MULTIMODALITY IMAGING OF URINARY TRACT INFECTIONS:

Radiological Spectrum, Diagnostic Features, and Complications

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ABSTRACT

Urinary tract infections are a common public health issue that may progress to severe complications if not properly managed. Imaging plays a central role in the evaluation of complicated or atypical cases.

This review presents the main imaging modalities, including ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI), detailing their indications, advantages, and limitations. Ultrasound is the first-line examination, whereas CT remains the reference technique for assessing complicated infections. MRI serves as an alternative in specific clinical situations.

The radiological features of the main urinary tract infections are described, including cystitis, pyelonephritis, renal abscesses, pyonephrosis, and specific forms such as emphysematous infections and urinary tuberculosis.

Imaging contributes to accurate diagnosis, assessment of severity, and appropriate therapeutic management.

Keywords:*Urinary tract infections; Imaging; Computed tomography; Magnetic resonance imaging; Ultrasound*

INTRODUCTION

In the world, urinary infection is considered as the most frequent urological problem, affecting approximately 150 million patients per year [1]

Urinary infections represent the largest proportion (31%) of nosocomial infections in American intensive care units, and are the 2nd nosocomial infections in frequency after respiratory infections in Europe [2]

The annual prevalence of urinary infections is 11% in women over 16 years old, and they constitute the most frequent reasons of consultation (3) and the 2nd reason of antibiotic prescription after respiratory infections (4)

Urinary infections can evolve towards serious complications sometimes fatal if they are not diagnosed and treated early.

Generalities: epidemiology

Urinary infections present a clear predominance in women. In small children the predominance is also female except before 1 year where the sex-ratio is equal to 1.

Serious urinary infections or at risk of complications occur in diabetic, pregnant woman, renal transplant, immunocompromised, elderly subject and on urinary malformations.

In men this infection is by definition “complicated” and must make search for a cause such as a prostatic infection or other obstructive cause of the lower urinary tract.

The responsible germs are Gram Negative Bacilli germs: uropathogenic Escherichia coli (UPEC) in 80% of cases [5], Proteus mirabilis (5%); however in hospital environment other germs are incriminated such as: Pseudomonas, Klebsiella, Enterobacter, Staphylococcus…

The positive diagnosis is posed on the results of the ECBU which affirms biologically the infection by numeration of germs and leukocytes: bacteriuria > 105/ml with leukocyturia >103/ml; identification of germs and antibiogram to better adapt the treatment.

Although in front of simple urinary infections imaging does not intervene; this one is very useful in front of complicated infections playing several roles notably it allows to orient the diagnostic assessment; to specify the diffusion of lesions and to search for predisposing factors thus allowing to adapt therapeutic strategy.

Imaging is mandatory in: *(a) an atypical presentation *(b) search for causes of urinary infection: malformations; tumors and stenosis *(c) persistence and recurrence of urinary infection despite adequate treatment *(d) search for complications requiring urgent management, like renal abscess [6]

Imaging means

In front of urinary infections the imaging means that can be indicated are: ultrasound; scanner and MRI.

Ultrasound is an accessible exam, cheap, non irradiating, rapid useful for the initial evaluation. The scanner is the ideal imaging technique in case of urinary infection; easier of access than MRI [7]. It is a rapid technique; allowing multiplanar reconstructions; and a better detection of air and calcifications than MRI. Its principal disadvantages are the risk of exposure to radiations and of secondary effects linked to iodinated contrast products [8]

MRI which is a precious diagnostic tool due to its better characterization of tissues thanks to dynamic MRI with contrast, diffusion and absence of exposure to radiations its compatibility with pregnancy; and its safety in patients presenting renal insufficiency or contraindications to contrast products; however with disadvantages are the high cost, its limited availability and its long duration [9]

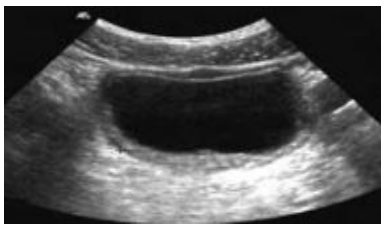
We will approach the aspect in imaging of the principal urinary infections

1-Acute cystitis

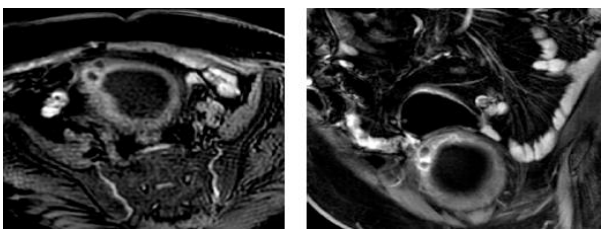
is an inflammation of the bladder wall of bacterial origin; schistosomiasis, tuberculosis, parasites, mycoses or radiotherapy. Clinically one can note a pollakiuria, micturition burns, hematuria, dysuria. In absence of risk factors it is a simple acute cystitis, not requiring complementary investigations and no imaging

Recurrent cystitis is defined by the occurrence of more than 4 episodes of urinary infections per year; the recurrence imposes the realization of an ECBU and an antibiogram to adapt the treatment. It is an indication of imaging which can objectify a favoring cause such as a bladder tumor, a foreign body, a diverticulum, or vesicodigestive fistulas [10]

Ultrasound can objectify an echogenic thickening of the bladder mucosa and intravesical debris, CT objectifies a diffuse or focal parietal thickening; MRI can detect a mural abscess.



Cystitis: ultrasound parietal thickening



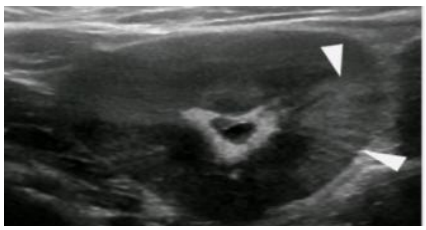
MRI: right anterolateral mural abscess

2-Acute pyelonephritis

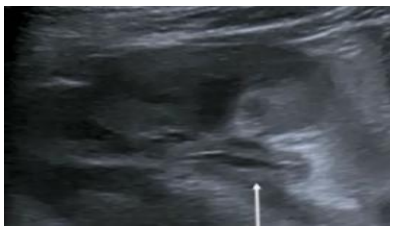
is an acute infection of the renal parenchyma and the collecting system. Not treated it can lead to chronic pyelonephritis or renal insufficiency. Clinically it is manifested by lumbar pains; a hyperthermia > 39 C, chills, dysuria, pollakiuria, nausea or vomiting. The ECBU shows a leukocyturia and a pyuria, sometimes a hematuria. Biology objectifies an elevation of CRP and a hyperleukocytosis with polynuclear and sometimes the presence of germs in blood cultures with bacteriuria >105 colonies/ml.

Obstructive pyelonephritis is a medico-surgical emergency imposing a surgical drainage or by nephrostomy of urines

Ultrasound can show a hydronephrosis on a stone or obstacle, a pyelitis or a hyperechogenic focus with striated aspect.

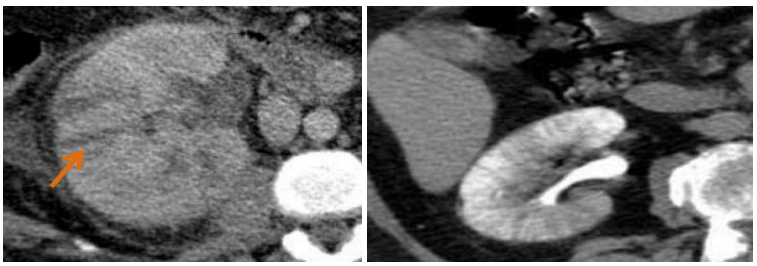


Acute pyelonephritis: hyperechogenic focus with striated aspect



Pyelitis

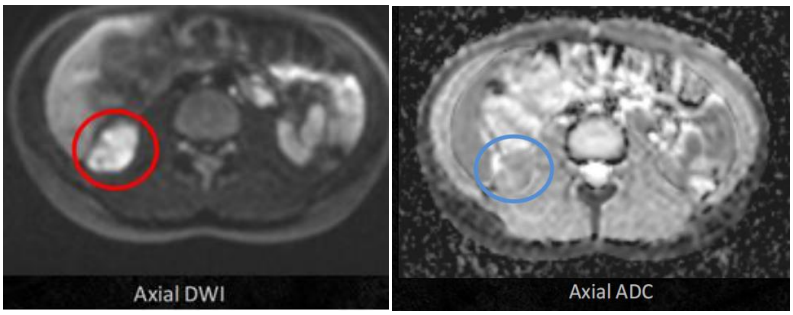
The scanner constitutes the most sensitive technique to detect a focus of acute pyelonephritis whose principal sign is a triangular defect of nephrography with peripheral base and central summit with striated aspect (11), a weak enhancement and a delayed nephrography associated to other indirect signs less specific: a nephromegaly, blurred renal contours, a thickening of Gerota fascia and an infiltration of the perirenal fat opposite.



Acute pyelonephritis: striated nephrography

At MRI the diffusion sequence can constitute a precious tool to confirm the diagnosis and follow the evolution of a pyelonephritis in young patients or during pregnancy objectifying

parenchymal zones round or wedge-shaped hyperintense in DWI with a low ADC due to edema (12)



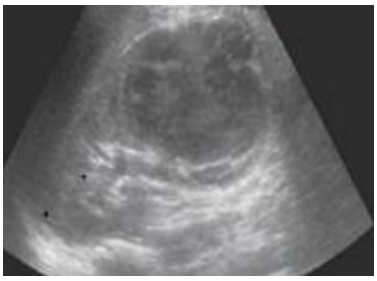
Acute pyelonephritis in MRI

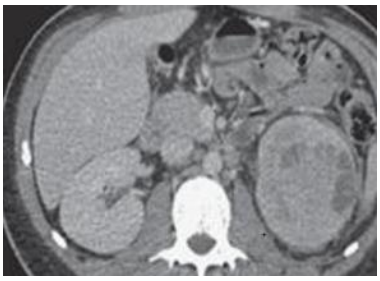
Acute bacterial and focal pyelonephritis

Acute bacterial and focal pyelonephritis constitutes a form of unfavorable evolution of pyelonephritis. It corresponds to the formation of an inflammatory mass, taking contrast with sometimes a necrotic component (14)

In imaging it is an inflammatory pseudo tumoral rounded mass, regular contours, homogeneous with a weak contrast enhancement, with small zones not taking contrast corresponding to micro-abscesses, or zones of necrosis

This infectious focus can simulate a tumoral mass that it is necessary to attach to its real inflammatory nature by the clinical and biological context. If this inflammatory mass persists after treatment a biopsy for the diagnosis of certainty is imperative.





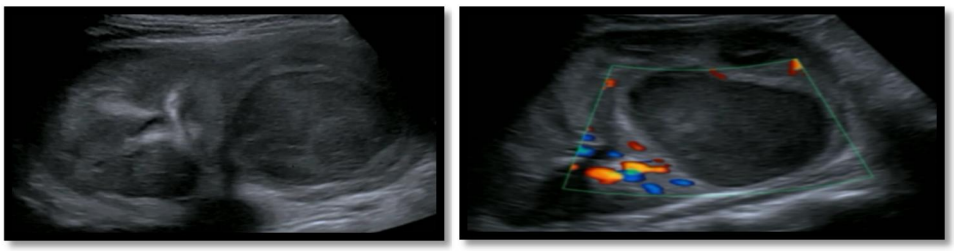
Acute focal bacterial nephritis at ultrasound **and at scanner**

3-Renal and perinephric abscesses

Occurs by aggregation of infectious lesions of pyelonephritis The risk of formation of abscess the favoring factors are obstructive uropathies, immunosuppression, and diabetes.

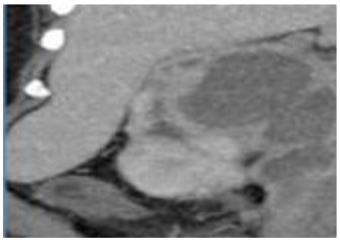
The principal responsible germs are Escherichia coli and Staphylococcus Aureus and Candida species are frequent in diabetics.

At ultrasound one can put in evidence a mass syndrome with liquid content; the color Doppler objectifies a peripheral hypervascularization with displacement of interlobar and arcuate arteries

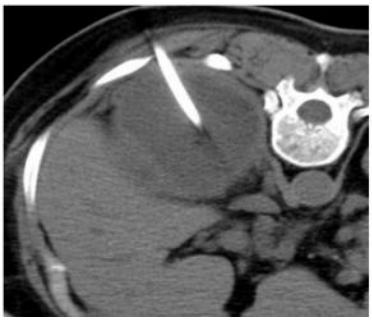


Renal abscess in ultrasound and in Doppler: collection with troubled content

At scanner the renal abscess translates by a hypodense collection, rounded, density (0-40 UH) not enhanced; with sometimes air bubbles inside After injection the wall of the abscess will enhance without enhancement of the liquid collection. The scanner also allows to appreciate the extra renal extension of the abscess in the perinephric spaces, the psoas muscle and adjacent organs Imaging also intervenes in the guidance of aspiration or drainage of abscesses under ultrasound or CT



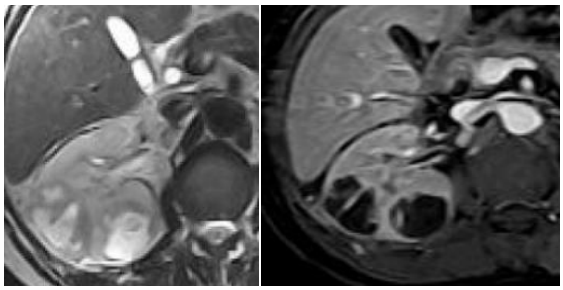
Renal abscess with extra renal extension in CT



CT guided drainage of a renal abscess

In MRI the renal abscess presents as a complex cystic lesion presenting a heterogeneous signal intensity low on T1 images and a high signal intensity on T2 images. The wall of the abscess is generally thick and irregular, with a slight enhancement during the late phase. The

presence of air bubbles inside the cystic lesion suggests abscess. In diffusion (DWI), the abscess presents a characteristic restriction

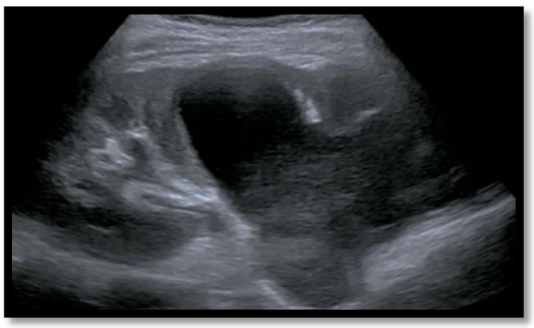


Renal abscess in MRI: T2 and T1 after gadolinium

4-Pyonephrosis

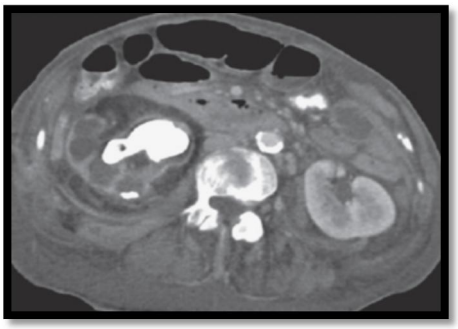
is a concomitant suppuration of the parenchyma and of the excretory tract with most often an alteration of renal function secondary to a stone and more rarely to other obstacles. It constitutes a diagnostic and therapeutic emergency making indicate an urgent drainage.

Ultrasound objectifies in this case very dilated cavities (excretory tract) containing numerous echoes and sediments, with intraparenchymal cavities and disappearance of all the thickness of the renal parenchyma as well as a thickening of the pyelic wall



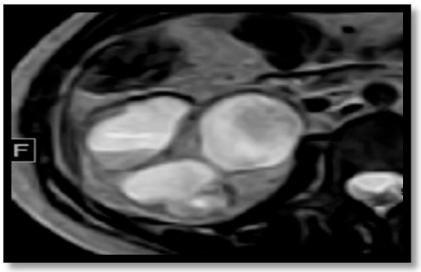
Pyonephrosis in ultrasound

The scanner objectifies a dense content in dilated collecting system with thickening and enhancement of the pyelic wall, and inflammatory lesions parenchymal or perirenal, with thinning of the renal cortex



Right renal pyonephrosis secondary to a staghorn stone

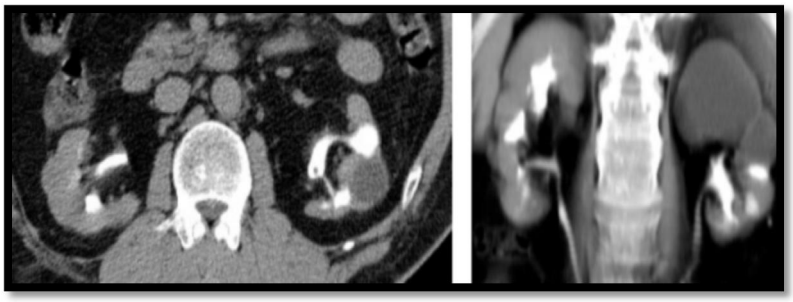
MRI is privileged compared to the scanner in the diagnosis of pyonephrosis demonstrating the following signs: the infected liquid presents a low to slightly high signal on T1 images and an intermediate signal on T2 images, allows to put in evidence a stratification urine-infected liquid as well as a thickening of the pelvis, indicating an involvement of the collecting system, finally pyonephrosis presents a characteristic diffusion restriction (12)



Pyonephrosis in MRI (axial T2)

5-Chronic pyelonephritis

can result from recurrent infections or from a reflux of infected urine during childhood. Ultrasound as well as CT objectify atrophied kidneys with irregular contours with corticomedullary dedifferentiation and an echogenic parenchyma. Cortical notches opposite dilated calyces realizing a “clubbing” deformation as well as cortical retractions and calyceal deformations can also be visualized



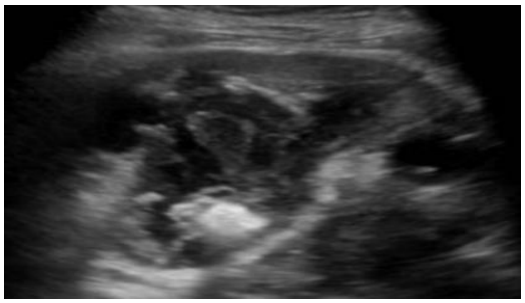
Chronic pyelonephritis in CT cortical notches and clubbing deformations

MRI without contrast provides the same information as the scanner. Renal scintigraphy with DMSA is reserved to the child to evaluate the degree of reflux but especially the renal functional impact. Finally retrograde cystography will search for a vesico-ureteral reflux

6-Xanthogranulomatous pyelonephritis (XGP)

is considered as an atypical immune response to a chronic infected obstruction of urinary tract. It touches preferentially perimenopausal women with a history of recurrent urinary infections, and in case of urinary obstruction, or diabetes. There exist two forms of XGP: a diffuse type and a localized pseudotumoral type. The diagnosis of certainty will be histopathological by percutaneous biopsy and the treatment is surgical

Ultrasound puts in evidence a kidney increased in volume and deformed. The renal architecture can be destroyed with disappearance of corticomedullary differentiation. The renal parenchyma is replaced by hypo-echogenic masses with calcifications (13)

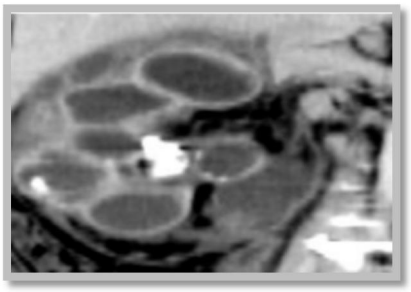


Xanthogranulomatous pyelonephritis in ultrasound

CT is the exam of choice to evaluate xanthogranulomatous pyelonephritis being able to show in its diffuse form a kidney of increased volume with dilated calyces, a parenchymal atrophy and the classical sign of the bear paw. These dilated calyces are filled with debris, hemorrhage or pus with lithiasis and calcifications

A hypertrophied non functional kidney associated to an obstructive stone in a non dilated pelvis and to dilated calyces with streaks in the perirenal fat is an aspect strongly evocative of a XGP

In its localized form, XGP presents at CT as a renal mass little or not enhanced, most often associated to a staghorn stone. This aspect can then mimic that of a renal tumor



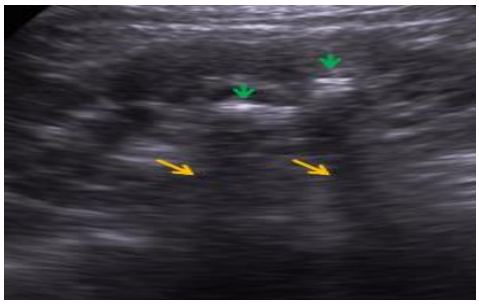
XGP at scanner caliceal and pyelic lithiasis with parenchymal cavities

7-Emphysematous urinary infections

are necrotizing infections mortal occurring most often in diabetics and immunocompromised subjects and are secondary to gas-forming organisms such as Escherichia coli

Emphysematous urinary infection includes: emphysematous pyelonephritis and emphysematous cystitis of which the clinical is variable, going from absence of symptoms to marked septicemia. Pneumaturia constitutes a specific symptom. The early diagnosis is very important, because the rapid treatment (intravenous antibiotherapy) is essential to avoid the morbidity and the mortality associated

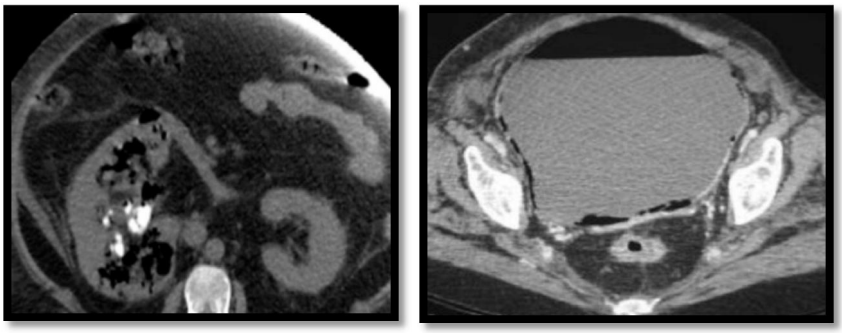
Ultrasound can reveal a hypertrophied kidney seat of coarse echoes within the renal parenchyma or the collecting system. Irregular echogenic foci accompanied by reverberation artifacts corresponding to the presence of gas “irregular shadows” can also be observed (13)



Emphysematous pyelonephritis in ultrasound

The scanner without contrast is the principal modality allowing the detection of air bubbles. In case of emphysematous pyelonephritis it objectifies an enlargement and a renal destruction, with linear streaks of air bubbles, an air-liquid level and foci of tissue liquefaction, and sometimes a renal and perirenal abscess

In front of emphysematous cystitis: the scanner shows the presence of air bubbles in the wall or the lumen of the bladder



Pyelonephritis and emphysematous cystitis in CT without contrast

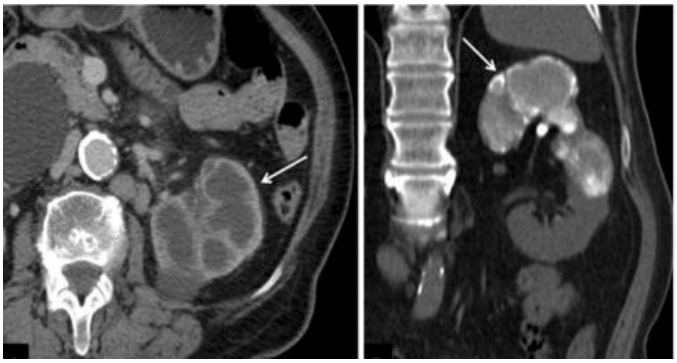
8-Urinary tuberculosis

the urinary tract are the second site the most often affected by tuberculosis after the lungs. The clinical is non specific translating by a pollakiuria, dysuria even a hematuria

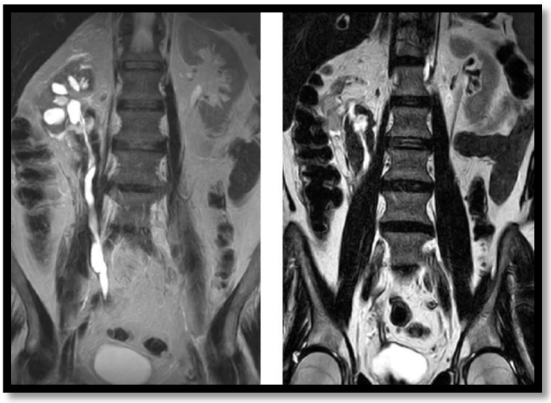
Urinary tuberculosis must be suspected in patients with sterile pyuria and persistent cystitis

CT urography finds all its interest putting in evidence the first radiological sign which is a dilated calyx or a phantom calyx at the late excretory phase. It can also objectify a stenosis of calyceal stems due to a fibrosis with upstream hydrocalyces in ball. Ureteral stenosis and calcifications of the renal parenchyma with aspect of putty kidney and a bladder with thickened wall and in chronic phase retracted can also be noted

MRI characteristics of renal tuberculoma include a hypointensity on T1 images and a thick irregular peripheral wall with an intralesional liquid-liquid level on T2 weighted images. Ureteral involvement can translate by a thickening of the wall at the origin of stenosis and shortening. Extra-renal extension can touch periureteral and retroperitoneal tissues



Renal tuberculosis at scanner: multiple masses of caseous necrosis, partially calcified on the left. ***C. Gaudiano et al.: Multidetector CT urography in urogenital tuberculosis Abdom Radiol (2017) DOI: 10.1007/s00261-017-1129-0***



Right urinary tuberculosis in MRI: ureterohydronephrosis, thickening of the pyelic and ureteral wall, associated to a thickening of dilated calyces

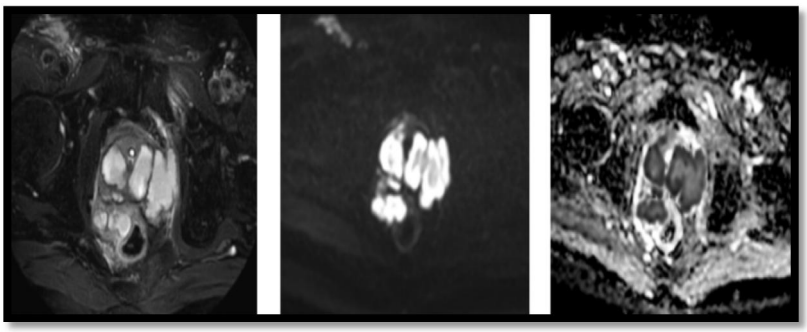
9-Acute bacterial prostatitis and prostate abscess

The way of contamination is generally ascending. Fever, dysuria, frequent micturition and pelvic pains are frequent. The prostate is generally hypertrophied and sensitive at rectal touch. The risk factors of acute bacterial prostatitis include urethral catheterization and prostate biopsy. Prostatic abscess requires an early diagnosis and management in order to avoid serious complications. The non specific symptoms of prostatic abscess render often the diagnosis difficult

Transrectal ultrasound (TRUS) objectifies in the framework of prostatitis a hyperemia with hypo-echogenic or hyper-echogenic areas and a dilatation of periprostatic venous plexuses

Prostatic abscess presents as a small hypo-echogenic collection surrounded by a hypervascularized crown or a hypo-echogenic focus that can occupy all the prostate in evolved forms. Transrectal ultrasound can guide the drainage of the abscess and allows to take samples for culture

MRI can detect a diffuse and asymmetrical hypertrophy of the prostate, it is generally indicated in case of suspicion of prostatic abscess, which presents as a cystic lesion with thick walls, with septa or a heterogeneous content hyperintense T1 and hypointense T2 due to the presence of pus and debris with a restriction on diffusion sequence. MRI also allows to evaluate the extent of the prostatic abscess and the extraprostatic involvement

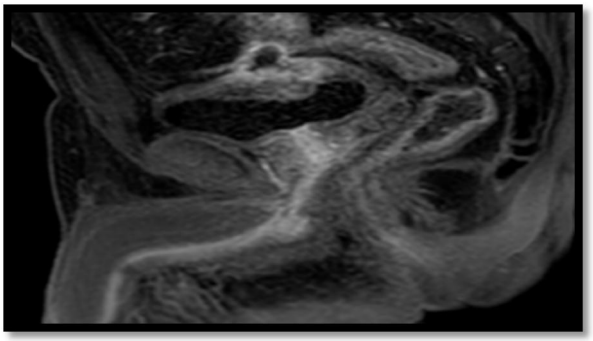


Prostatic abscess in MRI: hypertrophied prostate with cystic lesion with thick wall, extraprostatic extension and restricted diffusion

10-Urethritis

often caused by sexually transmitted infections: rubella, chlamydia, trachomatis. Alternatively urethral infection results from permanent or intermittent catheterization. The symptoms include dysuria, mucopurulent discharge and pruritus. Acute urethritis is often diagnosed on the basis of clinical and biological results however, it may be necessary to perform imaging to exclude complications such as peri-urethral abscess

In MRI acute urethritis translates by a diffuse thickening of the urethra as well as periurethral tissues, with intermediate to high signal in T2 and an intense enhancement sometimes perineal and periurethral abscess. The complications of urethritis can be urethroperineal fistulas, Fournier gangrene or fasciitis

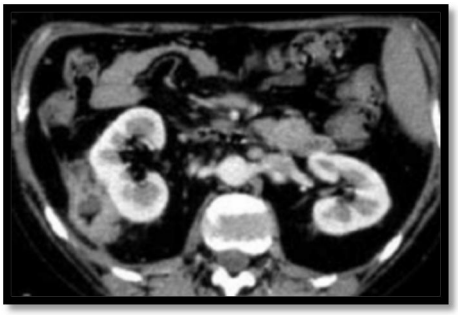


Cystitis and urethritis in sagittal MRI in T1 after injection of contrast: diffuse thickening of the urethra with enhancement, cystitis and abscess of the bladder wall

11-Malacoplakia

is a chronic granulomatous reaction of the urinary tract secondary to a chronic affection with E. coli and to the intracellular presence of Michaelis-Gutman bodies. The involvement is more frequent in women than in men and touches with predilection the urinary tract. The other forms (gastro-intestinal, retroperitoneal, etc.) are rare. The parenchymal involvement is most often extensive. The diagnosis rests on the histological examination of biopsies (14)

Imaging objectifies multiple solid renal parenchymal masses, taking contrast, with perirenal infiltration. Percutaneous biopsy confirms the diagnosis allowing the identification of Michaelis-Gutman bodies. Vitaminotherapy C at high doses allows regression of lesions



Malacoplakia at scanner after injection: right juxtarenal mass syndrome

CONCLUSION

Imaging is indispensable for the evaluation of urinary infectious emergencies. The scanner is the privileged technique with very precise results, ultrasound remains a precious first intention tool. MRI constitutes a complementary option, particularly in specific cases such as pregnancy or in case of contraindication to contrast product and in certain situations of urinary infections. Imaging plays a primordial role in the early diagnosis of these infections in complement of clinical and biological data allowing an appropriate management in order to avoid sometimes very formidable complications.

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