Urinary tract infections through the eye of the radiologist.

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Learning objectives

To demonstrate the spectrum of urinary tract infections findings detected in different imaging modalities. The study emphasizes on certain rare entities that have clinical and radiological significance as well as pyelonephritis, which is one of the most common diagnosis that a radiologist can deal with during daily practice.

Background

Urinary tract infections account for the most common urologic disease and have an enormous impact on public health as they represent direct and indirect costs in the United States that approach nearly 3 billion dollars.

This type of infection is more frequently found in women because of the anatomic disposition and length of the female urethra. The etiologic organism is mostly E. coli. The majority of these infections are uncomplicated and comprise only the urinary bladder (cystitis). Additionally, a significant number of patients present with symptoms of upper urinary infection (fever with unilateral or bilateral pain and tenderness), demonstrating that the infection has reached the kidneys.

The virulence mechanisms of the uropathogens, like the release of endotoxins that inhibit urethral peristalsis, facilitate the ascending migration of the bacteria towards the collecting system. At this point, urethritis, pyelitis or both are established. Once the germ enters the renal tubules of the papillae, inflammatory mechanisms are activated that result in pyelonephritis and interstitial compromise.

Even though imaging studies are not indicated for confirming the diagnosis of an upper urinary tract infection, specific situations determine the need of a radiologic study:

- No response to appropriate antibiotic treatment after 72 hours.
- Investigate for an occult structural or functional abnormality.
- Assessment of the diabetic, elderly or immunosuppressed patient.
- Detect organ damage after a resolved acute infection.
If performing a radiologic study is indicated, the selection of the appropriate technique is
based upon the clinical status of the patient as well as assuring to provide the clinician
the most relevant information within a reasonable cost-benefit ratio.

Generally, urinary tract infections are treated with the administration of empirical
antibiotics. When the diagnosis is uncertain or an atypical pathogen is suspected, these
cases should be addressed with imaging or interventional diagnostic procedures.

Findings and procedure details

We conducted a 2 year retrospective study at our institution, period in which a total of
698 cases of pyelonephritis were identified. Ultimately, 596 cases were included as their
medical records could be recovered. The analysis included 321 cases that had imaging
as part of their workup plan (including the official radiology report and the original set
of images).

We also revised other types of urinary tract infections obtained during a 1 year period,
including: 20 imaged cystitis cases (from which 17 medical records could be obtained), 11
ureteritis imaged cases (from which 7 medical records could be obtained) and 35 cases
of diverse pathologies: ureteritis, pyeloureteritis, pyonephrosis and pyelitis, (from which
29 medical records could be obtained).

We collected the most frequent findings both expressed in the radiological report and
retrospectively confirmed in the set of original images (usually ultrasound or computed
tomography, see table 1 and 2). Comparison was made between this database and
current literature on the subject.

<table>
<thead>
<tr>
<th>Imaging Technique</th>
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<tbody>
<tr>
<td>Ultrasound</td>
<td>258 cases - 80%</td>
</tr>
<tr>
<td>Computed Tomography</td>
<td>61 cases - 19%</td>
</tr>
<tr>
<td>Retrograde Pyelography</td>
<td>2 cases - 1%</td>
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Table 1. Distribution of cases according to employed imaging technique as initial study.
Table 2. Results of posterior computed tomography (CT) after negative ultrasound study.

<table>
<thead>
<tr>
<th>Ultrasound Finding in Focal Pyelonephritis</th>
<th>CT</th>
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<tbody>
<tr>
<td>No accompanying features - 17 cases</td>
<td></td>
</tr>
<tr>
<td>Associated renal abscess - 2 cases</td>
<td></td>
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<tr>
<td>Low vascularity on the lesion - 3 cases</td>
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**PYELONEPHRITIS**

**Ultrasound (US)**

Ultrasound is the most frequently used imaging tool in the setting of a urinary tract infection and is a widely available technique with renowned advantages. Unfortunately it is not a very good technique at characterizing interstitial nephritis (including pyelonephritis). The most common finding is focal pyelonephritis, previously known as nephronia, which translates into two basic pathologic mechanisms: cortical edema and/or haemorrhage, identified in gray scale mode as hypoechoic and hyperechogenic parenchymal lesions, respectively (see Fig. 1 and Table 3). These lesions may variably sustain microvascular hemodynamic changes which can be detected with Doppler ultrasound. Usually relative absence of vascularization is seen although an increase in Doppler flow has also been observed.

Signs of complication include low echogenicity lesions, better defined than focal pyelonephritis, that represent **small abscesses** that tend to grow and extend to the perirrenal space. The latter retroperitoneal compartment may also be affected without the presence of renal abscess and this can be demonstrated with ultrasound as **altered echogenicity of the perirrenal fat, free fluid and/or infected collections**.

**Figure 1. A)** Longitudinal view gray scale ultrasound of the left kidney in a patient with fever and left flank pain. An echogenic, poorly defined, lesion is identified in the upper pole corresponding to focal hemorrhagic pyelonephritis. **B)** Same image as in **A)** but with Doppler mode on, showing the lack of perfusion of the affected area.
Table 3. Ultrasound demonstrated focal pyelonephritis distribution according to echogenicity and accompanying features.

Figure 2. Dynamic contrast enhanced MDCT for detection of renal abscess A) Hypodense nodular lesion in the superior pole of the left kidney. B) Abscess in lower pole of right kidney of another patient. C) Correlation with gray scale ultrasound showing abscess from patient in A)

Multi- Detector Computed Tomography (MDCT)

Computed tomography exquisitely shows pyelonephritis manifestations as well as its complications because of its excellent temporal and spatial resolution combined with the possibility of contrast medium administration to show functional repercussion.

The most important dynamic phase to study parenchymal changes in pyelonephritis is the nephrographic phase, in which both cortex and medulla show similar attenuation, because the cortico-medullary phase (obtained in routine portal venous abdominal protocols) may not be as sensitive as the former to detect small hypodense lesions. Our standard protocol for achieving this phase is to scan 70-90 seconds after contrast administration.

The most common findings in contrast-enhanced CT are parenchymal hypodense lesions (Table 4). Another common finding is loss of parenchymal differentiation between papillae and cortex, presumably because of diffuse cortical oedema. This sign that can also be found in ultrasound imaging but that is better visualized in CT (Fig. 3).
**Figure 3.** Contrast-enhanced abdominal CT: Loss of cortico-medullary differentiation of the left kidney (big arrow) compared with normal right kidney (small arrow).

CT also exceeds in established renal abscesses and retroperitoneal extension of the infection (Fig. 4). Kidney function can be assessed with CT by studying contrast media excretion in late-phase scanning.

**CT Findings in Pyelonephritis**

<table>
<thead>
<tr>
<th>Hypodense lesions corresponding to focal pyelonephritis</th>
<th>No accompanying features - 6 cases</th>
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<tbody>
<tr>
<td>Perirrenal fat stranding - 5 cases</td>
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<tr>
<td>Pelvicalyceal parietal thickening - 4 cases</td>
<td></td>
</tr>
<tr>
<td>Increased renal size - 4 cases</td>
<td></td>
</tr>
<tr>
<td>Renal Abscess - 3 case</td>
<td></td>
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<tr>
<td>Thickening of retroperitoneal fascias - 2 cases</td>
<td></td>
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<td>Includes retroperitoneal collections, nephrolithiasis and hydronephrosis.</td>
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**Other**

<table>
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<th>24 cases</th>
<th>37 cases</th>
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**Table 4.** Common features of pyelonephritis in MDCT.

**Figure 4. A)** Gray scale ultrasound. Longitudinal view with perirrenal abscess identified as a hypoechoic lesion adjacent to the superior pole of right kidney. **B)** Coronal reconstruction of contrast-enhanced CT showing extension of the abscess to liver parenchyma.

**Magnetic Resonance Imaging (MRI)**

Not frequently used as a first aid technique, magnetic resonance has gained an important role in patients that have contraindications for the use of CT, such as the pregnant patient and the patient allergic to iodine contrast media. The imaging findings are similar to those on CT predominating the expected signal intensity pattern of fluid in the inflammatory lesions.
**Special situations:**

**Xanthogranulomatous pyelonephritis:**

In our review, seven cases of this type of chronic infection were found. 6 of them showed typical characteristics and the last case showed atypical features. Typical imaging features include a hydronephrotic kidney with multiple low density parenchymal lesions replacing the cortex (some of them corresponding to dilated calyceal groups filled with semi-solid material) and usually associating staghorn pelvicalyceal lithiasis (Fig. 5).

Atypical findings have been described in a few case reports in current literature and include presence of an atrophic kidney (such as the one in our case).

Complications include abscess fistulisation to retroperitoneal tissues, vicinity organs or abdominal wall (Fig. 6).

**Figure 5. Typical features of three cases of pathology confirmed xanthogranulomatous pyelonephritis.**

A) Oblique view on gray scale ultrasound of right kidney with dilated calyceal system (arrow) and an echogenic central staghorn calculus. B) Axial contrast-enhanced MDCT from another patient with staghorn calculus and dilated calyceal system. C) Coronal reconstruction of non-enhanced MDCT showing an upper pole staghorn calculus measuring 3.6cm.

**Figure 6. Atypical xanthogranulomatous pyelonephritis.**

Gray scale ultrasound (A and B) show a fluid collection in the left perirenal space (asterisk). Note the relationship between the atrophic left kidney (arrow in B, not totally included) and the collection and its anterior superficial extension to the abdominal wall (arrow). Contrast-enhanced MDCT. Coronal D) and axial C) images in venous phase and coronal image in delayed phase E) show an atrophic left kidney with a large lower caliceal calcium lithiasis (arrow in D) and a large fluid collection with peripheral enhancement (asterisk in C, D and E) in the left flank in contact with the lower renal pole (C) and with extension to the posterior abdominal wall (C) and to the left iliac fossa (D and E). Note the delay in contrast elimination of the left kidney in image E.

**Tuberculous pyelonephritis:**

Infection by *M. Tuberculosis* in the urinary system has had an increasing rate in the last years probably due to the rise in VIH cases and use of immunosuppressants.
Characteristics of this type of pyelonephritis are chronic affection with resultant bilateral kidney atrophy and scarring as well as pelvicalyceal clubbing and dilatation (Fig. 7).

**Figure 7.** *Axial abdominal contrast-enhanced CT* showing typical features of chronic tuberculous pyelonephritis showing dilated pelvicalyceal system in an atrophic left kidney with cortical thinning and mild perirrenal fat stranding.

**PYONEPHROSIS**

Pyonephrosis can be identified both in gray scale ultrasound and MDCT as a dilated pelvicalyceal system filled with echogenic/isodense material. It is part of the spectrum of urinary tract infections but it can also be seen without renal or bladder involvement and clinical findings are variable (Fig. 8)

**Figure 8.** *Ultrasound features of pyonephrosis in different patients complaining of dysuria and fever:* All images show dilated pelvicalyceal systems with echogenic content (arrows).

**PYELITIS**

Pyelitis refers to inflammatory urothelium thickening during ascending infections through the renal pelvis. It is best seen in gray scale ultrasound associating echogenic debris (sometimes creating fluid-fluid levels) occupying the pelvicalyceal system. Same findings can be identified in MDCT (Fig. 9)

**Figure 9. A)** *Gray scale ultrasound.* Marked pelvic uroretelial thickening of left kidney. **B)** *Axial contrast enhanced CT.* Uroretelial thickening with hydronephrosis.

**URETERITIS AND PYELOURETERITIS**

A patched dilatation of the ureter with inflammatory response of the adjacent fat are the most common findings during ureteral infection although in our review ectopic ureteral air and associated lithiasis were also found (Table 5). Ultrasound can show this in the proximal and distal portions of the ureters because, most of the time, bowel gas difficult the visualization of the rest of the ureter. CT once again surpasses ultrasound in showing this process particularly when multi-planar reconstructions are employed (Fig. 10)
**Figure 10.** Coronal reformed abdominal contrast-enhanced MDCT in patient with urinary obstructive symptoms and fever. Marked dilatation of the proximal segment of the right ureter with mild parietal thickening (thick arrow) with distal lithiasis (thin arrow).

**Imaging findings in pyeloureteritis**

- **Ultrasound**
  - Urotelium thickening with fat stranding

- **Multi-Detector**
  - Ectopic ureteral air - 2 cases

- **Computed Tomography**
  - Urotelium thickening with fat stranding - 2 cases
  - Urotelium thickening and lithiasis - 1 case

**Table 5.** Imaging findings in pyeloureteritis.

**CYSTITIS**

Bladder infection`s most common imaging sign is parietal thickening. This may be obscured, both in ultrasound as well as on CT, by poor bladder distension. If suspected, and distension is correct, parietal thickening accompanied by luminal debris, can aid in detecting cystitis. Other findings such as adjacent fat stranding can also be seen, especially in CT studies (Fig. 11)

**Figure 11.** Different aspects of cystitis. A) *Gray scale ultrasound.* Urinary bladder that presents marked parietal thickening with adjacent fat stranding and its corresponding appearance (arrow) in *axial venous phase MDCT* in B) *Axial contrast-enhanced MDCT.* Peripheral low density air bubbles (arrow) following the internal bladder mucosa corresponding to emphysematous cystitis in C)

**Images for this section:**
Fig. 1

Fig. 2
Fig. 3

Fig. 4
Fig. 11
Conclusion

Urinary tract infections, as was found in our review, are an exceedingly frequent diagnosis in our medium that comprises many different levels of disease that are amenable of analysis with imaging techniques.

Although pyelonephritis and cystitis are the most common infections in this spectrum of pathologies, our work shows that no absolute imaging finding can solely characterize or predict them. There are however a few repetitive patterns observed in each type of study that may aid the imaging specialist in suspecting one or other site of involvement, for example finding hyperechoic lesions during kidney ultrasound usually expresses focal pyelonephritis as well as their corresponding hypodense counterparts on computed tomography, in the correct clinical setting.

Pyelitis, pyeloureteritis, ureteritis and pyonephrosis have also relatively specific imaging findings, for instance when a radiologist finds himself encountering an echogenic or isodense occupation of a dilated pelvicalyceal system, he or she must immediately think of pyonephrosis as a possibility, as found in current literature and corroborated by our review.

More specific types of infection including tuberculosis and xanthogranulomatous pyelonephritis have also their corresponding characteristic features however; the information that can be provided by the radiologist has not been able yet to replace biopsy or other interventional diagnostic procedures in these particular cases.

We aimed to review the characteristic imaging features found in each type of urinary tract infection that can be addressed by radiologic techniques by analyzing our study population. We hope that by doing this we can help the imaging specialist in better understanding the urinary tract pathology.

Personal information

References