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SPECIAL SECTION : UROTHELIAL DISEASE

Benign diseases of the urinary tract at CT and CT urography

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Introduction

There are many benign conditions that can affect the urinary tract. With respect to CT urography, these can be divided into two broad groups: (1) abnormalities that often have a distinctive appearance and (2) abnormalities that may be mistaken for urothelial cancers. This article will illustrate the CT or CT urographic appearance of some of the many benign urinary tract lesions. When applicable, the article will provide explanations as to how to minimize the likelihood that benign but clinically relevant entities will go undetected during the search for common causes of hematuria (stones, renal cancers, and urothelial neoplasms) and will provide information as to how some patients with cancer mimics can have suggestive clinical presentations or CT imaging that allows for benign diagnoses to be considered. It is important to identify benign abnormalities, as this may explain why a patient with no other urinary tract pathology has hematuria. In other instances, the suggestion that a detected urinary tract abnormality could be benign might help prevent unnecessary aggressive treatment.

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Distinctive-appearing benign urinary tract pathology

Upper and lower tract

Pyeloureteritis and cystitis cystica

Pyeloureteritis cystica and cystitis cystica are benign urinary tract abnormalities, with cystitis cystica being more common. The process, which is felt to be secondary to chronic urothelial inflammation, consists of glandular metaplasia of submucosal cysts (von Brunn nests), which enlarge within the wall of the urothelium and then project into the lumen of the urothelium. Most affected patients have a history of urinary tract infections and urolithiasis. The condition does not predispose patients to urothelial malignancy [1].

On CT urography, large numbers of tiny (2–3 mm) mural filling defects are seen in the affected parts of the urinary tract [2]. These tiny filling defects are best identified on excretory phase images, viewed using wide windows, and are most easily visualized on coronal reformatted images (Fig. 1). Although multiple urothelial cancers can be considered in the differential diagnosis, the imaging appearance of this entity is often diagnostic. No other pathology produces as many comparably sized tiny urinary tract filling defects [3].

Non-enhancing intraluminal filling defects

A number of benign soft tissue attenuation intraluminal abnormalities can mimic mural lesions [4, 5]. These entities can usually be distinguished on CT urography from urothelial neoplasms due to their lack of enhancement between non-contrast and contrast-enhanced images. The most common of these benign soft tissue filling defects are blood clots and mucus. Fungus balls can produce this imaging finding, but are much rarer.

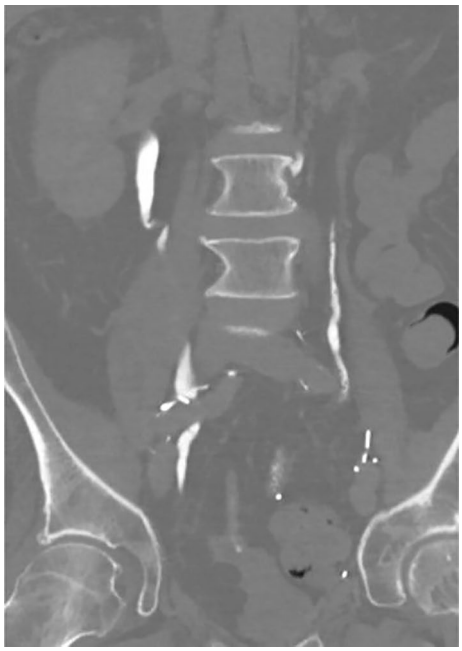

Fig. 1 Ureteritis cystica. A coronal reformatted excretory phase contrast-enhanced CT image shows multiple tiny filling defects within the mid left ureter. The multiplicity of these findings and the similar size of the filling defects to one another suggest the diagnosis. The cysts are much more easily seen on wide window coronal reformatted and three-dimensional reconstructed images than on axial images

Patients with blood clots almost always will have a history of gross hematuria. On non-contrast CT, blood clots often have attenuation values of 60–80 Hounsfield units, well above that of other soft tissue attenuation structures. Blood clots tend to conform to the shape of the renal collecting system or ureter. When they form in the bladder, they may sometimes have irregular serpiginous shapes (Fig. 2). When blood clots are detected, it is important to search for an underlying etiology because spontaneous bleeding into the urinary tract is very unusual. Blood clots can result from bleeding renal and urothelial neoplasms or can be seen as the result of trauma or a bleeding diathesis.

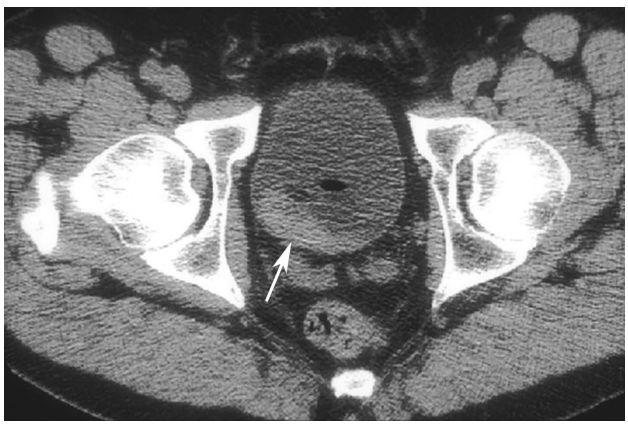

Fig. 2 Blood clot. An axial non-contrast CT image through the pelvis shows a lobulated, high density mass which is in the dependent portion of the bladder

In patients who have had urinary reconstructive or urinary diversion procedures involving bowel, particularly procedures in which no antireflux procedure is performed at ureteral anastomoses, mucus from the bowel may reflux into the upper urinary tract. Mucus is a common non-enhancing intraluminal filling defect in patients who have had cystectomy with ileal loop urinary diversion, cystectomy with neobladder creation, or bladder augmentation. The margins may be smooth or irregular (Fig. 3). The location of the mucus may change from a CT scan performed on one day to a CT performed at a later date.

Fungus balls are occasionally seen in patients with chronic indwelling nephrostomy catheters usually due to colonization with Candida albicans.

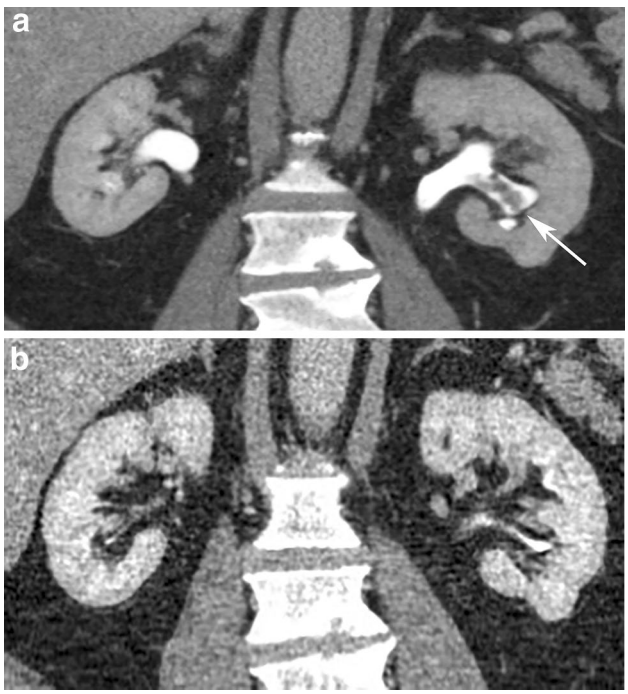

Fig. 3 Mucus. **a** A coronal reformatted excretory phase contrast-enhanced CT image through the kidneys in a patient who had undergone cystectomy and an ileal loop urinary diversion shows an irregular filling defect in a left lower pole calyx and infundibulum (arrow). This filling defect was non-enhancing. The non-enhancing nature of this filling defect led the urologist to decide to follow the lesion with imaging. **b** On this coronal reformatted excretory phase contrast-enhanced image from a repeat CT obtained 5 months later, the filling defect was no longer present

Urinary tract tuberculosis (TB)

The genitourinary tract is the most common site of TB involvement outside of the lungs [6]. 4–8% of patients with pulmonary TB also demonstrate findings of renal TB [6]. Conversely, fewer than 50% of patients who present with genitourinary TB will demonstrate pulmonary imaging abnormalities [7]. Thus, the absence of pulmonary disease should not dissuade the radiologist from suggesting urinary tract tuberculosis when suggestive imaging findings are present.

Urinary tract tuberculosis is most often due to hematogenous dissemination after initial pulmonary inoculation, with the bacilli ensnared in periglomerular capillaries, leading to the development of small abscesses [6]. A granulomatous response then occurs in immunocompetent patients, limiting the disease to the renal cortex. However, if the host becomes immunocompromised, the previously dormant granulomas can become active and grow (reactivation tuberculosis), causing capillary rupture and progression of infection into the intrarenal collecting system. Involvement of the ureters and bladder can then be seen in a descending fashion, as well as spread across fascial planes [6] to extraurinary tissues. The disease is often indolent for 5 to 20 years following initial inoculation [7]. Genitourinary symptoms, when present, include dysuria and urinary urgency as well as abdominal, flank, and back pain. Constitutional symptoms such as fatigue and fever are less common [8].

Because urinary TB is a progressive disease, the CT findings depend on when during the process the imaging occurs. The earliest intrarenal collecting system finding of urinary TB is "feathery-appearing" or "moth-eaten" calyces [6, 9]. As the disease progresses, the granulomas merge and form mass-like lesions called tuberculomas [9]. These are typically cavitary, with the central low attenuation areas representing necrosis. As the tuberculomas rupture into their respective calyces and infect the renal pelvis and downstream collecting system, an immune response by the host causes a fibrotic reaction, leading to stricturing and stenosis of the calcyes and infundibula [6]. This, in turn, causes irregular caliectasis; if the stricture prevents calyceal opacification, the absence of an expected calyx in that location is known as a phantom calyx [6]. If the TB is not treated, renal obstruction and granulomatous tissue destruction can eventually lead to loss of renal function (i.e., autonephrectomy). The term putty kidney is used to describe the final result of end-stage renal TB, characterized by dystrophic calcifications in granulomatous material, which can sometimes be very dense [6]; this may affect part or all of a kidney (Fig. 4).

Initial ureteral findings include dilatation and mucosal irregularity, known as "sawtooth" ureter, which can progress to ureteral stricturing and shortening, known as "pipe-stem" ureter [8]. Long segments of ureteral narrowing can occur from the confluence of multiple strictures. Alternatively, multiple non-confluent ureteral strictures can result in a corkscrew appearance. When long segment or multiple strictures are noted in a ureter, TB should be included in the differential diagnosis. Periureteral fibrosis, as well as ureteral wall thickening and calcification, can also be seen [8].

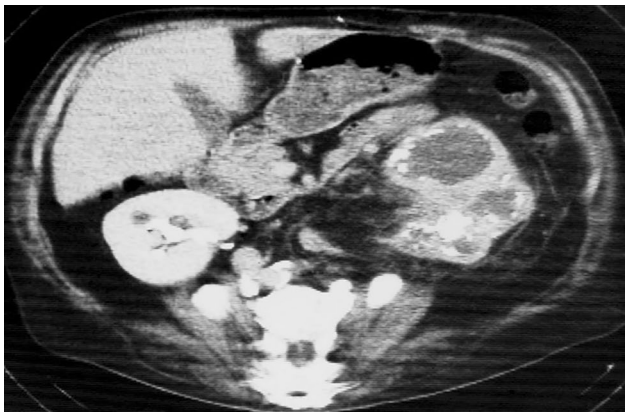

Fig. 4 Renal tuberculosis. An axial excretory phase contrast-enhanced image shows a markedly abnormal non-functioning left kidney, with central low attenuation cavitary areas and dystrophic calcifications. There are calcified chronic ("cold") abscesses in both psoas muscles. Deformity of the spine is the result of tuberculous spondylitis

Tuberculous cystitis most commonly results in decreased bladder capacity. As the disease progresses, the bladder can become irregular and small, known as a "thimble" bladder, with pronounced bladder wall thickening and calcification [6, 8].

Urinary tract TB can spread to the perirenal and pararenal tissues to involve the spine, psoas muscle, and other tissues (Fig. 4). Fistulas to nearby organs or the skin may occur.

Schistosomiasis

Schistosomiasis, previously known as bilharziasis after Thomas Bilharz, who described the disease in 1851, describes infections caused by the parasitic *Schistosoma* genus [10]. Humans become infected when they come in contact with parasite-containing water, with cases primarily due to unhygienic methods of human and animal waste disposal [10]. The disease is endemic to Asia, the Middle East, Africa, South America, and the Caribbean, but has been seen globally [10].

There are two general categories of schistosomiasis: gastrointestinal and genitourinary. The genitourinary form is caused by *Schistosoma haematobium*, a blood fluke with a complex life cycle. Human disease arises when larvae in contaminated water attach to and penetrate the skin. Eventually the mature organism reaches the vesical venous plexus to lay eggs. The eggs travel through the

bladder wall, often inducing a granulomatous response, and are shed in urine [10].

Genitourinary symptoms, often due to host response to the eggs, include hematuria, dysuria, suprapubic pain, cystitis, and hemospermia. In women, polypoid mass-like lesions of the genital skin can be seen, and tubal infertility can occur as a late manifestation [10].

Imaging findings are most common in the bladder, with the ureter next most commonly involved. Renal manifestations are uncommon [11]. Early in the disease, the bladder wall can be thickened due to submucosal edema. This progresses to bladder wall thickening with ulceration, with formation of small flat mural papules which are commonly biopsied to distinguish from bladder cancer [10]. Bladder wall calcification is commonly seen. The degree of calcification is related to the concentration of dead calcified eggs located within the mucosa [10, 12]. Calcification usually begins at the bladder base and progresses laterally in a linear fashion to involve the entirety of the organ. Multiple bladder calcification patterns have been reported including coarsened and thick (often when the bladder is empty), fine linear, fine granular, and thick irregular. A pathognomonic CT finding of chronic genitourinary schistosomiasis is an apparent "fetal head in the pelvis" corresponding to the calcified bladder [10]. Schistosomiasis is one of the few diseases that can result in calcification in a normal-capacity bladder (Fig. 5); however, as the disease progresses, the bladder wall usually fibroses and contracts, leading to a small, irregular bladder shape [10].

When the ureters are involved (usually as a result of retrograde spread of disease from the bladder), ureteral dilatation is often associated with fibrosis and stricturing [10]. Early ureteral strictures are most commonly seen within the intravesical portion, 2–5 cm proximal to the ureterovesical orifice [10]. As the disease progresses, the entirety of the ureter may demonstrate multifocal strictures [11]. Pelviectasis and ureteric obstruction are late complications which can result in formation of calculi and infection due to urine stasis [12]. Scattered areas of fine ureteral calcification can be seen early, coalescing to involve the entire ureter and producing a circular pattern of calcification on axial CT [10]. Calcification tends to occur earlier and more commonly in the distal ureter [11].

In areas endemic for schistosomiasis, the infection constitutes a major risk factor for development of squamous cell carcinoma of the bladder. The diagnosis of squamous cell carcinoma in patients with schistosomiasis can be difficult due to the concomitant infection-related bladder wall thickening and calcification.

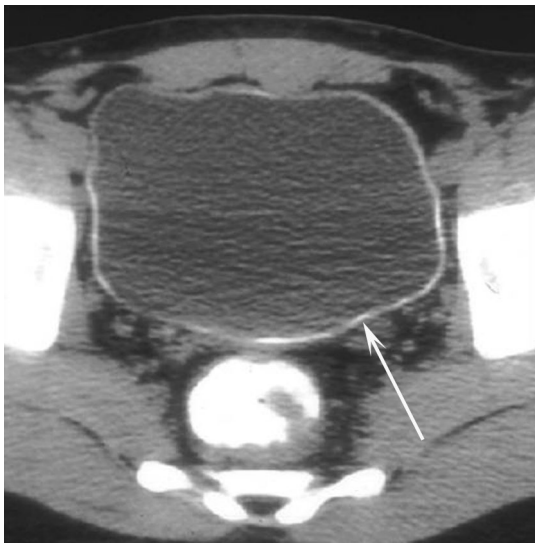

Fig. 5 Schistosomiasis. An axial non-contrast CT imaged through the pelvis shows smooth, continuous, linear high attenuation consistent with calcification (arrow) of the entire urinary bladder wall. Note that the bladder has retained its normal capacity. Bladder wall calcification can be a manifestation of several entities including radiation cystitis, schistosomiasis, or tuberculosis, although schistosomiasis is most strongly associated with calcification occurring in a normal-capacity bladder

Upper tract only

Papillary necrosis

Papillary necrosis is a condition in which the tips of the renal pyramids or the renal papillae become ischemic and then necrotic. Predisposing factors include conditions in which the blood supply to the naturally hypoxic renal medulla may be compromised, such as diabetes mellitus and sickle cell anemia [13]. Papillary necrosis has also been observed in patients taking long-term high-dose anti-inflammatory medication (analgesic nephropathy) and in patients with urinary tract infections (including tuberculosis) and urinary tract obstruction [14]. Papillary necrosis may affect one or many renal papillae in one or both kidneys. Affected patients commonly present with painless microscopic or gross hematuria.

It is important to identify papillary necrosis, as this abnormality can be a cause of otherwise unexplained hematuria. The appearance of papillary necrosis on CT urography is variable, but most commonly consists of tiny collections of extra-caliceal contrast material in necrotic papillae (termed the "ball on tee" sign) [15]. Other manifestations include outlining of necrotic papillae by contrast material and blunted calyces (in patients in whom the necrotic papillae have already sloughed into the renal collecting systems or ureters, with these patients also potentially demonstrating intraluminal filing defects corresponding to sloughed

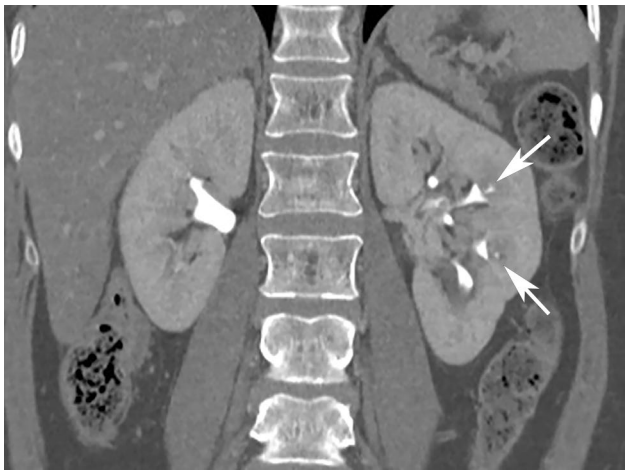

Fig. 6 Papillary necrosis. A coronal reformatted excretory phase contrast-enhanced CT image through the kidneys shows two small high attenuation foci in the renal pyramids (arrows). The appearance is diagnostic of papillary necrosis. This finding is often overlooked on CT urography

papillae) [14]. The diagnosis is best made on excretory phase coronal reformatted CT images viewed at wide windows (Fig. 6) [16]. On early enhanced images, the necrotic papillae are sometimes identified as small triangular-shaped hypoenhancing regions in the renal medulla [13].

Renal tubular ectasia/medullary sponge kidney

Renal tubular ectasia is an abnormality in which there is cystic dilation of the collecting tubules in the renal pyramids [17]. The diagnosis is usually made in adults. It can be unilateral or bilateral and can affect one or many renal pyramids, although, most commonly, all renal pyramids are involved [18]. Many use the terms renal tubular ectasia and medullary sponge kidney interchangeably, although some reserve the latter term for patients who also develop stones in the renal tubules or renal collecting systems.

Patients with renal tubular ectasia are often asymptomatic; however, some present with microscopic or gross hematuria, or flank pain. Detection of this abnormality is important, because it identifies patients at risk for the commonly encountered complication of urinary tract stones and who, therefore, will need follow up and who may be prescribed therapy to reduce the likelihood of stone formation.

On CT urography, renal tubular ectasia is only detected on excretory phase images, where the dilated collecting tubules appear as linear collections of contrast material radiating perpendicularly to the calyces. Multiple dilated tubules are usually visualized in each affected renal pyramid, giving the renal pyramids a "paint-brush" appearance, a term that refers to the appearance of alternating lines of high and low attenuation that is likened to brush strokes [19]. Excretory phase CT images should be viewed using wide windows, since, otherwise, the paint-brush nature of this abnormality may be overlooked (Fig. 7). Coronal or volume-rendered three-dimensionally reconstructed images usually demonstrate the finding most conspicuously [18]. When the characteristic appearance is seen, the diagnosis can be made with certainty. Non-contrast series are also helpful, as they facilitate the detection of urinary tract stones.

Renal tubular ectasia must be differentiated from a renal papillary blush, which is a normal finding resulting from concentration of contrast material in the renal medulla [16]. A papillary blush produces a hazy area of increased attenuation in the renal papillae and usually affects all of the papillae equally (Fig. 8). Papillary blush does not demonstrate the discrete linearity in the renal pyramids that is visualized in renal tubular ectasia.

Ureteral pseudodiverticulosis

Ureteral pseudodiverticulosis is an unusual inflammatory response to chronic urinary tract irritation or infection in which urothelium proliferates deep into the lamina propria of the ureter. This results in the formation of small ureteral outpouchings [20, 21].

Most patients with ureteral pseudodiverticulosis demonstrate tiny outpouching which are often multiple and in both ureters [21]. The upper and mid ureters are most commonly involved. A strong association with urothelial malignancy has been reported [21, 22], with about a quarter of affected patients also having bladder tumors at the time of diagnosis.

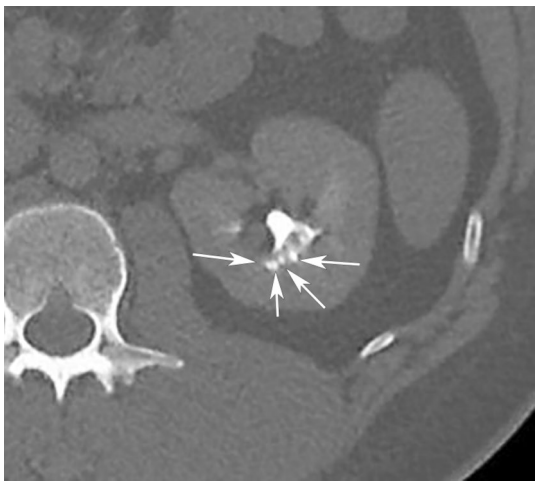

Fig. 7 Renal tubular ectasia. An axial excretory phase contrast-enhanced CT image through the abdomen, viewed using wide windows, demonstrates multiple linear high attenuation areas in each of the imaged renal pyramids (i.e., arrows). These represent excreted contrast material in dilated collecting tubules, with the appearance characteristic of renal tubular ectasia. This finding is often overlooked on CT urography

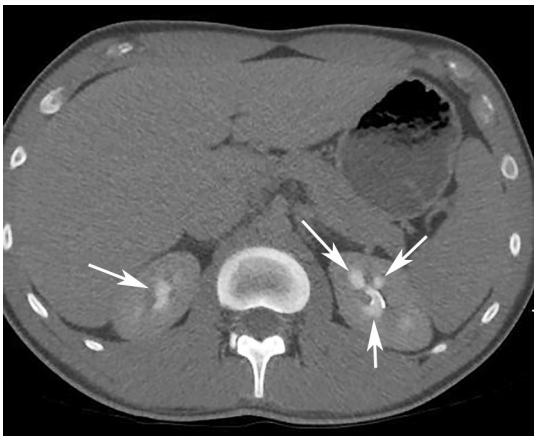

Fig. 8 Papillary blush. An axial excretory phase contrast-enhanced CT image through the abdomen demonstrates increased attenuation in all of the imaged renal pyramids (arrows). This represents concentrated contrast material in the renal pyramids, a normal finding. The appearance can be differentiated from that of papillary necrosis or renal tubular ectasia, because all of the renal pyramids are involved and there are no focal linear or rounded collections of high attenuation

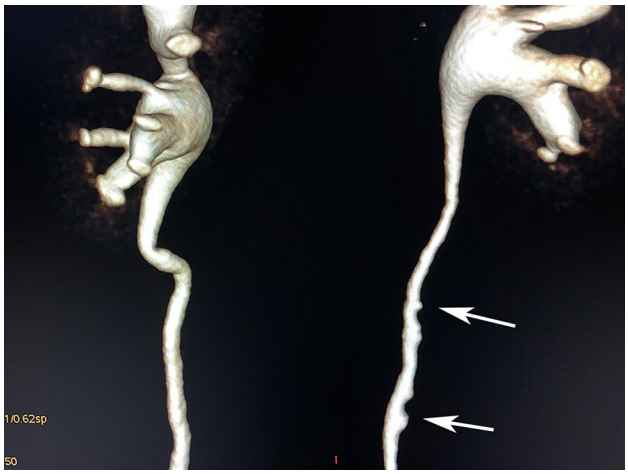

Fig. 9 Ureteral pseudodiverticulosis. A volume-rendered excretory phase contrast-enhanced posterior CT image demonstrates multiple tiny outpouchings projecting from the mid left ureter (arrows) in this patient who had previously had a cystectomy with creation of a neobladder for treatment of bladder cancer. The pseudodiverticula are easier to identify on three-dimensional reconstructed CT than on axial images

Due to this association, regular follow up of patients with ureteral pseudodiverticulosis has been recommended, including annual cystoscopy, and annual or biannual CT urography to evaluate the upper tracts. Recently, a study [23] has found that patients without urothelial cancer at the time of diagnosis of ureteral pseudodiverticulosis have no greater rate of later development of urothelial cancer than do patients without pseudodiverticulosis, challenging the idea that continued follow up of patients with this abnormality is necessary.

On excretory phase CT urography, ureteral pseudodiverticula produce distinctive small rounded collections of contrast material that project into or seemingly beyond the ureteral wall. Because they are so small, ureteral pseudodiverticula can be difficult to detect on axial images. The tiny outpouchings are much more likely to be detected on coronal reformatted or three-dimensionally reconstructed images, especially when viewed at wide windows (Fig. 9).

Fibroepithelial ureteral polyp

A fibroepithelial polyp is a rare benign urinary tract neoplasm that usually arises in the ureter, although it has also been reported in the renal pelvis, bladder, and urethra [24]. It is the most commonly encountered benign ureteral tumor, and consists of a fibrovascular stalk surrounded by normal urothelium [25]. In a meta-analysis [26] of 134 patients with fibroepithelial polyps, most patients had one polyp originating in the proximal to mid ureter, and the median polyp length was 4 cm. While some patients with fibroepithelial polyps are asymptomatic, many patients present with flank pain or hematuria [26, 27], the former usually the result of ureteral obstruction. An association with urolithiasis has been observed in approximately 20% of patients [26].

On CT urography, fibroepithelial polyps might be confused with much more common urothelial malignancies or with other filling defects. However, most fibroepithelial polyps have a characteristic smooth, long, slender, elongated appearance, and they conform to the shape of the surrounding ureter. The polyp, except for the attachment site, is completely surrounded by contrast-enhanced urine at excretory

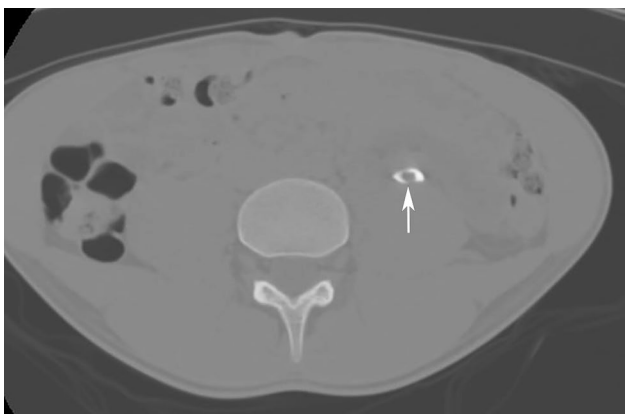

Fig. 10 Fibroepithelial polyp. An axial excretory phase contrast-enhanced CT image shows a smooth filling defect in the left ureter (arrow). This was seen on multiple consecutive axial images, indicative of an elongated tubular configuration

phase imaging [25], an appearance that usually allows for the correct diagnosis to be made (Fig. 10).

Lower tract only

Radiation cystitis

The bladder is the most radiosensitive organ within the urinary tract [28]. Radiation injury to the bladder can occur from intracavitary, interstitial, or external beam radiation therapy, and may be acute or delayed [28, 29].

Acutely, urothelial denudation with subsequent production of fibrinous exudates causes hemorrhagic cystitis [28]. Symptoms in the acute phase include dysuria, urinary frequency, hesitancy, and hematuria, with more severe complications such as incontinence, bladder necrosis, and formation of fistulas occurring less frequently. As the acute phase progresses, edema within the bladder wall accounts for its abnormal, usually diffusely thickened, appearance. Intraluminal clot can be seen on CT during this time due to mural hypervascularity and resultant bleeding [28].

Chronic sequelae of radiation to the bladder, occurring greater than 1 year after treatment, are due to ischemia from mural endarteritis resulting in fibrosis [28]. Symptoms of this phase include dysuria, hematuria, frequency, urgency, and incontinence, mainly due to the contracted, low-volume status of the bladder. The bladder is small and has a thickened wall on imaging (Fig. 11). There may be resultant upstream collecting system dilatation [28]. Mural calcification can be present, albeit rarely [28]. Intraluminal gas in the absence of recent instrumentation is suggestive of fistula formation, with pneumaturia and fecaluria being highly suggestive symptoms [28].

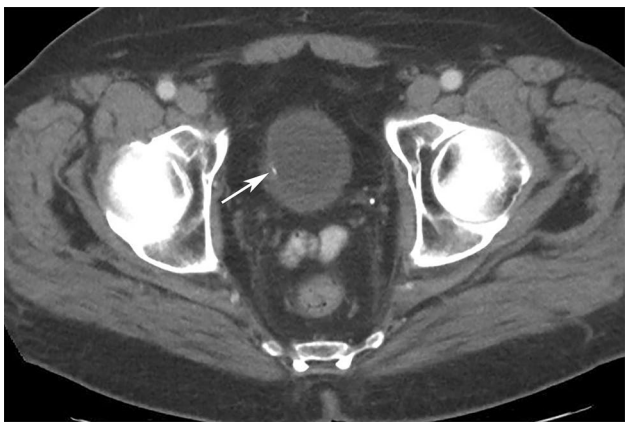

Fig. 11 An axial portal venous phase contrast-enhanced CT image throught the pelvis in a patient who has undergone radiation therapy for prostate cancer demonstrates the bladder to be small and thick-walled. There is a focus of linear mural calcification along the right lateral wall of the bladder

On CT, the most commonly encountered finding in patients with acute and chronic radiation cystitis is diffuse circumferential bladder wall thickening. The bladder size may be normal during the acute phase, but is often small when chronic changes are present. These findings are suggestive of a benign abnormality, but cannot be distinguished from other entities, including other types of cystitis, neurogenic bladders, and outlet obstruction. In most patients, a history of radiation exposure will allow for the correct diagnosis to be made.

Benign urinary tract pathology that mimics malignant disease

Upper and lower tract

Circumferential symmetric wall thickening

Diffuse circumferential thickening of the renal pelvis and ureter is a non-specific finding and may result from either urothelial cancer, urothelial inflammation, or engulfment of the ureter by an extrinsic process. In one series [5], half of all cases of circumferential ureteral wall thickening were due to malignancy and half were due to benign abnormalities. Benign causes of urothelial thickening include infectious pyelitis and ureteritis, inflammation related to stone disease or indwelling urinary tract catheters or stents, retroperitoneal fibrosis, and IgG4-related disease. On CT urography, variable degrees of symmetric thickening can be seen that uniformly involve the renal pelvis or ureter (Fig. 12). When

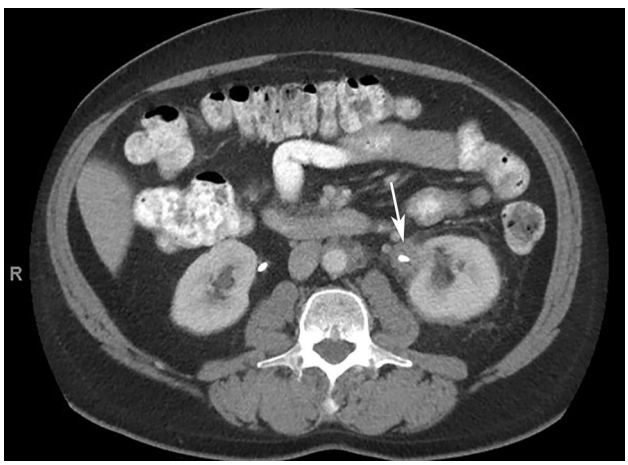

Fig. 12 Circumferential ureteral wall thickening due to retroperitoneal fibrosis. An axial portal venous phase contrast-enhanced CT through the abdomen in a patient with bilateral ureteral stents shows marked proximal left ureteral wall thickening (arrow). There is also a small rind of circumferential para-aortic soft tissue, characteristic of the diagnosis. The patient was subsequently treated with and responded to high-dose corticosteroids

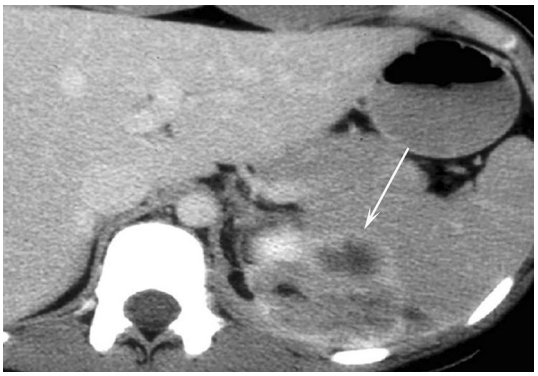

Fig. 13 Malacoplakia. An axial venous phase contrast-enhanced image through the abdomen demonstrates a heterogeneously enhancing, infiltrative soft tissue mass (arrow) arising from the collecting system of the upper left renal pole. As the imaging appearance was concerning for infiltrative renal or urothelial carcinoma, this mass was resected and shown to be malacoplakia upon pathologic review

longer segments of the renal collecting system and/or ureter are involved a benign etiology is more likely. Urothelial cancers often, but not always, affect shorter segments.

Uniform circumferential bladder wall thickening is almost always due to benign disease, with the differential diagnosis including any type of cystitis, neurogenic bladder, and chronic mechanical bladder outlet obstruction. Rarely, infiltrative diffuse bladder cancer can have a similar appearance.

Focal masses and asymmetric wall thickening

In general, focal urinary tract masses and asymmetric wall thickening are produced by urothelial malignancies; however, a large number of benign entities (e.g., benign neoplasms, cystitis) can produce these abnormalities.

Malacoplakia Malacoplakia is an unusual granulomatous condition of the urinary tract, usually producing multiple plaque-like mural nodules. Although this condition most commonly affects the bladder, it can be seen in the upper urinary tract and in other organs [30]. Women are more commonly affected than men (4:1 ratio). The disease often affects patients who are immunocompromised or diabetic [31].

Patients with malacoplakia often present with hematuria or symptoms of urinary tract infection, such as urinary retention or dysuria [28, 31]. The imaging appearance of the plaques varies and overlaps with that of urothelial carcinoma, ranging from multiple discrete, polypoid masses projecting into the collecting system lumen, to circumferential bladder wall thickening [31]. Associated upper tract dilatation can be seen [28]. When the kidney is involved, CT may demonstrate solid, infiltrative, and multifocal lesions that only mildly enhance [31], with the appearance similar to that of either invasive renal or urothelial cancers (Fig. 13). Biopsy generally is required for diagnosis.

Nephrogenic adenoma/metaplasia Nephrogenic adenoma (also called nephrogenic metaplasia) is a rare benign slow-growing lesion that can occur throughout the urinary tract, but that is most commonly encountered in the bladder [32]. Most patients in whom nephrogenic adenoma is diagnosed have a history of urothelial carcinoma with multiple transurethral resections or instillation of intravesical therapy. Other patients have histories of urologic surgery, infection, or stone disease. Patients with nephrogenic adenoma can present with irritative symptoms, microscopic hematuria, or gross hematuria [33].

Nephrogenic adenoma has imaging, cystoscopic, and pathologic appearances that mimic those of malignant disease, especially low-grade urothelial neoplasms or adenocarcinomas. On CT urography, nephrogenic adenoma can result in asymmetric bladder wall thickening or small sessile or polypoid masses [34]. The appearance is indistinguishable from that of a urothelial cancer, but can be considered in the differential diagnosis of patients who develop asymmetric bladder wall thickening and who have undergone topical treatment of bladder cancer (Fig. 14).

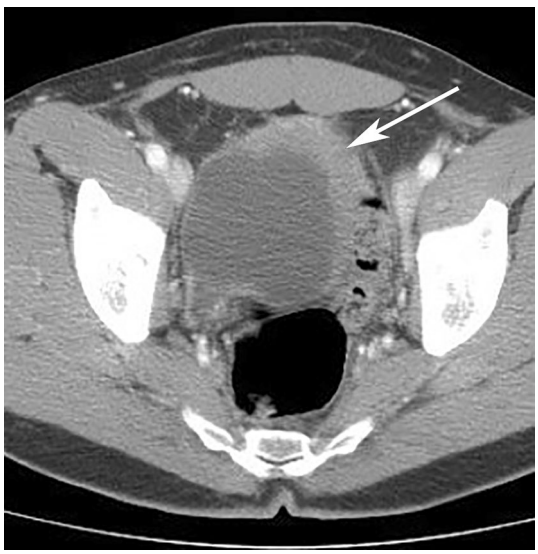

Fig. 14 Nephrogenic metaplasia. An axial portal venous phase contrast-enhanced CT image through the pelvis in a patient who had undergone transurethral resection of a bladder tumor and topical treatment with BCG 6 months earlier demonstrates marked asymmetric thickening of the bladder wall on the left side laterally and anteriorly (arrow). At subsequent cystoscopy, the urologist suspected that this was recurrent urothelial malignancy; however, pathology results revealed that this represented nephrogenic metaplasia

Upper tract only

Keratinizing desquamative squamous metaplasia

Keratinizing desquamative squamous metaplasia (KDSM) is a rare condition of unknown etiology that affects the upper urinary tract. It is known by several names, including: hyperkeratosis, cholesteatoma, and leukoplakia [35]. KDSM is a histologic term which refers to a metaplastic layer of keratinized squamous epithelium without basal layer atypia [35].

Patients with KDSM generally present with non-specific symptoms, the most common of which is flank pain. Hematuria, dysuria, and pyuria have also been reported. A cloudy appearance of the urine, secondary to the presence of pliable gray flakes or stones, is considered to be pathognomic [35, 36].

In the past, KDSM has been believed to be a premalignant condition with a high risk of local recurrence after resection [36]. However, it is now believed KDSM is unlikely to be premalignant. As a consequence, newer management strategies have been recommended, including surgical excision of debris and surveillance [36].

On CT, KDSM usually appears as a filling defect within the upper urinary tract, and may be confused with malignancy [35, 37]. On occasion, this entity may produce multiple linear non-enhancing filling defects that produce a striated appearance (Fig. 15). When these findings are present, KDSM should be included in the differential diagnosis.

Papilloma and inverted papilloma

Papillomas and inverted papillomas are rare benign urinary tract neoplasms. In comparison to papillomas, inverted papillomas demonstrate inverted growth of urothelial cells into the submucosa rather than growing into the renal collecting system, ureteral, or bladder lumena. With inverted papillomas, the overlying urothelium is normal in appearance. These benign tumors are most commonly diagnosed in middle-aged and older men, with a nearly 4–6:1 male to female predominance [38, 39]. They nearly always occur in the bladder (often at the trigone and bladder neck), but have been diagnosed elsewhere in the urinary tract, including the kidneys, ureters, and urethra [38]. Patients with papillomas and inverted papillomas usually present with hematuria [38]. Less commonly, the lesions may cause bladder outlet obstruction. Most papillomas and inverted papillomas are <3 cm in size [38].

There are few reports on the imaging appearance of these lesions [40–42], with to our knowledge the largest series assessing MRI findings in 16 patients [41]. The tumors are smooth polypoid lesions that usually have a stalk [41]. While it has been suggested the smooth surface could suggest a benign etiology [41], there is enough overlap in the appearance of these lesions with that of urothelial cancers to question whether this imaging feature is useful (Fig. 16) [40, 42].

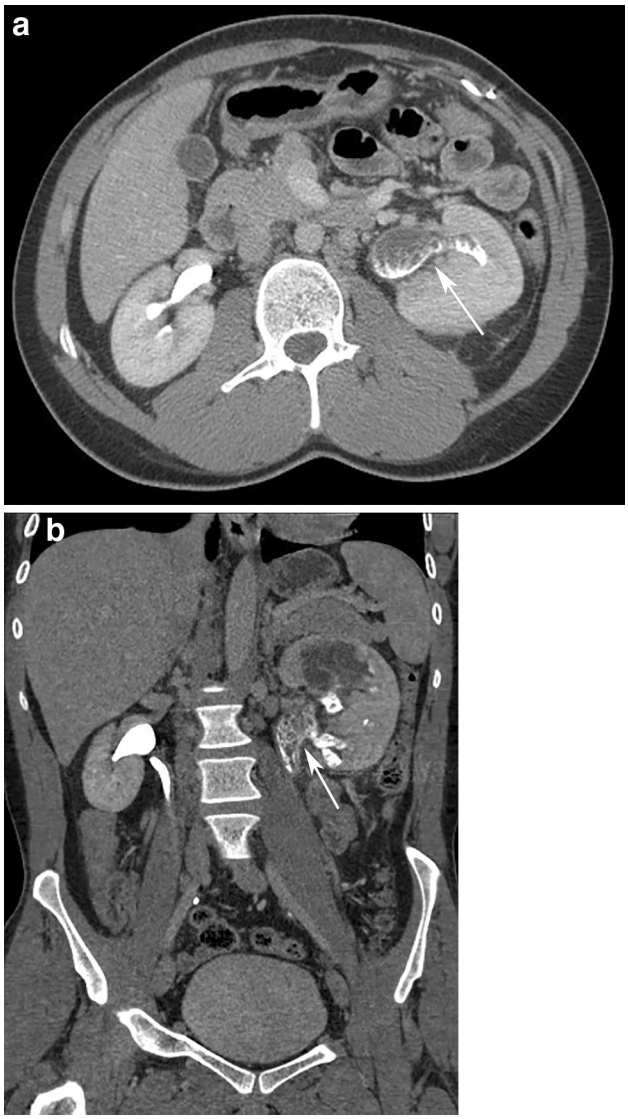

Fig. 15 Keratinizing desquamative squamous metaplasia. **a** An axial excretory phase contrast-enhanced CT image through the abdomen demonstrates multiple linear filling defects distorting the dependently layering excreted contrast material in a mid left renal infundibulum and in the left renal pelvis (arrow). **b** A coronal reformatted image demonstrates a large number of linear and ovoid filling defects occupying the nearly all of the left renal collecting system (arrow). The process extends into the upper pole of the left kidney

Lower tract only

Bladder leiomyoma and lipoma

Leiomyomas are rare bladder tumors, accounting for less than 1 in 200 bladder neoplasms; however, they are the most

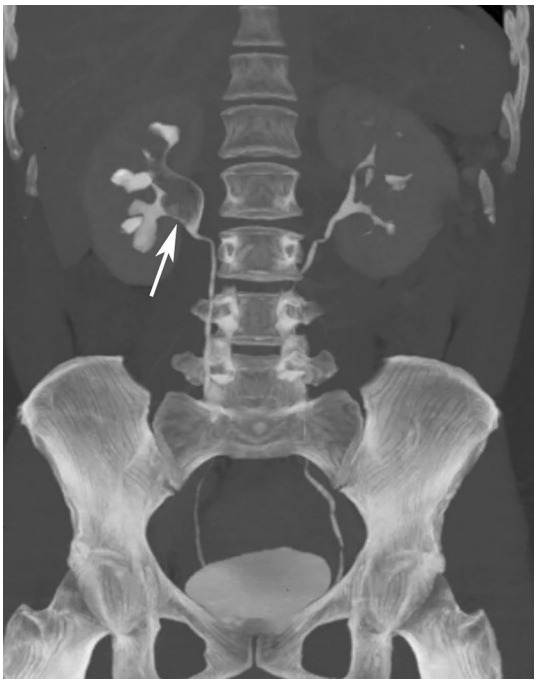

Fig. 16 Renal papilloma. A coronal reformatted excretory phase contrast-enhanced CT image shows a large smooth well-defined filling defect in the right renal pelvis (arrow). This lesion demonstrated enhancement when attenuation measurements were obtained from the non-contrast and contrast-enhanced series. This lesion cannot be distinguished from a urothelial cancer

common benign bladder tumor. Leiomyomas can occur elsewhere in the urinary tract, but less commonly than in the bladder. The majority (70%) of affected patients are women. Patients with bladder leiomyomas may present with a variety of symptoms, including obstructive or incomplete voiding, hematuria, and pain. Some patients are asymptomatic [43]. When cystoscopy is performed, the overlying urothelium is almost always intact and smooth, confirming the intramural location of these masses [44].

On CT, leiomyomas can be mistaken for urothelial neoplasms; however, the diagnosis can be considered when a bladder mass is homogeneous, well-circumscribed, ovoid, and has smooth contours (Fig. 17). Leiomyomas measure greater than water attenuation both prior to and following contrast material administration and many enhance avidly [45].

Bladder lipomas are even rarer than bladder leiomyomas, with only a handful of cases having been reported, generally in middle-aged and elderly men. Many patients in whom these lesions are diagnosed present with microscopic or gross hematuria or lower urinary tract symptoms, although it is unclear whether any of these symptoms are actually secondary to the lipoma [46]. These neoplasms can often be definitively diagnosed on CT and MRI due to the presence of macroscopic fat (Fig. 18) [47, 48].

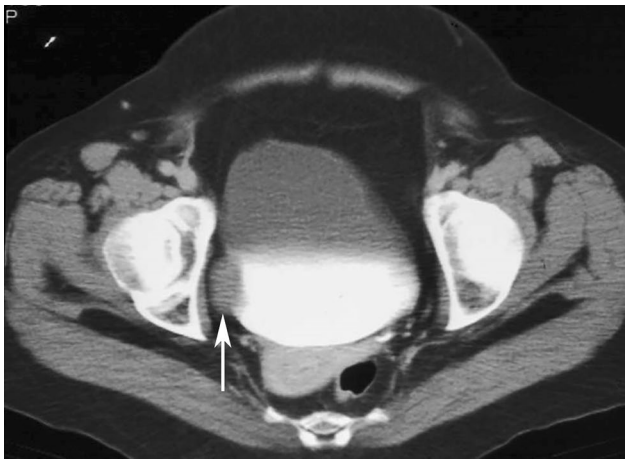

Fig. 17 Leiomyoma. An axial excretory phase contrast-enhanced CT through the pelvis shows an ovoid circumscribed intramural mass along the right lateral aspect of the bladder (arrow). The mass exerts mass effect upon the bladder lumen and perivesical region. The shape, circumscribed contour, and intramural location suggest the diagnosis

Bladder paraganglioma

Paragangliomas are uncommon neuroendocrine neoplasms of chromaffin cell origin. Approximately 85–90% of these tumors are found in the adrenal medulla and termed pheochromocytomas [49]. The remaining 10–15% are extra-adrenal [36], of which only 10% occur in the urinary bladder. Bladder paragangliomas usually arise in the trigone or dome and tend to be solitary. These lesions are less commonly hormonally active but more commonly malignant than their adrenal counterparts [49, 50].

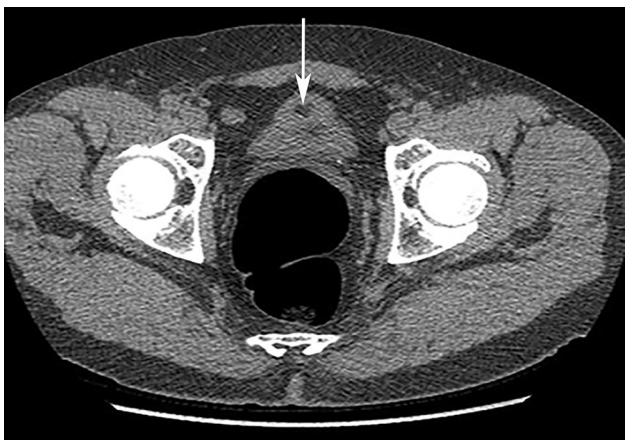

Fig. 18 Lipoma. An axial unenhanced CT image through the pelvis demonstrates a small low attenuation mass in the anterior aspect of a decompressed bladder (arrow). The internal components of the mass measured—50 Hounsfield Units, confirming that the mass is comprised of macroscopic fat

Signs and symptoms of extra-adrenal paragangliomas are related to their functional status, with many non-functional tumors being clinically silent and only detected incidentally. Most functional extra-adrenal paragangliomas produce an excess of norepinephrine that results in the classic triad of sweating, headaches, and palpitations [50]. Bladder paragangliomas often cause this symptom triad, as well as blurred vision and fainting during micturition [50].

On CT, bladder paragangliomas usually appear as hyperenhancing focal bladder masses. Functioning paragangliomas can be quite small when first detected (Fig. 19). An imaging review by Sahdev et al. suggests that bladder wall paragangliomas can be overlooked on excretory phase CT secondary to excreted intraluminal contrast obscuring the intensely enhancing mural lesion [49]. For this reason, contrast-enhanced images obtained prior to contrast material excretion may be needed for identification.

^{123}I-MIBG with accompanying SPECT/CT image acquisition can be very helpful in detecting paragangliomas, although some studies have suggested significantly lower sensitivity in the detection of extra-adrenal paragangliomas compared to pheochromocytomas [51].

Bladder endometriosis

Endometriosis is the implantation of endometrial stroma and glands outside of the uterine cavity. The urinary bladder is the most common site of urinary tract involvement, affecting 1–2% of women with endometriosis [52]. Implants are typically seen at the bladder dome or in the vesicouterine space [53]. Bladder endometriomas can be primary, occurring spontaneously, or secondary, produced iatrogenically following pelvic instrumentation such as hysterectomy or cesarean delivery [54]. Approximately 30% of patients with bladder endometriosis remain asymptomatic with lesions detected incidentally, while the remaining 70% present with symptoms related to detrusor muscle implant involvement, including dysuria, frequency, and suprapubic discomfort [54]. Symptoms can vary with the patient's menstrual cycle. Because most deposits do not invade or ulcerate the bladder mucosa, hematuria is infrequent [53].

CT urography is insensitive for bladder endometriosis. When observed, bladder wall implants often appear as small masses that cannot be reliably differentiated from other bladder masses. Occasionally, larger bladder wall masses will be detected (Fig. 20). Endometriosis can be included in the differential diagnosis of bladder mass that is detected on CT in a premenopausal woman, at least in those circumstances when there is a known history of endometriosis and/or when cyclical symptoms are encountered.

It should be noted that pelvic MRI is generally considered the most sensitive and specific imaging test for patients in whom this disease is suspected.

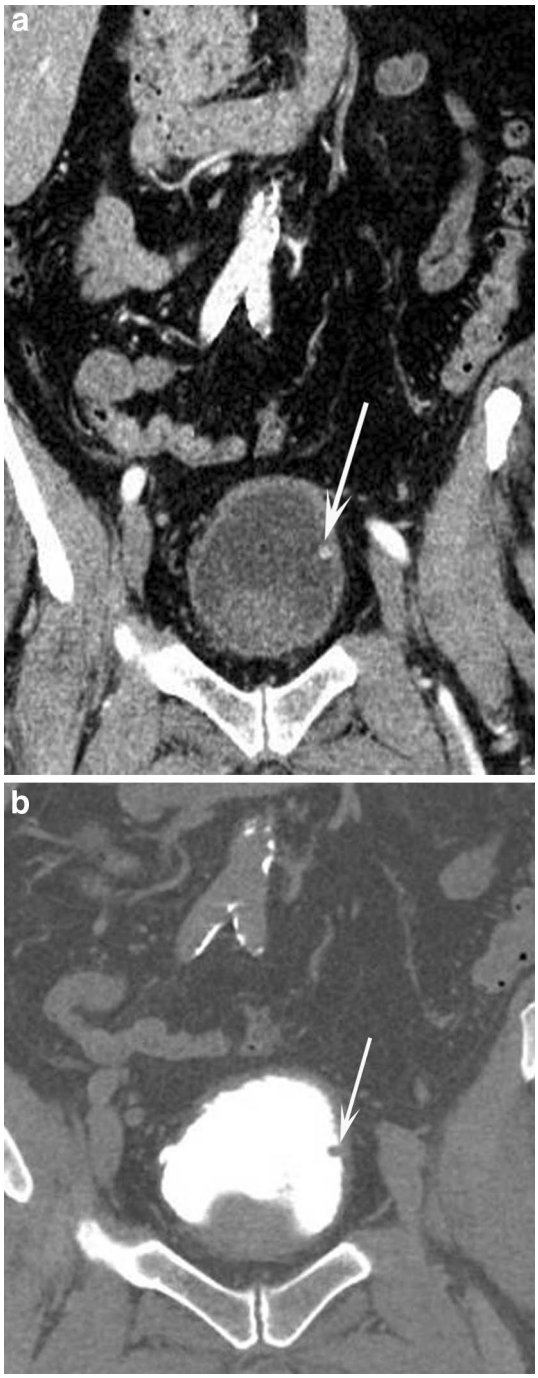

Fig. 19 Bladder paraganglioma. **a** A coronal reformatted portal venous phase contrast-enhanced CT image through the pelvis shows a small hypervascular mass (arrow) arising from the left bladder wall. It can be easily seen against the background of low attenuation urine within the bladder lumen. **b** The mass can again be seen on the corresponding image acquired during excretory phase

Inflammatory myofibroblastic tumor

Inflammatory myofibroblastic tumors are rare spindle cell soft tissue masses that also have been referred to

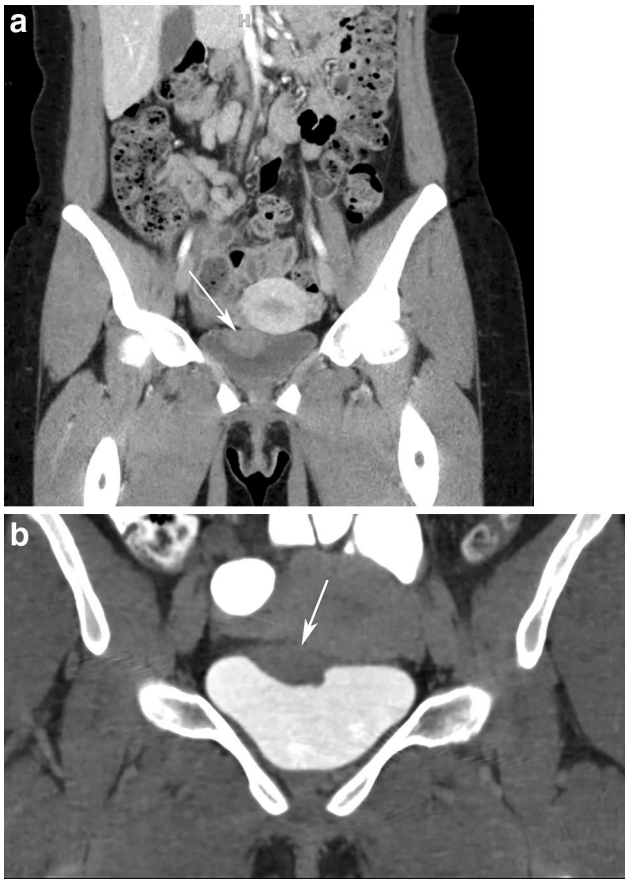

Fig. 20 Bladder endometrioma. **a** A coronal reformatted portal venous phase contrast-enhanced CT image shows a large lobulated mass projecting into the bladder lumen, characteristically located at the bladder dome (arrow). **b** This lesion is also well seen on a coronal reformatted excretory phase image (arrow) (Images courtesy of Cary Siegel, Mallinckrodt Institute of Radiology, St. Louis, MO)

as inflammatory pseudotumors, xanthomatous pseudotumors, and atypical myofibroblastic tumors. Most of these tumors grow very slowly and behave as benign lesions, though it has been suggested by some that they might actually be low-grade sarcomas [54, 55].

These tumors can occur throughout the urinary tract, but the vast majority are in the bladder [54, 55]. They are most commonly diagnosed in teenage children or younger adults [56]. Patients with these neoplasms usually present with non-specific symptoms, of which hematuria is the most common [55]. Cystoscopic biopsy is required for diagnosis.

On imaging studies, inflammatory myofibroblastic tumors appear as mass-like lesions and are likely to be misdiagnosed as urothelial neoplasms (Fig. 21) [57], although their common occurrence in younger patients should suggest the possibility of an alternate diagnosis.

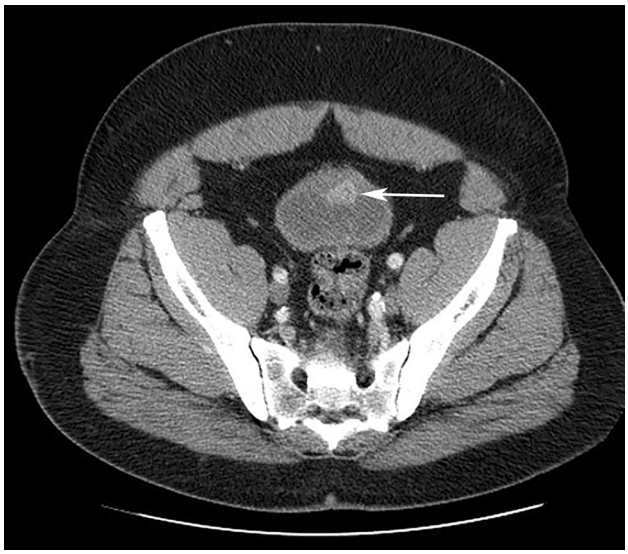

Fig. 21 Inflammatory myofibroblastic tumor. An axial portal venous phase contrast-enhanced CT image through the pelvis shows a soft tissue mass originating in the anterior bladder wall projecting into the bladder lumen (arrow). This was initially suspected to represent a urothelial tumor, but was demonstrated to be an inflammatory myofibroblastic tumor at subsequent cystoscopy

Eosinophilic cystitis

Eosinophilic cystitis is a rare inflammatory process of the bladder that can be encountered in patients of any age, although involvement in children is unusual. There is no known cause in the majority of patients. Most patients present with non-specific urinary symptoms of frequency, dysuria, hematuria, and suprapubic pain. Urine cultures are negative. Some patients may have peripheral eosinophilia. When cystoscopy is performed, areas of bladder wall thickening may be confused with urothelial cancers. Cystoscopic biopsy is required for diagnosis. Treatment with corticosteroids is usually effective [58].

On CT urography, affected patients usually present with diffuse circumferential bladder wall thickening [20], although a minority will have asymmetric areas of bladder wall thickening that mimic urothelial neoplasms (Fig. 22) [59]. On occasion, patients with this disease may have no CTU detectable abnormalities [58].

Intravesical infusion of topical agents for treatment of bladder cancer

A variety of complications can be identified on CT in patients who receive topical intravesical agents (e.g., Bacille Calmette–Guerin [BCG], mitomycin) for the treatment of bladder cancer.

BCG is a live attenuated strain of mycobacterium bovis which has been used effectively for many years for topical

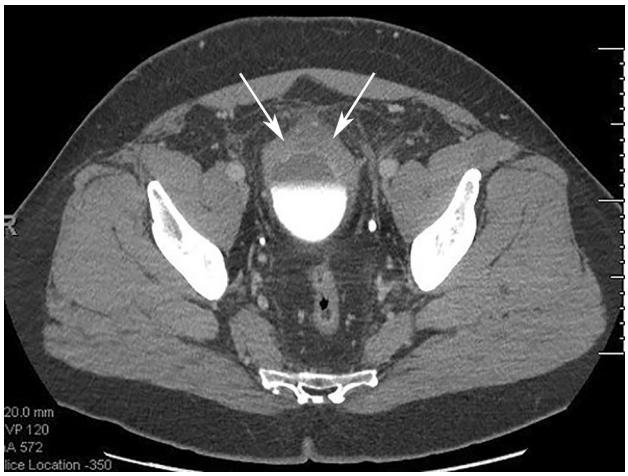

Fig. 22 Eosinophilic cystitis. An axial excretory phase contrast-enhanced CT image through the pelvis shows asymmetrically increased wall thickening along the anterior aspect of the bladder (arrows). The appearance mimics that of a urothelial malignancy. Cystoscopy was performed and demonstrated wall thickening that was suspected to represent a urothelial cancer. Cystoscopic biopsy was non-diagnostic. Percutaneous biopsy revealed eosinophilic cystitis. The patient was treated with high-dose steroids. Follow up CT obtained 3 months later showed complete resolution of the bladder wall thickening

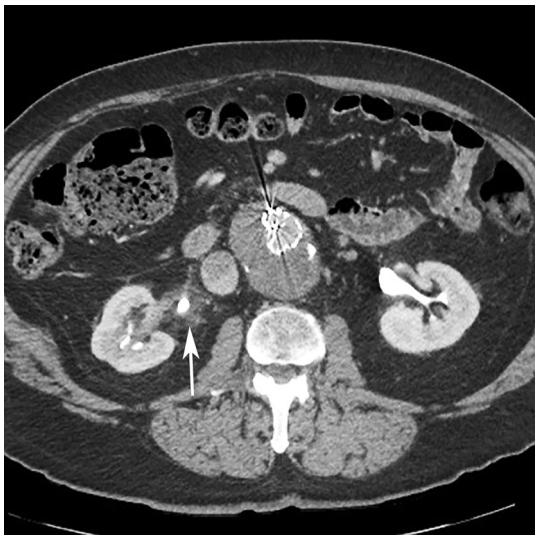

Fig. 23 BCG toxicity. An axial split-bolus portal venous and excretory phase contrast-enhanced CT image through the abdomen in a patient who had an upper tract urothelial neoplasm treated with resection and topical BCG shows marked proximal right ureteral wall thickening (arrow). The patient subsequently underwent ureteroscopy with biopsy, which demonstrated that this was an inflammatory granulomatous process

treatment of superficial bladder cancer following transurethral resection. BCG is likely effective because it induces a local immune response. As a result, local symptoms can be encountered after instillation in many patients [60]. Symptoms of BCG-induced cystitis are typical of common cystitis and include frequency, urgency, and dysuria. Rarely, continguous structures may become involved, with development of prostatitis, ureteritis, pyelonephritis, and abscess [60]. Intraprostatic granulomatous abscess can mimic prostate cancer on non-contrast MRI [61].

Most patients undergoing intravesical BCG therapy have no related imaging abnormalities other than generalized bladder wall thickening. In some cases, focal wall thickening can resemble residual or recurrent bladder cancer [62]. The diagnosis should be suspected, however, in patients with new-onset lower urinary tract symptoms during the course of BCG treatment, especially in patients with fevers. Ureteral involvement, which can result from reflux of urine from the bladder or as a result of topical treatment of a ureteral cancer, may produce circumferential urothelial thickening (Fig. 23). Renal findings are uncommon but may include enhancing mass-like lesions [62].

Mitomycin is an alkylating chemotherapeutic agent that has proved effective when used topically in patients with superficial bladder cancers. Some patients receiving topical mitomycin develop a symptomatic eosinophilic cystitis after treatment [63]. On imaging studies, the cystitis can produce diffuse circumferential bladder wall thickening or areas of asymmetric thickening that can mimic bladder masses (Fig. 24) [63]. A discussion of eosinophilic cystitis has been provided earlier.

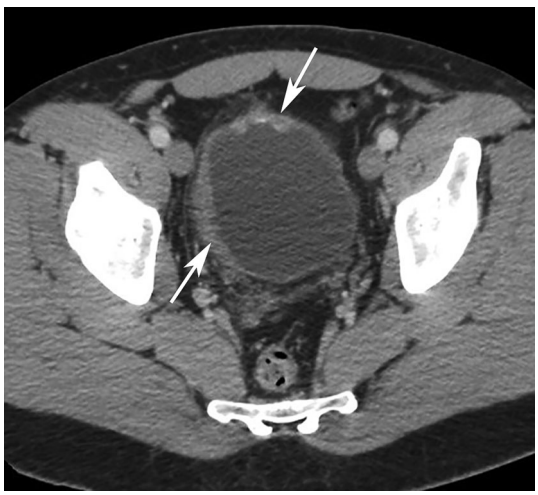

Fig. 24 Cystitis due to mitomycin toxicity. An axial portal venous phase contrast-enhanced CT image through the pelvis in a patient who had had a transurethral resection of a bladder tumor followed by topical mitomycin therapy demonstrates the bladder wall to be irregularly thickened, with lobulated mass-like thickening particularly along the right lateral and anterior walls (arrows). The appearance mimics multifocal urothelial cancer

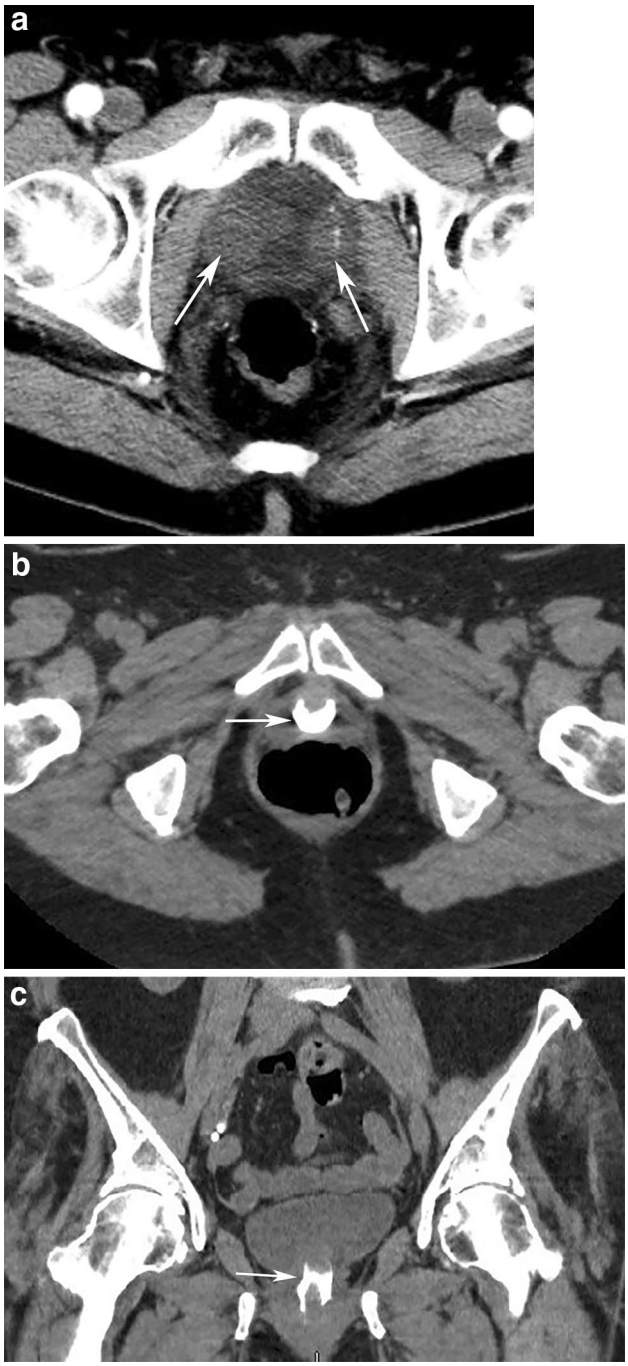

Fig. 25 Injection of a urethral bulking agents. **a** An axial arterial phase contrast-enhanced CT image through the pelvis in this patient who previously had a prostatectomy and who currently has undetectable prostate specific antigen levels shows lobulated masses on either side of the bladder neck (arrows), with calcification on the left. Upon further investigation of the patient's electronic medical record, it was determined that the patient had previously undergone injection of a urethral bulking agent for treatment of incontinence. Coronal imaging can be helpful to localize the abnormality. **b** An axial portal venous phase contrast-enhanced CT image through the pelvis in a different female patient with incontinence demonstrates high attenuation material in a crescentic shape in the periurethral region, consistent with the carbon-coated bead type of bulking agent. **c** A coronal image from this same female patient's CT helps localize the agent

Urethral bulking agents

Urethral bulking agents have been used as a minimally invasive method for treating patients with stress urinary incontinence. Most commonly, these agents are used in women; however, they can be used in men with stress incontinence following prostatectomy or pelvic trauma.

Injection of urethral bulking agents is performed as an outpatient procedure and is usually repeated every few years [64]. A variety of bulking agents have been utilized, with some having fallen into disfavor due to ineffectiveness or complications. Some currently used agents are silicone particles, calcium hydroxyapatite, carbon beads, and polyacrylamide hydrogel [65]. Collagen was widely used in the past, but is no longer manufactured in the United States [66].

Urethral bulking agents have variable imaging appearances and can be mistaken for other pathologies of the bladder base and perineum, including urothelial and squamous neoplasms. The differences in appearance are due to the varying compositions of the different agents. A history of bulking agent injection in patients who have bladder base or perineal abnormalities helps facilitate the correct diagnosis. Otherwise, the bulking agents may be misdiagnosed as bladder and periurethral calcification, ureteral diverticula with stones, or urinary tract malignancy [66]. On CT, urethral bulking agents may be isoattenuating or hyperattenuating to soft tissue (Fig. 25) [67]. Collagen, in particular, is of soft tissue attenuation and can be confused with a bladder base mass [68].

Summary

A variety of benign urinary tract abnormalities can be encountered during CT and CT urography. Some have characteristic appearances, but in many cases they can be confused with urinary tract malignancies. Use of portal venous and excretory phase imaging reconstructed in the coronal and axial plane, with and without wide window settings at CT, can be helpful in facilitating detection. In many circumstances, the clinical presentation coupled with the imaging features can direct the radiologist to consider the correct diagnosis.

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