Upper and Lower Tract Urothelial Imaging Using Computed Tomography Urography

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KEYWORDS

• Transitional cell carcinoma • Computed tomography (CT) • Kidney • Ureter • Bladder
• Single-bolus • Split-bolus

KEY POINTS

- Appropriate technique is critical in the diagnosis of urothelial tumors anywhere in the urinary tract, because subtle or small tumors may be virtually impossible to identify without appropriate distension and the correct phase of contrast.
- There are several options when designing a computed tomography (CT) urography protocol, the most important of which are the single-bolus and split-bolus techniques, which offer a trade-off between maximal sensitivity and increased radiation dose.
- The most important CT imaging features of urothelial malignancy (whether in the urinary bladder, ureters, or intrarenal collecting systems) include focal urothelial thickening, urothelial hyperenhancement, a focal nodule/mass, asymmetric collecting system dilatation, and urothelial calcification.

INTRODUCTION

Computed tomography (CT) urography is the best noninvasive method of evaluating the upper urinary tract for urothelial malignancies, most importantly transitional cell carcinoma. In particular, CT urography has proved to be effective in the assessment of the upper urinary tracts in patients who present with painless hematuria, with sensitivities of more than 90%.[1] Accordingly, CT urography is now a widely accepted part of the routine evaluation of patients who present with hematuria, serving as the primary means of screening the upper urinary tract for malignancy. Just as importantly, although CT has historically been considered purely as a means of evaluating the upper urinary tracts (ie, intrarenal collecting systems and ureters), with the evaluation of the bladder having largely been left to the domain of direct visualization under cystoscopy, it has increasingly become evident that many bladder tumors are readily visible on CT, provided that the proper CT protocols are used and that the bladder is appropriately evaluated during image review. Although cystoscopy is (rightly) recommended on a routine basis for patients who present with gross hematuria, many patients, particularly when presenting in the emergency room setting, do not go on to undergo cystoscopy and are subsequently lost to follow-up, making careful examination of the bladder increasingly important when evaluating patients with CT on their initial presentations.

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However, the utility of CT urography, whether in the upper or lower urinary tract, is heavily contingent on the use of optimized CT protocols and proper image acquisition techniques, because poor technique can create significant barriers to making a correct radiologic interpretation, particularly given that identification of subtle tumors can be nearly impossible in the absence of good collecting system distension and opacification. Moreover, although standard axial image review may be sufficient in most other parts of the abdomen and pelvis, evaluation of the collecting systems and ureters presents a prime example of an application for which standard axial images may not be sufficient to identify many subtle urothelial tumors, and for which the use of multiplanar reformations and three-dimensional (3D) imaging techniques may be helpful (or even necessary) for the identification of small or difficult-to-see lesions.

This article focuses primarily on the appropriate protocols for optimizing CT urography acquisitions, including a discussion of the many different protocol options available, both in terms of contrast administration and the timing of imaging acquisitions, as well as the use of several ancillary techniques designed to increase collecting system distention and opacification. In addition, this this article discusses the imaging findings that should raise concern for urothelial carcinoma at each of the 3 segments of the urinary tract, namely the intrarenal collecting systems, ureters, and the bladder, and the best means of using 3D reconstructions at each of these 3 sites for augmenting standard axial image review.

BACKGROUND

Urothelial carcinoma of the upper urinary tract (including the intrarenal collecting systems, renal pelvis, and ureters) is uncommon, although the renal pelvis is probably the second most common location for urothelial carcinoma following the bladder. Although exact numbers are difficult to obtain for the incidence of upper urinary tract tumors given their rarity, it is thought that roughly 2300 patients in the United States were diagnosed with transitional cell carcinoma of the ureter (with 700 deaths) in 2008. Upper tract tumors account for only 5% of all urothelial carcinomas and ~15% of all renal tumors.[2] The major risk factors for urothelial carcinoma of the upper urinary tract include male gender, increasing age, cigarette smoking and tobacco use, phenacetin abuse, exposure to certain chemicals and drugs (such as cyclophosphamide), chronic hydronephrosis, and a history of prior recurrent or severe urinary tract infections. Patients with upper tract tumors most commonly present with hematuria (microscopic or gross) or flank pain, although many tumors (~20%) may be discovered incidentally.[3]

In contrast, bladder cancer is very common, representing the most common primary malignancy of the urinary tract, with more than 70,000 new cases and more than 14,000 deaths in 2010.[4] Almost all bladder cancers represent transitional cell carcinomas, although other possible subtypes include squamous cell carcinoma, adenocarcinoma, and rare mucinous neoplasms. Risk factors for bladder cancer are similar to those of upper tract malignancy, including age, male gender, smoking, repeated urinary tract infections, chronic urinary obstruction, and chemical carcinogens. As with upper tract malignancies, these tumors commonly present with hematuria, although macroscopic or gross hematuria is a much bigger risk factor than microscopic hematuria. Other less common presenting symptoms include urinary urgency, urinary frequency, or symptoms caused by metastatic disease.[3–5]

One of the unique features of transitional cell carcinoma, regardless of whether it arises in the upper or lower urinary tract, is its strong tendency for both recurrence and multifocality, with almost 4% of patients with bladder cancer going on to develop a transitional cell carcinoma in the upper urinary tract.[3–5]

TECHNIQUE

In general, when designing a CT urography protocol, the primary goals of the study are to maximize opacification and distension of the collecting systems and ureters in the delayed excretory phase, so as to increase sensitivity for transitional cell carcinoma, while still having sufficient sensitivity to identify a variety of other abnormalities that may potentially cause hematuria, including renal stones and renal cell carcinoma. Accordingly, there must be a balance between acquiring images of sufficient quality in several different phases so as to maximize sensitivity for significant disorder, while at the same time minimizing radiation dose. The 2 most important CT urography protocols in wide clinical use are[1] the single-bolus technique and[2] split-bolus technique.[6–8]

The single-bolus technique is the most widely used protocol across a spectrum of different clinical practices, and entails giving a single full-strength dose of intravenous contrast (typically roughly 120 mL of Omnipaque-350), followed by the acquisition of separate arterial, venous, and delayed excretory phase images (**Fig. 1**). Given that the entirety of the contrast dose contributes toward the excretory phase and is excreted into