Cross-Sectional Imaging of Acute Pyeloureteritis and Pyonephrosis

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8.1 Computed Tomography (CT) Role and Techniques in Acute Urinary Infections

Albeit with disadvantages of radiation exposure, superior cost compared to ultrasound, and the use of iodinated contrast medium, multidetector computed tomography (CT) currently represents the "workhorse" modality to investigate emergency patients with acute abdominal complaints, fever or elevated acute-phase reactants of unclear source [1–4].

Furthermore, CT is arguably the preferred technique to comprehensively investigate most urologic disorders. Unless contraindicated by history of allergy or renal impairment, contrast medium (CM) administration is recommended to comprehensively assess the renal parenchyma structure, perfusion and function as well as the walls of the collecting systems, ureters and bladder. As most European radiologists do, we suggest to refer to the guidelines from the European Society of Urogenital radiology (ESUR) to prevent CM-induced nephrotoxicity in patients with risk factors. Alternatively, the latest American College of Radiologists (ACR) Manual on contrast media may be used [5, 6].

Nowadays, the widely available fast multidetector scanners allow to image the abdominal organs in well-defined dynamic phases of enhancement. In the setting of suspected urinary infection or abdominal sepsis, the nephrographic phase which acquired 75–100 s after intravenous CM injection provides the maximum detection and visualization of both infectious and solid renal changes and is therefore warranted as the only indispensable acquisition. A preliminary unenhanced phase may allow to detect unilateral renal enlargement, perinephric fat stranding and thickening of Gerota's fascia, coexisting urolithiasis or the presence of blood. However, precontrast phase may be obviated, particularly in younger patients, in order to limit the CT radiation dose administered. Unless characterization of a suspected solid or complex renal mass is required, the corticomedullary phase scan (25–45 s after CM injection) is generally unnecessary, as characteristic imaging appearances of acute pyelonephritis are barely or not perceptible. Additional excretory-phase imaging obtained 8–10 min after CM may be acquired at the discretion of the attending radiologist, is recommended in cases of obstructive uropathy and may be useful to improve characterization in cases of delayed nephrogram, renal hypoattenuating changes or filling defects in the urinary tract. Multidetector CT studies tailored to the urinary tract should be routinely reviewed along both axial

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and coronal planes: the latter provide a panoramic representation the renal and excretory structures and easily allow assessment of renal length, contours and parenchymal enhancement. Image reading using narrow CT window settings may allow an improved identification of perinephric fat changes and of subtle renal hypoenhancing regions [7–13].

8.2 Acute Pyeloureteritis

Due to the widespread use of multidetector CT, acute pyeloureteritis (APU) currently represents a not uncommon finding in cross-sectional studies performed to investigate haematuria, flank pain or suspected urinary tract infection (UTI). Moreover, its characteristic imaging signs are sometimes incidentally encountered in patients with unrelated clinical features: in this situation, the aware radiologist provides the first indication of the presence of an active UTI. APU may be observed in the context of acute pyelonephritis (APN) or cystitis; alternatively, it may represent the only feature suggesting an ongoing ascending UTI, before characteristic renal changes of APN appear. Therefore early CT diagnosis allows preventing further disease progression [8, 12, 14–16].

AT CT, infectious APU is heralded by diffuse, mild or moderate circumferential pelvicalyceal and/or ureteral mural thickening (≥2 mm) with uniform, more or less prominent contrast enhancement corresponding to urothelial inflammation; inflammatory stranding of the peripelvic and periureteral fat is commonly associated (Figs. 8.1, 8.2, 8.3, and 8.4). These

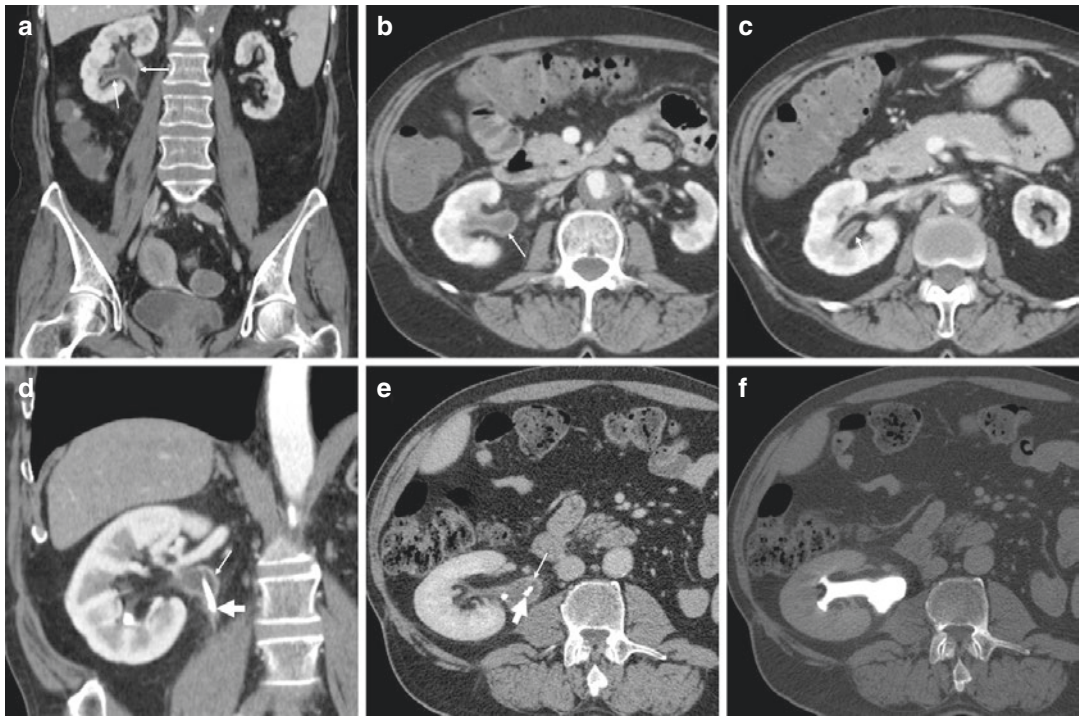

Fig. 8.1 A 59-year-old female with chronic HIV and hepatitis C virus coinfection was hospitalized because of low-grade fever, lumbar pain, dysuria and urinary incontinence. Multiplanar images from contrast-enhanced CT (**a**–**c**) showed mild, uniform, diffusely enhancing pelvicalyceal mural thickening (thin arrows) as the only sign of active urinary tract infection (UTI) from multiresistant *Escherichia coli*; the same finding was absent on the contralateral collecting system. A 69-year-old male with solitary right kidney and urolithiasis was investigated with multidetector CT (**d**–**f**) after retrograde ureteroscopy and stent (thick arrows) positioning. The thin, hyperenhancing mural thickening (thin arrows) was best perceptible in corticomedullary (**d**) and nephrographic (**e**) phase images and obscured in the delayed excretory phase (**f**). Note normal renal parenchymal enhancement and function, calyceal stone at lower renal pole in (**d**)

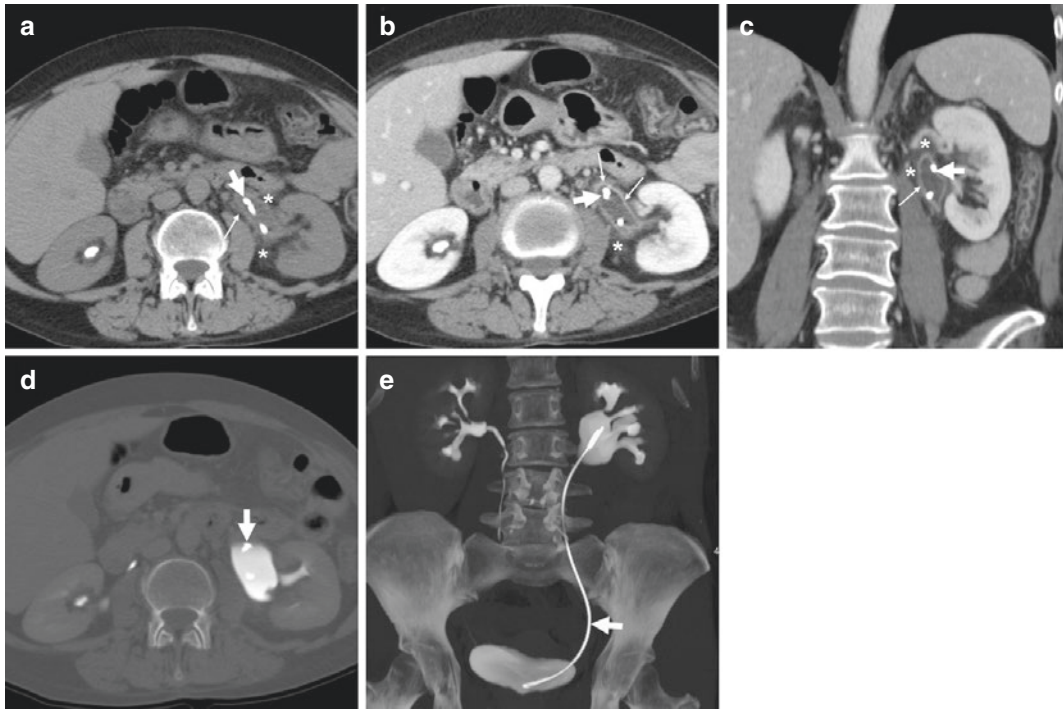

Fig. 8.2 A 59-year-old female suffered from postprocedural fever after left-sided ureteral stenting (thick arrows) to relieve pyeloureteral junction syndrome and underwent CT including unenhanced (**a**), nephrographic (**b**, **c**) and delayed excretory (**d**, **e** with maximum intensity projection reconstruction) acquisition phases. With normal renal function on both sides, the left renal pelvis showed mild-enhancing mural thickening (thin arrows) and subtle inflammatory stranding of the peripelvic fat (*)

CT appearances are often relatively subtle, best perceptible in comparison with the unaffected contralateral side, by far most conspicuous in the nephrographic phase of enhancement, and potentially reversible with successful treatment of UTI (Fig. 8.3). Occasionally, the presence of air within the collecting system or ureter (Fig. 8.5) without previous instrumentation or surgery indicates UTI by gas-forming bacteria [8, 12, 14–16].

Conversely, CT signs consistent with APU are often obscured in the excretory phase because of the decreased mural enhancement and the adjacent high-attenuation-enhanced urine. This is true not only for the usual multiphasic CT studies including preliminary unenhanced, corticomedullary, nephrographic and delayed phases but also for the modern dual or triple split-bolus CT urography techniques which provide combined nephrographic and excretory imaging in a single acquisition [15, 17, 18].

The CT differential diagnosis of APU encompasses tuberculosis, primary urothelial malignancies, ureteral metastases and other uncommon conditions such as ureteritis cystica, amyloidosis and periureteral haematoma (Fig. 8.6). The key consideration is that APU does not narrow nor obstruct the renal pelvis and ureter. Conversely, the identification of focal, asymmetric or mass-forming mural thickening and of filling defects protruding in the renal pelvis or ureteral lumen suggests an underlying malignant process, most usually transitional cell carcinoma (Fig. 8.7). As discussed in the dedicated chapter of this book, urinary tuberculosis results from haematogenous spread and often involves the ureters with

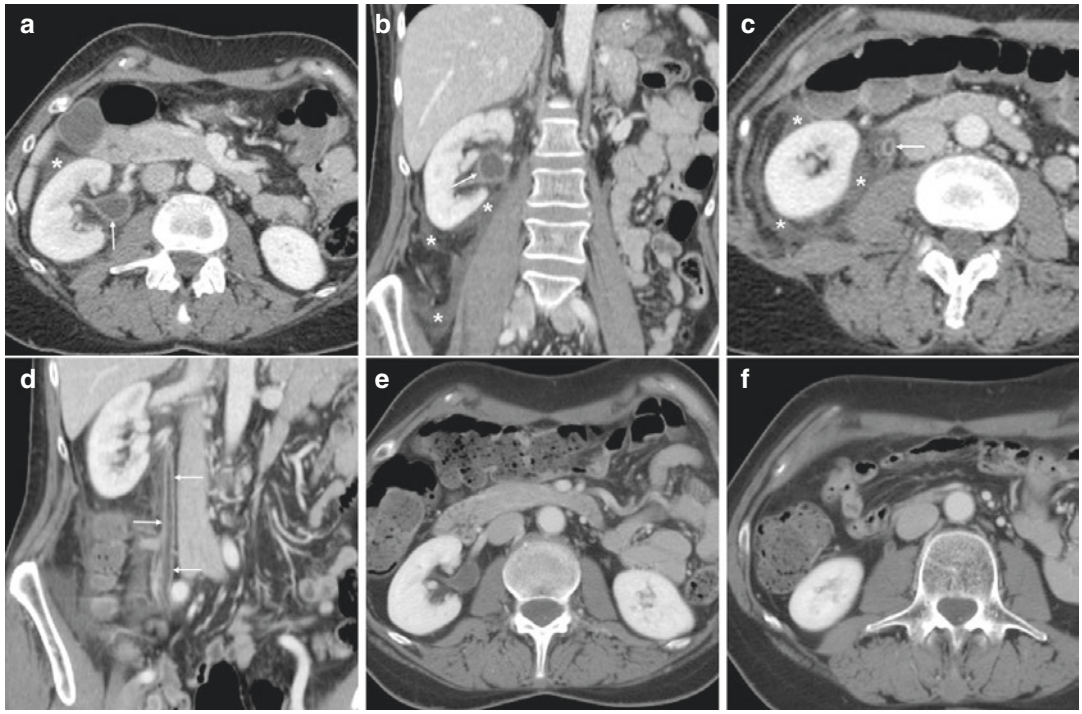

Fig. 8.3 A 49-year-old woman with demyelinating disease suffered from diffuse abdominal pain, emesis and irritative voiding symptoms, without fever. Contrast-enhanced multidetector CT (**a**–**d**) showed normal, symmetric size, parenchymal thickness and enhancement of both kidneys. On the right side, some perinephric and pararenal fluid (*) was present. The ipsilateral renal pelvis showed mild, circumferential mural thickening with urothelial hyperenhancement (thin arrows) compared to the contralateral side, which extended along the ureter and was consistent with an acute ascending UTI without signs of pyelonephritis. Urine cultures disclosed infection from multiple Gram-negative bacteria. After prompt clinical and laboratory improvement on antibiotic therapy, repeated CT (Fig. **e**, **f**) depicted regression of perinephric changes and of pyeloureteritis (Adapted with permission from Ref.no. [21])

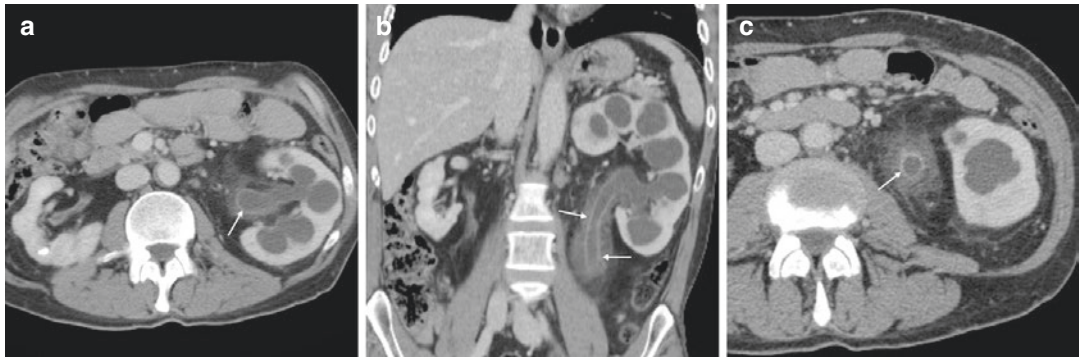

Fig. 8.4 A 44-year-old male had history long-standing HIV infection on antiretroviral treatment, known left-sided hydronephrosis and previously resected nephrogenic adenoma of the urinary bladder. Currently suffering from fever and macroscopic haematuria, he underwent contrast-enhanced CT (**a**–**c**) which showed worsening hydronephrosis compared to previous studies (not shown) with parenchymal thinning and appearance of urothelial enhancement (thin arrows) and of marked periureteral stranding. The patient's clinical conditions and laboratory changes improved after ureteral stenting

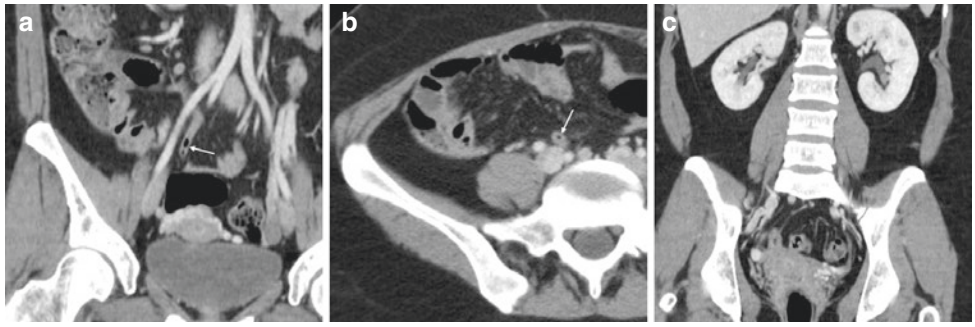

Fig. 8.5 A 34-year-old female suffered from recurrent UTIs after caesarean section a few months earlier. After inconclusive sonography and without previous instrumentation, contrast-enhanced CT showed some air (thin arrows in **a**, **b**) in the right ureter, with minimally thickened walls and inhomogeneous perfusion at the upper third of the contralateral kidney (**c**)

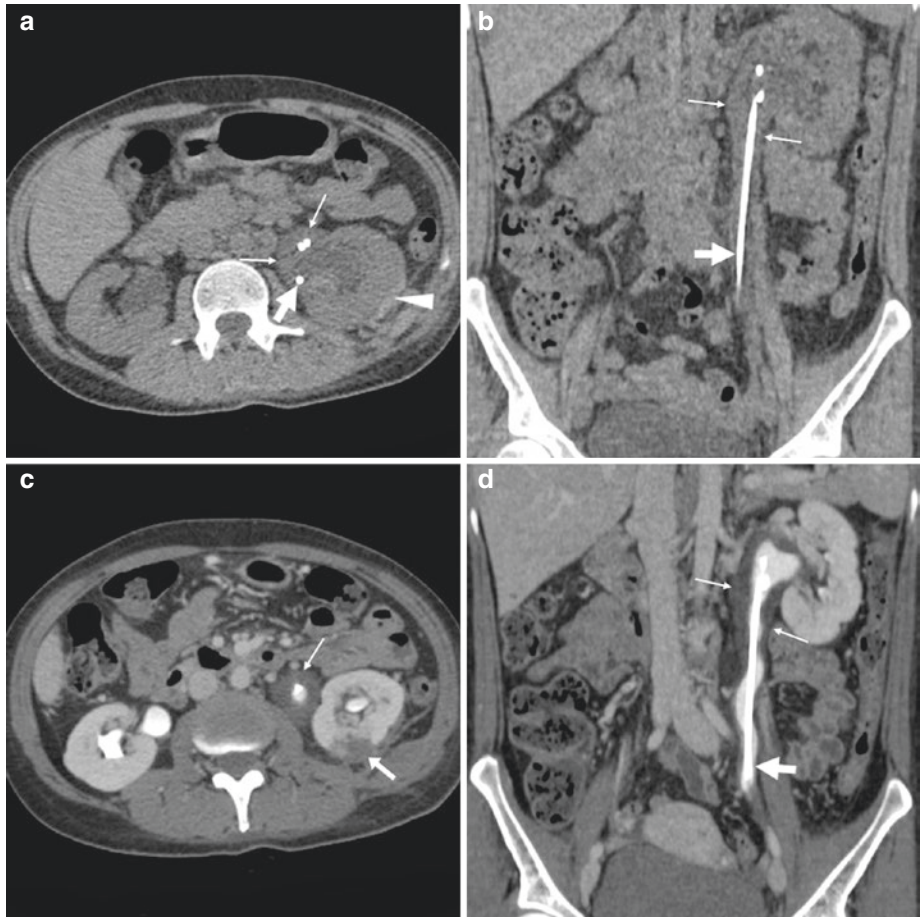

Fig. 8.6 Following percutaneous nephrolithotomy (PCNL) treatment performed to treat a 2-cm left renal pelvis stone, a 46-year-old woman was not discharged because of progressive, asymptomatic haemoglobin drop (nadir 8.4 g/dL). Four days later, unenhanced CT showed ureteral stent (thick arrows) in place, hyperattenuating (50 HU) circumferential mural thickening of the renal pelvis and proximal ureter (thin arrows in **a**, **b**) consistent with suburothelial haemorrhage and minimal blood in the ipsilateral perirenal and posterior pararenal spaces (arrowhead in **a**). CT urography (**c, d**) showed functioning left kidney with a 2-cm devascularized injury (arrow in **c**) at the dorsal middle third and hypodense suburothelial haemorrhage (thin arrows) compared to the well-opacified pyeloureteral lumen. Conservative management including blood transfusions allowed hospital discharge in a few days, normalization of clinical, biochemistry and imaging abnormalities within a month (Reproduced from Open Access Ref. no. [22])

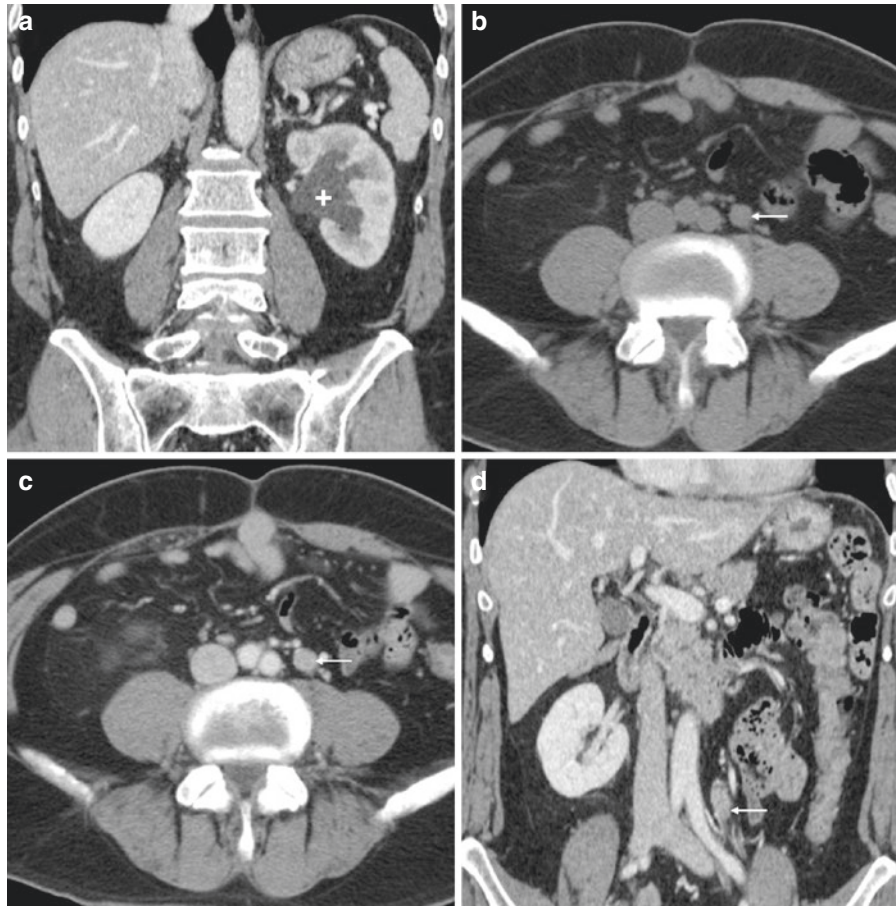

Fig. 8.7 In a 60-year-old male undergoing follow-up for resected colon cancer, multidetector CT (**a**–**d**) showed first-degree hydronephrosis (+) with delayed nephrogram on the left side (**a**). The ipsilateral lumbar ureter (thin arrows) showed higher-than-water precontrast attenuation (**b**) with homogeneous mural enhancement and strictured lumen, corresponding to metachronous transitional cell carcinoma

"ragged" irregular mural thickening, ureteral filling defects, calcification and strictures [14, 15].

8.3 Pyonephrosis

In the context of UTI, hydronephrosis represents a key finding, which requires early diagnosis and immediate treatment. Pyonephrosis, defined by an infected and obstructed collecting system, represents a true urological emergency: if left untreated, it is associated with impending risk of sepsis and rapid and permanent loss of renal function. In the adult population, pyonephrosis may result from either acute or chronic obstruction from lithiasis, tumours, strictures or congenital anomalies with superimposed infection. Clinically, patients with pyonephrosis generally present with the usual signs and symptoms of UTI, but more subtle manifestations such as low-grade fever, malaise, weight loss and dull pain are not uncommon: it has been reported that as many as 15% of patients are afebrile. Practically, pyonephrosis should be suspected in any patient with urinary tract obstruction and accompanying fever and flank pain. As discussed in the interventional radiology chapters of this book, prompt decompression of pyonephrosis should be performed by means of percutaneous nephrostomy or ureteral stenting, to relieve obstruction and also to confirm the diagnosis [8, 12, 19].

Radiologists should maintain a high level of suspicion, since imaging differentiation of pyo-

nephrosis from noninfected dilatation is challenging. Although it readily detects pelvicalyceal dilatation, ultrasound has limited sensitivity for pyonephrosis, which may be confidently diagnosed only when mobile echogenic intraluminal debris or a urine-debris level are visualized within the distended renal collecting system. Pyonephrosis is difficult to distinguish from uninfected hydronephrosis also at CT. Its most specific findings are rarely observed and include:

(a) Gas bubbles within hydronephrosis without history of previous instrumentation
(b) Higher-than-water (10–50 HU) attenuation of the dilated collecting system corresponding to purulent fluid
(c) Contrast layering with opacified urine above dependent purulent urine in excretory-phase acquisition

However, distinguishing simple hydronephrosis on the basis of fluid attenuation measurements is unreliable. As with APU, the key finding which should be always sought for is pelvic mural thickening which has a reported sensitivity of 76% for pyonephrosis (Figs. 8.8 and 8.9). Other useful but nonspecific accessory findings suggesting infection include perinephric fat stranding, thickening of the bridging septa and Gerota's fascia (Figs. 8.8 and 8.9), variable degrees of renal oedematous enlargement with poor nephrographic enhancement or the characteristic "striated nephrogram" of APN.

The key differential diagnosis is acute obstructive uropathy without infection, which is commonly associated with perinephric stranding (Fig. 8.10) and decreased or delayed parenchymal enhancement (Fig. 8.11). However, noninfected acute obstruction generally lacks the characteristic hyperenhancing pyeloureteral thickening and has a detectable obstructing

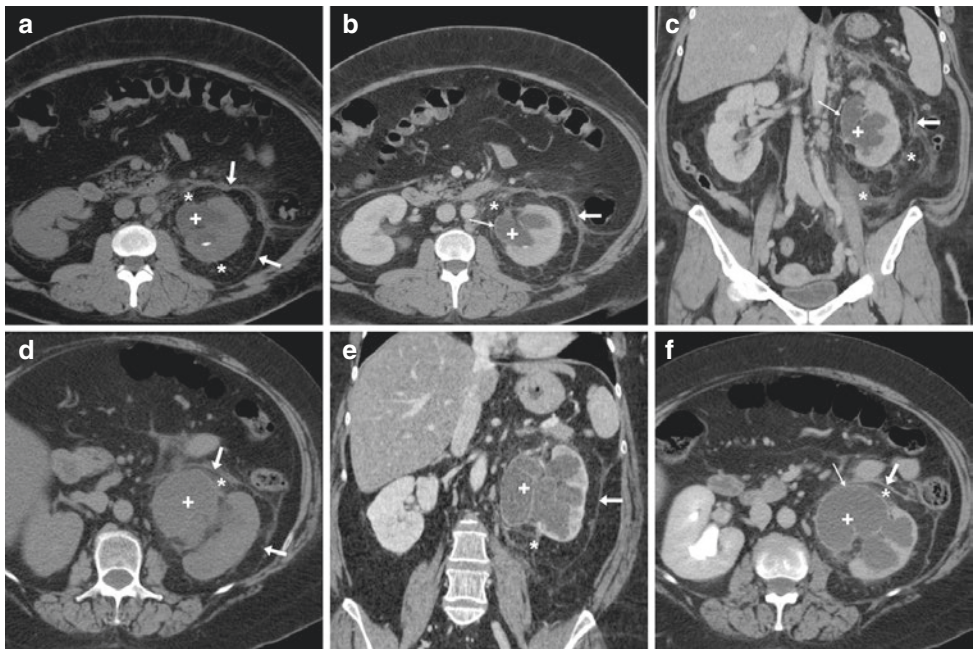

Fig. 8.8 A 40-year-old female experienced septic fever 3 days after a PCNL treatment. Unenhanced (**a**) and contrast-enhanced (**b**, **c**) images showed left-sided pelvicalyceal dilatation with inflammatory-type stranding of the surrounding fat (*), mild-enhancing urothelial thickening (thin arrow in **b**), ipsilateral fascial effusion (arrows) and decreased nephrographic parenchymal enhancement compared to the contralateral kidney. Hydronephrosis was due to small residual stone fragments in the lumbar ureter (not shown). Clinical and imaging suspicion of pyonephrosis was confirmed and relieved by positioning of ureteral stent plus intensive antibiotic therapy (Adapted from Open Access Ref. no. [22]). Analogous pre- (**d**) and post-contrast (**e**, **f**) CT signs were present in a 53-year-old female with history of psychiatric disease and acute lumbar pain, consistent with superimposed UTI on pre-existent pyeloureteral junction stricture, which was relieved by long-term ureteral stenting

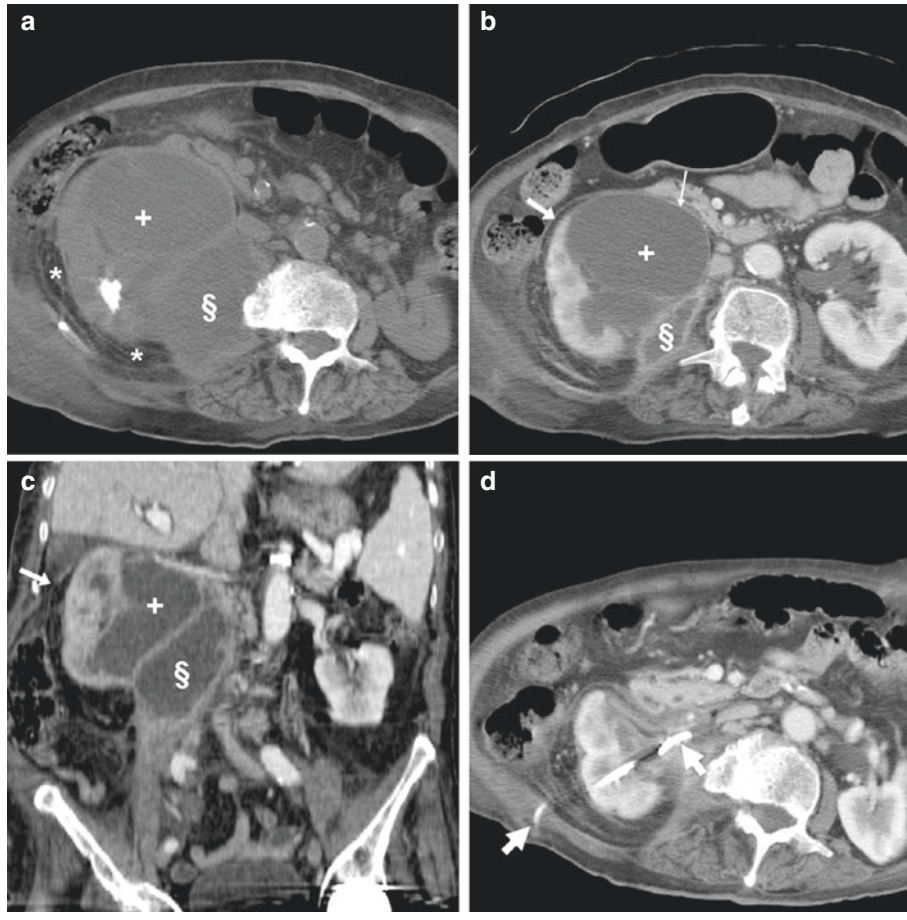

Fig. 8.9 An elderly female with septic fever and abdominal pain had CT diagnosis of severe right-sided hydronephrosis (+) with associated perinephric fat stranding (on unenhanced image **a**), hyperenhancing pyelic wall (thin arrow), fascial effusion (arrows) and psoas muscle abscess (§) in post-contrast images (**b** and **c**). Note calcific calyceal lithiasis in **a**. The picture resolved after percutaneous drainage of psoas abscess and nephrostomy (thick arrow in follow-up CT **d**)

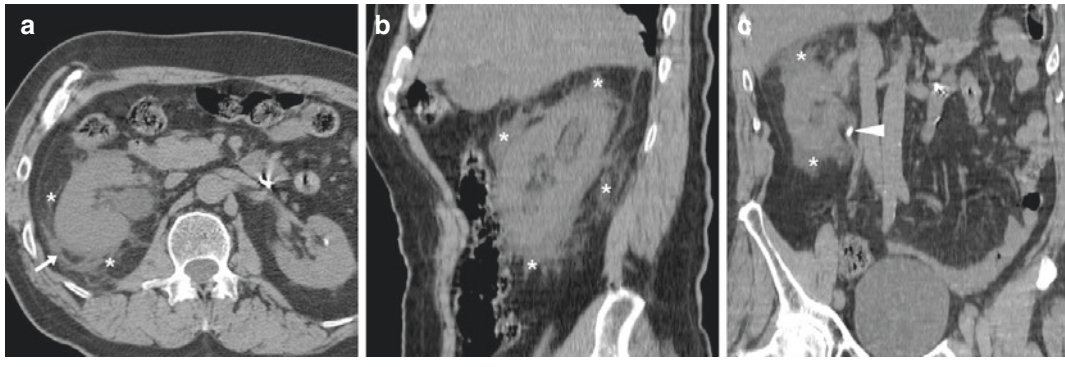

Fig. 8.10 A 78-year-old overweight male suffered from acute right flank pain. Unenhanced CT (urolithiasis protocol, **a**–**c**) showed mild thickening of the renal parenchyma, marked perinephric fat stranding (*) and fascial fluid (arrows) and first-degree hydronephrosis caused by a 6-mm stone (arrowhead in **c**) of the pyeloureteral junction

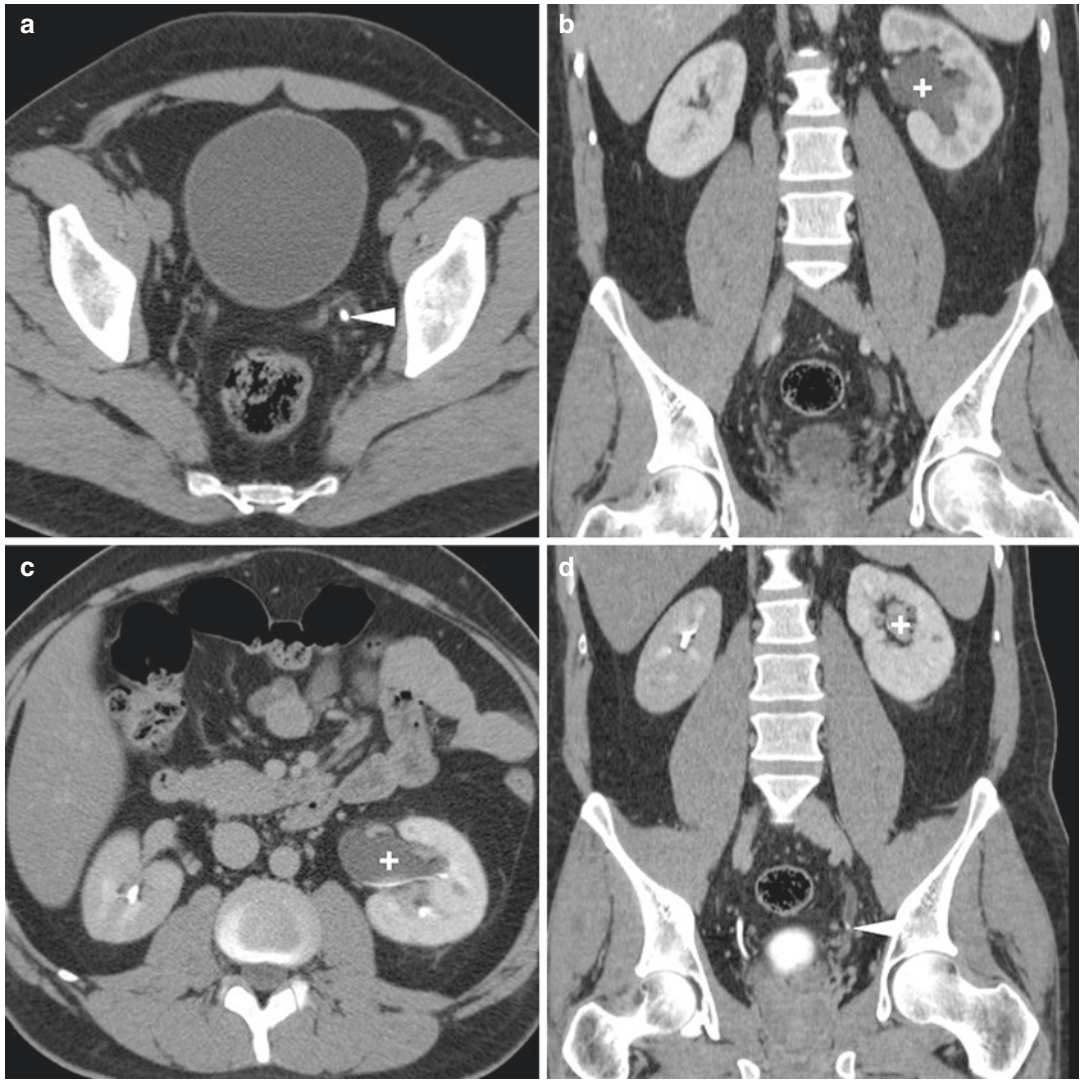

Fig. 8.11 In a 49-year-old male suffering from acute left renal colic, urgent unenhanced CT (**a**) detected a small-sized calculus (arrowhead) of the distal ureter. The attending urologist requested study completion with intravenous contrast (**b**–**d**), which confirmed ipsilateral first-degree hydronephrosis (+) with associated delayed nephrogram (**b**) compared to the contralateral kidney, preserved contrast excretion (**c**, **d**) and persistent ureteral calculus (arrowhead in **d**), without signs of UTI

cause, most commonly a ureteral stone (Figs. 8.10 and 8.11) [8, 11–13, 19].

Although seldom used, MRI consistently depicts the urine-filled collecting system by the use of static-fluid MR urography techniques. In pyonephrosis, dependent debris and fluid-fluid levels may be seen within the dilated urine-filled cavities. Furthermore, increasing reports describe that the use of diffusion-weighted MRI with calculation of apparent diffusion coefficients (ADC) is highly reliable in the differentiation between hydronephroses from pyonephrosis (Fig. 8.12): the infected pelvicalyceal system appears markedly hyperintense on high b-value DWI images, with corresponding very low ($0.64 \pm 0.35 \times 10^{-3}$ mm^2/s) ADC values compared to $2.98 \pm 0.65 \times 10^{-3}$ mm^2/s of noninfected urine [19, 20].

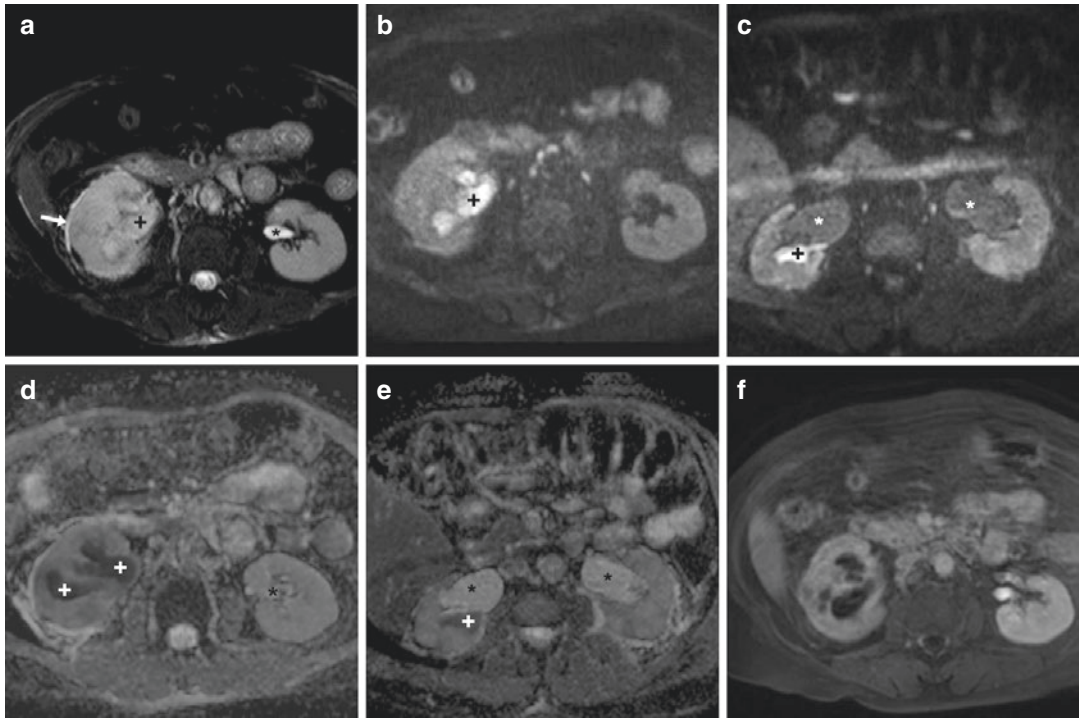

Fig. 8.12 In a 68-year-old male with previous radical cystectomy with ileal conduit (Bricker's technique), fat-suppressed T2-weighted MR image (**a**) showed enlarged right kidney with perinephric fluid (arrows) and hydronephrosis (+) characterized by different signal intensity of urine compared to the contralateral renal pelvis (*). Diffusion-weighted images (**b** value 700) showed visually high signal (+) of urine in the dilated right collecting system consistent with pyonephrosis, forming a fluid-fluid level (in **c**) with the nondependent, noninfected urine with normal low signal (*). Corresponding apparent diffusion coefficient (ADC) maps (**d**, **e**) showed hypointensity from low ADC values in infected (+) compared to noninfected urine (*). Excretory-phase T1-weighted acquisition after intravenous gadolinium contrast (**f**) showed lack of urinary opacification in the right-sided dilated urinary cavities. Pyonephrosis ultimately resolved after 2 months of intensive antibiotic therapy (Courtesy of dr. D.Gned, Hospital "San Luigi Gonzaga", Orbassano—Italy)

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