



CT imaging of acute and chronic pyelonephritis: a practical guide for emergency radiologists

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Abstract

Contrast-enhanced CT is not routinely indicated in uncomplicated urinary infections, but it may be necessary in patients with specific risk factors (i.e., diabetes, immunocompromised patients, history of stones, or prior renal surgery) or in patients not responding to antibiotics and in detecting complications of pyelonephritis. CT is the gold standard for imaging assessment of pyelonephritis severity. Imaging appearance of acute pyelonephritis, including focal (i.e., wedge-shaped zones of decreased attenuation or hypodense mass) and diffuse (i.e., global enlargement, poor parenchymal enhancement, lack of excretion of contrast, fat stranding) forms, needs to be differentiated from renal infarction, renal lymphoma, and interstitial nephritis. Chronic pyelonephritis—which appears as focal polar scars with underlying calyceal distortion, global atrophy, and hypertrophy of residual tissue—may mimic at imaging lobar infarcts. This pictorial essay reviews the CT imaging appearance of acute and chronic pyelonephritis, their uncommon subtypes, and their complications, with key features for early diagnosis. Their knowledge is crucial for emergency and abdominal radiologists to avoid misdiagnosis with malignancy and to guide the clinician towards the appropriate medical or surgical treatment.

Keywords Computed tomography · Imaging · Emergency · Pyelonephritis · Kidney

Background

The diagnosis of urinary tract infections is usually based on clinical data and laboratory tests [1]. Imaging is not required in patients with uncomplicated pyelonephritis who respond to

treatment [2]. Imaging assessment may be necessary in patients with specific risk factors (i.e., diabetes, immunocompromised, history of stones, or prior renal surgery) or in patients not responding to antibiotics and in detecting complications of pyelonephritis [3, 4].

CT is the gold standard for the diagnosis and evaluation of severity of acute pyelonephritis and its complications [5]. Contrast-enhanced CT is needed to define the extent of the disease and identify complications [6]. The recommended CT protocol for renal infections includes a nephrographic phase—which usually begins 80–120 s (commonly 90–100 s) after onset of contrast injection—and an excretory phase if there is obstruction [2, 7]. The accuracy of nephrographic phase CT in the diagnosis of acute pyelonephritis is about 90–92% [8]. When precontrast phase is acquired, reduced dose techniques should be considered [2].

The aim of this pictorial essay was to describe CT imaging appearance of acute and chronic pyelonephritis, their uncommon subtypes, and their complications, with key features for early diagnosis.

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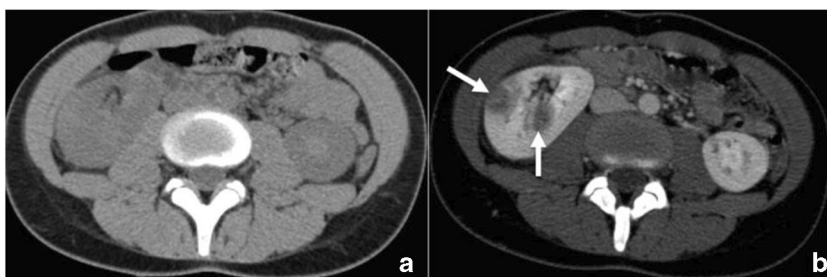
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Fig. 1 A 50-year-old man with acute pyelonephritis of the right kidney. Unenhanced CT scan (a) shows mild enlargement of the right kidney. Axial CT scan in the nephrographic phase (b) shows two focal hypoattenuating areas (arrows)



Acute pyelonephritis

Acute pyelonephritis is a sudden and severe kidney infection and may present as focal or diffuse pyelonephritis.

In patients with focal pyelonephritis, kidneys may appear normal on unenhanced scan [6] or may occasionally show calculi, gas, hemorrhage, calcifications, obstruction, renal enlargement (Fig. 1), or inflammatory masses [9]. Rarely, unenhanced CT may demonstrate some hyperdense areas in hemorrhagic bacterial nephritis [10].

Intravenous contrast agent injection is needed to demonstrate acute nephritis [10]. In the nephrographic phase, focal pyelonephritis is characterized by a poorly defined triangular area of hypoattenuation that extends from the papilla in the medulla to the cortical surface, with or without swelling and reduced corticomedullary differentiation [7] (Fig. 2). These areas tend to have a lobar distribution and can be unifocal, bilateral, or multifocal [10]. These typical areas are probably due to poorly or nonfunctioning parenchyma for vasospasm, tubular obstruction, and/or interstitial edema [11, 12]. Focal pyelonephritis may also demonstrate the so-called striated CT nephrogram, which refers to a typical appearance of high and low attenuation alternate linear areas parallel to the axis of the tubules and collecting ducts (Fig. 3). This pattern is not specific for pyelonephritis and may occur in acute urinary obstruction, renal vein thrombosis, renal contusion, hypotension, medullary sponge kidney, or tubular obstruction due to myoglobinuria [13].

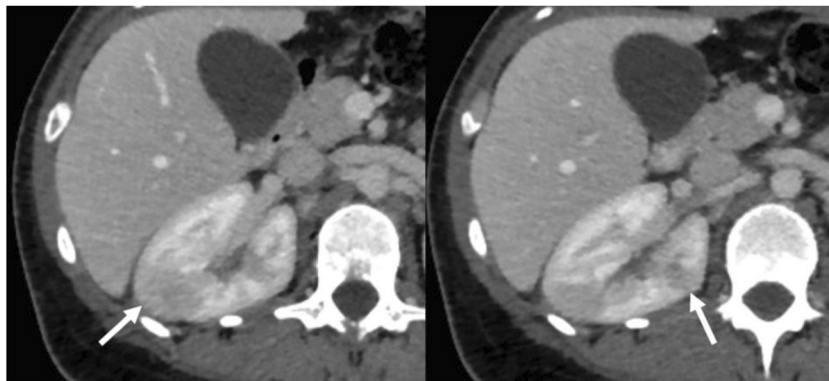
Differential diagnosis of focal pyelonephritis includes renal masses, renal infarction, tumors, or scarring. The

hypoattenuating areas caused by renal infarction and tumors persist after antibiotics, whereas pyelonephritis resolves after appropriate treatment [7]. The cortical rim sign—which describes the thin, viable rim of subcapsular cortex seen on contrast-enhanced images (Fig. 4)—may be helpful for differential diagnosis with acute pyelonephritis: in acute pyelonephritis, the abnormal areas involve a complete wedge of renal parenchyma, extending from medulla peripherally to the capsule, while in up to 50% of segmental renal infarcts there is relative sparing of the cortex with normal cortical perfusion [14]. In acute tubulointerstitial infection, inflammatory infiltrate increases parenchymal pressure within the affected medullary or cortex and may cause the nephrographic reversal sign on delayed phase with decreased enhancement initially and increased attenuation on delayed images compared with the adjacent normal tissue likely due to cellular accumulation in tubules [13].

The diffuse form of acute pyelonephritis may cause global enlargement, decreased enhancement of the kidney, lack of contrast excretion, thickening of Gerota's fascia, stranding of perinephric fat (Fig. 5), and obliteration of perirenal space [5, 7, 15]. Bulging of renal parenchyma may produce compression of calyces; thickening of the wall of pelvis and calices can also be detected [16].

One-third of patients with acute obstructive pyelonephritis have a clinical worsening with septic evolution. Risk factors are diabetes, older age, and elevated serum creatinine [17].

Fig. 2 A 30-year-old woman with pulmonary abscess since 2 months and acute pyelonephritis of right kidney. Contrast CT scan in the nephrographic phase reveals two focal hypoattenuating areas (arrows) in the mesorenal region of the right kidney



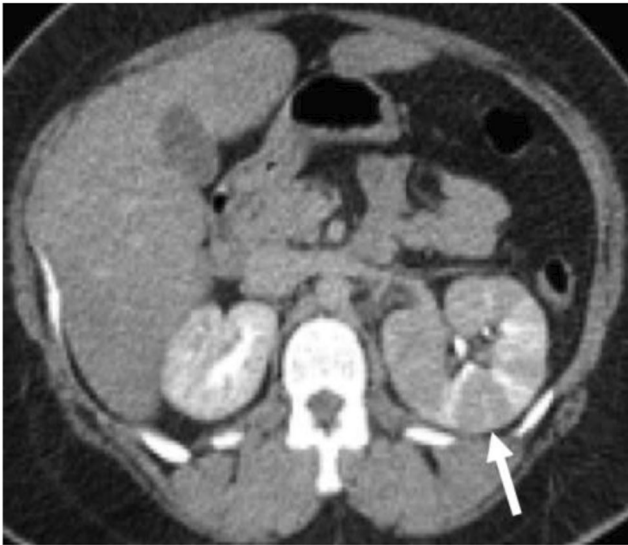


Fig. 3 A 27-year-old woman, acute left pyelonephritis and striated nephrogram. Axial contrast CT image in the delayed phase at 5 min shows global enlargement of left kidney with alternating hyper and hypoattenuating areas (arrow) consistent with striated nephrogram

Chronic pyelonephritis

Chronic pyelonephritis is a chronic pyogenic infection of the kidney usually caused by recurrent episodes of vesicoureteral and infrarenal infected urine reflux in childhood, but it can also be due to other risk factors like calculi and chronic obstruction, neurogenic bladder, urinary diversions, and other causes of stasis [6]. The typical radiologic findings of chronic pyelonephritis are focal scars in the polar regions of the kidney with calyceal distortion, pelvicalyceal dilatation, and global



Fig. 4 A 62-year-old man with renal infarct. Axial CT scan in the excretory phase shows a hypodense area in the mesorenal parenchyma of the left kidney, with the «cortical rim sign» (arrow) due to sparing of the cortex, thus suggesting the diagnosis of segmental renal infarct

atrophy caused by reduced growth of the kidney due to chronic disease; compensatory hypertrophy of contralateral kidney is common. The differential diagnosis of chronic pyelonephritis includes fetal lobulations and lobar infarcts. Fetal lobulations are described like depressions lying between calyces rather than overlying calyces [5], while lobar infarcts can be differentiated because of the typical cortical involvement with calyceal sparing [9].

Subtypes and complications of pyelonephritis

Emphysematous pyelonephritis

Emphysematous pyelonephritis is an uncommon severe acute necrotizing infection of the renal parenchyma which is usually unilateral and more often occurring in women [18–20]. Risk factors are diabetes and immunocompromised status [18, 19].

CT is the most accurate modality to detect gas and define disease extension [21, 22]. CT usually demonstrates multiple small bubbles or linear bands of gas radiating from the papilla. Large gas collections, perirenal fluid, gas–fluid levels, abscesses, and parenchymal destruction can be detected [23].

The Huang and Tseng classification of emphysematous pyelonephritis is the most widely used and provides four classes [23], including presence of gas in the collecting system only (Fig. 6) in class I, parenchymal gas only in class II, extrarenal extension of gas or abscess (Fig. 7) in class III, and emphysematous pyelonephritis in a solitary kidney or bilateral disease in class IV (Table 1).

Class I and II can be treated with antibiotics and percutaneous catheter drainage if there is obstruction. In classes III and IV, percutaneous catheter drainage and antibiotic treatment can be attempted (especially on IIIA stage), while in patients with fulminant and extensive emphysematous pyelonephritis, nephrectomy is necessary [24, 25].

Another classification distinguishes two forms with different severity, prognosis, and management [5], including type 1 characterized by severe parenchymal destruction, intraparenchymal gas, and paucity of pus collection due to a reduced immune response (Fig. 8), and type 2 characterized by less parenchymal destruction, presence of renal or perirenal fluid collections, and lower mortality.

Type 1 is less common than type 2, but more severe with higher risk of mortality (80% vs. 20%) and nephrectomy is usually indicated [5].

Radiologists should differentiate emphysematous pyelitis and emphysematous pyelonephritis: indeed, emphysematous pyelitis is characterized by the presence of air only in the pyelocalyceal system and is less severe compared with emphysematous pyelonephritis [5].

Fig. 5 A 59-year-old woman with acute diffuse pyelonephritis. Axial (a) and coronal reformatted (b) CT images in the nephrographic phase show an enlarged right kidney with small bubbles of gas in the pelvis, diffuse hypoattenuation of the kidney, thickening of right renal septa and perirenal fascia, and edematous imbibition of the surrounding fat

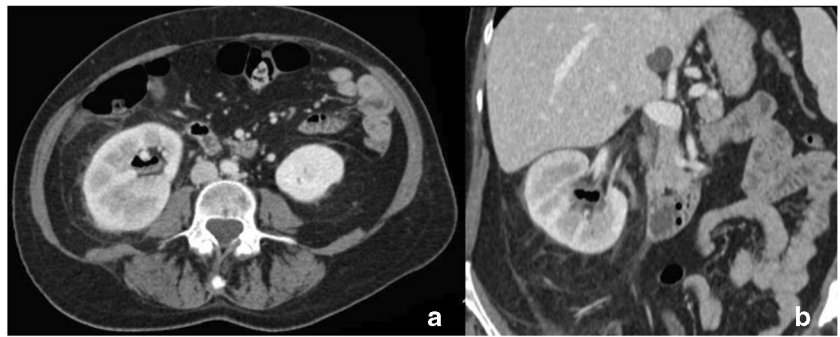


Fig. 6 A 77-year-old man with emphysematous pyelitis. Axial (a) and coronal (b) CT images in the delayed phase show some air bubbles only in the pyelocalyceal system of the left kidney. A staghorn calculus in the renal pelvis causing hydronephrosis is demonstrated

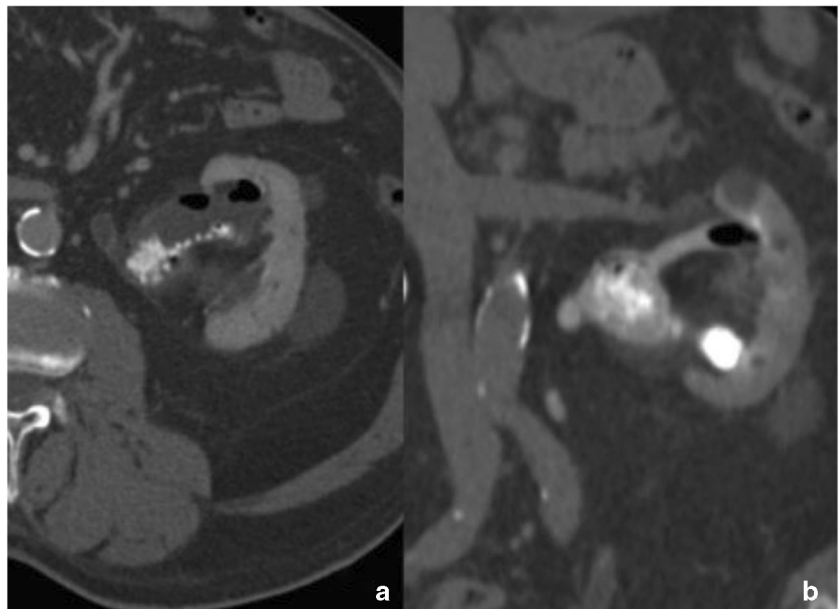


Fig. 7 Axial precontrast CT image in a 64-year-old man with abscess collection and air bubbles in the right kidney (arrow in a) and in the pararenal space (arrows in b), between the kidney and the psoas muscle. In agreement with the nephrologist, intravenous contrast agent was not injected in this patient due to extremely elevated levels of serum creatinine

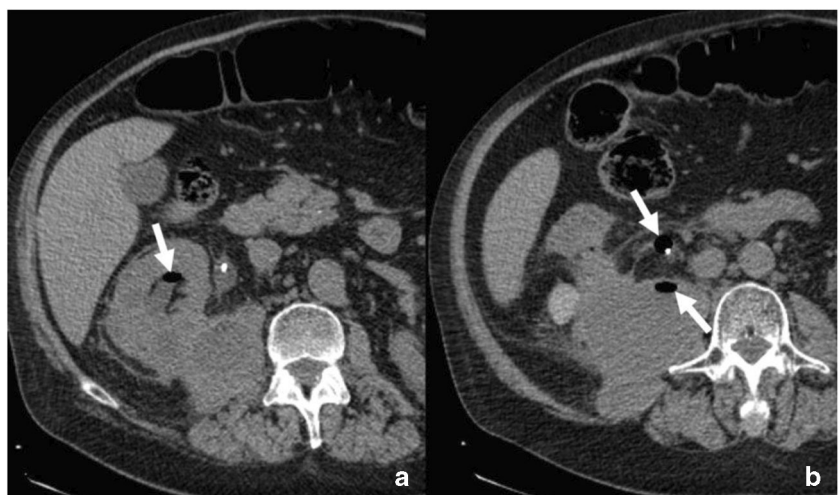


Table 1 Huang and Tseng classification of emphysematous pyelonephritis

Class	CT features
I	Gas in the collecting system only (i.e., emphysematous pyelitis)
II	Gas within the renal parenchyma, but not in the perirenal space
IIIA	Gas or abscess in the perinephric space (i.e., the area between the fibrous renal capsule and renal fascia)
IIIB	Gas or abscess in the pararenal space (space beyond the renal fascia and/or extending to the adjacent tissues such as the psoas muscle)
IV	Bilateral emphysematous pyelonephritis or in a solitary functioning kidney

Xanthogranulomatous pyelonephritis

Xanthogranulomatous pyelonephritis is a rare form of chronic destructive granulomatous process of renal parenchyma associated with long-term urinary tract obstruction, infection, and staghorn calculi [5]. It usually occurs in middle-aged women and it is rarely bilateral.

Symptoms are often not specific and CT is indicated for diagnosis. On CT, xanthogranulomatous pyelonephritis can manifest as diffuse (80%) or focal (15%) forms. Typical CT findings are renal enlargement, calcifications filling the renal pelvis, and replacement of the renal parenchyma by multiple hypodense dilated calyces and abscess cavities filled with pus and debris. These cavities typically show strong enhanced walls after contrast injection, due to the high vascularity of the granulation tissue and thinning of normal parenchyma (Fig. 9).

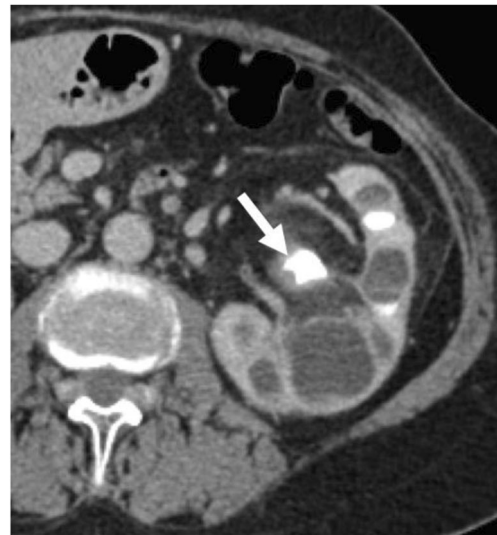


Fig. 9 A 67-year-old woman with xanthogranulomatous pyelonephritis. Axial contrast-enhanced CT images in the nephrographic phase shows global enlargement of the left kidney with multiple fluid-filled cavities filled that give an aspect similar to the footprint of a bear (i.e., bear paw sign) and surrounding inflammatory changes. A staghorn stone is demonstrated in the renal pelvis (arrow)

CT is the best modality to demonstrate the extension and complications of xanthogranulomatous pyelonephritis, which include the following:

- Extension in perinephric space (more common)
- Extension in pararenal spaces, psoas muscle, small bowel, diaphragm, lung, soft tissues of the flank (not common) [26].

Fig. 8 A 79-year-old-man with emphysematous pyelonephritis. CT scan in the axial (a–c) and coronal (d) planes in the precontrast (a), nephrographic (b, d), and excretory (c) phases shows subtotal destruction of the right kidney with sparing of a small portion of renal parenchyma (arrow), but lack of contrast excretion on delayed phase (d)

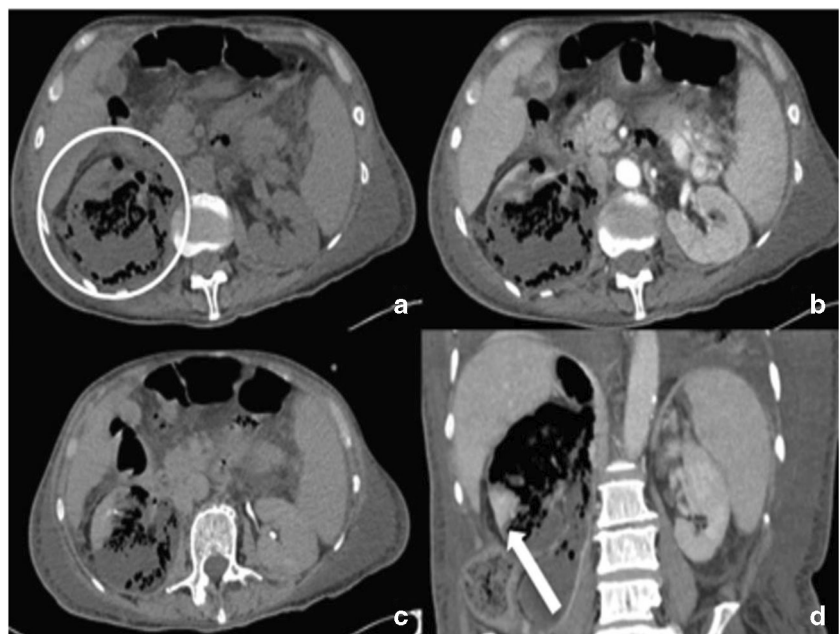
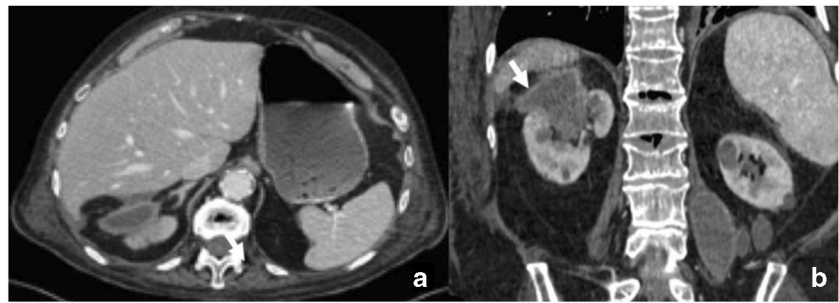


Fig. 10 A 58-year-old man with renal abscess. Contrast-enhanced CT images in the axial (a) and coronal reformatted (b) planes in the corticomedullary phase show in the superior pole of the right kidney a fluid collection (arrows) with well-defined margins and peripheral enhancement



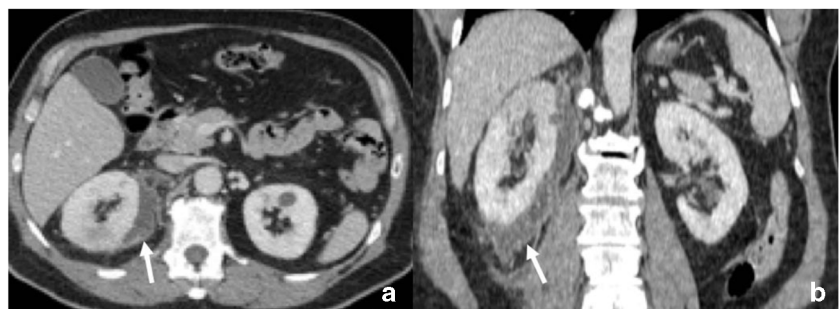
Nephrocutaneous fistula may be a rare complication of xanthogranulomatous pyelonephritis, especially in patients without surgical history. Usually, the involved kidney is poorly functioning and nephrectomy is the indicated treatment [27].

Focal xanthogranulomatous pyelonephritis may occasionally mimic a malignant renal tumor [28].

Renal abscess

Acute pyelonephritis can heal with time or progress to abscess formation if it is not treated properly or the patient is immunocompromised. Lobar nephronia refers to an intermediate stage between acute pyelonephritis and renal abscess. Early abscess is characterized by an ill-defining hypodense area. A mature abscess appears as a well-defined zone of hypoattenuation with a thick, irregular wall or pseudocapsule that demonstrate a peripheral rim enhancement after contrast injection (Fig. 10). The suspicion of an abscess is also suggested by the presence of gas into a low-attenuating or cystic mass [5, 9]. Some small collections can coalesce into a single larger cavity. If there is not any obstruction, the drainage of the abscess usually occurs into the calyces and ureter [6].

Fig. 11 A 63-year-old man with perirenal abscess. Contrast-enhanced CT images in the axial (a) and coronal reformatted (b) planes in the nephrographic phase show a fluid collection in right perirenal space with enhancing wall (arrows) and extends craniocaudally for about 16 cm



Perinephric abscess

A perinephric abscess may be the consequence of the rupture of a renal abscess into the perirenal space or the extra renal extension of acute pyelonephritis. Perirenal abscesses are contained within Gerota's fascia. Risk factors are diabetes and septic emboli. Perinephric abscesses' appearance is a hypoattenuating collection in the perirenal space with or without gas (Fig. 11). Percutaneous or surgical drainage is recommended [9].

Conclusions

In conclusion, most cases of acute pyelonephritis are uncomplicated and do not require imaging assessment. More complicated cases of acute pyelonephritis and chronic pyelonephritis often require imaging with contrast-enhanced CT. Knowledge of CT imaging features of acute and chronic pyelonephritis and their uncommon subtypes and complications is crucial for emergency and abdominal radiologists to avoid misdiagnosis with malignancy and to guide the clinician towards the appropriate medical or surgical treatment.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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