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Seminars Article

Advances in medical imaging for the diagnosis and management of common genitourinary cancers

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Abstract

Medical imaging of the 3 most common genitourinary (GU) cancers—prostate adenocarcinoma, renal cell carcinoma, and urothelial carcinoma of the bladder—has evolved significantly during the last decades. The most commonly used imaging modalities for the diagnosis, staging, and follow-up of GU cancers are computed tomography, magnetic resonance imaging (MRI), and positron emission tomography (PET). Multiplanar multidetector computed tomography and multiparametric MRI with diffusion-weighted imaging are the main imaging modalities for renal cell carcinoma and urothelial carcinoma, and although multiparametric MRI is rapidly becoming the main imaging tool in the evaluation of prostate adenocarcinoma, biopsy is still required for diagnosis. Functional and molecular imaging using 18-fluorodeoxyglucose-PET and sodium fluoride-PET are essential for the diagnosis, and especially follow-up, of metastatic GU tumors. This review provides an overview of the latest advances in the imaging of these 3 major GU cancers.

Keywords: Renal cell carcinoma; Bladder urothelial carcinoma; Prostate adenocarcinoma; CT; MRI; PET

Introduction

Genitourinary (GU) cancers are some of the most common malignancies. Renal cell carcinoma (RCC) is the most common kidney tumor, with an estimated 62,700 new cases and an estimated 14,240 deaths in 2016 [1,2] in the United States. Urothelial carcinoma of the bladder is more common than RCC, with an estimated 77,000 new cases and 16,390 deaths in 2016 [2] in the United States. Adenocarcinoma of the prostate is the second most common cancer in men and the most common GU cancer, with more than 180,000 new cases in the United States estimated in 2016 and an estimated 26,120 deaths per year [2].

Computed tomography (CT) is the major imaging modality for RCC and urothelial carcinoma (UC) of the bladder. The current recommendation of the National Comprehensive Cancer Network for initial staging of muscle-invasive bladder cancer (MIBC) is CT scan of the chest, abdomen, and pelvis or magnetic resonance imaging (MRI) of the abdomen and pelvis with noncontrast CT scan of the chest.

MRI is helpful in patients allergic to iodinated contrast agents and in patients with renal insufficiency, and may

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provide more information for the evaluation of locally advanced disease [3,4]. Advanced MRI techniques are providing better assessment of renal and bladder tumors, whereas multiparametric MRI (mpMRI) is increasingly being used to diagnose prostate adenocarcinoma.

Positron emission tomography (PET)/CT is a powerful noninvasive tool used by major medical centers and many community hospitals for characterizing solid tumors. Fluorodeoxyglucose (FDG)-PET, and sodium fluoride (NaF)-PET are common functional and molecular imaging modalities used for staging and assessing treatment response [3,5].

In this review, we discuss the latest advances in imaging and their potential effect on the diagnosis and management of RCC, UC of the bladder, and prostate adenocarcinoma.

Renal cell carcinoma

CT in RCC

CT is the primary modality for the diagnosis, staging, treatment planning, and surveillance of RCC [6–8]. CT can be performed in multiple phases before and after injection of an intravenous (IV) contrast agent. The most reliable phase for the detection of RCC is the nephrographic phase, 70 to 100 seconds after injection of IV contrast [6]. As papillary carcinoma is hypovascular, the arterial phase of a kidney CT examamination can differentiate between clear cell and papillary carcinoma with 95.7% accuracy and a sensitivity and specificity of 98.3% and 92%, respectively [9]. Clear cell carcinoma, which accounts for 60% to 65% of RCCs, appears as a hypervascular mass with a heterogeneous texture due to cystic or necrotic components [10]. Papillary RCC is usually homogeneous, well-defined, and hypovascular [10]. Chromophobic RCC has an intermediate vascularity, is usually well-circumscribed, and measures >4 cm [10]. Multiphasic multidetector CT scan is useful in differentiating clear cell RCC from other subtypes of RCC and oncocytoma [11].

An important and unique finding in RCC is tumor extension and thrombosis to renal vein and inferior vena cava (IVC) [12]. This has been reported in 4% to 10% of all renal neoplasms, having therapeutic and prognostic importance [13,14]. This invasion can only be limited to the vessel wall. CT is very helpful for venous extension of RCC, best seen in the corticomedullary phase of contrast enhancement [15]. Enhancement of the thrombus helps to differentiate tumor thrombus from bland thrombus [15]. Although CT can be as sensitive as MRI in assessment of tumor thrombus, in some cases it may fail because of extrinsic pressure over the vein or inadequate filling of IVC [16].

Dual-energy CT (DECT) is a new type of CT scanner in which 2 sets of x-ray beams with 2 different energy levels are passing through the body, in contrast to traditional CT scans that have an x-ray beam with only 1 energy level [17–19]. The interaction of these 2 x-ray beams with body tissues can help in material identification and quantification [18]. These 2 CT datasets at a low or high polychromatic peak tube energy (kV) provide material-specific information that allows for additional characterization of the kidneys and urinary tract [20]. The 2 varying energy levels can enhance or mute the conspicuity of IV contrast. DECT can be used to interrogate iodine and calcium concentrations and increase the iodine signal to help differentiate pathologic processes and clarify the internal structure of mass lesions [21]. The capability to decompose materials and extract iodine can improve differentiation of lesions such as minimal enhancement in a hypodense kidney tumor (papillary renal cell carcinoma) from a cyst. Quantification of iodine in the lesion can be a biomarker of tumor vascularity [18].

Improving lesion conspicuity can potentially reduce the need for or frequency of follow-up imaging. DECT is helpful in differentiating between clear cell and papillary cell RCC, the latter of which accounts for about 15% to 20% of all RCCs [6,21], with an overall accuracy of 95.3% and a sensitivity and specificity of 98.2% and 86.3%, respectively [20]. DECT can also help to assess tumor response, such as changes in tumor vascularity and necrosis [22]. Another clear benefit of DECT is the potential to reduce the radiation dose by applying virtual noncontrast (VNC) images, negating the need for precontrast CT series [23]. This is described in more detail later (Section 3.1).

MRI in localized invasive RCC: Morphologic and functional information

MRI offers a wealth of morphologic and functional information for characterizing and staging of RCCs, which makes it a tool for preoperative staging of RCCs when used with chest CT [24,25]. Inherent T1 and T2 signal intensity of the mass can be used to differentiate subtypes of RCC. For example, macroscopic fat within angiomyolipomas can easily be differentiated by detecting India ink artifacts surrounding the macroscopic fat-containing areas of the mass on in- and out-of-phase images [26]. Similarly, T2-weighted and postcontrast images can delineate the complexity of cystic or necrotic RCCs. Multiple studies have demonstrated close sensitivity and specificity of CT and MRI in detection of the contrast enhancement and complexity of renal masses. In a study of 69 renal masses, Israel et al. [27] were able to demonstrate similar results for categorization of masses into different Bosniak categories in 81% of CT and MRI examinations. In the reminder of the cases, magnetic resonance (MR) images may depict additional septa, thickening of the wall or septa, or both, or enhancement, which may lead to an upgraded Bosniak cyst classification and can affect case management. Given the higher accuracy of MRI in depicting the fine details of complex cystic lesions, use of MRI is preferable to CT in