

# Usefulness of Blood Cultures and Radiologic Imaging Studies in the Management of Patients with Community-Acquired Acute Pyelonephritis

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**Background:** The objective of this study was to examine the usefulness of blood cultures and radiologic imaging studies for developing therapeutic strategies in community-acquired acute pyelonephritis (CA-APN) patients.

**Materials and Methods:** We prospectively collected the clinical data of CA-APN patients who visited 11 hospitals from March 2010 to February 2011.

**Results:** Positive urine and blood cultures were obtained in 69.3% (568/820) and 42.7% (277/648), respectively, of a total of 827 CA-APN patients. Blood culture identified the urinary pathogen in 60 of 645 (9.3%) patients for whom both urine and blood cultures were performed; the organisms isolated from urine were inconsistent with those from blood in 11 and only blood cultures were positive in 49 patients. Final clinical failure was more common in the bacteremic patients than the non-bacteremic ones (8.0% vs. 2.7%,  $P = 0.003$ ), as was hospital mortality (3.6% vs. 0.3%,  $P = 0.003$ ). Likewise, durations of hospitalization and fever were significantly longer. Bacteremia was independent risk factor for mortality (OR 9.290, 1.145-75.392,  $P = 0.037$ ). With regard to radiologic studies, the detection rate of APN was 84.4% (445/527) by abdominal computed tomography and 40% (72/180) by abdominal ultrasonography. Eighty-one of 683 patients (11.9%) were found to have renal abscess, perinephric abscess, urolithiasis, hydronephrosis/hydronephrosis or emphysematous cystitis, which could potentially impact on clinical management. Patients with Pitt score  $\geq 1$ , flank pain or azotemia were significantly more likely to have such structural abnormalities.

**Conclusion:** Blood cultures are clinically useful for diagnosis of CA-APN, and bacteremia is predictive factor for hospital mortality. Early radiologic imaging studies should be considered for CA-APN patients with Pitt scores  $\geq 1$ , flank pain or azotemia.

**Key Words:** Pyelonephritis; Blood culture; Diagnostic imaging; Tomography scanners X-ray computed; Ultrasonography

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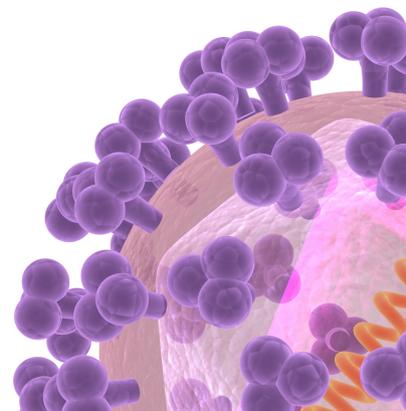
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## Introduction

Acute pyelonephritis (APN) refers to infection of the renal pelvis and the parenchyma. It generally occurs due to ascending infection via the bladder [1, 2]. The annual prevalence of acute pyelonephritis in Korea is 35.7/10,000 people, and is higher in women than in men (59/10,000 vs. 12.6/10,000) [3]. The disease is diagnosed by identifying the pathogen in urine cultures, as well as by the clinical symptoms of fever, flank pain, costovertebral angle (CVA) tenderness and urinary symptoms such as frequency of urination, urgency, and dysuria [4]. In addition, blood cultures are commonly conducted in patients with APN, but the usefulness of these has not been supported in several reports [2, 5-7]. However, the utility of the test may differ according to the host, antibiotic exposure before hospital visit and rate of positive culture.

Radiologic imaging studies such as computed tomography (CT) and renal ultrasonography (US) are conducted to diagnose structural problems such as ureteral obstruction or renal abscess in some patients with unsatisfactory clinical response to antibiotic treatment [2].

The aforementioned diagnostic tools have been widely used in clinical practice, but little is known about how frequently they are used and whether they influence the management of APN patients. Accordingly, this prospective study was conducted in a cohort of community-acquired APN (CA-APN) patients to examine the usefulness of blood cultures and radiologic imaging studies for making therapeutic decisions.

## Materials and Methods

Clinical data on CA-APN patients were collected from 11 general hospitals with 500-1,250 beds from March 2010 to February 2011. Ten of the 11 hospitals were university hospitals. The study protocol was reviewed and approved by the Institutional Review Boards (IRBs) of the participating hospitals. Personal information was encrypted, and informed consent was waived by the IRBs.

Patients with fever  $\geq 37.8^{\circ}\text{C}$  who satisfied at least 3 of the following 5 conditions were included in this study: (1) frequency of urination, dysuria, or suprapubic tenderness as symptoms of lower urinary tract infection; (2) flank pain; (3) CVA tenderness; (4) pyuria defined as white blood cell (WBC) count  $\geq 10$  in a high power field in urinalysis; and (5) leukocytosis defined as WBC count  $\geq 20,000/\text{mm}^3$  or polymorphonuclear cell count  $\geq 65\%$  in peripheral blood tests [8, 9]. Patients under 15

years old, those with other reasons for pyuria and fever, and those with insufficient data were excluded. The study subjects were clinically diagnosed by infectious disease experts in the participating hospitals.

Urine and blood cultures were processed at the time of admission. Etiologic agents were determined when organisms at  $\geq 10^5$  colony forming unit (CFU)/mL were identified in urine cultures and/or urinary pathogens were isolated from blood cultures. Species identification and susceptibilities to antimicrobial agents were determined by means of a semiautomated system (VITEK, bioMerieux, Hazelwood, MO, USA; or Microscan, DADE Behring, West Sacramento, CA, USA) [10]. CT was considered diagnostic for APN if single or multiple hypodense parenchymal areas were seen after infusion of contrast medium, and local low-echo contrast with an unclear boundary caused by renal interstitial edema was diagnostic in abdominal US [11] performed by radiologists in each hospital.

The patients' demographics, disease history, clinical symptoms and signs, and treatment outcomes were prospectively collected via a web-based medical records system. Disease history included antibiotic use, history of urinary tract infection (UTI), and history of admission in the past year. The clinical symptoms and signs included flank pain, signs of lower urinary tract infection, CVA tenderness, and nausea/vomiting. Pitt score was made up of: (1) oral temperature (2 points for  $\leq 35^{\circ}\text{C}$  or  $\geq 40^{\circ}\text{C}$ , 1 point for  $35.1-36.0^{\circ}\text{C}$  or  $39.0-39.9^{\circ}\text{C}$ , and 0 point for  $36.1-38.9^{\circ}\text{C}$ ); (2) acute hypotension (2 points for an systemic blood pressure decrease  $>30$  mmHg and a diastolic blood pressure decrease  $>20$  mmHg; (3) ventilator use (2 points); (4) heart failure (4 points); and (5) consciousness (0 point for alertness, 1 point for disorientation, 2 points for stupor, and 4 points for coma) [12]. Azotemia was defined as serum blood urea nitrogen (BUN)  $\geq 20$  mg/dL and/or serum creatinine  $\geq 2.0$  mg/dL. Discordant therapy was defined as cases whose empirical antimicrobial therapy regimen was changed due to the drug resistance. Variables reflecting clinical outcome included final clinical failure, hospital mortality, hospitalization days, and time to fever clearance. Final clinical failure was defined as recurrence of symptoms of UTIs within 7-14 days of follow-up, or death.

In terms of evaluation of the diagnostic tests, positive rates and agreement between urine and blood culture were investigated, and positive rates of abdominal US and CT were examined. In addition, we assessed whether the above diagnostic tests affected therapeutic decisions such as interventional treatment or treatment duration. In connection with the radiologic findings, structural abnormalities were defined as le-

sions which could potentially impact treatment duration or modalities such as urolithiasis, hydronephrosis/hydronephrosis, renal abscess, perinephric abscess and emphysematous nephritis or cystitis.

Statistical methods: Categorical variables were compared with the Chi-square test or Fisher's exact test, and continuous variables with the Mann-Whitney tests. Univariate and multivariate logistic regression analysis was performed using backward method. A *P*-value of <0.05 was considered statistically significant. Statistical analyses were conducted using SPSS version 18.0 for Windows (SPSS Inc., Chicago, IL, USA).

## Results

A total of 827 patients with CA-APN were enrolled. Their demographic characteristics, underlying diseases and past histories are summarized in Table 1.

### 1. Performance and positive rates of urine and blood cultures

Urine and blood cultures were carried out in 820 (99.2%) and 648 (78.4%) of the 827 patients, respectively, and the positive rates were 69.3% (568/820) and 42.7% (277/648), respectively (Table 2). *Escherichia coli* was the most commonly isolated pathogen in both urine and blood cultures: 90.1% (512/568) in urine and 82.7% (229/277) in blood. Among 225 patients with positive urine and blood cultures, the organisms isolated from urine were consistent with those isolated from blood in 214 patients (95.1%), but inconsistent in 11 patients (4.9%). Of the 645 patients who underwent both of urine and blood cultures, 49 (7.6%) were diagnosed via their blood cultures because their urine cultures were negative. The initial antibiotic regimen was modified in 179 patients (21.7%), 95 of whom changed regimen because of the results of antimicrobial susceptibility tests: 15 patients (15.8%) after blood culture results and 80 (84.2%) after urine culture results.

### 2. Clinical influence of positive blood cultures on the patients with CA-APN

We investigated the effect of bacteremia on disease course among the 648 patients from whom blood cultures were obtained, by dividing them into those with bacteremia and those without bacteremia according to the culture results. Clinical characteristics and treatment outcomes of the two groups were compared (Table 3). The numbers of elderly patients  $\geq$

**Table 1.** Demographics and underlying diseases of the study subjects

Characteristics	No. (%), total = 827
Age (years, mean $\pm$ SD)	55.4 $\pm$ 19.0
Sex	
Male	54 (6.5)
Female	773 (93.5)
Co-morbidity	
Cerebrovascular disorder	77 (9.3)
Congestive heart failure	41 (5.7)
Connective tissue disease	13 (1.6)
Malignancy	30 (3.6)
Chronic pulmonary disease	21 (2.5)
Liver disease	27 (3.3)
Pregnancy	8 (1.0)
Diabetes mellitus	
Chronic renal disease	50 (6.0)
Underlying urinary tract abnormality	
Hyperplasia of prostate	11 (1.3)
Neurogenic bladder	7 (0.8)
Urolithiasis	14 (1.7)
Vesicoureteral reflux	3 (0.4)
Intermittent catheterization	6 (0.7)
Polycystic kidney disease	7 (0.8)
Past history	
History of admission within 1 year	192 (23.2)
History of antibiotics use within 1 year	232 (28.1)
History of urinary tract infection within 1 year	99 (12.0)

**Table 2.** Positivity of cultures of blood and urine

	Total = 827 N (%)
Obtained cultures	
Urine	820/827 (99.2)
Blood	648/827 (78.4)
Both	645/827 (78.0)
Positive isolates in urine culture only	343/820 (41.8)
Positive isolates in blood culture only <sup>a</sup>	52/648 (8.0)
Positive isolates in blood and urine culture	225/645 (34.9)
Identical pathogens	214/225 (95.1)
Different pathogens	11/225 (4.9)
No growth in urine and blood cultures	144/645 (23.3)

<sup>a</sup>Three of the 52 patients with only positive blood cultures did not undergo urine culture.

**Table 3.** Comparison of the clinical features of the CA-APN patients with positive and negative blood cultures

Clinical characteristics	Positive	Negative	P-value
	Blood culture (N = 277) n (%)	Blood culture (N = 371) n (%)	
Age $\geq$ 70 years	111 (40.1)	80 (21.6)	<0.001
Past history			
History of urinary tract infection within 1 years	64/231(27.7)	100/341(29.3)	0.674
History of admission within 1 year	81/256 (31.6)	72/345 (20.9)	0.003
History of antibiotics use within 1 year	69/217 (31.8)	117/323 (36.2)	0.289
Co-morbidities			
Charlson comorbidity index $\geq$ 1	151 (54.5)	117 (31.5)	<0.001
Diabetes mellitus	98 (35.4)	81 (21.8)	<0.001
Chronic renal disease	25 (9.0)	12 (3.2)	0.002
Clinical features			
Pitt score $\geq$ 1 <sup>a</sup>	129 (46.6)	105 (28.3)	<0.001
Flank pain	69 (24.9)	97 (26.1)	0.721
Symptom of lower urinary tract infection	164 (59.2)	249 (67.1)	0.038
Costovertebral angle tenderness	164 (59.2)	242 (65.2)	0.117
Laboratory findings			
WBC $\geq$ 20,000/mm <sup>3</sup>	36 (13)	24 (6.5)	0.005
CRP $\geq$ 20 mg/dL	100(36.1)	93 (25.1)	0.002
Clinical outcomes			
Discordant therapy <sup>b</sup>	22 (7.9)	20 (5.4)	0.192
Duration of hospitalization (days, mean $\pm$ SD)	10.8 $\pm$ 7.2	8.1 $\pm$ 5.4	<0.001
Defervescence time (days, mean $\pm$ SD)	3.2 $\pm$ 2.9	2.1 $\pm$ 2.5	0.014
Hospital mortality	9/251 (3.6)	1/338 (0.3)	0.003
Final clinical failure	20/251 (8.0)	9/338 (2.7)	0.003

<sup>a</sup>See method for calculation of Pitt scores.

<sup>b</sup>Discordant therapy was defined as cases whose empirical antimicrobial therapy regimen was changed due to the drug resistance. CA-APN, community-acquired acute pyelonephritis; WBC, white blood cell; CRP, C-reactive protein; SD, standard deviation.

70 years and those with a Charlson comorbidity index  $\geq$ 1 were higher in the bacteremia group than the non-bacteremia group, and clinical illness was more severe in the former: there were more patients with Pitt score  $\geq$ 1, WBC count  $\geq$ 20,000/mm<sup>3</sup> and C-reactive protein (CRP)  $\geq$ 20 mg/dL in the bacteremia group. Accordingly, final clinical failure was more common in the bacteremia group (8.0% vs. 2.7%,  $P = 0.003$ ) and deaths were also more frequent: 3.6% (9/251) vs. 0.3% (1/338). Likewise, durations of hospitalization and fever were also longer in the former group. For evaluation of clinical effect of bacteremia on clinical outcomes including hospital mortality and final clinical failure, univariate and multivariate logistic regression test was performed (Table 4). Input variables was included as follows: age  $\geq$ 70 years, Chalson comorbidity index  $\geq$ 1, diabetes mellitus, chronic renal disease, WBC

$\geq$ 20,000/mm<sup>3</sup>, CRP  $\geq$ 20 mg/dL, positive blood culture and discordant therapy. Among above variables, positive blood culture was significant predictor for hospital mortality (OR 9.290, 95% CI 1.145-75.392,  $P = 0.037$ ), although not for final clinical failure.

### 3. Results of radiologic imaging studies

Of the 872 patients with CA-APN, 683 (78.3%) underwent abdominal CT (503, 57.7%), abdominal US (154, 17.7%) or both (24, 2.8%) within 7 days of admission. Abdominal CT was conducted in 527 patients at median 0 day (range, 0-7 days) after they visited the hospital because of: an uncertain diagnosis in 339 patients (64.3%), suspected structural abnormality in 86 (16.3%), persistent fever after 72 hours of antibiotic use in 20 (3.8%), male gender and adolescence in 32 and 4

**Table 4.** Risk factors related to mortality in Community-acquired acute pyelonephritis

Characteristics	Hospital mortality (n = 12)						Final clinical failure (n = 38)					
	Univariate			Multivariate			Univariate			Multivariate		
	N (%)	OR (95% CI)	P-value	OR (95% CI)	P-value	N (%)	OR (95% CI)	P-value	OR (95% CI)	P-value		
Age ≥70 years	8 (66.7)	5.038 (1.501-16.912)	0.007			17 (44.7)	2.062 (1.066-3.991)	0.029				
<b>Co-morbidities</b>												
Charlson comorbidity index ≥1	9 (75.0)	4.521 (1.214-16.838)	0.018	3.964 (0.817-19.229)	0.087	26 (68.4)	3.396 (1.685-6.842)	<0.001	3.909 (1.610-9.493)	0.003		
Diabetes mellitus	4 (33.3)	1.406 (0.419-4.723)	0.526			14 (36.8)	1.679 (0.851-3.316)	0.132				
Chronic renal disease	1 (8.3)	1.532 (0.193-12.157)	0.505			6 (15.8)	3.490 (1.371-8.882)	0.005				
<b>Laboratory findings</b>												
WBC ≥20,000/mm <sup>3</sup>	5 (41.7)	6.863 (2.121-22.205)	0.004			11 (28.9)	4.158 (1.969-8.779)	<0.001	3.472 (1.406-8.574)	0.007		
CRP ≥20 mg/dL	3 (25.0)	0.812 (0.218-3.029)	1.000			15 (39.5)	1.639 (0.839-3.204)	0.145				
Positive blood culture	9/10 (90.0)	12.533 (1.577-99.578)	0.003	9.290 (1.145-75.392)	0.037	20/29 (69.0)	3.165 (1.416-7.076)	0.003				
Discordant therapy <sup>a</sup>	1 (8.3)	1.325 (0.167-10.483)	0.554			12 (31.6)	1.770 (0.872-3.593)	0.110	2.217 (1.001-4.912)	0.050		

<sup>a</sup>Discordant therapy was defined as cases whose empirical antimicrobial therapy regimen was changed due to the drug resistance. OR, odds ratio; CI, confidence interval; WBC, white blood cell; CRP, C-reactive protein.

(6.1%, 0.76%), respectively, severe sepsis in 19 (3.6%) and other reasons in 27 (5.1%). Abdominal US was conducted in 180 patients at median 1 day (range, 0-8 days) after hospital visit, due to diagnostic uncertainty in 74 patients (41.1%) and suspected structural abnormality in 30 patients (16.7%). Final radiologic findings were in Table 5. The APN detection rates were 84.4% (445/527) and 40% (72/180) by abdominal CT and abdominal US, respectively. As the final outcome of the radiologic imaging studies, 21 (4.0%) of the 527 patients undergoing abdominal CT and 5 of the 180 patients undergoing abdominal US (2.8%), respectively, underwent interventional procedures.

#### 4. Clinical characteristics of the CA-APN patients with structural abnormalities

In order to identify patients whose treatment might need to be modified by, for example, extending the treatment or carrying out interventional procedures, we compared the clinical characteristics of 81 patients with structural abnormalities, such as renal abscess, perinephric abscess, urolithiasis, hydronephrosis/hydronephrosis and emphysematous cystitis, with those of 602 patients without such lesions (Table 6). Patients with Pitt score  $\geq 1$ , flank pain and azotemia were significantly more likely to have structural abnormalities that could potentially impact on treatment modalities. With regard to clinical outcomes in the 2 groups, defervescence time (3.5 vs. 2.5 days,  $P = 0.001$ ) and duration of hospitalization (11.5 vs. 8.8 days,  $P < 0.001$ ) were significantly longer in the group with structural abnormalities, but there was no difference in final clinical failure or hospital mortality. For the evaluation of relationship between the early clinical failure and structural abnormalities, sub-group analysis was performed with 30 patients who underwent imaging studies for the reason of non-response of therapy after 72 hours. We divided into two groups depending on the structural abnormalities, and compared their clinical characteristics. However, there were no significant differences including final clinical failure and hospital mortality between two groups (data not shown).

## Discussion

APN is diagnosed by clinical signs and symptoms of upper urinary tract infection, and isolation of the pathogen from urine [4]. In clinical practice, blood cultures and radiologic imaging studies such as CT are commonly used [5, 6, 13]. Although these tests have been performed on a substantial

**Table 5.** Radiologic findings in abdominal computed tomography and abdominal ultrasonography

Radiologic finding	Computed tomography		Ultrasonography	
	Number	%	Number	%
Normal	29	3.98	66	36.67
APN	407	77.23	65	36.11
APN with urolithiasis	8	1.52	0	0.00
APN with hydronephrosis	6	1.14	3	1.67
APN with urolithiasis & hydronephrosis	1	0.19	0	0.00
Urolithiasis	14	2.66	4	2.22
Hydronephrosis/hydronephrosis	16	3.04	6	3.33
Renal abscess	21	3.98	2	1.11
Perinephric abscess	1	0.19	1	0.56
APN with emphysematous cystitis	1	0.19	1	0.56
Medical renal disease/ PKD	3	0.57	18	10.00
Others	20	3.80	14	7.78
Total	527	100	180	100

APN, acute pyelonephritis; PKD, polycystic kidney disease.

number of patients, there has been controversy as to their accuracy and usefulness. The purpose of this study was to evaluate the impact of blood cultures and radiologic tests on the management of CA-APN patients.

Retrospective studies have found that, generally, 70-90% of CA-APN patients undergo blood cultures [7, 14]. Several reports have evaluated the usefulness of blood cultures in women with uncomplicated APN, and proposed that blood cultures do not provide additional useful information for clinical managements [2, 5, 7, 14, 15], as was also reported in the case of pregnant women with APN [16]. Even in complicated APN patients with structural or functional urinary tract abnormalities, blood cultures have limited value for treatment choices [6]. One report has shown that complicated CA-APN patients with bacteremia had more severe clinical manifestations with more severe sepsis or septic shock, resulting in longer defervescence and hospitalization times than those without bacteremia [17]. In the present study, different microorganisms were isolated from urine and blood cultures in 11 patients, and in 49 patients pathogens were isolated from blood only; therefore, blood cultures provided important information in

**Table 6.** Clinical characteristics of the CA-APN patients with structural abnormalities

Clinical characteristics	With Structural abnormalities N = 81 n (%)	Without Structural abnormalities N = 602 n (%)	P-value
Age ≥ 70 years	28 (34.6)	171 (28.4)	0.252
<b>Underlying conditions</b>			
Charlson co-morbidity index ≥ 1	33 (40.7)	248 (41.2)	0.938
Diabetes mellitus	17 (21.0)	174 (28.9)	0.136
Cerebrovascular disorder	10 (12.3)	54 (9.0)	0.328
Congestive heart failure	2 (2.5)	36 (6.0)	0.299
Dementia	6 (7.4)	18 (3.0)	0.054
Chronic pulmonary disease	1 (1.2)	16 (2.7)	0.708
Chronic liver disease	2 (2.5)	19 (3.2)	1.000
Chronic bed ridden state	3 (3.7)	23 (3.8)	1.000
<b>Past history</b>			
History of urinary tract infection within 1 year	23/68 (33.8)	147/526 (27.9)	0.313
History of admission within 1 year	24/73 (32.9)	131/548 (23.9)	0.096
History antibiotics use within 1 year	24/59 (40.7)	163/494 (33.0)	0.238
<b>Clinical findings</b>			
Pitt score ≥ 1 <sup>a</sup>	42 (51.9)	191 (31.7)	<0.001
Costovertebral angle tenderness	58 (71.6)	393 (65.3)	0.259
Flank pain	33 (40.7)	179 (29.7)	0.044
Lower urinary tract infection symptoms	49 (60.5)	389 (64.6)	0.468
<b>Laboratory findings</b>			
Hematuria (urine RBC > 5-9/HPF)	51 (63.0)	314 (52.2)	0.067
Azotemia <sup>b</sup>	25 (30.9)	88 (14.6)	<0.001
WBC > 20,000/mm <sup>3</sup>	11 (13.6)	61 (10.1)	0.343
CRP > 20 mg/dL	23 (28.4)	173 (28.7)	0.949
<b>Clinical outcomes</b>			
Duration of hospitalization (days, mean ± SD)	11.5 ± 6.7	8.8 ± 5.8	<0.001
Defervescence time (days, mean ± SD)	3.5 ± 3.2	2.5 ± 2.3	0.001
Hospital mortality	3 (4.2)	8 (1.4)	0.119
Final clinical failure	6 (8.5)	25 (4.5)	0.150

<sup>a</sup>See method for calculation of Pitt score.

<sup>b</sup>Azotemia was defined as serum BUN ≥ 20 mg/dL and/or serum creatinine ≥ 2.0 mg/dL.

CA-APN, community-acquired acute pyelonephritis; RBC, red blood cell; HPF, high-power field; WBC, white blood cell; CRP, C-reactive protein; SD, standard deviation; BUN, blood urea nitrogen.

60 of the 645 patients (9.3%) in whom both urine and blood cultures were performed. Since quite a few patients coming to a tertiary hospital via a primary clinic have already been prescribed antibiotics, the 49 patients yielding only positive blood cultures could be explained by the fact that they had already taken sufficient antibiotic to sterilize their urine but not to their blood. Indeed, the positive rate of urine culture was low-

er (69.3%) in this report than in the aforementioned reports. Furthermore, CA-APN patients with positive blood culture were shown worse clinical outcomes and bacteremia was independent risk factor for hospital mortality in this study.

With regard to radiologic imaging studies for CA-APN, the American College of Radiology recommends waiting for 72 hours before carrying out any imaging [18, 19], and proposes

CT as the imaging method of choice for diagnosing patients with atypical pyelonephritis [18]. Abdominal CT increases the sensitivity and specificity of diagnosis of APN, which enables confirmation of early lesions and is useful for locating the anatomical lesions in infected tissues and confirming abscesses and perirenal inflammation. Abdominal US has low sensitivity for detecting early APN but avoids radiation exposure, may be used in pregnant mothers and in children, and is useful for detecting renal parenchymal inflammation and confirming abscess formation [11, 20]. Generally, radiologic tests are performed in the following cases: 1) patients that are unresponsive in the first 72-hours of treatment, 2) intervention-requiring patients with structural and functional abnormalities of the urinary system, 3) high-risk patients with diabetes mellitus, old age, or taking immunosuppressants, and 4) cases requiring confirmation of bacterial infection infiltrating other organs [21]. However, intervention-requiring pyelonephritis patients could not be identified prior to imaging study. In a report that found very low rates of positive urine or blood cultures, CT and nuclear magnetic resonance were proposed as tools for diagnosis of APN, especially for detecting progression to abscess [13].

In this study, US and CT scans were carried out in more than 80% of CA-APN patients regardless of their responses to treatment, and mostly within 3 days. When we compared the demographic and clinical characteristics of the groups that did and did not undergo radiologic testing, we found no difference (data not shown), which suggests that clinicians did not follow any consistent principle in ordering radiologic tests. The rate of detection of infections in the kidney by US was very low, and CT missed over 10% of APN in this study, probably because most radiologic studies were performed early in the disease course. Nevertheless, radiologic imaging detected 81 patients (11.9%) with structural abnormalities which could potentially impact on clinical management, such as interventions and extension of treatment, among 683 patients with CA-APN. The prevalence of structural or functional abnormalities in CA-APN may vary according to the patient population, and the characteristics of the medical center or community; the 11.9% prevalence in this study was probably due to the fact that most of the enrolled patients were hospitalized and all but one of the institutions involved were university-affiliated tertiary hospitals. Nevertheless, we were able to identify clinical features that were more common in patients with structural abnormalities, namely Pitt score  $\geq 1$  and presence of flank pain or azotemia. Therefore, it might be helpful to use these abnormalities as indicators for deciding whether to car-

ry out early radiologic studies in clinical practice.

The significance of this study is that it is a prospectively performed multi-center study of a large number of cases of CA-APN aiming to assess the impacts of blood cultures and radiologic imaging studies on therapeutic decision-making. Although it was principally an observational study without intervention, more than 80% of the patients underwent radiologic imaging studies. Because of this overuse of these tools, we were able to analyze the radiologic findings in a large number of CA-APN patients. However, this study also has a potential limitation in that most of the patients were hospitalized in a tertiary university hospital, and the patient population might have had on average a severe form of CA-APN. In addition, the impact of positive blood culture tests on severe sepsis or septic shock was not assessed due to lack of collecting variables.

In conclusion, blood cultures performed early were clinically useful for diagnosing CA-APN, and bacteremia is predictive factor for hospital mortality. In terms of radiologic studies, more than 10% of the patients had structural abnormalities potentially influencing clinical management. Early radiologic imaging studies should be considered for CA-APN patients with Pitt score  $\geq 1$ , or have flank pain or azotemia.

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## Conflicts of Interest

No conflicts of interest.

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