Kidney and Renal Pelvis: Inflammation 110

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Pathogenesis

Acute pyelonephritis is defined as inflammation of the kidney and the renal pelvis. The diagnosis is mainly clinical. Acute pyelonephritis represents a severe but common infection of the upper part of the urinary tract. The infection induces an interstitial nephritis involving the renal pelvis and tubules but excludes the glomeruli. Granulocytes infiltrate the medulla between renal papilla ending in the pelvis and the renal cortex in a hilifugal pattern (Schaefer and Schaefer 2012).

Typical symptoms are rapidly developing fever, uni- or bilateral flank pain, shaking chills, nausea, vomiting, and diarrhea. Additional signs of an infection of the lower urinary tract such as dysuria, increased urinary frequency, and urgency can be present but are not mandatory. Advanced stages of acute pyelonephritis can lead to septic attendant symptoms which can predominate in some subjects. Tapping at the skin area over the kidney provokes costovertebral angle tenderness. Hypertonia can be possibly observed (Stamm and Hooton 1993).

The vast majority of infections (98 %) of the kidney are due to ascending bacteria from the bladder. Most common are gram-negative uropathogens such as *Escherichia coli*, *Proteus mirabilis*, Klebsiella, and *Pseudomonas aeruginosa*. Bacterial spectrum is changed toward other bacilli including gram-positive in hematogenous spread and consecutive infection of the kidneys, e.g., *Staphylococcus aureus* if pneumonia or cutaneous infection are the underlying cause (Rubin et al. 1992).

Differential diagnosis of acute pyelonephritis includes appendicitis, diverticulitis, and pancreatitis with similar, although different located, pain. However, urine analysis under these conditions is normal.

Risk Factors

Urinary tract obstruction, pregnancy, urolithiasis, as well as every pathology of the urinary tract and neurogenic bladder are being accounted as the most relevant risk factors for acute pyelonephritis. Likewise immune compromised patients after renal transplantation or patients suffering from diabetes mellitus as well as intensive care patients especially with Foley catheter in place have an elevated risk for renal infection.

Complications

Complications in acute pyelonephritis include renal abscess or paranephritic abscess formation in capsule-exceeding disease. Urosepsis, renal failure, and hypertonia are further potential sequelae.

Emphysematous pyelonephritis represents a fulminant urologic emergency characterized by an acute necrotizing parenchymal and perirenal infection caused by gas-forming uropathogens leading to a high mortality. It is often associated with diabetes

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and urinary tract obstruction with urinary calculi. Emphysematous pyelonephritis is subdivided into two types:

Type 1 (classic, worse prognosis) means gas bubbles are limited to renal parenchyma with parenchymal destruction and no or little fluid.

Type 2 describes gas in fluid formations perirenal, respectively, in retroperitoneal space.

Imaging

Intravenous pyelography is not the method of choice in diagnostics of acute pyelonephritis since pathological findings are observed in only 75 % of not complicated inflammations of the kidney. Observed alterations can be accentuated renal pelvis, enlarged kidney, or deferred excretion of the intravenous administered contrast agent.

Ultrasound is the first step in radiological diagnosis as it reveals not only enlargement of the kidney but also detects loss of corticomedullary differentiation of the parenchyma. Elevated echogenicity of the surrounding renal fat compartment indicates inflammatory response of the adjacent tissue. Complications as developing renal abscess and fistula can be detected in early stages. Furthermore, ultrasound is a valuable tool to diagnose affiliated pathologies such as urinary obstruction or stone disease. Moreover, ultrasound using color flow imaging shows alterations in vascular perfusion, while contrast enhanced ultrasound is a valuable tool for discovering cortical intraparenchymatous abscess.

Native Computed Tomography (CT) is sensitive in detecting renal or urinary calculi but beyond that contrast enhanced CT imaging should be preserved for complicated courses of disease. CT is, in particular indicated, in patients with fever lasting for more than 72 h to rule out renal abscess (Fig. 110.1), parenchymal destruction, and perirenal infections (Souson et al. 1989). In hemorrhage, native CT presenting typical attenuation coefficients about 50 HU may be useful. For detecting gas forming in emphysematous pyelonephritis CT using a sharp convolution kernel with pulmonary windowing is unexcelled. CT is a mighty imaging modality in handling complications with appearance of renal abscess, since it empowers the radiologist/urologist to drain the abscess in a CT/ultrasound-guided technique. Regularly, a safe and effortless interventional approach from the back is chosen with low risk of harming vessels or nerval structures.

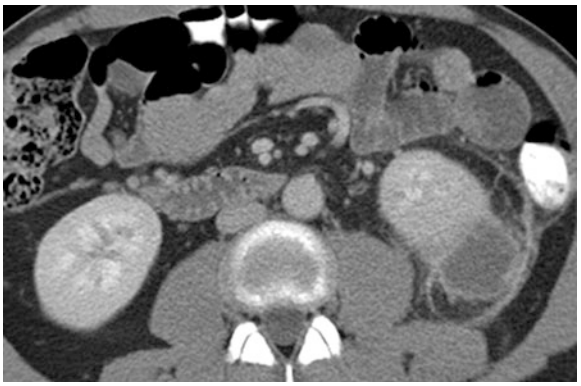

Fig. 110.1 Abscessus with adjacent fat tissue reactions and thickening of Gerota's fascia (CT)

The diagnosis of fulminant emphysematous pyelonephritis can be established radiographically showing mottled gas shadows over the involved kidney representing tissue gas formation in the renal parenchyma. Ultrasonography also can demonstrate focal echoes indicating the presence of intraparenchymal gas formation. However, CT is the imaging method of choice in defining the extent of the inflammation process and guiding management. The presence of streaky or mottled gas with or without bubbly and loculated gas (in the absence of fluids) indicates rapid destruction of renal parenchyma with mortality rates (Best et al. 1999). In case of intraparenchymal or perirenal fluids as well as in case of urinary obstruction a rapid drainage is indicated which can be performed ultrasound/CT guided.

In case of repeat episodes of pyelonephritis, a cystourethrogram is recommended to rule out vesicoureteral reflux. Radionuclide imaging might be useful to visualize long-term functional changes associated with pyelonephritis as well as cortical defects due to vesicoureteral reflux (Fishman and Roberts 1982). In particular, scanning with ^{99m}Tc-dimercaptosuccinic acid (^{99m}Tc-DMSA) is a valuable tool visualizing renal scars and quantifying impaired renal function (Raz et al. 2003).

Advantages of MRI in complicated acute pyelonephritis consist in less nephrotoxic gadolinium based contrast agents, lack of radiation exposure, and superior differentiation of malignant or suspicious,

e.g., cystic, lesions. Native T1 and T2 imaging, optional fad saturation, fast dynamic contrast enhanced gradient sequences in coronal planes and additional excretion urography are recommended properties of MR examination.

Chronic Pyelonephritis

Relapse or acute episode of chronic pyelonephritis can only be distinguished from acute pyelonephritis in knowledge of the patient's medical history. Long-term inflammation leads into chronic renal failure with corresponding loss of renal parenchyma, focal scarring at the polar regions of the kidney, and impaired renal parenchyma pyelon index as a sign of global atrophy. Dilatation of the collecting system may be present.

Xanthogranulomatous Pyelonephritis

Chronic infection of the kidney can lead to a rare form of inflammation of the kidney characterized by destruction and replacement of the renal parenchyma by lipid-laden macrophages. Apart from unilateral renal enlargement and nephrolithiasis peripelvic fibrosis and hydronephrosis can be typical features. Predominantly the kidney is diffuse infiltrated; focal manifestation is less common and makes differential diagnosis difficult. Most cases are unilateral and lead to a nonfunctioning, enlarged kidney mostly due to obstructive uropathy as a result of urinary calculi. Differential diagnosis to every form of inflammatory disease of the kidney as well as renal cell carcinoma on radiographic examination has to be considered. Tumor lesions as adenosarcoma, renal cell carcinoma, and cystic nephroma have to be considered in focal disease. Loss of renal function is typical for xanthogranulomatous pyelonephritis. Extent of disease is classified according to Malek into three states, ranging from confinement to the kidney to pararenal inflammation with infiltration of the retroperitoneal space (Malek and Elder 1979). Risk factors are same as for acute pyelonephritis but also include alteration of lipid metabolism, arterial insufficiency, and venous occlusion. About 70% of patients are female. Pyuria and proteinuria are frequent, additional hematuria is possible.

CT is the most useful imaging modality showing unilateral renal enlargement, cortical atrophy, and a central pelvic calcification without dilatation of the renal pelvis (Goldman et al. 1984). Imaging also can show dilated calyces, cortical atrophy, and fat-enriched tissue masses with consecutive diminished X-ray attenuation coefficients in native CT (10–15HU or even negative HU values). Other than expected xanthogranulomatous tissue bulks in MRI are signal diminished in T1 weighting and elevated in T2 weighting probably as a result of necrosis (Fig. 110.2). Peripheral enrichment of contrast media around xanthoma lesions can be observed both in CT and MRI as an equivalent of granulation tissue. CT and with some restrictions even conventional X-ray demonstrate calcifications or calculi. Ultrasound usually demonstrates renal enlargement of the kidney showing areas with low echogenicity and irregular internal echoes corresponding to debris-filled dilated calyces and lesions of parenchymal destruction. A solid mass with a calculus in the collecting system can be visible ultrasonographically making differential diagnosis to a solid renal tumor difficult.

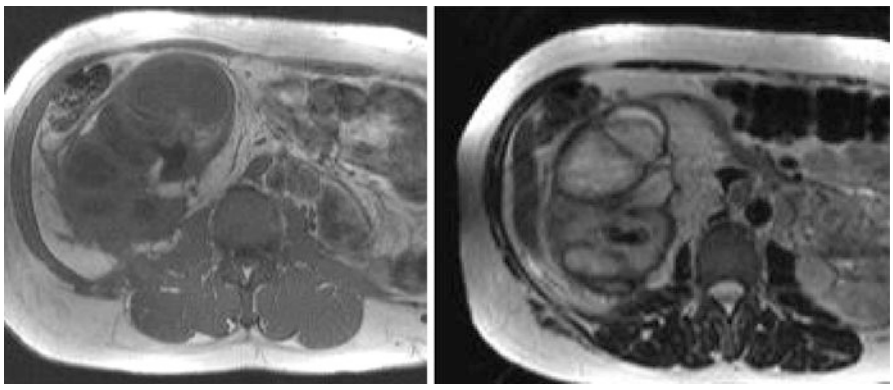

Fig. 110.2 MRI of xanthogranulomatous pyelonephritis: Infection focus shows high signal intensity in T2 weighted MRI (*right*), while T1 sequence shows corresponding areas with low signal intensity

Malacoplakia

Malacoplakia of the kidney contributes for about 15 % of the overall urinary tract cases. It can occur multifocal or bilateral. Histopathologically malacoplakia is characterized by histiocytes with basophilic inclusions (Michaelis Gutmann bodies). Macroscopically gray plaque and ulcerations of the urinary tract can be found; renal involvement shows solitary cell masses. Gram-negative bacteria like *Escherichia coli* are most common underlying cause of this granulomatous inflammation, therapeutic results have improved by the use of fluoroquinones. Cross-sectional imaging can detect tumorous renal lesions; differential diagnosis of malignant diseases may be difficult as immunosuppression due to lymphoma, e.g., is an important risk factor.

The masses are confluent leading to an overall increase of the echogenicity of renal parenchyma. On CT the lesions of malacoplakia are less dense than the surrounding enhanced parenchyma. CT also may detect a solid or cystic structure due to necrosis. Unifocal malacoplakia on intravenous pyelography shows a noncalcified mass similar to other inflammatory uropathologies or renal masses (Trillo et al. 1977). Multifocal malacoplakia on intravenous pyelography typically shows an enlarged kidney with multiple filling defects.

Tuberculosis

Tuberculosis of the kidney nearly always arises from hematogenous spread contemporaneous with initial pulmonary infection. Numerous bilateral small abscesses sprout in the cortex but usually cannot be detected in early stages by imaging due to limited spatial resolution. If immune defense takes effect, these early foci are confined and converted into granulomas with calcifications.

When cellular immunity is compromised reactivation may result. Infection spots tend to extend and to caseate and cavitate later on. Progression of disease provokes necrotic ulcerations with subsequent rupture into the calyces. Infectious discharge into the pelvis implicates genitourinary spread. Fulminant disease patterns show abscesses with potential retroperitoneal or even cutaneous fistula or pyonephrosis.

Long-term consequences of renal tuberculosis include fibrosis and stenosis of calyceal system. Inevitable obstruction of renal flow and hydronephrosis produce further damage to the kidney, as an uttermost outcome autonephrectomy can result.

Ultrasound, CT, and MRI are appropriate to demonstrate urinary congestion, distorted calyces, and renal caverns (Fig. 110.3). Mucosal tubercles and ulcerations of renal papilla demand high spatial resolution imaging provided by intravenous pyelography.

Echinococcus

Humans are an intermediate host of Echinococcus; predominant locations of disease are liver and lung. Hydatid cyst of the kidney is a very rare condition caused by the larval stage of *Echinococcus granulosus*. Cysts are typically slow in growth; flank pain or even palpable flank masses can be found during clinical

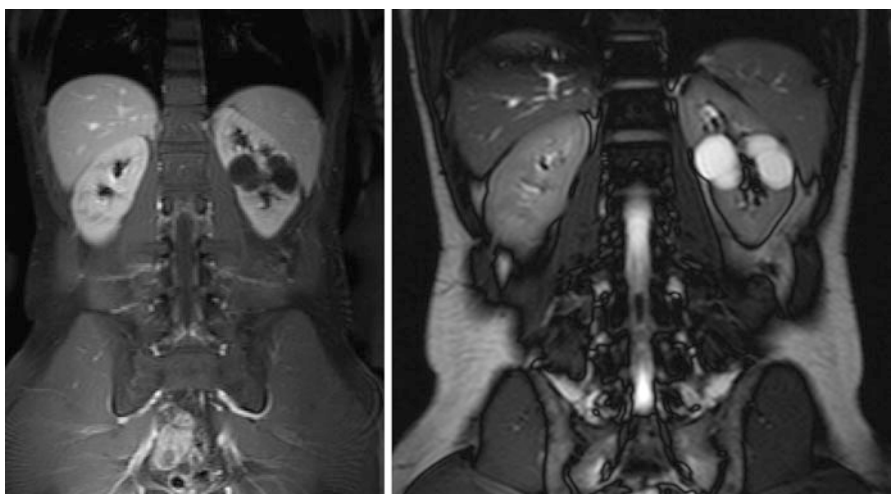

Fig. 110.3 MRI of tuberculosis. Dilated calyces and abnormal upper urinary tract with irregular morphology

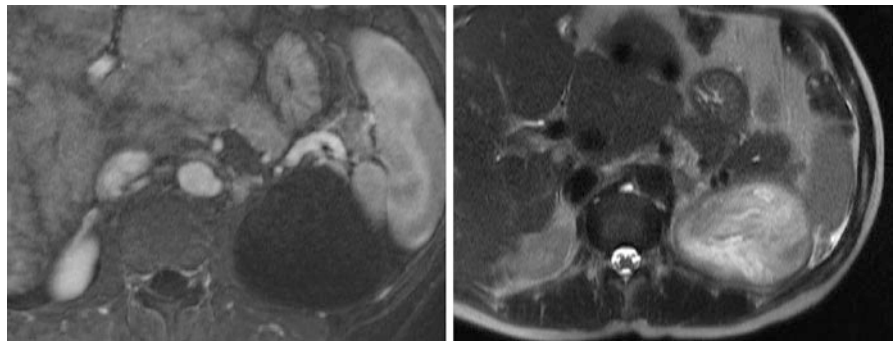

Fig. 110.4 MRI of Echinococcus. Cystic renal lesion with internal structures in T2 MRI

examination. Hematuria and hydatiduria are possible in advanced disease.

Radiological signs of *Echinococcus granulosus* are extensive cystic formations with multiple hyperechoic septations and optional daughter cysts (Fig. 110.4). The "water lily sign" might be found in the cyst cavity. Inactive cysts can develop calcifications of the cystic wall especially after treatment with albendazole.

Parenchyma sparing techniques in surgery remain a good option if feasible; integrity of the removed cyst should not be compromised. Otherwise nephrectomy is recommended. Advanced imaging modalities like CT and MRI are suited in terms of therapy monitoring both in conservative as well as in surgical approach. CT or US guided percutaneous aspiration of the cyst and administration of anti-zoonotic agents as albendazole or alcohol directly into the cyst are an option for patients not fulfilling requirements for surgery.

Atypical and Rare Renal Infections

Rare infections of the kidney include mycosis and viral diseases. In general, they show more or less unspecific radiologic findings such as nephromegaly and increased cortical echogenicity. Possible infectious agents are HIV with consecutive HIV nephropathy or the spread by rodents hantavirus.

More characteristic changes are found in Candidiasis with delineation of multiple microabscesses. In immunodeficient patients cytomegalovirus and extrapulmonary pneumocystis jirovecii become an issue. Pneumocystis is associated with typical disseminated renal calcifications; the appearance of these calcifications does not necessarily determine avitality of infection.

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