perivesical tissue
pT3a	Microscopically
pT3b	Macroscopically (extravesical mass)
T4	Tumor invades any of the following: prostatic stroma, seminal vesicles, uterus, vagina, pelvic wall, abdominal wall
T4a	Tumor invades prostatic stroma, uterus, vagina
T4b	Tumor invades pelvic wall, abdominal wall

Adapted from American Joint Committee on Cancer (AJCC), Chicago, Illinois.

Squamous cell carcinoma is the next most common tumor accounting for 8% of cases in the US. Squamous cell carcinoma often is associated with recurrent urinary tract infection or chronic indwelling catheters [12]. However, in areas of the world where *Schistosoma haematobium* is endemic, squamous-cell carcinoma is more prevalent accounting for up to 40% of tumors [13,14].

The 3rd most common cell type is adenocarcinoma, which may be urachal or non-urachal in origin [15]. The urachal type of adenocarcinoma, discussed in further detail later in the article, often occurs in the dome of the bladder within the urachal remnant [16].

2.4. Staging

The TNM staging system of the American Joint Committee on Cancer (AJCC) is most commonly used [17](Table 1, Bladder Cancer TNM Staging). This is preferred as the extent of tumor within the bladder wall and involvement of adjacent or distal sites are both important [8].

It is important to note that approximately 5% of patients who present with UCB will develop metachronous tumors in the upper urinary tract. Conversely up to 50% of patients with tumors in the upper urinary tract will develop metachronous tumors in the bladder [18–20]. For this reason any patient with identified UCB should have dedicated imaging of the upper and lower urinary tract.

Clinical staging, including cystoscopy, is typically sufficient for staging of NMIBC. For NMIBC (carcinoma in situ, cTa or cT1) the American Urological Association (AUA) and National Comprehensive Cancer Network (NCCN) recommend upper tract imaging. However for MIBC, stage T2 and above, clinical staging may only be accurate in 25% to 50% of patients [21]. Therefore if the bladder tumor has an appearance suggestive of invasion into the muscle, more advanced imaging, such as CT of the abdomen and pelvis, should be undertaken prior to TURBT [22].

CT and MRI have relatively high sensitivity and specificity for the differentiation of patients with transmural spread of disease to the extravesical space versus those with tumor confined to the bladder [11,23,24]. The overall accuracy for local bladder cancer staging approaches 60% with a tendency to over stage [21].

CT and MRI are also useful in detection of lymphatic metastases. The obturator, internal iliac, external iliac and presacral lymph nodes are the primary nodal groups impacted [25]. However CT and MR are both dependent on lymph node enlargement to detect potential metastases. Typically lymph nodes with a short axis diameter greater than 1 cm are considered suspicious [26].

Table 2
Prognostic Group/TNM staging*.
Original source [1].

Group	T	N	M
Oa	Ta	N0	M0
Ois	Tis	N0	M0
I	T1	N0	M0
II	T2a	N0	M0
	T2b	N0	M0
III	T3a	N0	M0
	T3b	N0	M0
IV	T4a	N0	M0
	T4b	N0	M0
	Any T	N1-3	M0
	Any T	Any N	M1

Adapted from American Joint Committee on Cancer (AJCC), Chicago, Illinois.
* TNM Definitions found in Table 1.

2.5. Prognosis

For all stages combined the 5 year survival rate is 77% which drops to 70% at 10 years and 65% at 15 years. Cancer-specific survival correlates highly with tumor stage. The clinical and imaging findings of the patient's disease determine the stage according to the AJCC stage groupings (Table 2, Anatomic stage and prognosis). The survival rate for people with stage 0 cancer is 98%, stage I 88%, stage II 63%, stage III 46%, and stage IV 15% [2,3].

2.6. Imaging of bladder cancer

Many modalities including ultrasound, CT, MRI and positron emission tomography-computed tomography (PET-CT) can be used for the staging of UCB, urachal and urethral cancers.

Some form of upper urinary tract imaging is recommended by the AUA and NCCN guidelines when NMIBC, which consists of carcinoma in situ, cTa or cT1, is discovered. Notably, when tumors are sessile, multifocal, or high grade on resection pathology, more advanced imaging of the abdomen and pelvis is recommended [7]. This is due in part to previously reported 25–40% rate of up-staging to of NMIBC to MIBC [27,28].

Staging of MIBC following diagnosis of cT2 disease usually requires more extensive imaging. The AUA and NCCN guidelines recommend contrast enhanced cross-sectional imaging of the abdomen and pelvis typically in the form of CT urography. MR urography may be an alternative in certain situations. These cross-sectional studies are performed in conjunction with chest x-ray or unenhanced CT of the chest. In patients with symptoms suggestive of a bony metastasis and/or elevated serum alkaline phosphatase level, a nuclear medicine bone scan is recommended [7,29].

3. Imaging modalities

3.1. Computed tomography urography (CTU)

CT imaging for detection and staging of urothelial carcinoma is typically obtained through the use of a CTU protocol. CTU provides comprehensive evaluation of the entire urinary system to allow for detection of urolithiasis, renal parenchymal lesions and urothelial carcinoma [30].

CTU in brief requires at least two series, one before and a second following contrast injection. The unenhanced series allows for identification of high attenuation blood clots, urolithiasis or calcifications in a mass.

There are different protocols for obtaining the enhanced series. A single bolus protocol will acquire enhanced images of the renal parenchyma and urinary tract mucosa approximately 90 s after injection.