CT of Renal Inflammatory Disease[1]

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Although computed tomography (CT) is not routinely indicated in uncomplicated renal infection, it is of value in establishing the diagnosis in equivocal cases, in evaluating high-risk patients, and in determining the extent of disease. Unenhanced CT is useful in demonstrating gas, calculi, parenchymal calcifications, hemorrhage, and inflammatory masses. However, a contrast material–enhanced study is essential for complete evaluation of patients with renal inflammatory disease to demonstrate alterations in renal excretion of contrast material that occur as a result of the inflammatory process. In severe acute pyelonephritis, enhanced CT scans obtained during the cortical nephrographic phase typically demonstrate solitary or multifocal areas of hypoattenuation with loss of the corticomedullary interface. Delayed CT scans obtained during the excretory phase are frequently more helpful than early CT scans in defining the extent of the disease process, identifying complications such as renal abscess, and confirming the presence of urinary obstruction.

■ INTRODUCTION

Although not routinely indicated in uncomplicated pyelonephritis, computed tomography (CT) plays an important role in establishing the diagnosis in clinically equivocal cases of renal infection, in evaluating high-risk patients, and in determining the extent of disease in suspected complicated cases (1–4). Unenhanced CT is useful in demonstrating calculi, gas-forming infections, hemorrhage, and parenchymal calcifications. Contrast material–enhanced CT is crucial in diagnosing renal inflammatory disease because it allows evaluation of renal excretion of the contrast material. With the introduction of slip-ring (helical or spiral) fast CT, understanding the CT appearances of the normal and abnormal nephrogram is important for accurate diagnosis of acute and chronic inflammatory diseases of the kidney.

Abbreviation: AIDS = acquired immunodeficiency syndrome

Index terms: Kidney, CT, 81.1211 • Kidney, diseases, 81.21 • Kidney, infection, 81.21 • Nephritis, 81.21

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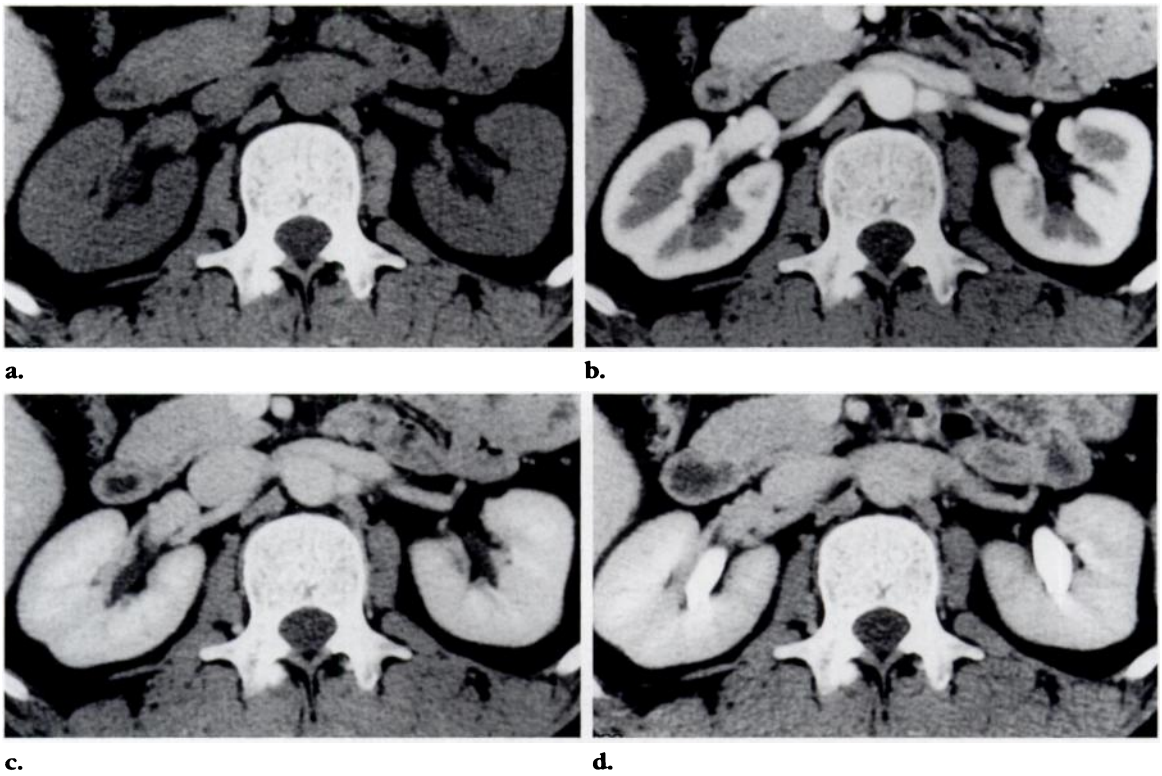


Figure 1. Normal CT appearance of nephrographic progression. **(a)** Unenhanced CT scan through the kidneys. **(b)** CT scan obtained 20–45 seconds after beginning contrast material administration shows a cortical nephrogram with a clear corticomedullary interface. **(c)** CT scan obtained at 45 seconds to 2 minutes shows a generalized nephrogram. **(d)** CT scan obtained at 2–3 minutes shows contrast material in the collecting system.

In this article, we describe normal nephrographic development at CT and the technical aspects of CT of renal inflammatory disease, with emphasis on state-of-the-art helical rapid volumetric acquisition. The spectrum of CT features of acute and chronic renal inflammatory disease is illustrated with representative cases from our experience of over 100 cases evaluated with helical CT. Special emphasis is also placed on CT features of inflammatory renal disease in patients with urinary tract obstruction, diabetes mellitus, acquired immunodeficiency syndrome (AIDS), renal transplants, and other immunocompromised states. These are the patients most likely to have complications (eg, abscess).

■ NORMAL NEPHROGRAPHIC DEVELOPMENT AT CT

Familiarity with time-attenuation relationships is essential for analysis of images of the normal and abnormal kidneys and collecting systems (5,6) (Fig 1). The CT appearance of renal enhancement after intravenous administration of contrast material can be categorized into four phases: vascular, cortical (corticomedullary junction) nephrographic, parenchymal (generalized) nephrographic, and excretory. Renal vascularity is evaluated during the vascular phase, approximately 10–15 seconds after beginning intravenous contrast material administration. A hyperattenuating cortical nephrogram with corticomedullary differentiation is obtained during the cortical nephrographic phase, generally 20–45 seconds after contrast material injection (Fig 1b). In this phase, normal renal anatomy can be exquisitely characterized. Scans obtained during the parenchymal nephrographic phase, generally 45 seconds to 2 minutes after contrast material administration, reveal homogeneous, uniform increased attenuation of the renal parenchyma (Fig 1c). In the excretory phase, contrast material starts to appear in the collecting system approximately 2–3 minutes after contrast material administration (Fig 1d). The precise timing of the various phases depends on the acquisition technique, the amount of con-

trast material and rate of administration, the cardiac output, the integrity of the renal vasculature, and the amount of renal function.

■ CT TECHNIQUE

Careful consideration of the CT technique is necessary to ensure optimal detection of pathologic changes. Our current CT protocol for the initial evaluation of renal infections consists of pre- and postcontrast CT scans unless the patient has a contraindication to iodinated contrast medium. With helical volumetric acquisition, contrast-enhanced CT should be started approximately 50–90 seconds after the initiation of intravenous contrast material administration so that a delayed cortical nephrographic phase or the parenchymal nephrographic phase can be imaged (5–7). Rapid bolus injection of 100–150 mL of 60% nonionic iodinated contrast material (iohexol [iodine, 300 mg/mL]) or 100 mL of 66% nonionic iodinated contrast material (iohexol [iodine, 330 mg/mL]) can be performed at a rate of 2–3 mL/sec with a mechanical power injector. Scanning parameters include 4–8-mm collimation and a pitch of 1.0–1.3. Scans through the kidneys should be performed during one breath hold to maximize the advantage of a volume data set without misregistration, if feasible. Delayed CT scans of the kidneys as well as the lower urinary tract are necessary when urinary obstruction, a delayed or persistent nephrogram, filling defects in the urinary tract, or focal areas of hypoattenuation in the nephrogram suggestive of abscess are noted on early-phase scans.

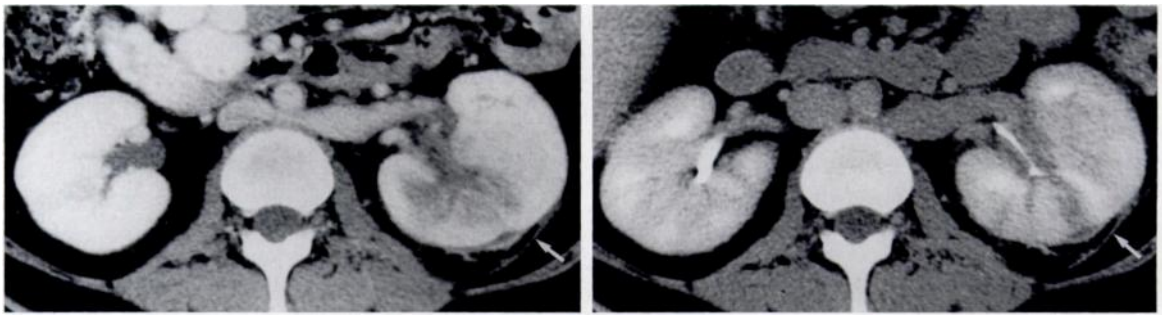
■ ACUTE RENAL INFECTION

• Acute Pyelonephritis

In acute pyelonephritis, the use of CT is usually reserved for patients whose clinical diagnosis is unclear, patients who fail to respond to conventional medical treatment, diabetic patients, and other immunocompromised patients (1–3). Bacterial renal infections, except those caused by gram-positive organisms, occur via the ascending route and span a continuum of varying severity from uncomplicated acute pyelonephritis through progressively worsening stages of interstitial inflammation to frank abscess formation (8). Because histologic specimens are difficult to obtain, exact clinical correlation with these various stages of inflammation is impossible. Therefore, the primary value of CT is in delineating the extent of the disease process and identifying significant complications such as renal emphysema and abscesses with or without perirenal extension or the presence of urinary obstruction (4,8–10).

With the advent of cross-sectional imaging, radiologists began using new terms to describe various degrees of parenchymal change on the basis of imaging studies without pathologic correlation, causing a great deal of confusion. In an effort to simplify the terminology used to describe acute renal inflammatory disease, the Society of Uroradiology has suggested the following nomenclature to describe the extent of the urologic findings in patients with acute pyelonephritis: (*a*) unilateral or bilateral, (*b*) focal or diffuse, (*c*) focal swelling or no focal swelling, and (*d*) renal enlargement or no renal enlargement (11).

A striated nephrogram on a conventional CT scan obtained during the excretory phase is typical of acute pyelonephritis (12,13). However, the precise CT features depend on the severity and extent of the disease process, the evolution or involution of the infection, the status of host immune defense mechanisms, the presence of urinary obstruction, and the timing of the CT scan. Helical scans obtained during the cortical and parenchymal nephrographic phases demonstrate wedge-shaped areas of hypoattenuating cortex and poor corticomedullary differentiation, probably corresponding to lobar or sublobar segments with hypoperfusion and edema (Figs 2, 3) (14). Delayed CT scans obtained during the excretory phase reveal smaller wedge-shaped areas of diminished enhancement than can be seen on the earlier views and show linear bands of alternating hyper- and hypoattenuation parallel to the axes of the tubules and collecting ducts (Fig 2). This appearance has been attributed to diminished concentration of contrast material in the tubules from ischemia and tubular obstruction by inflammatory cells and debris (12,13).



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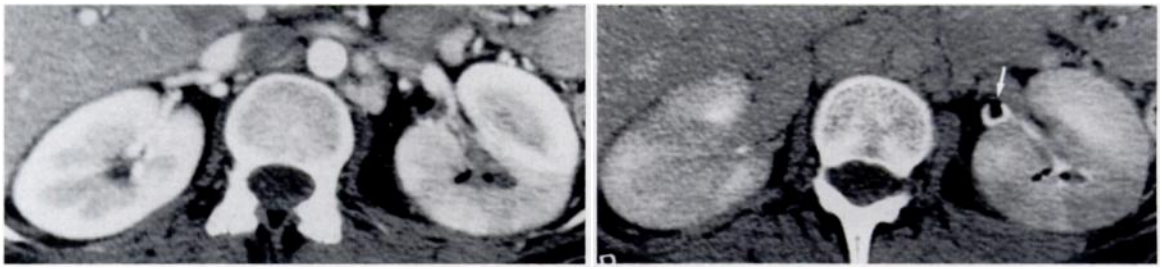


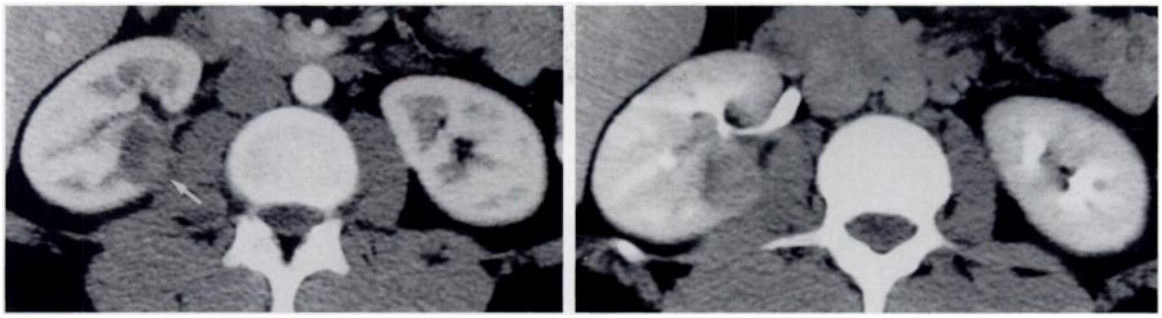
3a. 3b.

Figures 2, 3. **(2)** Acute pyelonephritis in a 44-year-old diabetic woman. A urine culture was positive for *Escherichia coli*. **(a)** Enhanced helical CT scan during the parenchymal nephrographic phase shows a wedge-shaped area of hypoattenuation in the left kidney with poor corticomedullary differentiation. **(b)** Helical CT scan during the excretory phase shows a striated nephrogram in the corresponding area. The CT features in **a** were considered better appreciable than that in **b**. Note the obliteration of the renal sinus, thickening of the wall of the collecting system, minimal subcapsular fluid, and thickened Gerota fascia (arrow in **a** and **b**) on the left side. A retroaortic left renal vein is incidentally noted. **(3)** Acute pyelonephritis with gas in the collecting system in a 51-year-old diabetic woman. A urine culture was positive for *E coli*. **(a)** Enhanced helical CT scan during the cortical nephrographic phase through the left kidney shows a wedge-shaped area of low attenuation with loss of corticomedullary differentiation. **(b)** Delayed CT scan during the excretory phase shows these features less distinctly. Note the gas in the left renal collecting system and pelvis (arrow).

In our experience with 14 cases of acute pyelonephritis studied with CT during both the cortical or parenchymal nephrographic phase and the excretory phase (unpublished data), the extent of the disease process was demonstrated better with early CT than delayed CT in three cases (21%) (Figs 2, 3), equally well with early CT and delayed CT in five cases (36%) (Fig 4), and better with delayed CT than early CT in six cases (43%) (Fig 5). In some cases, CT during the cortical or early parenchymal nephrographic phase can demonstrate the anatomic distribution of the inflammatory process better than delayed CT. However, early CT may not depict a subtle alteration in the nephrogram from minimal parenchymal inflammation.

Further-delayed CT may show persistent enhancement that corresponds to the area of early diminished enhancement (15). In a recent report by Dalla-Palma et al (16), delayed CT performed 3 hours or longer after contrast material administration was reported to be more useful than early CT in evaluating the extent of infection. Delayed scans are of value if delayed enhancement of renal parenchyma is demonstrated; this finding confirms the presence of functioning renal parenchyma, thereby excluding true abscess formation.

In hemorrhagic bacterial nephritis, an uncommon manifestation of acute renal infection, unenhanced CT demonstrates wedge-shaped or rounded areas of increased attenuation due to parenchymal bleeding (17). CT commonly demonstrates other signs of renal infection including soft-tissue stranding and thickening of the



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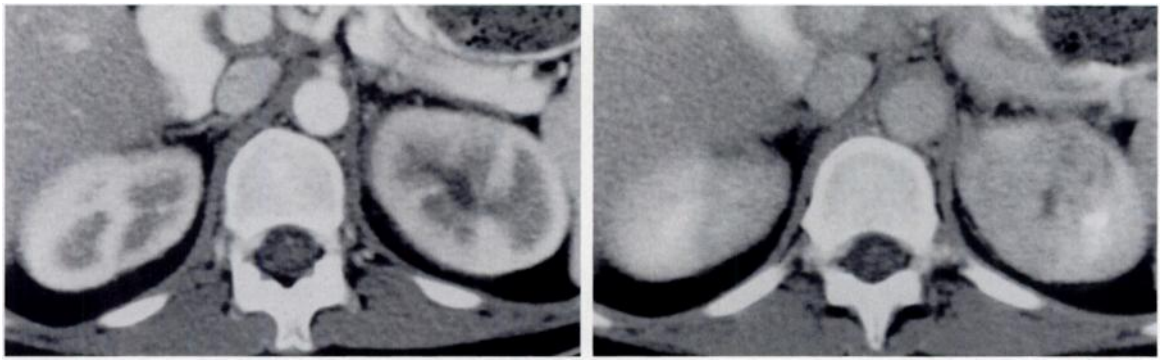


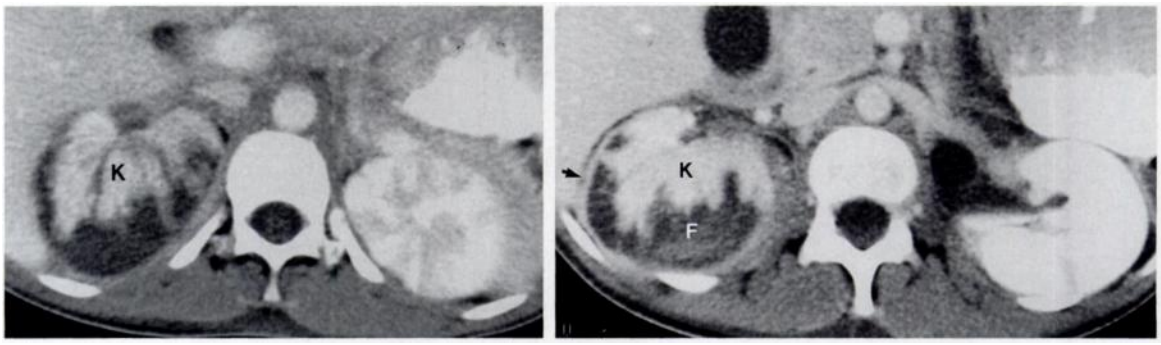
5a. 5b.

Figures 4, 5. **(4)** Acute pyelonephritis in a 27-year-old woman with irritation of the psoas muscle. **(a)** Enhanced helical CT scan during the cortical nephrographic phase through the right kidney shows a focal area of low attenuation with loss of the corticomedullary interface. Note the obliteration of the perirenal fat plane between the right kidney and psoas muscle (arrow). **(b)** Delayed CT scan during the excretory phase shows partial enhancement of the area of low attenuation. **(5)** Acute pyelonephritis in a 25-year-old insulin-dependent diabetic woman. **(a)** Enhanced helical CT scan during the cortical nephrographic phase through the upper kidneys shows a near-normal cortical nephrogram. **(b)** Helical CT scan during the excretory phase clearly shows a hypoattenuating nephrogram of the upper poles of the kidneys, which is more prominent on the left side than on the right.

Gerota fascia (Fig 2), obliteration of the renal sinus and caliceal effacement due to adjacent affected renal parenchyma (Fig 2), thickening of the walls of the pelvis and calices (Fig 2), and mild dilatation of the renal pelvis and ureter. Soft-tissue filling defects in the collecting system may represent sloughed tissue from papillary necrosis, inflammatory debris, or blood clots. Excretory urography remains necessary to diagnose papillary necrosis, especially in diabetic patients with hematuria. Gas may also be present in the collecting system. Helical CT may demonstrate gas more frequently than conventional CT (Fig 3).

• Renal and Perirenal Abscesses

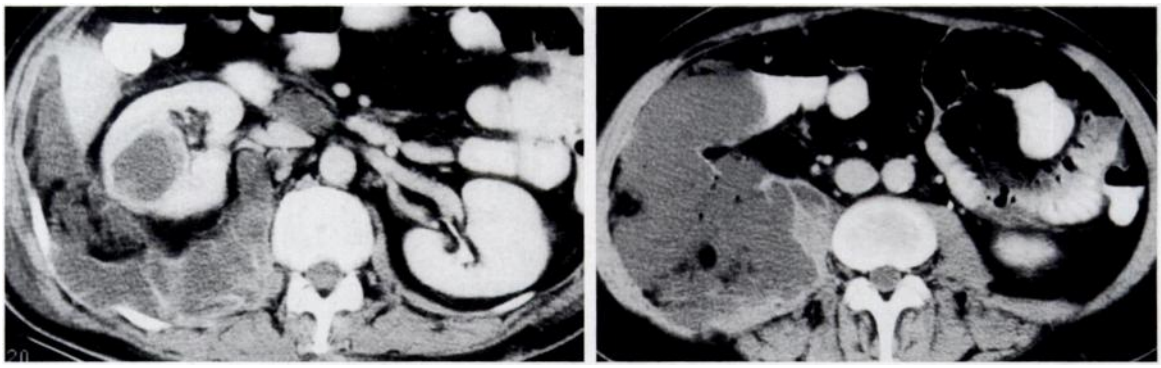
CT is currently the most accurate modality for detection and follow-up of renal abscesses (9,10). In most cases of acute pyelonephritis, the inflammatory process is reversible, but severe vasospasm and inflammation may occasionally result in liquefactive necrosis and abscess formation (Fig 6). An abscess usually appears as a well-defined mass of low attenuation with a thick, irregular wall or pseudocapsule, which is better imaged with contrast enhancement (Fig 7) (9,10). Gas within a low-attenuating or cystic mass strongly suggests abscess formation (18). Renal parenchyma around the abscess cavity may appear poorly enhanced on early views; the hypoattenuating renal parenchyma may appear hyperattenuating on delayed views (Fig 8). Fascial and septal thickening and perinephric fat obliteration are usually present.



a. b.

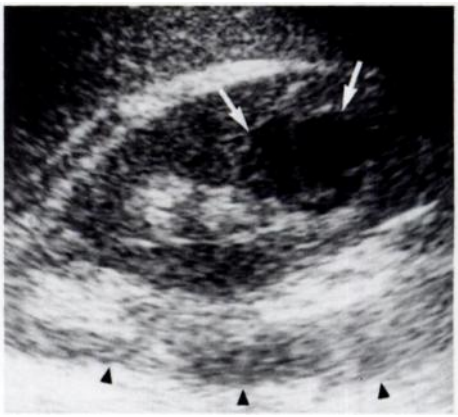
c.

Figure 6. Postinflammatory renal necrosis and abscess in a 23-year-old postpartum woman with a history of substance abuse. **(a, b)** Enhanced CT scans (**a** obtained at a higher level than **b**) show a subcapsular, high-attenuating fluid collection (*F* in **b**) and irregular contour of the right kidney (*K*) associated with capsular enhancement (arrow in **b**). Note the striated nephrogram in the left upper kidney in **a**. Cultures of urine and the fluid collection were positive for *E coli*. **(c)** Two-month follow-up helical CT scan after successful percutaneous drainage shows scarring of the right kidney.



b. c.

Figure 7. Renal abscess with extensive retroperitoneal and pelvic extension in a 42-year-old man. **(a)** Longitudinal sonogram of the right kidney shows a 3 × 4-cm, complex, cystic mass with an irregular wall and septum (arrows). Note the hypoechoic layer posterior to the right kidney (arrowheads). **(b)** Enhanced helical CT scan shows a thick-walled cystic mass in the right kidney, which is displaced by large right perirenal and pararenal fluid collections. **(c)** CT scan above the iliac crest shows a large retroperitoneal abscess involving the right iliopsoas muscle and displacing the right colon.



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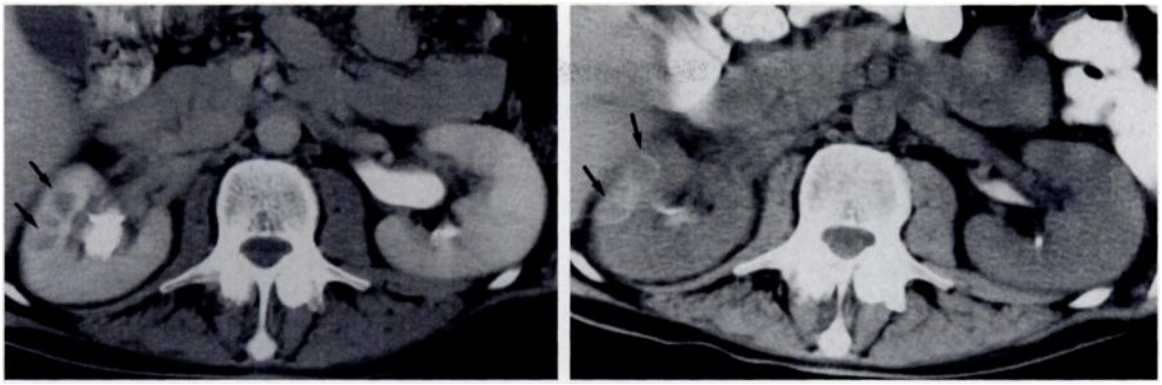
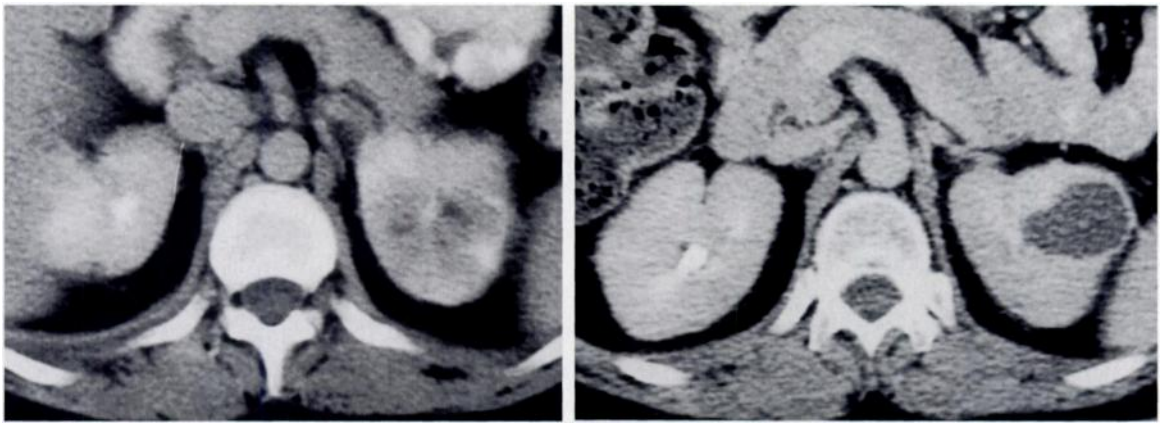


a. b.

Figure 8. Presumed microabscesses in a 37-year-old man with a long-standing right ureteral stent. **(a)** Enhanced CT scan through the right kidney shows several small, hypoattenuating lesions (arrows). **(b)** Repeat CT scan after stent replacement shows hyperattenuating rims (arrows) around the sites of the hypoattenuating lesions in **a**. No discrete area of fluid attenuation is present.

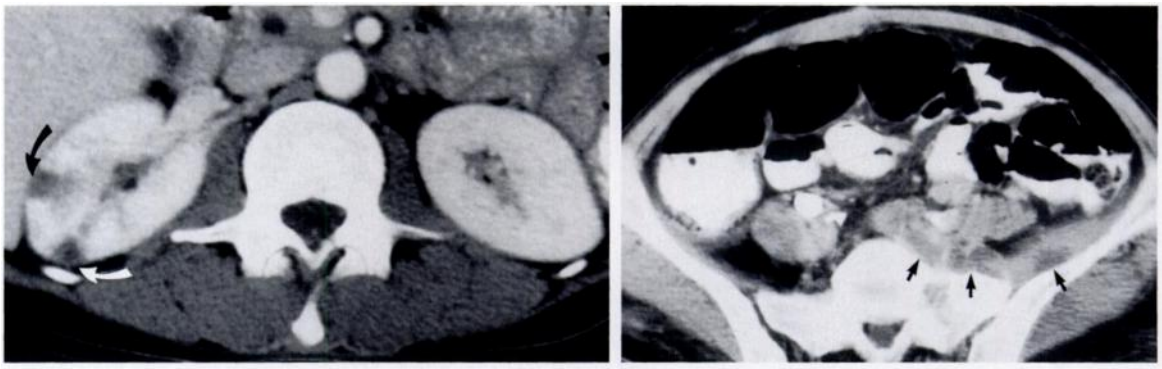


a. b.

Figure 9. Postinflammatory cystic fluid collection in a 55-year-old diabetic woman 1 month after antibiotic treatment for acute pyelonephritis. Brownish fluid was obtained with CT-guided needle aspiration, but no organisms grew in the culture medium. **(a)** Enhanced helical CT scan through the superior left kidney shows a striated nephrogram. **(b)** Follow-up enhanced helical CT scan 1 month later shows interval development of an approximately 2 × 3-cm fluid collection in the upper left kidney. Neither thickening nor enhancement of the collection wall is present.

A perinephric abscess may result from rupture of a renal abscess into the perirenal space but most often develops directly from acute pyelonephritis. Perirenal abscesses may also develop from extension of inflammatory disease outside the Gerota fascia. Diabetic patients with calculi and patients with septic emboli are particularly prone to this complication. On CT scans, perinephric abscesses appear as areas of soft-tissue or fluid attenuation within the perirenal space. Abscesses may involve the psoas muscle and may extend to the pelvis and groin (Fig 7). Gas may occasionally be present. Percutaneous or surgical drainage may be indicated.

Rarely, a postinflammatory cystic fluid collection may develop in an area of acute pyelonephritis during or after antibiotic treatment. These collections are usually small (<3 cm in diameter) without appreciable thickening or enhancement of the wall of the collection (Fig 9). However, CT-guided needle aspiration may be required to exclude an abscess.



a. b.

Figure 11. Septic emboli to the kidney and contralateral psoas abscesses in a 40-year-old woman with subacute bacterial endocarditis and a history of drug abuse. A blood culture was positive for methicillin-resistant *S aureus*. **(a)** Enhanced helical CT scan through the right kidney shows small, peripheral lesions of low attenuation (arrows). **(b)** CT scan through the pelvic brim shows hypoattenuating fluid collections anterior to and to the left of the sacrum and in the left iliac muscle.

• Emphysematous Pyelonephritis

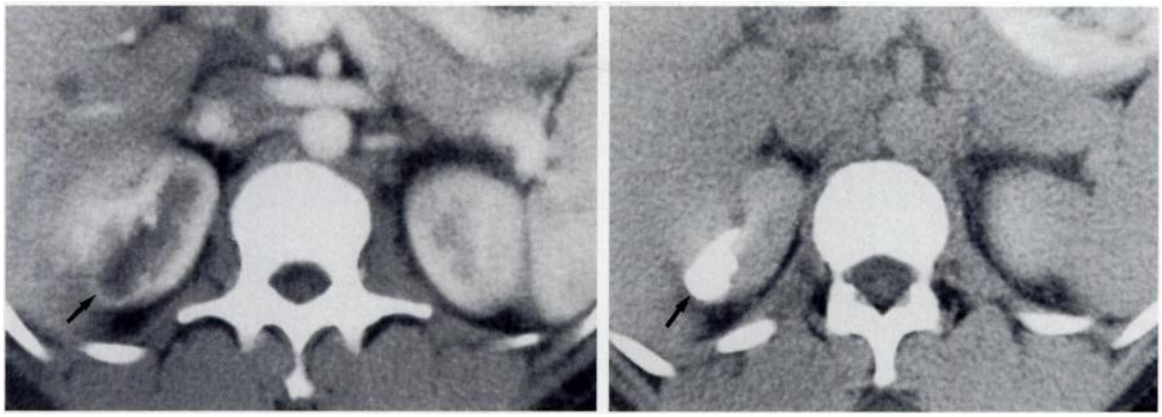
Emphysematous pyelonephritis is a fulminant, gas-forming infection of the renal parenchyma (19,20). Most patients have uncontrolled diabetes mellitus and present with symptoms of severe acute pyelonephritis, urosepsis, or shock. *E coli*, *Klebsiella pneumoniae*, and *Proteus mirabilis* are the most common organisms. Calculi may also be present. CT is the best modality for detecting gas and for defining the extent of the disease (Fig 10) (18,21). CT is also of value in identifying and localizing gas in the renal parenchyma; the subcapsular, perinephric, or pararenal space; the collecting system; or occasionally the vascular system (Fig 10).

Gas can be limited to the renal collecting system (Fig 3), ureter, or bladder; gas in these locations is distinct from true emphysematous pyelonephritis and has a better prognosis (22). In a recent study by Wan et al (21), acute gas-forming bacterial infection of the kidneys was classified into two types on the basis of CT and plain radiographic features. Classic emphysematous pyelonephritis is characterized by parenchymal destruction, streaky or mottled gas, and little or no fluid. This entity has a worse prognosis than renal infection, which is characterized by renal or perirenal fluid collections with bubbly or loculated gas in the parenchyma or collecting system.

Figure 10. Emphysematous pyelonephritis in a 62-year-old woman with poorly controlled diabetes and disseminated intravascular coagulopathy who was in a coma. Unenhanced CT scan shows an enlarged left kidney with extensive gas in the renal parenchyma, collecting system, and perirenal space. Bilateral renal calculi are present (straight arrows). Note the gas in the inferior vena cava (curved arrow). (Courtesy of Kouji Masuda, MD, DMSc, and Hiroshi Honda, MD, Kyushu University, Fukuoka, Japan.)

• Septic Emboli

A cause of acute renal infection in adults is hematogenous seeding of the kidney due to intravenous drug abuse with nonsterile syringes or to subacute bacterial endocarditis. This type of infection is much less common than ascending urinary tract infection but is still of clinical importance (2,13). Over 90% of such infections are due to *Staphylococcus aureus* and *Streptococcus* species. Cortical abscesses are commonly found and may be associated with perirenal extension of the parenchymal abscess (13). Enhanced CT typically shows multiple wedge-shaped or rounded areas of hypoattenuation in the renal cortex (Fig 11a). CT features of typical cortical abscesses (eg, a rim of enhancement at the periphery of the lesion) may be present. Ancillary CT findings in the lung, spleen, muscle, and skeleton are indicative of septic emboli (Fig 11b).



a. b.

Figure 13. Chronic pyelonephritis in a 31-year-old woman. **(a)** Enhanced helical CT scan during the cortical nephrographic phase shows a small, hypoattenuating region in the right upper kidney (arrow). **(b)** Helical CT scan during the excretory phase reveals filling of excreted contrast material in a dilated calix (arrow) associated with thinning of the overlying renal parenchyma.

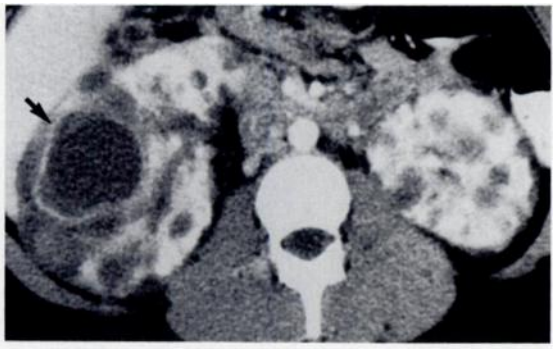


Figure 12. Infected cyst in a 22-year-old woman with autosomal dominant polycystic kidney disease. Enhanced helical CT scan during the parenchymal nephrographic phase through the middle of the right kidney shows an approximately 4-cm-diameter, thick-walled, dominant cyst (arrow) surrounded by edema. Note the multiple renal cysts replacing the kidneys bilaterally.

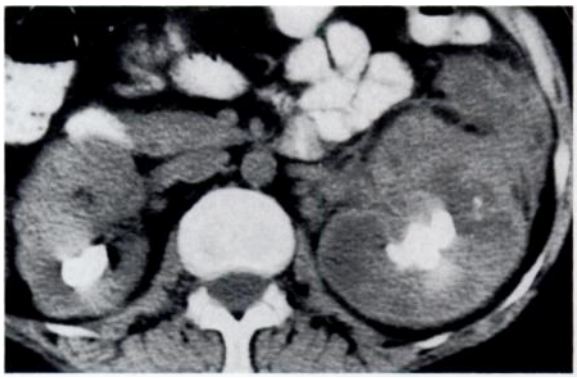
• Infected Cyst

Occasionally, a renal cyst may be secondarily infected. Clinical diagnosis of superimposed infection of a renal cyst is difficult because specific symptoms and pyuria are typically absent. It is difficult to differentiate an infected simple renal cyst from an abscess both clinically and radiologically (2). CT demonstrates thickening and enhancement of the cyst wall and inflammatory changes surrounding the affected cyst (Fig 12); these features may also be found in abscesses. Internal debris and calcification may occur in infected cysts.

■ CHRONIC RENAL INFECTION

• Chronic Pyelonephritis

Chronic pyelonephritis usually results from an episode of vesicoureteral and intrarenal reflux of infected urine in childhood. The classic radiologic findings of chronic pyelonephritis are focal scars in the polar regions of the kidney with underlying caliceal distortion (Fig 13) (1,2). Dilatation of the entire involved collecting system may be present. Global atrophy may occur as a result of growth failure from chronic pyelonephritis; contralateral compensatory hypertrophy may be present. Calculi may also be seen. A variable amount of fatty replacement in the renal sinus is present and may stretch the calices. When fast scanning is used, focal caliceal clubbing may mimic a renal cyst or hypovascular mass when the kidneys are scanned during the cortical nephrographic phase (Fig 13). Delayed images allow confirmation of dilated calices filled with excreted contrast material. CT is helpful in identifying focal areas of compensatory hypertrophy adjacent to the areas of renal scars; such hypertrophy may simulate a mass at excretory urography or renal sonography. Lobar infarcts can be differentiated because of their lack of caliceal involvement and preferential cortical involvement.



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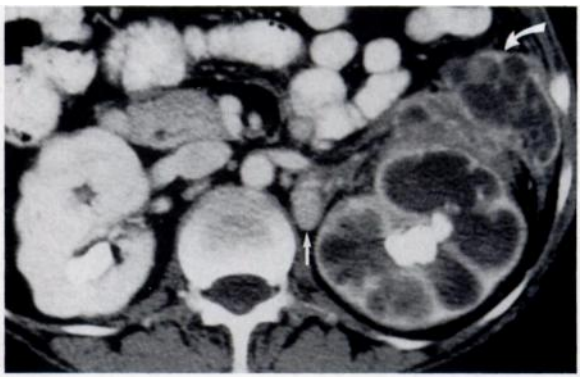

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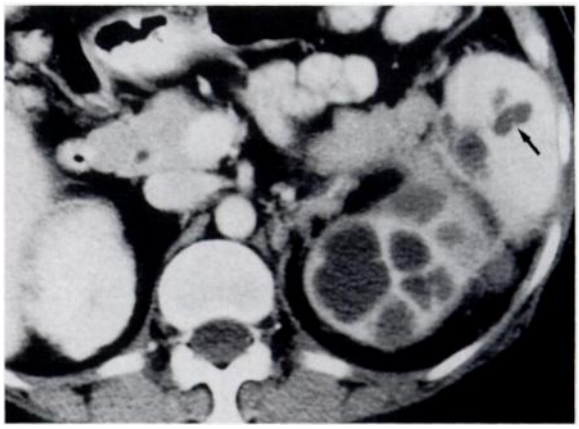


c.

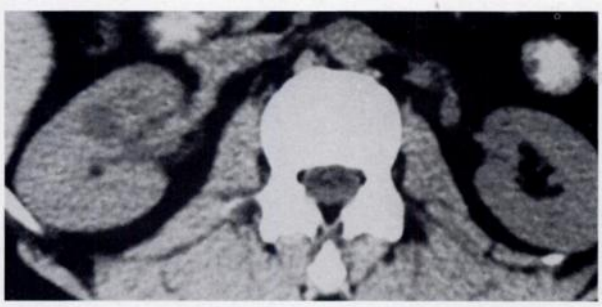
Figure 14. Xanthogranulomatous pyelonephritis with pararenal and splenic extension in a 52-year-old woman. A urine culture was positive for *P mirabilis*. **(a)** Unenhanced helical CT scan at the renal pelvis shows bilateral calculi. **(b)** Enhanced helical CT scan shows a diffusely enlarged left kidney with the parenchyma replaced by multiple hypoattenuating masses arranged in a hydronephrotic pattern, representing dilated calices or abscesses. Note the anterior pararenal extension of the inflammatory process (curved arrow). Enhancing left renal hilar adenopathy is seen (straight arrow). **(c)** CT scan through the superior left kidney shows hypoattenuating nodular masses within the spleen, indicative of intrasplenic extension (arrow).

• Xanthogranulomatous Pyelonephritis

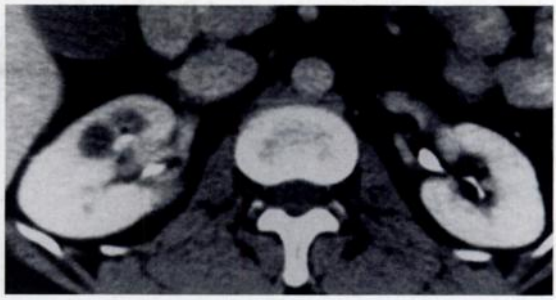
Xanthogranulomatous pyelonephritis is an uncommon complication of long-standing urinary tract obstruction with a superimposed chronic infection, usually with *P mirabilis* or *E coli* (23). This type of pyelonephritis is most common in middle-aged women. Xanthogranulomatous pyelonephritis is characterized by destruction of the renal parenchyma and its replacement by solid sheets of lipid-laden macrophages. Excretory urography typically shows staghorn calculi and a nonfunctioning kidney. At CT, there is usually an enlarged, nonfunctioning kidney that contains multiple rounded, hypoattenuating masses, typically arranged in a hydronephrotic pattern (Fig 14) (24,25). The rounded areas of low attenuation correspond to dilated calices or inflammatory tissue. The peri- and pararenal spaces are commonly involved, and extension to adjacent structures (eg, the psoas muscles, back or abdominal wall muscles, pancreas, and spleen) may occur (Fig 14). Cutaneous or renocolic fistulas may be present. Reactive lymphadenopathy may occur and demonstrates minimal enhancement (Fig 14). Delayed scans obtained during the excretory phase may reveal slightly more enhancement in the inflammatory tissues than those obtained during the cortical nephrographic phase. Xanthogranulomatous pyelonephritis is usually diffuse but may be focal or segmental. Occasionally, a focal (tumefactive) type of xanthogranulomatous pyelonephritis occurs in the functioning kidney; this process may mimic a renal tumor or abscess in a patient without a history or clinical symptoms of urinary tract infection or calculi.

• Renal Tuberculosis

Renal tuberculosis (infection with *Mycobacterium tuberculosis*) is a result of secondary hematogenous infection from the lungs (26). The genitourinary system is the second most common site of tuberculous infection. Renal tuberculosis is identified in 4%–8% of patients with evidence of pulmonary tuberculosis. Radiographic evidence of pulmonary tuberculosis is present in less than 50% of patients with renal involvement (26). Only 5% of such patients have active cavitary pulmonary disease. At CT, a spectrum of findings, which depend on the stage of infection and the host response, may be present (27). Small cortical granulomas without calcifications or papillary necrosis may not be depicted with CT; these are better demon-



15a.



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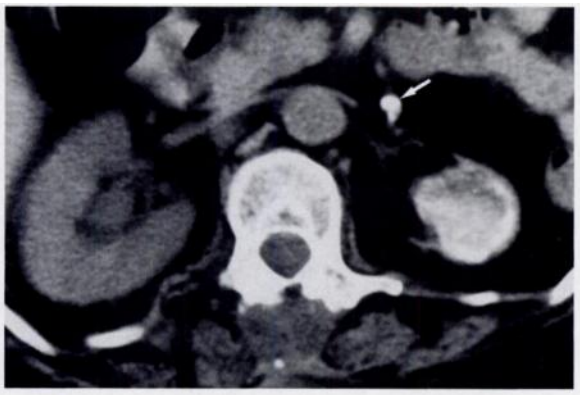


16.

Figures 15, 16. **(15)** Renal tuberculosis in a 40-year-old man. Unenhanced **(a)** and enhanced **(b)** CT scans show several small areas of low attenuation in the right kidney representing dilated calices or tuberculous abscesses. **(16)** Autonephrectomy in a 63-year-old man with advanced tuberculosis. Unenhanced CT scan through the left kidney shows marked parenchymal atrophy; the parenchyma is replaced by amorphous, puttylike calcification with a rim of dense calcification. Incidental findings include a calcified left paraaortic lymph node (arrow) and evidence of a lumbar laminectomy.

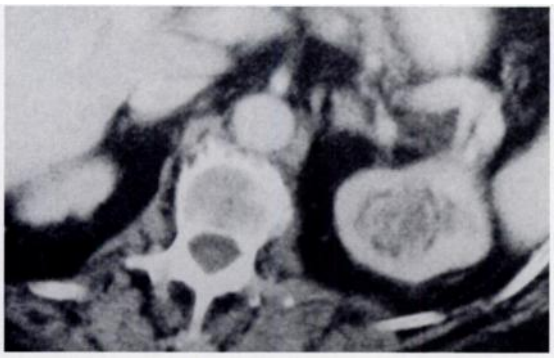
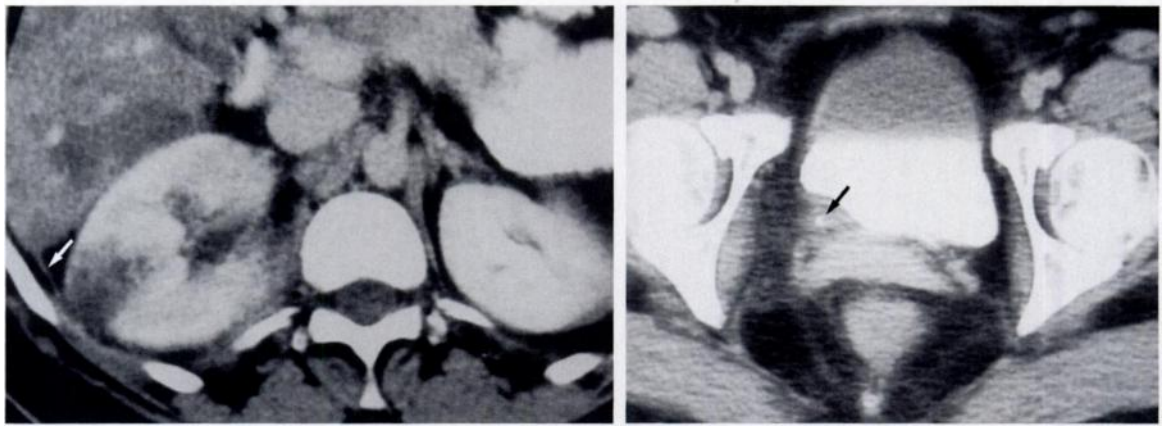


Figure 17. Fungus ball in a middle-aged woman. Enhanced CT scan through the superior left kidney shows an ill-marginated mass with central low attenuation.

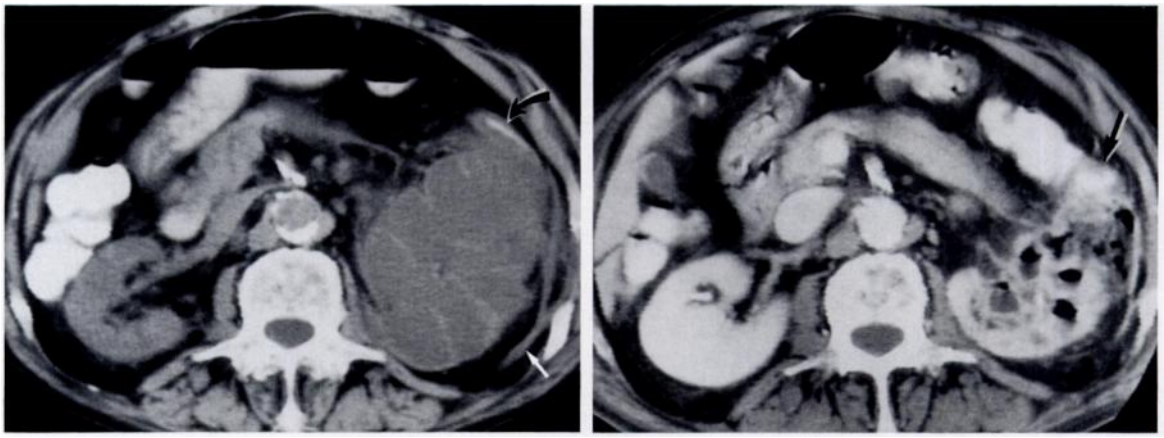
strated with urography. In a relatively early stage, hydrocalix formation with or without stones may be demonstrated due to focal strictures of the infundibula (Fig 15). Granulomas with calcifications may also be seen. In advanced disease, CT may show cavities that communicate with the collecting system, large caseating granulomas, focal or diffuse cortical scarring and nonfunction, and dystrophic amorphous calcifications. Wall thickening and fibrosis of the collecting system are also commonly present. In end-stage disease, a small, calcified, nonfunctioning renal remnant indicative of autonephrectomy may be seen (Fig 16). An enlarged, calcified kidney may also be seen when there is a significant degree of hydronephrosis associated with tuberculous involvement of the collecting system.

• Fungus Ball

A fungus ball (mycetoma, urobezoar) results from hematogenous seeding or ascending urinary tract infection, usually with *Candida albicans* or *Aspergillus* species (28). Immunosuppression, prolonged antibiotic or steroid therapy, diabetes mellitus, and urinary obstruction are common predisposing factors for fungal infection. Fungus balls are a conglomeration of inflammatory cells, fungus, necrotic or mucoid debris, and a calculous matrix (29). Contrast-enhanced CT shows a fungus ball as an irregularly marginated filling defect of soft-tissue attenuation in the collecting system (Fig 17). CT may also show associated chronic or acute pyelonephritis, uni- or multifocal abscesses, or pyonephrosis. The CT appearance of a fungus ball is nonspecific; therefore, other causes of intraluminal filling defects such as blood clots or sloughed papillae should be considered.



18a. 18b.



19a. 19b.

Figures 18, 19. **(18)** Pyonephrosis due to a ureteral stone in a 44-year-old woman. Blood and urine cultures were positive for *E coli*. **(a)** Enhanced CT scan through the right kidney shows a diffusely enlarged kidney with a wedge-shaped area of hypoattenuation. There was diminished renal function. Minimal right hydronephrosis and minimal thickening of the Gerota fascia (arrow) are present. **(b)** CT scan through the pelvis shows a distal ureteral calculus (arrow) surrounded by an area of soft-tissue attenuation near the ureterovesical junction with elevation of the bladder wall. **(19)** Spontaneous renocolic fistula in a 71-year-old man with pyonephrosis. **(a)** Unenhanced CT scan shows marked dilatation of the left collecting system. Inflammatory changes abut a collapsed descending colon (curved arrow). Note the thickening of the Gerota fascia (straight arrow). **(b)** Enhanced 7-day follow-up CT scan shows gas in a partially decompressed and thick-walled collecting system. A perinephric abscess involves the posterior wall of the descending colon (arrow). (Fig 19a and 19b reprinted, with permission, from reference 33.)

• Replacement Lipomatosis of the Kidney Secondary to Infection

Replacement lipomatosis of the kidney is a relatively rare form of extensive renal sinus lipomatosis with parenchymal atrophy associated with chronic inflammation and with calculi in approximately 75% of cases. CT shows a nonfunctioning, atrophied kidney with the parenchyma replaced by sinus fibrofatty tissue surrounding staghorn calculi (30,31). Obstructed calices, pararenal fascial thickening, or a perirenal abscess may be present. In patients with staghorn calculi and a nonfunctioning kidney at excretory urography, CT is of value in differentiating renal replacement lipomatosis from xanthogranulomatous pyelonephritis, chronic hydronephrosis, and tumor (31).

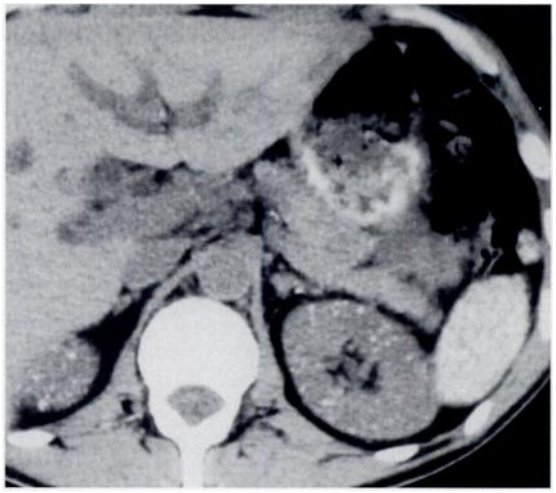


Figure 20. Disseminated *P carinii* infection in a 46-year-old man with AIDS. Unenhanced CT scan shows almost complete calcification of the spleen and punctate calcifications in the kidneys, left adrenal gland, pancreas, and lymph nodes. (Courtesy of Alec J. Megibow, MD, and Ronald P. Lee, MD, New York University Medical Center.)

■ PATIENTS AT HIGH RISK FOR RENAL INFECTION

• Patients with Urinary Tract Obstruction

Pyonephrosis (infected hydronephrosis) is usually considered a urologic emergency requiring urgent drainage. It results from acute or, more frequently, chronic obstruction and superimposed urinary infection.

CT is helpful in identifying hydronephrosis and determining the level and cause of the obstruction (2,32). In most cases, pyonephrosis is indistinguishable from uninfected hydronephrosis. A striated nephrogram is noted in both acute pyonephrosis and obstructive nephropathy. CT can demonstrate wall thickening of the pelvis and ureter, calculus formation, a delayed persistent nephrogram with or without striation, renal enlargement, hydronephrosis, fluid-fluid levels (pus-urine, urine-debris, or contrast material–debris), and gas in the collecting system. Extension of the inflammatory process into the retroperitoneal space may also be seen (Figs 18, 19). Chronic suppurative renal infection from calculi or obstruction occasionally results in spontaneous renocolic fistula formation (Fig 19) (33).

• Patients with Diabetes Mellitus

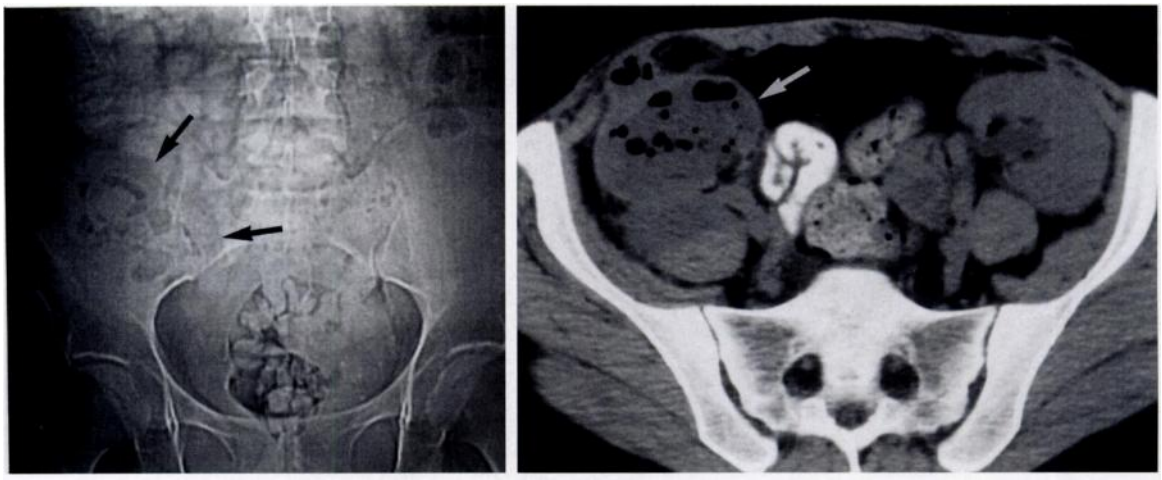
Urinary tract infection is common in diabetic patients (34,35). Not only are these patients more vulnerable to the development of a complication from acute pyelonephritis, but it is also more difficult to differentiate upper from lower tract infection on clinical grounds in diabetic patients. Asymptomatic bacteriuria is two to four times more frequent in diabetic outpatients than in control patients. Renal abscesses occur twice as often in diabetic patients than in nondiabetic patients. Diabetes mellitus is found in 14%–75% of patients with perinephric abscesses, in 85%–100% of patients with emphysematous pyelonephritis, and in 44% of patients with fungal urinary tract infection.

• Patients with AIDS

Recurrent urinary tract infection occurs in 50% of patients with AIDS (36). The spectrum of urinary tract infections includes cystitis, pyelonephritis, and renal abscess with or without perirenal extension (37,38). Septic emboli are common in AIDS patients with a history of intravenous substance abuse.

Although *Pneumocystis carinii* is usually considered a respiratory pathogen, generalized dissemination of *P carinii* infection from the lungs of immunocompromised patients may occur due to failure to achieve adequate blood levels of aerosolized pentamidine. Unenhanced CT reveals punctate calcifications in the kidneys, lymph nodes, spleen, liver, and adrenal glands (39). The calcifications are usually confined to the renal cortex (Fig 20) and are likely to be obscured after contrast material administration. Opportunistic organisms other than *P carinii*, especially cytomegalovirus (40) and *Mycobacterium avium-intracellulare* (41), may cause visceral calcifications in AIDS patients.

Fungal renal involvement is uncommon in patients with AIDS. Renal mucormycosis has been reported in AIDS patients. A propensity for vascular invasion can cause extensive cortical infarcts and medullary necrosis in the kidneys (42,43). CT shows a mixed pattern of hypo- and hyperattenuation in the entire kidney.



a. b.

Figure 21. Emphysematous pyelonephritis in a transplanted kidney in a 30-year-old woman. **(a)** Scout radiograph shows a rounded area of soft-tissue opacity (arrows) with gas bubbles in the right iliac fossa. **(b)** Unenhanced CT scan through the pelvis shows a right renal transplant replaced by an abnormal area of low attenuation mottled with gas (arrow). Perirenal extension of gas is seen. Note the left renal transplant, which was placed after chronic rejection of the right renal transplant.

• Patients with Renal Transplants

Infection continues to be a major source of morbidity and the major source of mortality in renal transplant recipients. Urinary infection occurs in 40%–60% of patients within the first 4 months after transplantation (44). Air in the collecting system usually indicates urinary tract infection but may be due to recent instrumentation. Emphysematous pyelonephritis has been reported in patients with renal transplants (Fig 21) (44,45). CT is helpful in assessing intrarenal gas collections and extrarenal extension of abscesses before drainage or nephrectomy. Transplant recipients who have poor renal function, are receiving high-dose steroid therapy, or were recently treated for transplant rejection are also susceptible to disseminated fungal infection.

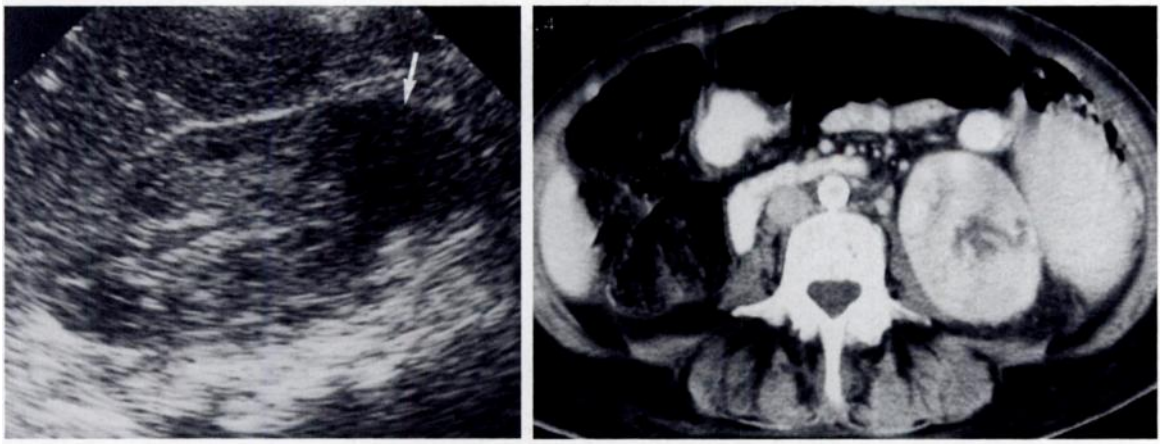
• Patients with Other Immunocompromised States

The immunocompromised host is at increased risk for the development of urinary tract infection (46). Ascending urinary tract infection is facilitated by instrumentation and indwelling Foley catheter placement. Resistant bacteria and fungi may develop in patients being treated with broad-spectrum antibiotics. Hematogenous spread to the kidneys is common as a result of a disseminated bacterial or fungal infection. A spectrum of severity of renal infections is encountered in immunocompromised patients, ranging from clinically unexpected acute pyelonephritis to frank abscesses and perirenal extension (Fig 22). Renal infection may be bilateral and multifocal in this setting.

Patients with acute leukemia and neutropenia are susceptible to hematogenous fungal infections that may seed the kidneys with multiple small abscesses. The most common form of fungal infection is an abscess due to *Candida* species. CT typically shows multiple small, hypoattenuating lesions in the spleen, liver, and kidneys (47) (Fig 23). Enhanced CT is superior to unenhanced CT in demonstrating the lesions. However, CT is not as sensitive as biopsy of the kidney in diagnosis of disseminated fungal disease (47).

■ CONCLUSIONS

Although not routinely indicated in uncomplicated renal infection, CT is of value in establishing the diagnosis in equivocal cases, in evaluating high-risk patients, and in determining the extent of disease. Because fast scanning software has become more available, particular attention must be paid to the CT technique. In our experience, CT scans obtained during the early phase of enhancement demonstrate the extent of acute inflammatory changes better than CT scans obtained during the excretory phase. In some cases, however, subtle inflammatory changes may be underestimated if delayed views are not obtained. Early-phase CT provides information on perfusion, but the influence of the results on patient care has yet to be determined.



a. b.

Figure 22. Acute pyelonephritis in a 72-year-old woman with Waldenström macroglobulinemia. **(a)** Longitudinal sonogram of the left kidney shows a hypoechoic mass in the lower kidney (arrow). **(b)** Enhanced CT scan through the lower pole of the left kidney shows an inflammatory mass of low attenuation. Splenomegaly is also present.

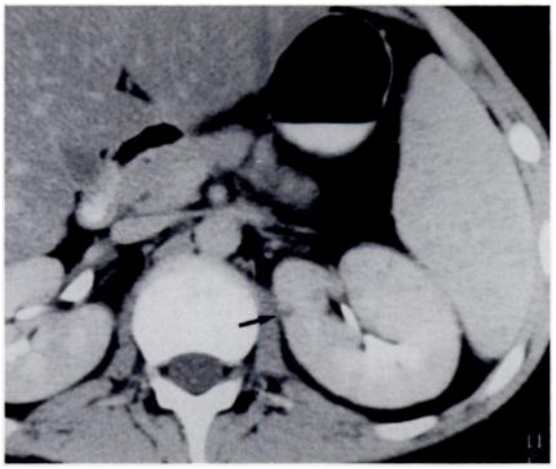


Figure 23. Disseminated candidiasis in the kidney and spleen of a 15-year-old boy with acute myelocytic leukemia. Enhanced CT scan through the left kidney shows a small, peripheral lesion (arrow). Note the subtle lesions of low attenuation in the spleen.

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