Patrice Taourel and Rodolphe Thuret

P. Taourel (✉)
Department of Imaging, H™pital Lapeyronie,
34295 Montpellier Cedex 5, France
e-mail: p-taourel@chu-montpellier.fr

R. Thuret
Department of Urology, H™pital Lapeyronie,
34295 Montpellier Cedex 5, France

Abstract

Renal colic pain due to an obstructing stone is the main renal cause of acute ßank pain; however, other causes may be responsible for the same clinical Þndings, including acute pyelonephritis, acute vascular conditions, and hemorrhage. The purpose of this review is to describe the differential diagnosis, the CT Þndings and pitfalls, and the role and impact of CT in the diagnosis and management of the renal causes of acute ßank pain.

1 Introduction

Renal colic pain due to an obstructing stone is the main renal cause of acute ßank pain; however, other causes may be responsible for the same clinical Þndings, including acute pyelonephritis, acute vascular conditions, and hemorrhage. The purpose of this review is to describe the differential diagnosis, the CT Þndings and pitfalls, and the role and impact of CT in the diagnosis and management of the renal causes of acute ßank pain.

Colic pain constitutes the most common cause of pain in patients with acute abdomen seen in an emergency department. However, in a patient referred for CT with suspicion of colic pain, 40Ð60% have an obstructing stone according to the clinical presentation

P. Taourel (ed.), CT of the Acute Abdomen, Medical Radiology. Diagnostic Imaging,
DOI: 10.1007/174_2010_88, Springer-Verlag Berlin Heidelberg 2011

and to the experience of the referring physician. C allows a wide spectrum of alternative genitourinar tract and non-genitourinary-tract diagnoses respo sible for the symptoms. The goal of this review is t describe the CT features in the renal causes of nc traumatic acute ßank pain.

2 Colic Pain

2.1 Clinical Findings and Problems

Flank pain due to urolithiasis is a common problem i patients presenting to the emergency department. Up 12% of the population will have a urinary stone durin their lifetime, and recurrence rates approach 50 (Teichman 2004). The disease affects men 3 times a often as it does women. Some factors increase the risk stones, such as genetics, diet, employment, and urinary tract infections, whereas speciÞc entities such as idiopathic or secondary hypercalciuria and hyperuricosuria are associated with a high prevalence of stones.

Colic pain is often spasmodic and increases to a peak level of intensity and then decreases before increasing again. The pain is severe and may rapidly rise to a level of discomfort, needing narcotics for adequate control. As the stone approaches the ureteral junction, pain may radiate to the lower abdomen and into the scrotum, the labia, or the tip of the urethra, or may be associated with urinary urgency or dysuria, and may mimic cystitis.

Urinalysis is often the initial laboratory examination, and some investigators have suggested that dipstick or microscopic urinalysis that is negative for blood can effectively exclude the diagnosis of an obstructing ureteral stone and avoid additional testing (Press and Smith 1995). However, this assumption was challenged by the study of Luchs et al. 2002). This study included 950 patients with suspected renal colic and a stone on CT in 62% of patients and showed that microscopic hematuria had a sensitivity, speciÞcity, positive predictive value, and negative predictive value of 84, 48, 72, and 65%, respectively. Consequently, the presence or absence of blood in urinalysis cannot be used to reliably determine which patients actually have ureteral stones, and additional tests are often necessary. It has been established for 10 years that the best modality to conÞrm the diagnosis of a urinary stone in a patient with acute

Right ureterovesical junction stone. The stone is well individualized at the right uterovesical junction and must be differentiated from a posterior phlebolith (arrow), easily recognized because it is not located on the course of the ureter, and it is associated with a posterior tail of soft-tissue attenuation

ßank pain is unenhanced helical CT of the abdomen (Teichman 2004; Vieweg et al. 1998).

2.2 CT Findings

CT shows direct and indirect Þndings of colic pain due to a stone. The direct Þnding is the visualization of the calculus itself. Regardless of composition, almost all renal and ureteral stones are detected by CT because the attenuation of stones is higher than that of surrounding tissue, even if attenuation of uric acid stones is lower than the attenuation of calcium. The most common locations for obstruction by a stone are at the three areas of the anatomic narrowing of the ureter: the ureteropelvic junction, the pelvic brim where the ureter crosses the iliac vessels, and the ureterovesical junction (Fig. 1). Secondary or indirect Þndings are hydronephrosis, hydrouereter, perirenal edema, periureteral edema, and swelling of the kidney (Tamm et al. 2003; Ege et al. 2003).

The size of the stone is important information that should be included in the CT report because the likelihood of spontaneous stone passage decreases as the size of the stone increases. Most stones that are less than 5 mm in diameter are likely to pass spontaneously (Teichman 2004; Segura et al. 1997) and generally pass within 4 weeks after the onset of symptoms (Teichman 2004). The degree of functional

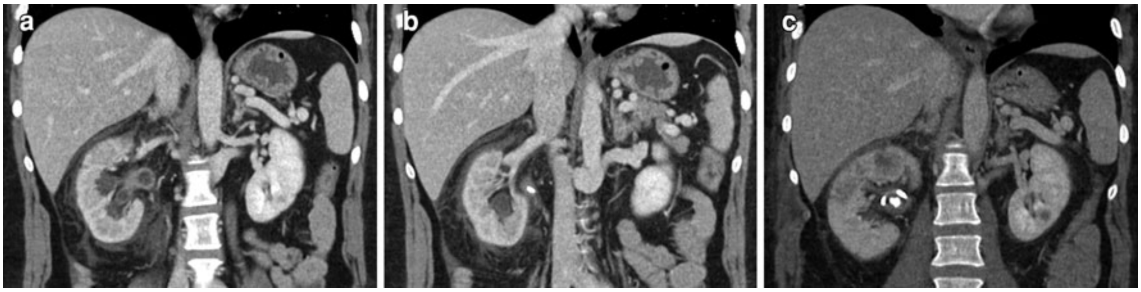
Left ureteral stone. The left lumbar ureteral stone is well identified on the axial (a) and coronal (b) views. Note a significant fat stranding around the kidney in contrast to a lack of ureteral dilatation. This is in favor of a rupture of the collecting system

obstruction may be concluded from the degree of perirenal edema. It has been shown by comparing CT and intravenous urography in a population of patients with acute ureterolithiasis that with a qualitative assessment of perirenal edema on CT images, the degree of ureteral obstruction seen on intravenous urography was accurately predicted in 94% of patients (Boridy et al. 1999). Significant perirenal edema may imply severe obstruction with rupture of the collecting system (Fig. 2). However, the degree of obstruction is not a key point in the treatment of a patient with a ureteral stone; the treatment of choice (noninterventional management, shock-wave lithotripsy, or ureteroscopy) depends on the size and the location of the stone, and on the duration of the symptoms (Teichman 2004; Tamm et al. 2003). In pure uric acid stone, oral dissolution therapy is efficient even for a big stone. The characteristic of the stone may be suspected on the basis of the history of the patient, of a low urinary pH, and on a calculus visible on CT but radiolucent on plain imaging or on the scout view.

2.3 CT Pitfalls

The most common difficulty is the differentiation of phleboliths from ureteral calculi. Some findings may be helpful to differentiate these two entities: a soft-tissue rim sign, which refers to a soft-tissue ring surrounding the calcification representing the edematous wall of the ureter, is in favor of a stone, whereas an associated tail of soft-tissue attenuation (representing the associated vein) that extends to the calcification is in favor of a phlebolith (Fig. 1) (Tamm et al. 2003; Rucker et al. 2004). In clinical practice, viewing on a workstation in interactive cine mode is helpful to follow the ureter on its entire course and to localize the origin of a calcification. We do not find that coronal reformations are helpful in differentiating stone from phlebolith and improving urinary stone detection. In a study including more than 200 uroliths in 72 patients, the only added value of coronal reformation performed with 1.25-mm axial acquisitions was to reduce the evaluation time; furthermore, coronal reformation was less sensitive than axial sections to diagnose alternative conditions (Memarsadeghi et al. 2007). In clinical practice, the main advantage of coronal reformatting is to give more readable views for physicians (Fig. 2).

False-negative CT findings may be due to the size and the composition of the calculus. In our experience, a 1-mm slice may exceptionally be helpful to diagnose a very tiny stone, even if our usual interpretation mode is 3 mm thick. In a study assessing the effect of section width, it was shown that overlapping 3-mm sections were sufficient for the detection of urinary stone disease. Sections measuring 1.5 mm thick did not have any added value, whereas small calculi (3 mm or less) might be missed on 5-mm-thick sections (Memarsadeghi et al. 2005). Stones radiolucent on CT are matrix stones that are made of organic material and are occasionally seen in patients with urease-producing bacteria (Liu et al. 2003) and indinavir stone; indinavir stone may be encountered in patients with the human immunodeficiency virus (HIV) who are undergoing treatment with this protease inhibitor, and for whom the medication can crystallize in the urine (Gentle et al. 1997).



a–c Pyonephrosis. Findings of obstruction of the right kidney with asymmetric nephrography and pyelic dilatation (a). There is also an abnormal enhancement of the pyelic wall, meaning pyelitis (a). The obstruction was due to a stone located at the ureteropelvic junction. A JJ tube well shown on a follow-up CT was set in an emergency with passage of infected urine. Note, at this time, there is development of infection of the parenchyma

In these two cases, stones may be or may not be detected with CT. In patients with colic pain, hydronephrosis, and/or hydroureter, and when no ureteral calcification can be identified, the differential diagnosis will include calcification too small to detect, indinavir stone in a HIV patient, but more often a pyelonephritis or a passed stone. In the case of peri-renal edema and renal swelling without either calcification or hydroureteronephrosis, renal infarction and renal vein thrombosis should be considered in the differential diagnosis, and a CT scan should be immediately repeated with intravenous contrast material (Tamm et al. 2003; Rucker et al. 2004).

An obstructing stone at the ureteral insertion can be difficult to differentiate from a stone that has recently passed into the bladder. In this case, prone imaging may be added to determine whether the calculus is free within the bladder lumen or fixed within the ureterovesical junction (Levine et al. 1999).

In patients with obstruction, enlargement of the kidney (Fig. 3), thickening of the renal pelvic wall, or nonhomogeneous filling of the collecting system after administration of intravenous contrast material is suggestive of pyonephrosis (Craig et al. 2008). However, CT evaluation generally does not allow one to distinguish simple hydronephrosis from pyonephrosis on the basis of fluid attenuation measurements (Fig. 3) (Fultz et al. 1993).

2.4 CT Accuracy

The sensitivity and specificity of CT for the diagnosis of stone are above 95%, superior to those of intravenous urography, which was the previous gold standard. Consequently, CT is becoming the new gold standard in the diagnosis of colic pain in the evaluation of other tests, which may be biological, such as hematuria testing (Luchs et al. 2002), or radiological, such as plain film (Poletti et al. 2006), or a combination of abdominal plain film and ultrasonography (US) (Catalano et al. 2002).

In addition to having a high accuracy in the diagnosis of colic pain, CT enables significant alternative or additional diagnoses to be made. In a large two-center study including 1,000 patients (Katz et al. 2000), with a diagnosis of ureteral calculi in 557 patients and a diagnosis of recently passed stone, CT permitted an alternative diagnosis to be established in 101 examinations (10%). There were 62 genitourinary tract and 39 non-genitourinary-tract diagnoses. Among the 62 genitourinary tract diagnoses, there were 23 adnexal masses and nine cases of pyelonephritis, whereas other causes of urinary tract obstructions were encountered in 12 cases, including three cases of ureteropelvic junction obstruction, one case of ureteral obstruction due to adenopathy, four cases of ureterovesical junction obstruction, and four cases of bladder outlet obstruction. Among the 39 non-genitourinary-tract diagnoses, the diseases were very diverse, with a predominance of colic disease (eight cases) and of appendicitis (five cases). There was only one case of aortic dissection and two cases of muscle hemorrhage. The disease pattern was remarkably similar in another study (Ahmad et al. 2003), including 233 consecutive patients with helical CT for suspicion of ureteral colic and that showed a ureteral calculus in 64% of patients, findings of recent passage of calculi in 4% of patients, and significant additional or alternative diagnoses in 12% of patients with a 50% rate of genitourinary tract and non-genitourinary tract diagnoses.

2.5 Role and Impact of CT

CT is rightly considered by urologists (Katz et al. 2000) as the technique providing the most rapid and most accurate information for both patients and the referring physician in patients with suspicion of colic pain. Despite the additional cost, they claim that the only reason for not using it is its lack of availability. More important than the cost are concerns about radiation exposure. It is now considered that CT is the major cause of radiation exposure. Consequently, in patients younger than 30 years, especially because they have a personal or a family history of urolithiasis, we believe that abdominal plain Þlm and US must be used Þrst. The stones missed by these techniques generally do not require any invasive treatment (Catalano et al. 2002). If CT is performed, a low-dose protocol must be used, especially in thin patients because it has been shown that low-dose CT (30 mA) achieves sensitivities and speciÞcities close to those of standard-dose CT (180 mA) in assessing the diagnosis of renal colic, depicting ureteral calculi of 3 mm or larger (Poletti et al. 2007) in patients with a body mass index of 30 or below. CT without intravenous contrast material is sufÞcient to diagnose colic pain. However, in some suspicions of alternative conditions, intravenous contrast material is mandatory. It must be kept in mind in patients with vascular risks that the clinical Þndings of acute aortic and splanchnic arterial conditions may overlap with those or renal colic. Even if unenhanced CT may diagnose a ruptured abdominal aortic aneurysm and aortic dissection (Rucker et al. 2004), intravenous contrast material is always required to exclude the latter. Furthermore, according to the results of the unenhanced CT scan, injection must be performed when there is suspicion of bleeding in the urinary tract or of the kidney, and when unenhanced CT shows unilateral perirenal stranding or nephromegaly without a stone to look for pyelonephritis or a serious vascular condition such as renal infarction, renal vein thrombosis, or renal artery aneurysm (Rucker et al. 2004).

3 Urinary Tract Infection

3.1 Clinical Findings and Problems

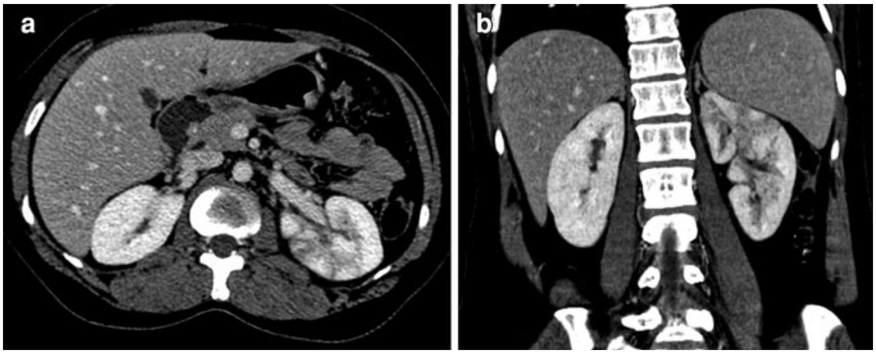
Urinary tract infections constitute the second most common urological disease after the colic pain responsible for emergency department visits. In adults, diagnosis of urinary tract infection is typically based on characteristic clinical features and abnormal laboratory values. In cystitis, diagnosis is performed on the basis of dysuria and urinary frequency and urgency. In pyelonephritis, symptoms include an abrupt onset of chills, fever, and unilateral ßank pain with costovertebral tenderness, which may be accompanied by the ÔÔlower tract signsÕÕ present in cystitis.

Cystitis is due to the action of an infectious organism, the usual urinary pathogens being *Escherichia coli* and *Proteus mirabilis*. Most infections are uncomplicated and involve only the urinary bladder, but in some cases the infection migrates up the ureter to the central collecting system, even in the absence of reßux, with the constitution of a ureteropyelitis, and then the bacteria may enter the renal tubules with the constitution of nephritis. Besides the ascending pyelonephritis, some infection may seed hematogenously.

Even if acute cystitis is generally noncomplicated, some conditions must be associated with complicated cystitis and the lack of pyelonephritis: diabetes, neurogenic bladder, bladder outlet obstruction, and enterovesical Þstulization. The main feature of complicated cystitis is emphysematous cystitis, a rare condition that is characterized by gas collections inside the bladder wall with varied clinical presentations from an incidental Þnding of abdominal-to-severe sepsis, with a mortality of 7% in a meta-analysis including 135 cases (Thomas et al. 2007). Two thirds of patients are women and two thirds of patients have diabetes mellitus.

3.2 CT Findings

CT is the imaging modality of choice in the evaluation of patients with acute bacterial pyelonephritis. As recently recommended (Stunell et al. 2007), we use precontrast imaging, followed by postcontrast imaging at approximately 50Ð90 s when the normal



Pyelonephritis of the left kidney. A striated nephrogram involving the whole left kidney is well shown on the axial slice (a) as well as on coronal reformatting (b)

Abscess of the left kidney. Hypodense mass in the upper part of the left kidney with a bean appearance, well seen on axial (a) and coronal (b) views. Note that the fat stranding around the kidney is very subtle

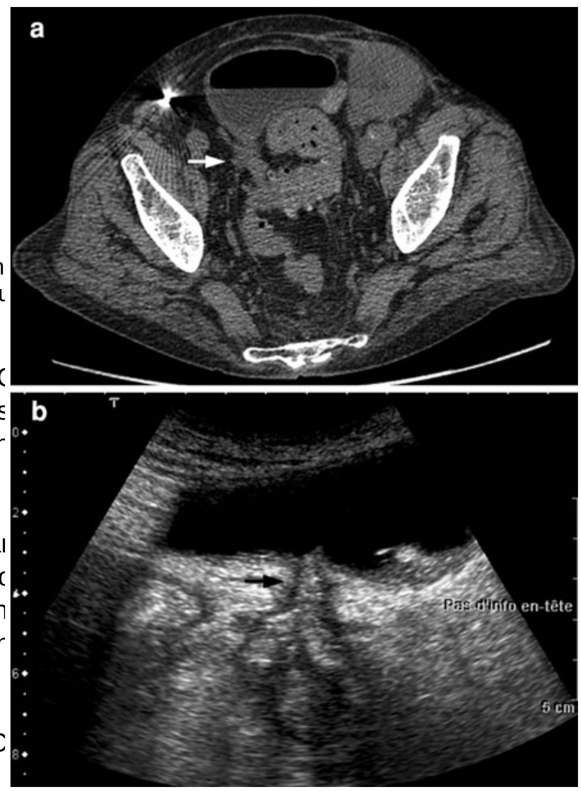
kidney is homogeneously enhanced and delayed imaging if urinary tract obstruction is suspected. We believe that vascular and corticomedullary phases recommended in some protocols (Browne et al. 2004) may be avoided.

Unenhanced CT is sufficient for identifying urinary tract gas, calculi, hemorrhage, renal enlargement, inflammatory masses, and obstruction.

The diagnostic features of acute bacterial nephritis after administration of intravenous contrast material are consecutive to the pathological state of the disease (Craig et al. 2008). The striated nephrogram is due to obstruction of the tubules by edema with intervening normal tubules, seen as linear bands of alternating hypodense and hyperdense striations parallel to the tubules. The striations have a lobar distribution, and may be unifocal or multifocal, and unilateral or bilateral (Fig. 4). The wedge-shaped hypodense areas radiating from the papilla to the cortical surface represent areas of poorly functioning parenchyma due to vasospasm, tubular obstruction, and/or interstitial edema. These disturbances lead to a decrease of the flow through the tubule and explain the pattern of delayed and persistent enhancement seen 3–6 h after intravenous contrast material administration (Fig. 4). Pelvic and caliceal wall thickening and enhancement may be the only finding of an affected kidney if the patient has pyelitis. However, diffusion of the inflammatory process leads to stranding or obliteration of perirenal fat and thickening of fascias. Unenhanced fluid collections within the abnormal renal parenchyma indicate the development of abscesses (Fig. 5) that are more common in diabetic patients. When these collections are round and bilateral, hematologic seeding must be suspected, and in such cases, blood and urine cultures grow the same organism. The presence of air within the kidney results in the diagnosis of emphysematous pyelitis or pyelonephritis. In emphysematous pyelitis, CT shows gas bubbles or gas–fluid levels within the renal calices or sinus (Craig et al. 2008). Emphysematous pyelitis has a better prognosis than emphysematous pyelonephritis, where gas is located within the parenchyma. Emphysematous pyelonephritis is a life-threatening necrotizing infection of the kidney associated in 90% of cases with poorly controlled diabetes;

Emphysematous pyelonephritis. Sagittal reformattin shows air that dissects the anterior perirenal space with ßu collection

Emphysematous cystitis. Air within the wall of the bladder, which is characteristic of emphysematous cystitis because of the lack of bladder instrumentation



Colovesical Þstula complicating diverticulitis. The colovesical track (arrow) is well seen on CT (a) as well as on ultrasonography (b). Note the thickening of the sigmoid wall, the colic diverticula, and the presence of air in the bladder

a classiÞcation with a prognosis value is based on C Þndings (Wan et al. 1996). The type 1 and 2 diseases are characterized by a parenchymal destruction th manifests itself as either streaky or mottled areas gas, but in type 1 diseases (Fig. 6), intrarenal or extrarenal collection is missing, whereas they ar present in type 2 diseases associated with a mo fulminant course and a higher mortality rate, and th necessity of an aggressive treatment with percutan ous drainage (Narlawar et al. 2004) and/or partial or total nephrectomy.

Emphysematous cystitis is easily detected by C that shows intraluminal or intramural gas (Fig. 7). The differential diagnosis must be established wit other causes of intraluminal gas such as consequen of urinary tract instrumentation or enteric Þstula for mation from adjacent bowel carcinoma or inßamma tory disease (sigmoid diverticulitis, Crohn disease) (Fig. 8). Crohn disease constitutes the most common cause of enterovesical Þstula; these Þstulas occur more often from the ileum than from the colon (Wong-You Cheong et al. 2006).

3.3 CT Pitfalls

The main difÞculties in CT diagnosis are because the Þndings encountered are not speciÞc to infection.

a–c Chronic abscess of the kidney. A first CT examination shows retroperitoneal lymph nodes (a) and a mass in the lower part of the right kidney (b). There is no fat stranding around the kidney. The biopsy of the mass did not confirm a renal tumor but diagnosed an abscess. One month later, the renal mass has decreased in size (c)

Striations that are a subtle finding of a moderate pyelonephritis may be seen in normal kidneys when low-osmolarity contrast materials are used or in poorly hydrated patients (Stunell et al. 2007). Low-enhancement areas within the parenchyma are the consequence of an interstitial nephritis, but there are other noninfectious causes of nephritis, such as drugs, granulomatous disease (e.g., sarcoidosis), and immunologic or metabolic disease. Perirenal stranding may be related to previous infection, trauma, or vascular disease. Air within the collecting system may have a noninfectious origin such as trauma, instrumentation, and fistula. Consequently, these different findings must be interpreted according to the clinical conditions and have a great value in patients with clinical findings consistent with pyelonephritis.

In practice, the most difficult question may be to differentiate pyelonephritis from pyonephrosis because pelvic and ureteral wall thickness, perirenal fat stranding, and a striated nephrogram can occur in these two diseases. Obstruction is, of course, a reason for pyonephrosis, but dilatation of the pelvis and ureter may be present in pyelonephritis because endotoxins may inhibit ureteral peristalsis (Stunell et al. 2007). This distinction is of great importance because pyonephrosis requires emergent drainage of the collecting system to prevent permanent loss of function and life-threatening Gram-negative septicemia.

In the same way, in patients with obstruction, parenchymal or perirenal changes, thickening of the renal pelvic wall, or nonhomogeneous filling of the collecting system after intravenous contrast material administration are the reasons for pyonephrosis (Craig et al. 2008). However, CT evaluation generally does not allow one to distinguish simple hydronephrosis from pyonephrosis on the basis of fluid-attenuation measurements.

Other pitfalls may be due to the confusion between a tumoral mass and an infectious mass. Fever may be due to either the inflammatory process or a paraneoplastic syndrome. Inflammatory changes around the mass and pyuria are the reasons for an infection. However, in some cases, the diagnosis of infection is a good surprise of the biopsy (Fig. 9).

3.4 CT Accuracy

CT is considered superior to intravenous urography and US in detecting parenchymal abnormalities, delineating disease, and detecting perirenal collections. In patients with consistent clinical findings, all regions of hypoattenuating parenchyma on CT are considered acute pyelonephritis, and the disease is specifically described in terms of unilateral/bilateral, focal/diffuse, focal swelling/no focal swelling, or renal enlargement/no renal enlargement (Talner et al. 1994). Consequently, because CT is used as the gold standard for the diagnosing and staging of pyelonephritis, its accuracy cannot be evaluated.

3.5 Role and Impact of CT

Diagnosis of acute pyelonephritis in the adult patient is still predominantly a clinical diagnosis. However, CT has a great role in selected clinical scenarios:

– When the diagnosis is doubtful on the basis of the symptoms or urinalysis or if other diseases such as ureteric colic or renal infarction are suspected

- Ð To assess those patients at signiÞcant risk severer life-threatening complications (diabetic elderly, or immunocompromised patients)
- Ð To assist in the diagnosis of acute pyelonephri when the patient fails to respond to appropriat therapy within the Þrst 72 h, which occurs in abou 5% of patients
- Ð When there is a possibility of pyonephrosis th would require urgent drainage. In this case, U may be an alternative to CT.

4 Fournier Gangrene

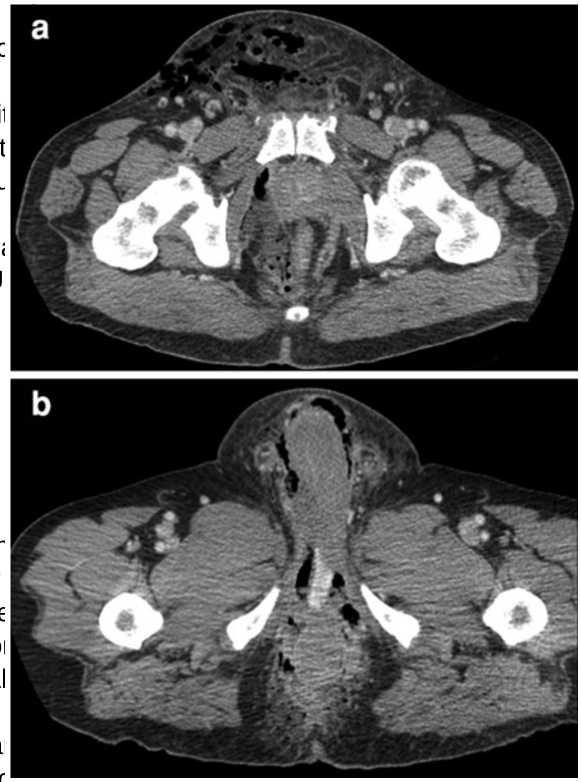
4.1 Clinical Findings and Problems

Fournier gangrene represents a urologic emergen with a potentially high mortality rate. It is a rapidly progressing, microbial necrotizing fasciitis of the perineal, perianal, and genital regions, with a mor tality rate ranging from 15 to 50% (Levenson et al 2008). The infection is most often polymicrobial, with clostridia, streptococci, and staphylococci species a coliform bacteria commonly cultured. Synergistic effects of the bacteria lead to thrombosis of sma subcutaneous vessels, and rapid gangrenous invol ment of the surrounding skin and deep fascia ensues. Bacterial sources originate from the adjacent skin, the rectum and anus, and the lower urinary tract. The disease is most often due to a local infection adjacent to a point of entry (including abscesses in the perianal, perirectal, and ischiorectal regions), or anal Þssures. However, bowel perforation and urological causes including urinary tract infection, neurogenic bladder, recent instrumentation, and epididymitis must be systematically looked for.

Predisposing factors reßect impaired host resistance from reduced cellular immunity. These factors include diabetes mellitus (seen in up to 60% of cases), alcoholism, and HIV infection.

The most common presenting symptoms of Fournier gangrene include scrotal swelling, pain, hyperemia, pruritus, and fever. Crepitus identiÞed on physical examination is very suggestive of the diagnosis.

Although the diagnosis of Fournier gangrene is most often made clinically, the role of imaging is to help in cases of early manifestation or ambiguous physical Þndings, and to better discern the extent of the disease.



a, b Fournier gangrene. Subcutaneous emphysema around the penis and the scrotum dissecting the perianal and periprostatic space

4.2 CT Findings

CT patterns (Levenson et al. 2008; Grayson et al. 2002) include suggestive Þndings, pathognomonic Þndings, and causal Þndings.

Suggestive Þndings are the presence of fascial thickening, fat stranding, ßuid collection, or abscess around the scrotum and perineum and extending to the inguinal regions, thighs, abdominal wall, and retroperitoneum. The pathognomonic Þnding in this setting is a subcutaneous emphysema that dissects along fascial planes (Fig. 10). Causal factors may be a perianal abscess, a Þstulous tract, an intra-abdominal or retroperitoneal infectious process, or a bowel perforation that is generally located in the infraperitoneal space.

4.3 CT Pitfalls

In early Fournier gangrene, CT can depict progressive soft-tissue inÞltration, possibly with no evidence of subcutaneous emphysema (in about 10% of patients). In Fournier gangrene due to bowel perforation, the extraluminal air consecutive to the bowel perforation must not be confused with the diffusion of the emphysema.

4.4 CT Impact

The impact of CT is threefold: it can favor an early diagnosis and a differentiation between Fournier gangrene and other less aggressive entities such as soft-tissue edema or cellulitis; it can allow one to diagnose the cause of the gangrene; and, overall, it plays an important role in the evaluation of disease extent for appropriate surgical treatment (Yanar et al. 2006) because complete surgical debridement of all necrotic tissue is the most important factor in improving survival of patients with Fournier gangrene.

5 Vascular Conditions

5.1 Clinical Findings and Problems

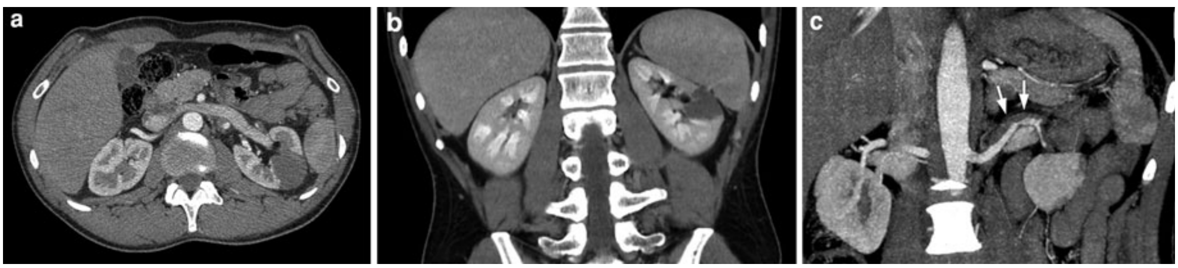
Symptoms of nontraumatic acute renal infarction may mimic exactly those of stone colic or acute pyelonephritis. Fever and leukocytosis are common if the volume of infarcted parenchyma is substantial, but generally they occur 1 or 2 days after the pain. An elevated serum lactate dehydrogenase level is characteristic of infarction and helps to distinguish it from infection. Classically, renal infarct is the consequence of renal embolism that generally occurs in the setting of cardiac disease, notably atrial Þbrillation. It may also be the consequence of an aortic dissection because more than one third of patients with aortic dissection have involvement of the visceral or iliac arterial branches. Other diseases may be responsible for renal infarction: vasculitis such as polyarteritis nodosa, systemic lupus erythematosus, drug-induced vasculitis, paraneoplastic syndrome, hypercoagulable state, or acute venous occlusion (Kawashima et al. 2000). However, in numerous cases, acute renal infarction may occur in previously apparently healthy individuals; in a study including 27 consecutive patients presenting with nontraumatic CT-documented renal infarction, 11 patients (41%) had obvious cardiac disease, whereas 16 patients (59%) had no discernible structural or arrhythmic cardiac disease (Bolderman et al. 2006). These patients were younger and besides smoking had fewer cardiovascular risk factors. Among these unknown causes of infarct, renal artery dissection should be considered. Renal artery dissection is usually the natural extension of aortic dissection, the consequence of percutaneous angioplasty, or the result of percutaneous angioplasty. However, isolated dissection of the renal artery must be kept in mind (Ramamoorthy et al. 2002). Spontaneous isolated dissection of visceral arteries such as the celiac artery, superior mesenteric artery, or renal artery has recently been described (DÕAmbrosio et al. 2007; Kanofskh and Lepor 2007), and it is likely that the incidence has been underestimated in the past because the diagnosis, now facilitated by the development of cross-sectional imaging, was previously not established.

The clinical manifestations of renal vein thrombosis depend on the age of the patient, the speciÞc disease process, and the speed with which it occurs. When the clinical manifestations are acute, the presentation includes gross hematuria, ßank pain, and loss of renal function, and the most common abnormality is membranous glomerulonephritis (Kawashima et al. 2000; Liach et al. 1980). In renal vein thrombosis associated with tumor, the clinical Þndings depend on the tumor, and thrombosis is often discovered in the staging of the renal tumor.

5.2 CT Findings

In renal infarct, contrast-enhanced CT readily shows absence of enhancement in the affected renal tissue. Acute infarcts appear as wedge-shaped areas of decreased attenuation within an otherwise normal-appearing kidney, which may be numerous and bilateral. In the acute phase, the infarct has an edematous appearance (Fig. 11a), with a retraction of the involved infarcted kidney in the chronic phase (Fig. 11b). When large areas of the kidney are involved, an increase in the size of the kidney due to edema can be seen (Kawashima et al. 2000). When no cardiac disease is known, special care must be taken on the examination of the renal arteries: identiÞcation of intimal ßap or thrombosed false lumen seen as a linear Þlling defect, and the presence of segmental fat

Bilateral renal infarct. Poorly enhanced area in the anterior part of the left kidney (a). On a follow-up CT scan, the involved infarcted left kidney was retracted (b), whereas Þndings of right ischemia appeared with a wedge-shaped unenhanced area (c)



Left renal infarct due to dissection of the renal artery. The infarct of the medial part of the left kidney is well seen on axial (a) and coronal (b) views as a wedge-shaped hypodense area. There is a segmental fat inÞltration (arrows) around the left renal artery that is thinned (c)

inÞltration around the artery is the reason for the diagnosis of dissection of the renal artery (Fig. 12).

In renal vein thrombosis, CT shows direct and indirect Þndings. The direct Þnding is the identiÞcation of the thrombus in the renal vein with or without extension into the inferior vena cava. Indirect Þndings are the consequences of the thrombus on the kidney with enlargement of the ipsilateral kidney, edema in the renal sinus and perirenal space, and the coarse striations of a diminished nephrogram (Kawashima et al. 2000).

5.3 CT Pitfalls

CT pitfalls are due to errors in the examination protocol, errors in the interpretation of Þndings present on CT, and lack of knowledge of the disease responsible for renal infarct. The CT protocol needs intravenous contrast material for renal infarct to be diagnosed, which may be lacking in the clinical setting of a presumed colic pain. For CT interpretation, one must know that the cortical rim, considered as speciÞc to infarct, usually appears several days after onset of the infarction, as shown in a study assessing the cortical rim sign in posttraumatic renal infarction (Kamel and Berkowitz 1996). Furthermore, this Þnding may be encountered in long-standing hydronephrosis, renal vein obstruction, and acute renal failure. Spontaneous renal artery dissection is a good example of misknowledge of a disease that may be diagnosed by CT with the interpretation of the thin slices and the attention focused on the wall and content of the renal arteries.

5.4 CT Accuracy

In a study including 44 cases of renal infarction in patients with atrial Þbrillation (Hazanov et al. 2004), over a period of nearly 20 years, renal isotope scan was performed in 37 cases, US in 27 cases, and contrast-enhanced CT in only 15 cases. US, CT, and renal isotope scan had a sensitivity of 11, 80, and 97%, respectively, so renal isotope scan was considered as the most sensitive diagnostic technique.

However, as concluded by the authors, CT requires further assessment because of the improvement of CT technology, and we believe that CT now has high predictive values to diagnose or rule out a renal infarct.

5.5 Role and Impact of CT

Classically, unenhanced helical CT is the ideal diagnostic test for patients with acute ßank pain. It is highly accurate for the diagnosis of a stone, and it may diagnose extrarenal causes of abdominal pain such as appendicitis and diverticulitis. However, in patients in whom there is doubt regarding a vascular cause of the pain, contrast-enhanced CT is recommended. It must be performed in patients at risk of thromboembolic occlusion of the renal artery, or if there is an elevated level of serum lactate dehydrogenase. In 50-year-old male smokers, with a clinical presentation consistent with colic pain but without a past history of a stone, we recommend intravenous injection if unenhanced slices did not show a stone, to look for a renal infarct due to a spontaneous renal artery dissection.

6 Hemorrhagic Conditions

6.1 Clinical Findings and Problems

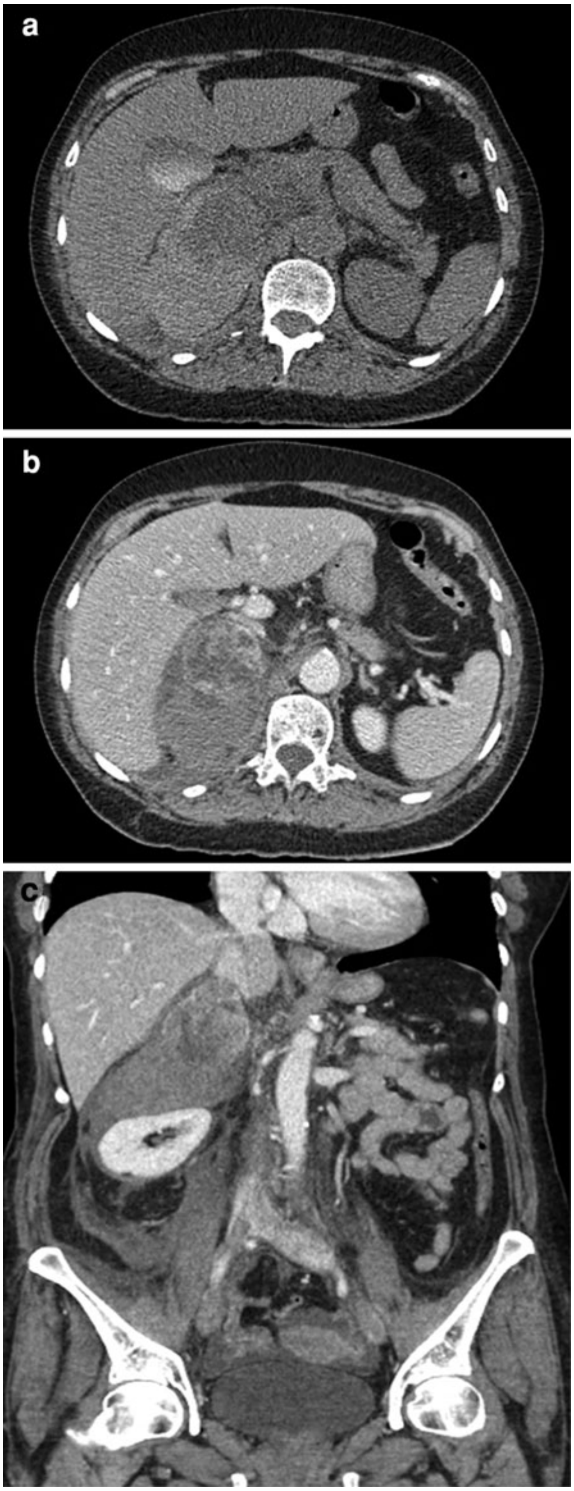
Spontaneous (nontraumatic) bleeding may affect the perirenal and subcapsular spaces, the renal parenchyma, or the collector system.

The main causes of spontaneous perirenal bleeding are tumors, vasculitis, and arteriovenous malformations. Long-term renal hemodialysis increases the risk of spontaneous hemorrhage, with or without an associated tumor. In a meta-analysis including 165 cases of spontaneous renal hemorrhage, the most common cause was benign or malignant neoplasm (101 cases, 61%), with angiomyolipoma being predominant (48 cases), followed closely by renal cell carcinoma (43 cases). Vascular disease was the next most common offender (28 cases, 17%), with polyarteritis nodosa occurring more frequently (20 cases) (Zhang et al. 2002). Adrenal tumors are rarer causes of bleeding than renal tumors. However, pheochromocytoma (Fig.13) corticosurrenaloma, myelolipoma, and metastases may be responsible for a unilateral cause of perirenal hematoma (Kawashima et al. 1999). Other causes of adrenal hemorrhage include stress and coagulopathy with other bilateral bleeding.

Hematuria has rarely hemodynamic consequences, and the task is often to identify its cause because hematuria can have a wide range of causes, including neoplasms, infection, trauma, drug toxicity, coagulopathies, vascular diseases, varices, and prolonged exercise, with infection and nephrolithiasis accounting for about 50% of cases (Joffe et al. 2003). However, some causes are more often responsible for severe bleeding with potentially shock: bladder tumors, hemorrhagic cystitis encountered, for instance, in an oncologic setting in patients with administration of ifosfamide and cyclophosphamide or as a complication of bone marrow transplantation, and vascular lesions.

6.2 CT Findings

CT without the use of contrast material will show the site of the bleeding, which may be an intraluminal bleeding, a subcapsular hematoma, or a perirenal hematoma. Because angiomyolipoma and renal cell carcinoma are the most common causes of spontaneous hemorrhage from a renal cause, CT must be use to look for this underlying tumor. Renal angiomyolipomas (Fig.14) more than 4 cm in diameter have a greater tendency to bleed spontaneously, whereas for carcinomas, tumor size is not a good indicator of bleeding risk because tumors smaller than 4 cm are nearly as likely to bleed as larger tumors (Zhang et al. 2002). These small tumors may be obscured by hemorrhage, and when the initial imaging examination does not demonstrate the cause of renal hemorrhage, repeat CT following resolution or evacuation of the hematoma is essential (Prando et al. 2006). In bilateral renal hemorrhage, reconstructions on the intrarenal vessels to look for aneurysm are

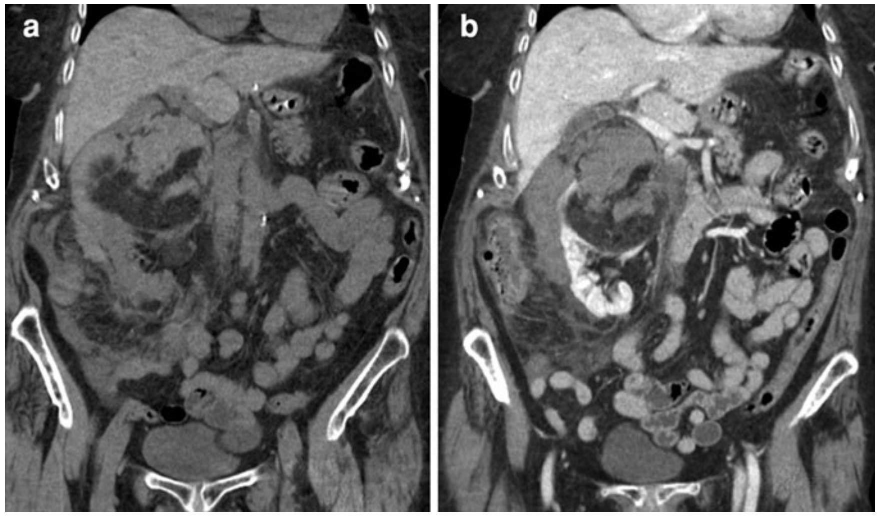


◄ aÐc Perirenal hematoma due to bleeding by pheochromocytoma. A right perirenal mass is well seen on the axial slices before (a) and after (b) intravenous contrast material administration and on the coronal reformatting (c). The mass has a double component: spontaneously hyperdense without contrast and not enhanced for the one corresponding to the hematoma, and hypodense and heterogeneously enhanced for the adrenal tumor. Surgery revealed a pheochromocytoma

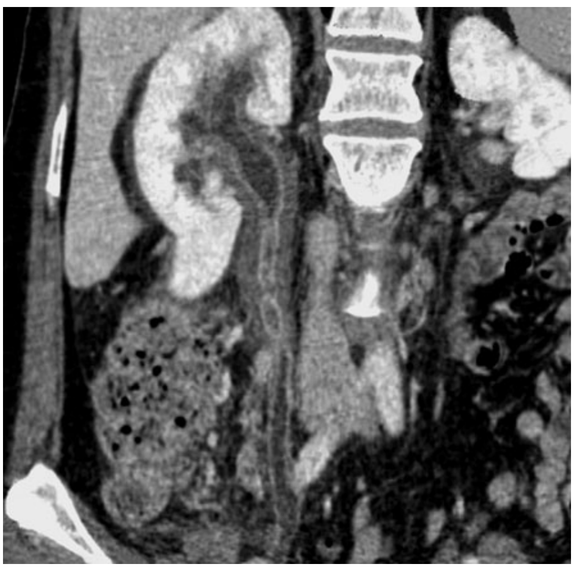
particularly helpful because renal vasculitis (polyarteritis nodosa) is the most common cause of this condition. Autosomal dominant polycystic kidney disease often presents clinically with acute ßank pain caused by cyst hemorrhage or rupture. A clot or hematocrit effect within a cyst suggests that hemorrhage is recent, whereas calciÞed and hyperdense cysts likely indicate older hemorrhage (Talner and Vaughan 2003; Levine and Grantham 1985). Subepithelial hemorrhage is encountered most often as a complication of anticoagulation therapy. CT shows diffuse thickening of the pelvic and ureteral wall (Fig. 15).

CT urography is helpful in the evaluation of hematuria (Joffe et al. 2003). It is used to look for renal masses, papillary, caliceal, pelvic, and ureteral abnormalities, and bladder diseases. For hematuria responsible for an emergent setting, CT will generally show bladder thickening generally in the context of advanced bladder cancer or of hemorrhagic cystitis such as from administration of ifosfamide and cyclophosphamide or a complication of bone marrow transplantation. In some cases, hematuria is caused by life-threatening vascular diseases (Muraoka et al. 2008). CT can show an iliac arteryÐureteral Þstula in patients with predisposing factors such as pelvic or vascular surgery, ureteral stent or pelvic irradiation, a renal arteriovenous malformation, or a ruptured renal artery aneurysm (Muraoka et al. 2008). In these conditions, arterial phase, thin section, and reformatting are often needed to identify the vascular abnormality, its relationship with the surrounding vessels, and to establish a vascular map before an eventual embolization.

Nutcracker syndrome is a cause of repeated bouts of gross hematuria and left ßank pain. It is deÞned by the compression of the left renal vein between the superior mesenteric artery and the aorta with an



a, b Perirenal hematoma due to bleeding by an angiomyolipoma. Mass containing fat developed in the upper part of right kidney with perirenal hyperdense collection. The tumor is poorly enhanced when comparing before (a) and after (b) intravenous contrast material reformatting



Subepithelial ureteral hemorrhage

increase in left renal pressure and rupture of collateral veins into the collecting system. CT can show the stenosis of the left renal vein with proximal distention and the presence of collateral pathways (Fig. 16) (Muraoka et al. 2008).

6.3 CT Pitfalls

Subcapsular soft-tissue attenuation, such as encountered in lymphoma, may mimic subcapsular hemorrhages on unenhanced scans, and intravenous contrast material is helpful to enable exclusion of a subcapsular soft-tissue mass (Rucker et al. 2004). As shown previously, a tumor may be masked by hematoma when the tumor is small and the hemorrhage large. In the same way, in patients with hematuria, the clot sometimes responsible for colic pain (clot colic) may mask a urothelial tumor, and the use on the unenhanced CT examination with a very narrow window may be helpful to identify the underlying tumor.

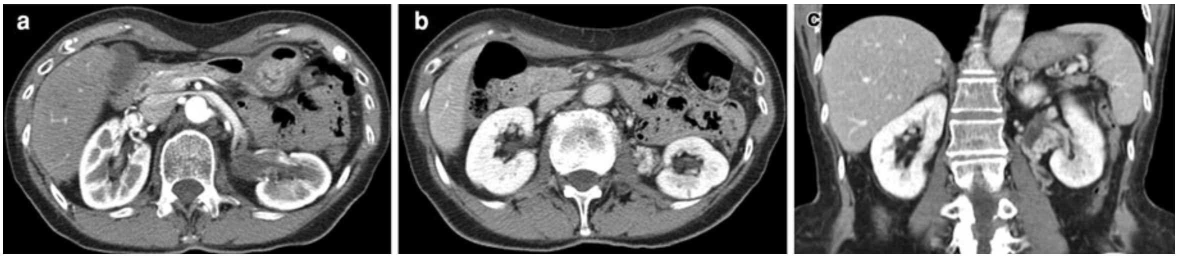
Aneurysm of the intrarenal arteries or arteriovenous fistula needs to be identified with thin slices and scanning in the adequate arterial phase, when they are tiny. Last, association of disease may be confusing. For instance, at least 10% of patients with autosomal dominant polycystic disease develop stones and therefore may present with classic ureteral stone colic.

6.4 CT Accuracy

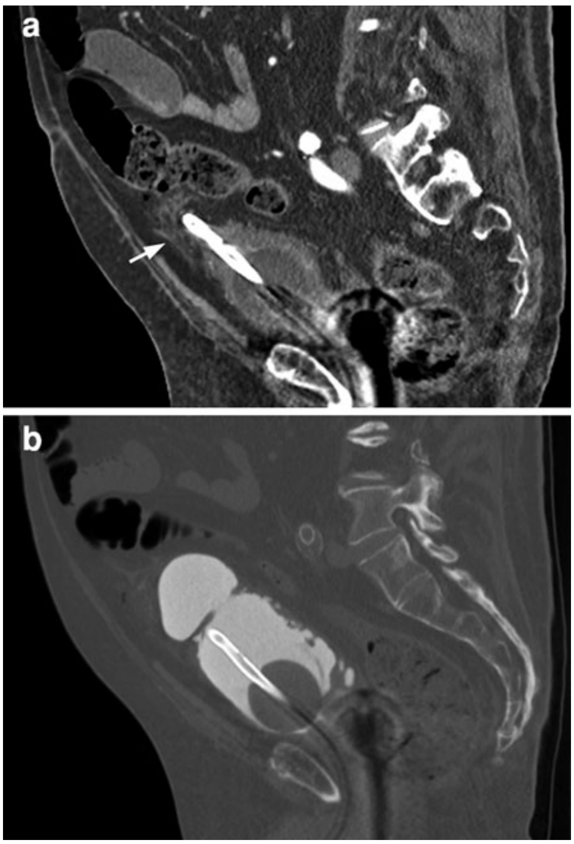
CT is the best imaging examination to diagnose renal bleeding and its cause. However, to our knowledge, no study has focused on its accuracy in this clinical setting, and failure in the acute phase in the identification of a small tumor responsible for the bleeding must be kept in mind.

6.5 Role and Impact of CT

Nontraumatic catastrophic hemorrhage from the urinary tract is uncommon and is rarely clinically



aÐc Nutcracker syndrome. The axial slice (a) shows compression of the left renal vein between the aorta and the superior mesenteric vein, with the development of the collateral vein within the left side of the pelvis well shown on a lower axial slice (b) and on the coronal reformatting (c)



a, b Pseudoperforation of the bladder. Sagittal reformatting shows the bladder probe crossing the bladder wall with some fat stranding around the bladder dome (a). On the same view in a delayed phase, a bladder diverticulum is Þlled by the contrast material, explaining this pseudopattern of the bladder perforation

suspected, except if there is hematuria. Consequently, the diagnosis is often revealed by CT, which has a great diagnostic impact. Besides its diagnostic impact, CT has a great impact on the management of the bleeding by allowing one to choose between a medical option, an embolization, or surgery, and by pointing out the bleeding vessel or vessels, which is helpful in the case of an embolization as well as in the case of a surgical option.

7 Bladder Perforation

Spontaneous rupture of the urinary bladder is an uncommon and life-threatening event. Prompt diagnosis followed by surgical intervention is the key for a successful outcome. The most common causes of atraumatic rupture of the urinary bladder are chronic inßammation, bladder outßow obstruction, cancer (Ahmed et al. 2009), and overall bladder augmentation cystoplasty because it is encountered in about 10% of children with an augmented urinary bladder (DeFoor et al. 2003). Clinically, most patients present with lower abdominal pain with associated symptoms of dysuria, being unable to void, anuria, and hematuria.

CT will show ßuid around the bladder, extraluminal air close to the bladder due to the migration of air after a bladder intubation, and will be used to look for the cause of perforation. Additionally, the identiÞcation of the bladder probe crossing the bladder wall is an argument for a bladder perforation by keeping in mind that such a feature may be mimicked in the setting of bladder diverticula (Fig. 17).

References

Ahmad NA, Ather MH, Rees J (2003) Incidental diagnosis of diseases on un-enhanced helical computed tomography performed for ureteric colic. BMC Urol 3:2

Ahmed J, Mallick IH, Ahmad SM (2009) Rupture of urinary bladder: a case report and review of literature. Cases J 2:7004

Bolderman R, Oyen R, Verrijcken A et al (2006) Idiopathic renal infarction. Am J Med 119:356.e9Ð12
Boridy IC, Kawashima A, Goldman SM, Sandler CM (1999) Acute ureterolithiasis: nonenhanced helical CT Þndings of perinephric edema for prediction of degree of ureteral obstruction. Radiology 213:663Ð667
Browne RFJ, Zwirewich C, Torreggiani WC (2004) Imaging of urinary tract infection in the adult. Eur Radiol 14: 168Ð183
Catalano O, Nunziata A, Altei F et al (2002) Prima, helical CT versus selective helical CT after unenhanced radiography and sonography. AJR Am J Roentgenol 178:379Ð387
Craig WD, Wagner BJ, Travis MD (2008) Pyelonephritis: radiologic-pathologic review. Radiographics 28:255Ð276
DÕAmbrosio N, Friedman B, Siegel D et al (2007) Spontaneous isolated dissection of the celiac artery: CT Þndings in adults. AJR Am J Roentgenol 188:W506ÐW511
DeFoor W, Tackett L, Minevich E, Wacksman J, Sheldon C (2003) Risk factors for spontaneous bladder perforation after augmentation cystoplasty. Urology 62:737Ð741
Ege G, Akman H, Kuzucu K, Yildiz S (2003) Acute ureterolithiasis: incidence of secondary signs on unenhanced helical CT and inßuence on patient management. Clin Radiol 58:990Ð994
Fultz PJ, Hampton WR, Totterman SM (1993) Computed tomography of pyonephrosis. Abdom Imaging 18:82Ð87
Gentle DL, Stoller ML, Jarrett TW et al (1997) Protease inhibitor-induced urolithiasis. Urology 50:508Ð511
Grayson DE, Abbott RM, Levy AD, Sherman PM (2002) Emphysematous infections of the abdomen and pelvis: a pictorial review. Radiographics 22:543Ð561
Hazanov N, Somin M, Attali M et al (2004) Acute renal embolisms. Forty-four cases of renal infarction in patients with atrial Þbrillation. Medicine 83:292Ð299
Joffe SA, Servaes S, Okon S, Horowitz M (2003) Multidetector row CT urography in the evaluation of hematuria. Radiographics 23:1441Ð1456
Kamel IR, Berkowitz JF (1996) Assessment of the cortical rim sign in posttraumatic renal infarction. J Comput Assist Tomogr 20:803Ð806
Kanofskh JA, Lepor H (2007) Spontaneous renal artery dissection. Urology 9:156Ð160
Katz DS, Scheer M, Lumerman JH et al (2000) Alternative or additional diagnoses on unenhanced helical computed tomography for suspected renal colic: experience with 1000 consecutive examinations. Urology 56:53Ð57
Kawashima A, Sandler CM, Ernst RD et al (1999) Imaging of nontraumatic hemorrhage of the adrenal gland. Radiographics 19:949Ð963
Kawashima A, Sandler CM, Emst RD et al (2000) CT evaluation of renovascular disease. Radiographics 20: 1321Ð1340
Levenson RB, Singh AK, Novelline RA (2008) Fournier gangrene: role of imaging. Radiographics 28:519Ð528
Levine E, Grantham JJ (1985) High-density renal cysts in autosomal dominant polycystic kidney disease demonstrated by CT. Radiology 154:477Ð482
Levine J, Neitlich J, Smith RC (1999) The value of prone scanning to distinguish ureterovesical junction stones from ureteral stones that have passed into the bladder: leave no stone unturned. AJR Am J Roentgenol 172:977Ð981
Liach F, Paper S, Massry SG (1980) The clinical spectrum of renal vein thrombosis: acute and chronic. Am J Med 69:819Ð827
Liu CC, Li CC, Shih MC et al (2003) Matrix stone. J Comput Assist Tomogr 27:810Ð813
Luchs JS, Katz DS, Lane MJ et al (2002) Utility of hematuria testing in patients with suspected renal colic: correlation with unenhanced helical CT results. Urology 59:839Ð842
Memarsadeghi M, Heinz-Peer G, Helbich TH et al (2005) Unenhanced multidetector row CT in patients suspected of having urinary stone disease: effect of section width on diagnosis. Radiology 235:530Ð536
Memarsadeghi M, Schaefer-Prokop C, Prokop M et al (2007) Unenhanced MDCT in patients with suspected urinary stone disease: do coronal reformations improve diagnostic performance? AJR Am J Roentgenol 189:60Ð64
Muraoka N, Sakai T, Kimura H et al (2008) Rare causes of hematuria associated with various vascular diseases involving the upper urinary tract. Radiographics 28:855Ð867
Narlawar RS, Raut AA, Nager A et al (2004) Imaging features and guided drainage in emphysematous pyelonephritis: a study of 11 cases. Clin Radiol 59:192Ð197
Poletti PA, Platon A, Rutschmann OT et al (2006) Abdominal plain Þlm in patients admitted with clinical suspicion of renal colic: should it be replaced by low-dose computed tomography? Urology 67:64Ð68
Poletti PA, Platon A, Rutschmann OT et al (2007) Low-dose versus standard-dose CT protocol in patients with clinically suspected renal colic. AJR Am J Roentgenol 188: 927Ð933
Prando A, Prando D, Prando P (2006) Renal cell carcinoma: unusual imaging manifestations. Radiographics 26: 233Ð244
Press SM, Smith AD (1995) Incidence of negative hematuria in patients with acute urinary lithiasis presenting to the emergency room with ßank pain. Urology 45:753Ð757
Ramamoorthy SL, Vasquez JC, Taft PM et al (2002) Nonoperative management of acute spontaneous renal artery dissection. Ann Vasc Surg 16:157Ð162
Rucker CM, Menias CO, Bhalla S (2004) Mimics of renal colic: alternative diagnoses at unenhanced helical CT. Radiographics 24:S11ÐS33
Segura JW, Preminger GM, Assimos DG et al (1997) Ureteral Stones Clinical Guidelines Panel summary report on the management of ureteral calculi. J Urol 158:1915Ð1921
Stunell H, Buckley O, Feeney J et al (2007) Imaging of acute pyelonephritis in the adult. Eur Radiol 17:1820Ð1828
Talner LB, Davidson AJ, Lebowitz RL et al (1994) Acute pyelonephritis: can we agree on terminology? Radiology 192:297Ð305
Talner L, Vaughan M (2003) Nonobstructive renal causes of ßank pain: Þndings on noncontrast helical CT (CT KUB). Abdom Imaging 28:210Ð216
Tamm EP, Silverman PM, Shuman WP (2003) Evaluation of the patient with ßank pain and possible ureteral calculus. Radiology 228:319Ð329
Teichman JMH (2004) Acute renal colic from ureteral calculus. N Engl J Med 350:684Ð693
Thomas AA, Lane BR, Thomas A et al (2007) Emphysematous cystitis: a review of 135 cases. Journal Compilation 100:17Ð20

Vieweg J, The C, Freed K et al (1998) Unenhanced helical computerized tomography for the evaluation of patients with acute ßank pain. J Urol 160:679Ð684
Wan YL, Lee TY, Bullard MJ et al (1996) Acute gas-producing bacterial renal infection: correlation between imaging Þndings and clinical outcome. Radiology 198:433Ð438
Wong-You Cheong J, Woodward PJ, Manning MA, Davis CJ (2006) From the archives of the AFIP: inßammatory and nonneoplastic bladder masses: radiologic-pathologic correlation. Radiographics 26:1847Ð1868
Yanar H, Taviloglu K, Ertekin C et al (2006) FournierÕs gangrene: risk factors and strategies for management. World J Surg 30:1750Ð1754
Zhang JQ, Fielding JR, Zou KH (2002) Etiology of spontaneous perirenal hemorrhage: a meta-analysis. J Urol 167:1593Ð1596