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Relationship Between Uncommon Computed Tomography Findings and Clinical Aspects in Patients With Acute Pyelonephritis

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Purpose: Computed tomography (CT) has become popular in the diagnosis of acute pyelonephritis (APN) and its related complications in adults. The aim of this study was to investigate the relationship between uncommon CT findings and clinical and laboratory data in patients with APN.

Materials and Methods: From July 2009 to July 2012, CT findings and clinical data were collected from 125 female patients with APN. The six uncommon CT findings (excluding a wedge-shaped area of hypoperfusion in the renal parenchyma) studied were perirenal fat infiltration, ureteral wall edema, renal abscess formation, pelvic ascites, periportal edema, and renal scarring. The clinical parameters analyzed were the age and body mass index of the patients as well as the degree and duration of fever. Laboratory parameters related to inflammation and infection included white blood cell count, C-reactive protein (CRP) level, erythrocyte sedimentation rate, pyuria, and bacteriuria.

Results: The most common CT finding was perirenal fat infiltration (69 cases, 55%). A longer duration of fever, higher CRP level, and grade of pyuria were related with perirenal fat infiltration (p=0.010, p=0.003, and p=0.049, respectively). The CRP level was significantly higher in patients with renal abscess and ureteral wall edema (p=0.005 and p=0.015, respectively).

Conclusions: The uncommon CT findings that were related to aggravated clinical and laboratory parameters of APN patients were perirenal fat infiltration, ureteral wall edema, and renal abscess formation. The inflammatory reaction and tissue destruction may be more aggressive in patients with these CT findings.

Keywords: *Pyelonephritis; X-ray computed tomography*

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INTRODUCTION

Acute pyelonephritis (APN) is the most common upper urinary tract infection, and approximately 20% to 35% of females experience an episode of APN in their lifetime [1]. The annual incidence of APN is reportedly as high as 35.7 per 10,000 individuals in South Korea, and the incidence of hospitalization for APN is reportedly 9.96 per 10,000 Korean women [2]. APN usually occurs secondary to an ascending infection of gram-negative bacteria in females, and the diagnosis is made clinically [3]. Computed tomography (CT) has not been primarily applied in patients with APN; it is preferred in patients with diabetes, equivocal diagnoses, no response to antimicrobial treatment, or immunosuppression. CT can provide important information on the range of inflammation and other accompanying complications to help to establish a precise diagnosis [4-6]. The most common radiologic CT finding of APN is a striated or wedge-shaped area of hypoperfusion or mass-like lesion after contrast injection [7,8]. Other uncommon radiologic findings such as perirenal fat infiltration, ureteral wall edema, renal abscess formation, pelvic

ascites, portal edema, and renal scarring are also observed on CT scans [9,10].

Although the use of CT in the diagnosis of APN has rapidly increased recently, the relationship between APN and CT findings has rarely been reported. We investigated the relationship between uncommon CT findings and clinical parameters in patients with APN.

MATERIALS AND METHODS

1. Inclusion criteria

This retrospective study was approved by the Institutional Review Board of the Soonchunhyang University Bucheon Hospital (IRB no. 2013-07-014). From July 2009 to July 2012, a total of 125 female patients (mean age, 42.8±13.5 years) with APN were included in this study. In all patients, CT showed a wedge-shaped area of hypoperfusion in the renal parenchyma. A clinical diagnosis of APN was made in patients with more than three of the following five diagnostic criteria:

(1) Clinical symptoms such as fever, chills, vomiting, or flank pain

(2) Costovertebral angle tenderness

(3) Fever of more than 37.5°C

(4) Leukocytosis in the complete blood count (>10,000/μL)

(5) Abnormal urine test results (pyuria: white blood cells [WBC] of >5/high-power field [HPF] or positive urine culture of $>10^5$ colony-forming unit/mL)

2. CT technique

Because CT scans were performed over a period of 3 years, multidetector helical CT of various types with either a 16- or 64-channel multidetector row scanner (Somatom Sensation 16, Siemens Medical Solutions, Erlangen, Germany) or LightSpeed VCT (GE Healthcare Life Sciences, Piscataway, NJ, USA) was applied in all patients. The CT findings were evaluated in the nonenhanced and nephrographic phases. Intravenous contrast material was administrated in an antecubital vein with an injector at a dose of 2 mL/kg body weight and rate of 3 mL/s to a maximum of 160 mL. Nephrographic-phase scans were started 90 to 100 seconds after contrast injection.

3. CT findings

The following six uncommon radiologic CT findings were evaluated by one radiologist in our hospital: perirenal fat infiltration, ureteral wall edema, renal abscess formation, pelvic ascites, periportal edema (Fig. 1), and renal scarring.

4. Clinical parameters

We investigated age, degree and duration of fever, body mass index (BMI), blood leukocytosis, hemoglobin (Hb), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) level, grade of pyuria, and positive urine/blood culture. Pyuria was graded from 1 to 6 by microscopic examination under HPF (grade 1, 0–1 WBC/HPF; grade 2, 1–4 WBC/HPF; grade 3, 5–9 WBC/HPF; grade 4, 10–29 WBC/HPF; grade 5, 30–50 WBC/HPF; grade 6, more than half the HPF filled with WBC).

5. Statistical analysis

The statistical analysis was performed by using SPSS ver. 14 (SPSS Inc., Chicago, IL, USA). Student t-test or the Mann-Whitney U-test was applied to compare the clinical parameters of fever, BMI, WBC count, Hb level, ESR, CRP level, grade of pyuria, and presence of the six CT findings described above. The chi-square test was used to evaluate differences between the presence of bacteriuria/bacteremia and the presence of the six CT findings. Values of $p < 0.05$ were considered to indicate statistical significance.

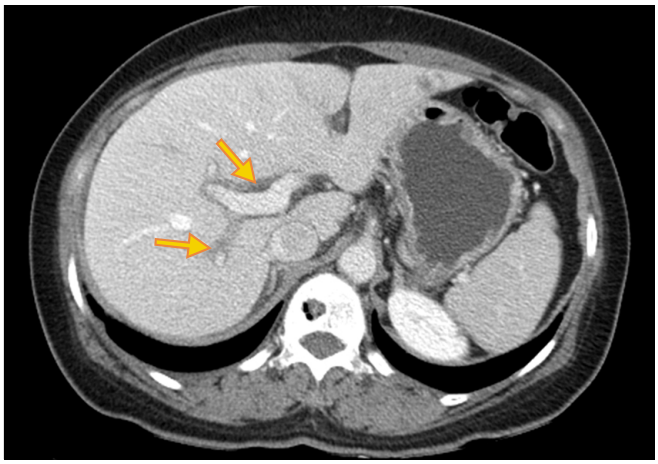

FIG. 1. Computed tomography finding of periportal edema. Contrast-enhanced computed tomography scan of a 58-year-old female patient who was referred to abdominal computed tomography for evaluation of clinically suspected pyelonephritis, which was confirmed. Computed tomography revealed periportal low attenuation, indicating periportal edema.

TABLE 1. Patients' characteristics

Characteristic	Value
Age (y)	42.8±13.5
Body mass index (kg/m^2)	22.9±3.7
Recurrent cases	22 (17.6)
Laterality	
Left	36 (28.8)
Right	62 (49.6)
Bilateral	27 (21.6)
Diabetes mellitus	12 (9.6)
Creatinine (mg/dL)	0.9±0.1
Peak fever (°C)	38.7±0.8
Duration of fever (d)	7.3±3.1
White blood cell (μL)	11,733±4,665
Erythrocyte sedimentation rate (mm/h)	46.5±25.1
C-reactive protein (mg/dL)	12.8±7.5
Mean pyuria (grade)	4.6±1.2
Positive urine culture	74 (59.2)

Values are presented as mean±standard deviation or number (%).

RESULTS

The mean peak fever was 38.7°C±0.8°C, and the mean fever duration was 7.3±3.1 days. The mean blood leukocyte count was 11,733±4,665 /μL, the mean CRP level was 12.8±7.5 mg/dL, and the mean grade of pyuria was grade 4.6±1.2 (Table 1). The most common CT finding was perirenal fat infiltration (69 cases, 55%), followed in turn by pelvic ascites (50 cases, 40%), ureteral wall edema (39 cases, 31%), and renal abscess formation (20 cases, 16%; Table 2).

TABLE 2. Incidence of six computed tomography (CT) findings in acute pyelonephritis

CT finding	Present	Absent
Perirenal fat infiltration	69 (55)	56 (45)
Ascites	50 (40)	75 (60)
Ureteral wall edema	39 (31)	86 (69)
Renal abscess	20 (16)	105 (84)
Periportal edema	15 (12)	110 (88)
Renal scarring	11 (8)	114 (92)

Values are presented as number (%).

When we compared the six CT findings with the clinical parameters, the fever duration was longer and the CRP level and grade of pyuria were higher in cases with perirenal fat infiltration (p=0.010, p=0.033, and p=0.049, respectively). The CRP level was significantly higher in patients with renal abscess formation and ureteral wall edema (p=0.005 and p=0.015, respectively). Pelvic ascites, periportal edema, and renal scarring had no relationship with clinical parameters (Table 3). Although bacteriuria was found in 74 patients (59.2%), bacteriuria positivity was not related to any of the CT findings (Table 3).

DISCUSSION

APN is usually diagnosed on the basis of typical clinical symptoms (fever, chills, nausea, and flank pain), physical examination findings (costovertebral angle tenderness), and laboratory findings including leukocytosis, pyuria, and a positive urine culture [3]. The clinical risk factors of APN are female gender, diabetes mellitus, immunosuppression, postmenopausal state, previous recurrent urinary tract infection, and vesicoureteral reflux [11]. Although intravenous pyelography (IVP) and renal

TABLE 3. Correlations between computed tomography findings and clinical and laboratory parameters

Variable	Renal abscess[a]			Perirenal fat infiltration[b]			Ureteral wall edema		
	Present (n=20)	Absent (n=105)	p-value	Present (n=69)	Absent (n=56)	p-value	Present (n=39)	Absent (n=89)	p-value
Age (y)	42.3±12.8	42.9±13.7	0.984	41.5±13.2	44.3±13.9	0.252	39.8±12.6	44.1±13.8	0.097
Peak fever (°C)	38.5±0.8	38.7±0.8	0.553	38.7±0.9	38.6±0.7	0.278	38.7±0.7	38.6±0.8	0.946
Duration of fever (d)	6.8±2.1	7.4±3.2	0.456	7.9±3.5	6.5±2.2	0.010	7.31±2.58	7.3±3.3	0.992
WBC (/μL)	13,803±5,815	11,527±4,730	0.136	12,063±4,565	11,325±4,795	0.381	12,759±5,130	11,267±4,391	0.098
Hb (g/dL)	11.4±1.3	11.7±1.2	0.407	11.4±1.3	11.9±1.1	0.064	11.5±1.3	11.7±1.2	0.348
ESR (mm/h)	55.5±26.1	45.2±25.0	0.080	45.5±25.8	44.0±24.2	0.325	47.2±25.1	46.1±25.2	0.820
CRP (mg/dL)	16.8±7.4	12.2±7.4	0.005	14.1±7.9	11.3±6.8	0.033	15.3±7.9	11.7±7.1	0.015
Pyuria (grade)	4.5±1.2	4.7±1.2	0.416	4.9±1.2	4.4±1.3	0.049	4.7±1.2	4.6±1.3	0.825
Bacteriuria (%)	11 (55.0)	63 (60.0)	0.677	38 (55.1)	36 (64.3)	0.297	20 (51.3)	54 (62.8)	0.225

Variable	Renal scarring[a]			Ascites[b]			Periportal edema[a]		
	Present (n=11)	Absent (n=114)	p-value	Present (n=50)	Absent (n=75)	p-value	Present (n=15)	Absent (n=110)	p-value
Age (y)	41.5±11.4	42.9±13.7	0.672	40.1±12.8	44.5±13.8	0.077	42.8±10.1	42.8±13.9	0.849
Peak fever (°C)	38.4±0.6	38.7±0.8	0.610	38.7±0.7	38.6±0.8	0.359	38.5±0.4	38.7±0.8	0.280
Duration of fever (day)	6.2±1.7	7.4±3.1	0.816	7.6±3.3	7.0±2.9	0.338	7.3±2.7	7.3±3.1	0.637
WBC (μL)	10,354±3,348	11,866±4,763	0.716	12,585±5,333	11,164±4,101	0.096	11,983±3,959	11,698±4,762	0.592
Hb (g/dL)	12.0±1.0	11.6±1.3	0.586	11.6±1.1	11.6±1.3	0.872	12.3±21.2	11.5±1.2	0.055
ESR (mm/h)	39.2±24.5	47.2±25.1	0.319	43.0±25.4	48.8±24.8	0.213	38.0±21.2.	47.6±25.4	0.213
CRP (mg/dL)	9.3±5.0	13.2±7.6	0.320	13.6±7.5	12.3±7.5	0.371	11.5±6.5	13.0±7.6	0.480
Pyuria (grade)	4.4±1.3	4.7±1.2	0.848	4.7±1.3	4.6±1.2	0.888	5.1±1.1	4.6±1.2	0.121
Bacteriuria (%)	4 (36.4)	70 (61.4)	0.107	30 (60.0)	44 (58.7)	0.882	12 (80.0)	62 (56.4)	0.081

Values are presented as mean±standard deviation or number (%).
WBC, white blood cells; Hb, hemoglobin; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein.
[a]:Mann-Whitney U-test. [b]:Student t-test.

ultrasound were the main radiologic diagnostic tools used in the past, CT has recently become popular in the diagnosis of APN and its related complications. Although IVP can show the anatomical structure of the renal pelvis and calyces as well as the urinary drainage from the kidney to the bladder, it is not suitable for evaluation of renal parenchymal diseases such as APN [12]. Ultrasonography is also frequently performed in patients with APN; however, positive findings have been shown in only 20% to 24% of patients in prospective studies [13,14]. CT is the new gold standard in the evaluation of APN. It can show pathologic states in both intrarenal and extrarenal areas as precise images and can provide comprehensive anatomical and physiological information.

After administration of contrast material, APN most commonly manifests as one or more striated or wedge-shaped areas of hypoperfusion or streaky zones of lesser enhancement that extend from the papilla to the renal cortex. This pattern of differential enhancement reflects the underlying pathophysiology of tubular obstruction caused by inflammatory debris within the lumen, interstitial edema, and vasospasm [9,12]. This area of hypoperfusion is formed by obstruction of blood vessels resulting from spasm, edema of the interstitium, and the presence of intraluminal inflammatory metabolites [9]. Radiologic CT findings other than wedge-shaped hypoperfusion include renal abscess formation or renal scarring found in intrarenal areas and perirenal fat infiltration, ureteral wall edema, pelvic ascites, and periportal edema found in extrarenal areas. Although other CT findings can be observed in intrarenal areas, including thickening of Gerota's fascia, obliteration of the renal sinus, pelvicalyceal wall thickening and enhancement, poor contrast excretion, urinary tract stones, and pelvicalyceal air, we excluded these findings because of difficulties in obtaining a precise diagnosis and their low incidence [15].

In the present study, perirenal fat infiltration was the most common CT finding in patients with APN, and the fever duration, CRP level, and grade of pyuria were more severe in these cases. Perirenal fat infiltration is observed when the inflammation of the renal parenchyma is severe and the inflammatory infiltration spreads beyond the renal capsule to the perirenal fat. The CRP level was significantly higher in patients with renal abscesses and ureteral wall edema in our study. Acute-phase inflammatory responses accompany increases in the levels of various proteins, such as CRP, fibrinogen, haptoglobin, lactoferrin, and various cytokines including interleukin-1 and tumor necrosis factor [16]. CRP is widely used in the diagnosis of various acute inflammatory diseases because it is increased as early as 6 hours after inflammation and doubles every 8 to 9 hours [17]. Renal abscess formation, perinephric abscess formation, and pyonephrosis are considered to indicate a more severe disease status than uncomplicated APN. Although gram-negative bacteria are the main cause of renal abscess formation, urine culture results are usually negative. CT is the diagnostic procedure of choice for renal abscesses, in which cases a focal rounded area of decreased enhancement is usually found [18].

Neither bacterial ureteritis nor pyeloureteritis have been reported in the literature because of their rarity as separate disease entities and because of difficulties in their precise diagnosis. The clinical significance and pathophysiology of ureteral wall or pelvicalyceal wall thickening in APN are also unknown for these reasons. Both renal abscess formation and ureteral wall thickening were risk factors for an increased CRP level in our study, and we regarded ureteral wall or pelvicalyceal wall thickening as an indicator of severe inflammation of the pelvicalyceal system or ureter and of ascending infection. Tsugaya et al. [10] reported that cortical scars were detected in six of seven patients in whom the inflammatory lesions occupied 30% or more of the renal parenchyma. Because we performed CT scans at admission, our renal CT scan findings seemed to be evidence of previous recurrent or severe renal inflammation. Although the CT finding of renal scarring was not related with the severity of inflammation and clinical parameters in our study, a follow-up CT scan or dimercaptosuccinic acid renal scan may be needed in patients with severe inflammation, even in adults.

Periportal edema and ascites are nonspecific radiologic findings representing accumulation of fluid within third spaces [19]. The periportal region is the area around the portal vein and its branches, within which the hepatic artery, bile duct branches, autonomic nerves, and lymphatics are found [20]. The other radiologic findings associated with hepatic periportal tracking include a thickened gallbladder wall, pleural effusion, and a dilated inferior vena cava [21]. A multifactorial etiology for periportal edema in acute infectious disease has been suggested, including altered sodium reabsorption as a result of the infectious process involving the renal interstitium and increased vascular permeability secondary to systemic sepsis or hypoalbuminemia [21].

Our study had several limitations. First, we did not include the most frequent CT finding in APN, namely, a focal or multifocal wedge-shaped area of hypoperfusion, because all patients had this finding and it was difficult to quantify. Exclusion of patients with only CT findings of a wedge-shaped area of hypoperfusion may be the reason for the relatively small number of cases in our study. Second, we used a retrospective design, and many other intrarenal and extrarenal findings were not included because of their low incidence, which was also likely due to the relatively small number of cases.

CONCLUSIONS

The uncommon CT findings that were related with aggravated clinical and laboratory parameters of APN were perirenal fat infiltration, ureteral wall edema, and renal abscess formation. The inflammatory reaction and tissue destruction may be more aggressive in patients with these CT findings. These results may helpful in terms of predict-

ing the clinical course and creating a treatment plan for patients with APN.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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