Abdom Imaging 18:82–87 (1993)

Abdominal Imaging

Genitourinary Radiology

Computed Tomography of Pyonephrosis

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Abstract. Computed tomographic (CT) findings of 17 pyonephrotic and 20 uninfected hydronephrotic kidneys were reviewed. Parameters evaluated included: renal pelvic wall thickness (none; grade 1, ≤2 mm; grade 2, 3–5 mm; and grade 3, >5 mm), renal pelvic contents, parenchymal, and perirenal findings. All patients underwent subsequent percutaneous nephrostomy within 1 week of CT. Common CT findings suggesting pyonephrosis include increased pelvic wall thickness and more severe perirenal fat changes than are seen in uninfected hydronephrosis. However, for any one patient, these findings are often not diagnostic. The presence of clinical signs of infection with hydronephrosis on CT is a more sensitive indicator of pyonephrosis than most CT findings.

Key words: Pyonephrosis, CT diagnosis — Kidney, infection — Hydronephrosis, CT.

Obstructed kidneys are at risk for superimposed infection, predominately from the same organisms that cause the more common, uncomplicated urinary tract infections. We use the term pyonephrosis to include infected obstructed pelvicalyceal systems with grossly purulent contents.

Patients with pyonephrosis often present with signs and symptoms of infection referable to the urinary tract and computed tomography (CT) is not routinely performed prior to treatment [1]. However, a series of 65 patients included ". . . 10 afebrile patients in whom the percutaneous aspiration of purulent urine provided the first clinical evidence of pyonephrosis" [2]. For these patients, and patients with signs of infection where a source of infection is unclear, CT may be the first study performed. Recognition of CT indicators of pyonephrosis could prompt early intervention.

The efficacy of CT is well established for detecting extrarenal extension of renal infection, as well as renal abscess. References to CT findings in pyonephrosis are limited to small numbers of patients as subsets of larger groups, with pyonephrosis or renal infection being studied for a variety of reasons [2–4]. Out goal was to define the CT manifestations of pyonephrosis by comparing CT findings in pyonephrotic kidneys with uninfected hydronephrotic kidneys in an effort to assess whether or not one can recognize a pyonephrotic kidney on CT with a high degree of certainty.

Materials and Methods

To identify patients treated for pyonephrosis or hydronephrosis who also had CT examinations, a computer search of medical records for the period from January 1984 to July 1991 was cross referenced with radiological records. During this time, 536 patients had percutaneous nephrostomy or cystoscopic guided ureteral catheter placement. The radiographic files for 31 of these patients were unavailable for review and were excluded. Thirty-seven patients with a CT scan including the kidneys *within 1 week* prior to urinary diversion by percutaneous nephrostomy were thus identified. None of the patients treated with ureteral stents fulfilled the inclusion criterion of a CT scan within 1 week prior to stent placement.

Records of the 37 patients were reviewed to determine indications for CT examination, cause and level of urinary tract obstruction, reason for urinary diversion, patient symptoms and signs, as well as upper urinary tract culture results. Patients were classified in the pyonephrotic group if they had a description of purulent urine at the time of nephrostomy and positive cultures or purulent urine at nephrostomy with a clinical history consistent with upper urinary tract infection responding to percutaneous nephrostomy and antibiotics. Two patients with positive upper tract cultures at nephrostomy were excluded because there was no description of purulent material at nephrostomy. Patients were placed in the hydronephrotic (control) group if they had no signs of upper uri-

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Table 1. Cause of Urinary Tract Obstruction in 35 cases

	Ureteral Calculus	Malignancy	UPJ Obstruction	Ureteral Stricture	Ectopic Ureter	Postpartum Obstruction
Pyonephrosis (N = 16 patients)	4	3	4	2	2	1
Uninfected hydronephrosis (N = 19 patients)	2	15	1	1	—	—

nary tract infection. In bilateral hydronephrosis, only the treated obstructed kidney was considered in this analysis.

Seventeen kidneys in 16 patients with pyonephrosis and 20 kidneys in 19 patients with hydronephrosis fulfilled the inclusion criteria. One patient in each group had bilateral percutaneous nephrostomies. Pyonephrotic group patients ranged in age from 27–80 years (mean, 61.6 years). Control group patients ranged in age from 26–81 years (mean, 62.7 years). There were 14 women and two men in the group with pyonephrosis and 10 women and nine men in the control group.

CT studies were performed with GE9800 or 8800 CT scanners (General Electric Medical Systems, Milwaukee, WI, USA) using 1-cm slice thickness at 1-cm intervals (18 patients), 1.5-cm intervals (nine patients), or 2-cm intervals (eight patients). Thirteen pyonephrotic group and 12 control group patients had CT studies with intravenous contrast.

The average time between CT and percutaneous nephrostomy was 0.7 days from the group with pyonephrosis (range 0–3 days) and 1.8 days for the control group (range 0–7 days). Each CT study was retrospectively reviewed simultaneously by three radiologists to arrive at a consensus reading for the following: (1) renal pelvic wall thickness; (2) maximal renal pelvic AP diameter; (3) renal pelvic contents; (4) real parenchymal appearance; and (5) perirenal fat septal and fascial thickening.

Wall thickness was classified based on a modification of the Nicolet et al. system [5]: none, imperceptible wall thickness; grade 1, $\leq$2 mm; grade 2, 3–5 mm; and grade 3, >5 mm. To eliminate confusion between the renal pelvic wall and adjacent blood vessels, wall thickness grades were assigned only when a perceptible wall was present around most of the perimeter of the renal pelvis. The pelvicalyceal system was assessed for gas, fluid–debris levels, or calculi, as well as relative attenuation of renal pelvic contents with respect to gallbladder on noncontrast studies. In patients that received intravenous contrast the parenchyma was assessed for nephrogram homogeneity and relative density compared with the contralateral kidney. Perirenal fat septal and fascial thickening was categorized as none, mild, moderate, or severe.

Results

CT indications in the pyonephrotic group included ruling out abscess (N = 6), renal obstruction (N = 6), and evaluating palpable mass (N = 4). CT indications in the control group included malignancy (N = 14), renal obstruction (N = 3), and aortic aneurysm (N = 2). Underlying causes of obstruction in both groups are outlined in Table 1.

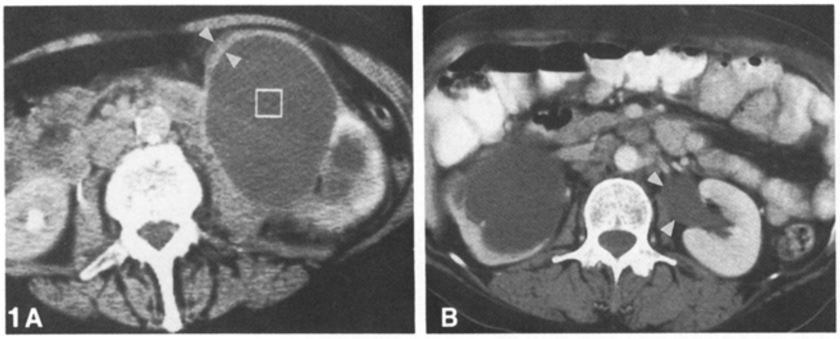
Indications for percutaneous nephrostomy in the 16 patients with pyonephrosis included 13 patients for clinical evidence of infection in the setting of hydronephrosis, two patients for impaired renal function, and one patient to relieve and assess severe postpartum obstruction. The vast majority (17 patients) of percutaneous nephrostomies in the control group were for impaired renal function due to obstruction.

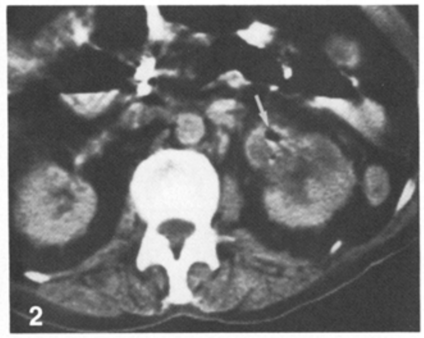
Fifteen of 17 pyonephrotic kidneys had records of renal pelvic urine culture, some also had Gram stains. Twelve of 15 cultures were positive. The most common organism was *E. coli*, other organisms included *Proteus, Pseudomonas, Morganella,* and fungi. The three pyonephrotic patients with negative cultures and two patients with no record of urine samples sent for culture did have gross descriptions of purulent urine at nephrostomy with clinical signs and symptoms of upper urinary tract infection with response to nephrostomy and antibiotics.

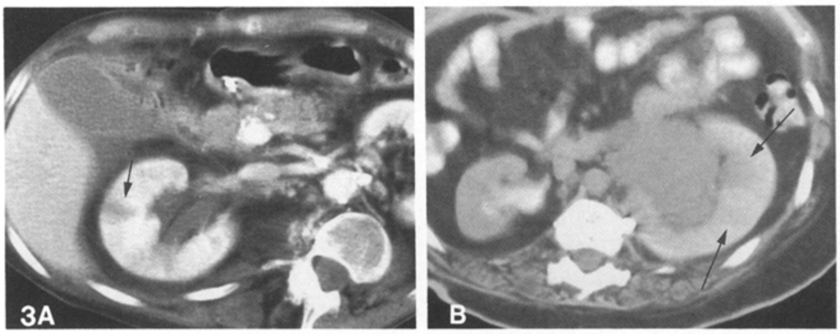
Renal pelvic urine cultures were obtained in 16 of the 20 kidneys in the control group. All of these showed no growth. All patients in the control group lacked clinical signs and symptoms of upper urinary tract infection.

Pyonephrotic kidneys manifested a greater degree of renal pelvic wall thickness on CT than uninfected hydronephrotic systems (Table 2, Fig. 1). This difference was statistically significant (χ^2 = 11.75, $p < 0.001$). The pyonephrotic group mean renal pelvis diameter was 3.32 ± 1.43 cm (range 1.7–7 cm), for the control group it was 3.68 ± 2.18 cm (range 1.8–11.8 cm). There was no significant difference in the mean pelvic diameter between the two groups (p = 0.87, Student's t test). Consequently, the degree of pelvic distension in each group was not considered a contributing factor to the difference in pelvic wall thicknesses between the two groups.

Two (12%) pyonephrotic collecting systems contained gas, none of the hydronephrotic kidneys had gas in the collecting system (Fig. 2). One pyonephrotic kidney had a calyceal calculus. No perceptible fluid–debris levels or inversion of the usual urine-contrast levels were present in either group.







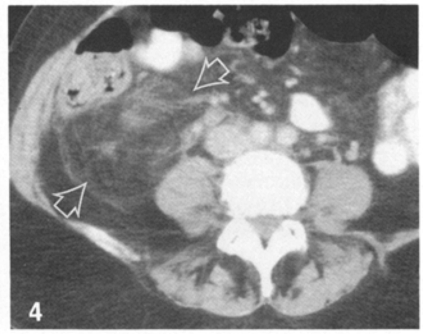


Fig. 1. **A** Pyonephrotic left kidney with predominately grade 3 pelvic wall thickness (*arrowheads*). **B** Left renal pelvis with no evidence of a perceptible circumferential pelvic wall (*arrowheads*) in uninfected hydronephrosis.

Fig. 2. Pyonephrotic left kidney with renal pelvic gas (*arrow*). Grade 2 pelvic wall thickness is present.

Fig. 3. **A** Pyonephrotic right kidney with inhomogeneous parenchymal enhancement (*arrow*). **B** Inhomogeneous striated parenchymal enhancement (*arrows*) in a patient with uninfected left hydronephrosis.

Fig. 4. Severe septal and fascial changes in the perirenal fat just below the lower pole of a pyonephrotic right kidney (*arrows*).

Table 2. Evaluation of renal pelvic wall thickness on CT

	None	Grade 1	Grade 2	Grade 3
Pyonephrosis (N = 17 kidneys)	24%	41%	29%	6%
Uninfected hydronephrosis (N = 20 kidneys)	85%	10%	—	5%

Region of interest (ROI) measurements of the renal pelvis were not routinely available in our patients, but visual comparison of gallbladder fluid with renal pelvic fluid on noncontrast CT scans was performed. Noncontrast images for four kidneys in the pyonephrotic group and seven kidneys in the control showed no perceptible difference between the fluid attenuation within these two structures. Two of the four kidneys with pyonephrosis and three of the seven control group kidneys had renal pelvic (ROI) measurements. All of these measured 15 Hounsfield units or less.

Twelve of 16 CT scans in the group with pyonephrosis and 13 of 19 CT scans in the control group were performed with intravenous contrast. Abnormal parenchymal enhancement occurred in five patients in each group. Abnormalities included combinations of increased and decreased homogeneous and inhomogeneous nephrograms. Inhomogeneous enhancement was seen in five of five nephrograms in the pyonephrotic group and three of five nephrograms in the control group (Fig. 3). The pattern of inhomogeneity in both groups consisted of predominantly ill-defined, sometimes wedge-shaped, areas of decreased attenuation.

All pyonephrotic kidneys and 50% of control group kidneys demonstrated thickening of the perirenal septa and fascia (Table 3, Fig. 4). The difference between the two groups was statistically significant ($\chi^2 = 10.80$, $p < 0.001$). No pyonephrotic kidneys and two of the hydronephrotic kidneys had evidence of perirenal urine extravasation demonstrated on prenephrostomy evaluation. Both kid-

Table 3. Perirenal septal and fascial thickening

	None	Mild	Moderate	Severe
Pyonephrosis (N = 17 kidneys)	0	41%	29%	29%
Uninfected hydronephrosis (N = 20 kidneys)	50%	25%	10%	15%[a]

[a] Two of three hydronephrotic kidneys in this category had evidence of urine extravasation on prenephrostomy evaluation.

neys associated with extravasation secondary to obstruction had severe thickening of the septa and fascia and accounted for two of the three kidneys with severe perirenal fat changes in the hydronephrotic group.

Discussion

The clinical presentation of pyonephrosis most often leads to a correct diagnosis following documentation of hydronephrosis by ultrasound, nuclear medicine renogram, or intravenous pyelogram (IVP). In the setting of suspected pyonephrosis, prompt urinary diversion is indicated. Therefore, at our hospital, CT is most often performed *following urinary diversion* when patients are stable if the site and cause of obstruction are unclear. However, with unsuspected pyonephrosis CT may be the first radiologic study performed to search for a source of infection. This was the case in most of our patients and, in fact, in three (19%) patients with pyonephrosis there were no clinical indicators of infection at the time of CT examinations. One of these three patients had no pelvic wall thickening and two had grade 1 thickening, all three had mild perirenal fat changes. Nevertheless, the presence of clinical signs of infection in conjunction with hydronephrosis is a more sensitive indicator of pyonephrosis (81% sensitivity in this series) than any single CT findings.

Previous reports about imaging of pyonephrosis have emphasized ultrasound findings and there is limited information specifically related to CT. The ultrasound findings of pyonephrosis enumerated previously have included diffuse and gravity-dependent echoes within the pelvicalyceal system [6–8], shadowing peripheral echoes secondary to gas from gas-forming organisms [6], and renal collecting system wall thickening [5, 9].

Pelvic Wall Thickness

A significant proportion of pyonephrotic kidneys in our series had an increased renal pelvic wall thickness compared with the control group (Table 2). The presence versus absence of pelvic wall thickening had a sensitivity of 76% for pyonephrosis in our series, specificity was 85%.

It should be noted that collecting system wall thickening can sometimes be seen on IVPs in the setting of pyonephrosis [10]. Furthermore, wall thickening demonstrated on IVP and ultrasound has been shown to be nonspecific in other studies. Wall thickening has been described in reflux, chronic obstruction, renal transplant rejection, ATN, and in total parenteral nutrition [5, 9, 11].

The relationship between pelvic wall thickening and the degree of hydronephrosis has been discussed previously [5]. In a series of patients studied with ultrasound, Nicolet et al. indicated that wall thickening may be less evident with increasing degrees of hydronephrosis [5]. This factor was not relevant in our study which showed no statistically significant difference in the average maximal AP renal pelvic dimension between the pyonephrotic and control groups. Interestingly, the maximum renal pelvic AP dimensions in both groups were in the kidneys with the greatest degree of pelvic wall thickening.

Renal Pelvic Contents

The number of reports about pyonephrotic pelvicalyceal findings in CT are limited. Among 70 patients with pyonephrosis in one study, a subset of *three patients* had CT [2]. One patient had inversion of the usual renal pelvic fluid–contrast layering with contrast overlying purulent debris. In another series of six patients with pyonephrosis from a group of 40 with inflammatory renal disease, collecting system gas was noted in two of the six and the ". . . kidney did not function in 5 patients" [3]. In addition, "dense urine (>10 H)" was listed as a finding of pyonephrosis, although the attenuation values for their patients were not mentioned. In a general discussion of pyonephrosis, Kenney [10] has indicated that renal pelvic fluid values greater than 20 Hounsfield units may be present in pyonephrosis, although he does not address the incidence of this finding. Our pyonephrotic group had neither increased unenhanced urine attenuation, contrast layer inversion, or recognizable fluid–debris levels.

Pelvicalyceal system gas in the absence of a history of urinary tract instrumentation is a strong diagnostic indicator of pyonephrosis. This was identified in only two of the 17 (12%) kidneys with pyonephrosis in our study.

Renal Parenchyma

There are a limited number of previous reports of the CT appearance of renal parenchyma in the setting of pyonephrosis. In a series of 62 patients with acute renal infections, four patients had pyonephrosis and three of these patients received intravenous contrast [4]. One patient had no opacification of the affected kidney and the other two had wedge-shaped areas of abnormal enhancement as can be seen with acute bacterial nephritis [4].

It is difficult to draw definite conclusions regarding the nephrogram appearance in our study because of variable modes of contrast administration, as well as variable time between injections and scanning. Parenchymal assessment may also have been limited by the lack of narrow window images through the kidneys because only routine soft tissue window settings were available for review.

The extrarenal obstructions in all of our patients likely contributed to abnormal nephrograms. Striated nephrograms are nonspecific and can be seen in uninfected kidneys with obstruction, as well as in acute pyelonephritis independent of obstruction. The inhomogenous parenchymal appearance of infectious and noninfectious nephritis can be similar at CT examination [13].

In the relatively small number of patients in each group with abnormal parenchymal enhancement it was more common to observe *inhomogeneous* patchy enhancement in the group with pyonephrosis (five of five abnormal nephrograms) compared with uninfected obstruction (three of five abnormal nephrograms). However, in these patients with inhomogeneously enhancing parenchyma a qualitative visual distinction between the uninfected and infected kidneys on the basis of the parenchymal appearance alone was not possible.

Perirenal Findings

A thin renal fascia and bridging septa within the perirenal fat can be seen on CT in normal patients [14, 15]. Thickening of the fascia and bridging septa is nonspecific and has been found with retroperitoneal neoplasms, inflammatory processes, trauma, renal infarction, and in peritonitis [14, 15]. In a subset of four patients with CT examinations in the setting of pyonephrosis noted previously, only one patient had inflammatory changes in the perirenal fat and Gerota fascia [4].

In our study the thickness of the septa and fascia were qualitatively evaluated as "perirenal fat changes" and in general they were increased to varying degrees in all patients with pyonephrosis and 50% of patients in the control group. The relatively high proportion of perirenal fat changes in the control group could reflect prior remote renal inflammatory conditions as it has been shown that perirenal inflammatory changes can persist at least 7½ months following renal infection [16]. Two hydronephrotic kidneys in our patients had severe perirenal fat changes that were undoubtably related to concomitant urine extravasation occurring secondary to obstruction. It is also plausible that edema from hypoproteinemia or the nephrotic syndrome could contribute to edematous changes in the retroperitoneal fat.

Conclusions

The limitations of our retrospective study include an inability to assess the possible influence of remote infections or of preceding short- and long-term antibiotics in some patients. Furthermore, the duration and relative grade of obstructions in our patients are variables that could also effect the degree of pelvic wall thickening and parenchymal appearance, respectively.

CT findings suggesting pyonephrosis included increased pelvic wall thickness and more severe perirenal fat changes than in uninfected hydronephrosis. Although collecting system gas is less common, it is the strongest indicator for pyonephrosis on CT. In our series, the absence of perirenal fat changes in hydronephrosis argues strongly against pyonephrosis. Focal abnormal parenchymal enhancement was more common in pyonephrosis than in our control group, but the patterns, when present, were similar.

In the majority of patients, CT findings cannot reliably distinguish between an uninfected and infected hydronephrotic kidney. Direct upper urinary tract access is needed for final diagnosis and treatment. The ancillary CT findings in pyonephrosis can focus attention to the urinary tract in CT examinations performed for unexplained fevers and to "rule out abscess."

Acknowlegments. The authors thank Beverly Pollet for secretarial assistance and Thomas Morris, Ph.D., for assistance with statistical analyses.

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Received: August 6, 1992; accepted: September 15, 1992