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Impact of the Timing of Percutaneous Nephrostomy on the Prognosis of Obstructive Urolithiasis With Sepsis: A Retrospective Cohort Study

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Purpose: The aim of this study was to investigate the prognostic impact of time to percutaneous nephrostomy (PCN) insertion on obstructive ureteral stones with sepsis.

Materials and Methods: Data were collected on patients who presented at our Emergency Department between 2017 and 2021 with obstructive uropathy due to urinary stones and underwent PCN insertion. Patients were stratified into 4 groups in accordance with the quick sepsis-related organ failure (qSOFA) score at presentation (<2 or ≥2) and time to PCN insertion (<4 hours or ≥4 hours) as follows: group 1, qSOFA < 2 and time to PCN insertion < 4 hours; group 2, qSOFA < 2 and time to PCN insertion ≥ 4 hours; group 3, qSOFA ≥ 2 and time to PCN insertion < 4 hours; group 4, qSOFA ≥ 2 and time to PCN insertion ≥ 4 hours. The prognostic impacts of the time to PCN insertion were compared between these groups

Results: The total cohort consisted of 96 patients, of whom 70 were classified as either group 1 or 2 (qSOFA < 2). Overall, 37 patients had a positive urine culture. The median time to PCN insertion was 218 minutes, and the median length of stay was 14 days. The hospitalization period was significantly shorter in group 3 than in group 4 (p=0.041).

Conclusions: A shorter length of stay was associated with more rapid PCN insertion in patients with obstructive uropathy and a high risk of sepsis.

Keywords: Urolithiasis, Sepsis, Percutaneous nephrostomy, Urinary diversion

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• **Conflict of Interest:** The authors have nothing to disclose.

HIGHLIGHTS

Increasing number of patients visit Emergency Department with obstructing ureteral stones every year. Triage all patients with quick sepsis-related organ failure (qSOFA) scores on degree of infection. Classify all patients with qSOFA scores and time to percutaneous nephrostomy (PCN) insertion. Rapid PCN insertion can reduce total length of stay in patients with high risk of sepsis.

INTRODUCTION

Urolithiasis is a common worldwide disorder with an overall prevalence of 7%–13% in North America and 1%–5% in Asia [1-4]. In South Korea, incidence of urolithiasis has increased from 3.5% to 11.5% from 1988 to 2013 [2,5]. According to the National Health Insurance data of South Korea, 321,817 patients were diagnosed with ureter stones in 2021 compared to 283,754 cases in 2017, and the increase in national health costs due to this disorder increased from United States dollar (USD) 200 million to USD 300 million in that period [6].

In patients with an obstructing ureteral stone, immediate renal decompression is needed if infection is suspected [7]. This intervention can prevent worsening of renal function, irreversible chronic kidney disease, and systemic infection including septic shock [8]. Although there is no standardized guideline for conducting a renal decompression, percutaneous nephrostomy (PCN) insertion and cystoscopic double-j (D-J) stent indwelling are the most widely used treatments of this nature for obstructive uropathy [9]. Both procedures are associated with variable success and complication rates, but PCN insertion is known to be safer with fewer adverse events [8-12]. A higher rate of procedure failure and complications, including fever and bleeding, have been reported following cystoscopic D-J stent indwelling compared to PCN [9]. Other studies have associated a lower quality of life (QoL) and more frequent lower urinary tract symptoms with D-J stent indwelling [13,14]. Moreover, PCN insertion has been demonstrated to be a better option not only in terms of favorable patient outcomes, but also with regard to procedure accessibility. In a prior study from Malaysia, PCN insertion was reported to be more frequently performed as a urinary diversion approach due to a better availability of interventional radiologists and a lower procedural cost compared to cystoscopic D-J stent indwelling [8].

The impact of the timing of a ureteral stent placement on the outcomes in patients with obstructing ureteral stones with sepsis has been reported previously [15]. In that study, a timelier stent placement decreased the overall length of stay (LOS) in cases showing a high risk of sepsis. However, although PCN insertion is an effective and safe alternative method for renal decompression, the impact of its timing on clinical outcomes is not well understood. The aim of this study was to investigate how the time to PCN insertion after presentation at an Emergency Department (ED) affects the eventual LOS in patients with either a low or high risk of sepsis.

MATERIALS AND METHODS

1. Data Source

We collected and retrospectively evaluated the medical records for all patients who visited our ED between 1 January 2017 and 31 December 2021 due to urolithiasis, and that underwent a PCN insertion. This retrospective cohort study was performed following the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guideline.

2. Study Population Demographics

Our study population comprised patients with a defined ureteral stone with hydronephrosis on a computed tomography (CT) scan and we categorized these cases into 4 groups according to their quick sepsis-related organ failure (qSOFA) score and time to PCN insertion. To define sepsis using qSOFA, we assessed 3 criteria including blood pressure (BP) (0 points for systolic BP $>$ 100 mmHg, 1 point for $\leq$ 100 mmHg), respiratory rate (0 points for $<$ 22 breaths per minute, 1 point for $\geq$ 22 breaths per minute), and mental status (0 points for a Glasgow coma scale [GCS] score $\geq$ 15, 1 point for a GCS $<$ 15). A qSOFA score $\geq$ 2 is suggestive of sepsis [16]. The GCS was assessed for patient consciousness using eye, verbal, and motor responses and comprised scores of 1–4 for eye responses, 1–5 for verbal responses, and 1–6 for motor responses. The GCS is then sum of these 3 category scores with a minimum of 3 and maximum of 15. A GCS of 3–8 indicates a severe brain injury, of 9–12 a moderate brain injury, and of 13–

15 a mild brain injury [17]. Accordingly, we classified patients with a qSOFA score of <2 as the low risk of sepsis group and patients with a qSOFA score ≥ 2 as a high risk of sepsis group.

For consistency, we utilized the initially presenting vital signs on arrival at the ED in each of the study patients. However, in any instances of changes to these vital signs, we took the lowest systolic BP, highest respiratory rate, and lowest GCS score during the ED stay. We collected demographic and clinical data for these cases, including age, sex, and body mass index, and investigated comorbidities including diabetes, hypertension, and chronic kidney disease. A positive urine culture was defined by the detection of 10^5 colony-forming units, and the maximal stone diameter was measured using a CT scan. Location of urinary stone was defined as upper ureter (above the sacroiliac joints), mid ureter (overlying sacroiliac joints), and lower ureter (below the sacroiliac joints) on CT scan [18].

We initially analyzed 108 patients in total but excluded 12 cases from further analysis: 5 patients with an obstructive uropathy due to ureteral stricture of ureter tumor, 4 cases with no definite ureteral stone on a CT scan, 2 cases that received cystoscopic D-J stent indwelling because of a PCN insertion failure, and 1 patient that had an accompanying pneumonia with the urinary tract infection.

3. Outcome Measures

Our primary outcome measure was the impact of the PCN insertion timing on the prognosis of the obstructive urolithiasis with sepsis. In a previous study, patients undergoing this procedure at 6, 10, and 14 hours were compared but only when there was a high risk of sepsis [15]. However, we here classified patients into 4 groups based on the qSOFA score of less or more than 2 and the timing of PCN insertion below or longer than 4 hours. This cutoff was chosen because the median time to PCN insertion among our total cohort was 3 hours and 38 minutes. Group 1 cases had a qSOFA score < 2 and a time to PCN insertion of below 4 hours; group 2 had a qSOFA score < 2 and a time to PCN insertion of longer than 4 hours; group 3 had a qSOFA score ≥ 2 and a time to PCN insertion below 4 hours, and group 4 had a qSOFA score ≥ 2 and a time to PCN insertion of longer than 4 hours.

The time to PCN insertion was the period between the commencement of the ED visit and initiation of the procedure. In a similar manner, the total LOS was the period between the initial presentation at the ED and eventual discharge from the hospital.

4. Statistical Analysis

Statistical analyses were all performed using IBM SPSS Statistics ver. 28.0 (IBM Co., Armonk, NY, USA) employing the Mann-Whitney test as a nonparametric test and the t-test as a parametric test for numerical data. Chi-square test was used for categorical data analysis. P-values < 0.05 were considered to indicate statistical significance.

RESULTS

A cohort of 96 patients was finally analyzed in this study, all of whom showed obstructive ureteral stones on a CT scan with signs of infection. Within this total study population, the median age was 73.50 years, 44 patients (45.8%) were male, and 52 patients (54.2%) were female, the median stone size was 8 mm, and 26 patients (27.1%) had a qSOFA score ≥ 2 (Table 1). Among the total cohort also, the median systolic BP, respiratory rate, and GCS score was 130 mmHg, 20, and 15, respectively. Thirty-seven patients showed a positive urine culture, which predominantly consisted of *Escherichia coli* (59.5%) and Proteus (16.2%). Nineteen patients (51.4%) showed extended-spectrum beta lactamase-positive *E. coli* in their urine culture.

Overall, 24 of the study patients were admitted to the intensive care unit (ICU), and one patient subsequently expired. The median time to PCN insertion was 218 minutes, and median LOS was 14 days for the total population. Among the total cohort also, 70 patients

Table 1. Clinical and demographic characteristics of the whole study population (n=96)

Characteristic	Value
Age (yr)	73.50 (61.75–80.00)
Sex	
Male	44 (45.8)
Female	52 (54.2)
BMI (kg/m^2)	23.58 (21.02–25.95)
Diabetes	36 (37.5)
Hypertension	56 (58.3)
Chronic kidney disease	26 (27.1)
Stone size (mm)	8.00 (5.00–13.00)
Stone location	
Upper	65 (67.7)
Mid	5 (5.2)
Lower	26 (27.1)
Degree of hydronephrosis (grade)	2.00 (2.00–3.00)
Admission systolic BP (mmHg)	130.00 (100.00–150.00)
Admission respiratory rate	20.00 (20.00–22.00)
Admission GCS score	15.00 (15.00–15.00)
qSOFA score	
< 2	70 (72.9)
≥ 2	26 (27.1)
Positive urine culture	37 (38.5)
Serum creatinine (mg/dL)	1.35 (0.92–2.58)
Time to PCN insertion (min)	218.00 (172.75–287.00)
ICU admission	24 (25.0)
Length of stay (day)	14.00 (8.00–19.25)

Values are presented as median (interquartile range) or number (%).
BMI, body mass index; BP, blood pressure; GCS, Glasgow coma scale; qSOFA, quick sepsis-related organ failure; PCN, percutaneous nephrostomy; ICU, intensive care unit.

(72.92%) had a qSOFA score < 2 (groups 1 and 2). Among these cases, there were no significant differences observed in age, sex, comorbidities, stone size, stone location, degree of hydronephrosis or serum creatinine that accorded with the time to PCN insertion. In addition, there was no correlation between the total LOS or ICU admission rate and the time to PCN insertion (Table 2).

Among the 96 study patients, 26 cases (27.1%) had qSOFA score ≥ 2 (groups 3 and 4). Among these patients, there were also no significant differences in age, sex, comorbidities, stone size, stone location, or ICU admission rate based on the timing of the PCN insertion. However, the hospitalization duration was significantly shorter in the cases that received a PCN insertion within 4 hours (Table 3).

DISCUSSION

Our observations in this present study have indicated that earlier PCN insertion in patients presenting with urolithiasis and an accompanying infection can lead to a shorter period of hospitalization, especially in group of high risk of sepsis. Since the patients were discharged after complete recovery from infection, the total LOS refers to the time required for infection control. These current findings are consistent with prior reports that have investigated the benefits of early renal decompression, using PCN insertion or cystoscopic D-J stent indwelling, on urolithiasis patients with sepsis. Blackwell et al. [19] showed that a delayed intervention via renal decompression in acute nephrolithiasis cases produced an increased mortality rate.

Borofsky et al. [20] likewise reported that a lack of surgical decompression is associated with increased mortality in patients with sepsis and ureteral stones. Faw et al. [15] indicated that a timelier cystoscopic stent placement has a positive prognostic impact among patients with obstructing ureteral calculi with infection. Notably however, that study used systemic inflammatory response syndrome (SIRS) criteria to estimate the degree of infection. These criteria include body temperature, respiratory rate, heart rate and the serum white blood cell (WBC) count. Assessments are made by a body temperature above 38°C or below 36°C, a respiratory rate of over 22 per minute or a CO_2 partial pressure below 32 mmHg, a heart rate over 90 per minute, and a WBC count over 12,000/mm^3 or less than 4,000/mm^3, or band neutrophils above 10%. SIRS positivity is then defined by 2 or more of these categories being met [21]. The Society of Critical Care Medicine and the European Society of Intensive Care Medicine announced the third international consensus definition of sepsis and septic shock, referred to as sepsis-3, at the 45th annual Critical

Table 2. Percutaneous nephrostomy insertion timing in patients with a qSOFA score < 2

Variable	Group 1 (before 4 hr; n=42)	Group 2 (after 4 hr; n=28)	p-value
Age (yr)	71.00 (58.25–76.00)	75.00 (59.00–79.25)	0.478
Sex			0.032
Male	26 (61.9)	10 (35.7)	
Female	16 (38.1)	18 (64.3)	
BMI (kg/m^2)	23.98 (22.31–26.12)	23.62 (20.16–26.02)	0.174
Diabetes	14 (33.3)	10 (35.7)	0.557
Hypertension	25 (59.5)	14 (50.0)	0.439
Chronic kidney disease	14 (33.3)	8 (28.6)	0.680
Stone size (mm)	8.00 (5.00–12.75)	8.00 (5.00–10.25)	0.893
Stone location			0.826
Upper	28 (66.7)	18 (64.3)	
Mid	3 (7.1)	2 (7.1)	
Lower	11 (26.2)	8 (28.6)	
Degree of hydronephrosis (grade)	20.00 (20.00–20.00)	20.00 (20.00–30.00)	0.356
Admission systolic BP (mmHg)	142.50 (128.50–150.00)	130.00 (120.00–150.00)	0.567
Admission respiratory rate	20.00 (20.00–20.00)	20.00 (20.00–20.25)	0.476
Admission GCS score	15.00 (15.00–15.00)	15.00 (15.00–15.00)	-
Positive urine culture	9 (21.4)	9 (32.1)	0.305
Serum creatinine (mg/dL)	1.07 (0.81–2.13)	1.57 (1.12–2.90)	0.489
ICU admission	3 (7.1)	4 (14.3)	0.336
Length of stay (day)	10.00 (7.25–16.00)	14.00 (8.00–19.00)	0.116

Values are presented as median (interquartile range) or number (%).
qSOFA, quick sepsis-related organ failure; BMI, body mass index; BP, blood pressure; GCS, Glasgow coma scale; ICU, intensive care unit.

Care Congress in 2016 [16]. Recent guidelines and comparative studies have shown that SIRS criteria is no longer used to define sepsis due to lack of specificity and validation for severe sepsis [22].

This study also provides an opportunity for early identification of patients with urolithiasis at high risk of sepsis. Once patients arrive at the ED, the qSOFA score can be used to triage patients and identify those who require urgent procedure [23]. Therefore, it is reasonable to promptly perform urinary diversion in patients with ureteral stones at high risk of sepsis to improve prognosis.

Our data also suggest an economic benefit in terms of healthcare costs for patients with urolithiasis. According to national health data from 2017 to 2021 in South Korea, the number of patients newly diagnosed with urinary stones increased, leading to a rise in national medical expenses [6]. Additionally, as the prevalence of stone disease increases in the United States, the cost of acute management of urolithiasis has also risen. This cost encompasses hospitalization expenses and overall medical care [24,25]. Therefore, shortening the hospitalization period can reduce medical expenses.

This study had some noteworthy limitations. First, only a small number of the included patients had a qSOFA score ≥ 2 (n=26) as it was a single-center cohort. We therefore used a Mann-Whitney test for nonparametric statistical analysis. A future larger-scale study involving patients from multiple centers and even different countries will significantly enhance the accuracy and statistical power of the analysis. Additionally, it is well known that qSOFA score ≥ 2 was a significant predictor of ICU admission in patients with obstructed infected ureteral stones [26]. However, there was no correlation between qSOFA ≥ 2 and ICU admission rates in this study. This may due to the small number of patients. Further study requires recruitment large numbers of patients to show

Table 3. Percutaneous nephrostomy insertion timing in patients with a qSOFA score ≥ 2

Variable	Group 3 (before 4 hr; n=12)	Group 4 (after 4 hr; n=14)	p-value
Age (yr)	75.00 (71.00–83.25)	79.00 (73.75–81.75)	0.560
Sex			0.667
Male	3 (25.0)	5 (35.7)	
Female	9 (75.0)	9 (64.3)	
BMI (kg/m^2)	23.61 (15.31–29.55)	21.87 (19.25–24.32)	0.667
Diabetes	2 (16.7)	6 (42.9)	0.274
Hypertension	8 (66.7)	9 (64.3)	0.940
Chronic kidney disease	1 (8.3)	3 (21.4)	0.595
Stone size (mm)	7.50 (5.00–12.25)	10.50 (5.50–13.00)	0.631
Stone location			0.841
Upper	9 (75.0)	10 (71.4)	
Mid	0 (0)	0 (0)	
Lower	3 (25.0)	4 (28.6)	
Degree of hydronephrosis (grade)	2.00 (2.00–2.25)	2.50 (2.00–3.00)	0.139
Admission systolic BP (mmHg)	80.00 (75.25–89.50)	100.00 (90.00–104.50)	0.027
Admission respiratory rate	21.50 (20.75–22.25)	22.50 (22.00–24.00)	0.160
Admission GCS score	15.00 (15.00–15.00)	15.00 (14.25–15.00)	0.742
Positive urine culture	9 (75.0)	10 (71.4)	0.899
Serum creatinine (mg/dL)	1.54 (1.05–1.84)	1.80 (1.25–2.38)	0.354
ICU admission	9 (75.0)	8 (57.1)	0.462
Length of stay (day)	16.00 (9.75–20.25)	22.00 (17.00–34.50)	0.041

Values are presented as median (interquartile range) or number (%).
qSOFA, quick sepsis-related organ failure; BMI, body mass index; BP, blood pressure; GCS, Glasgow coma scale; ICU, intensive care unit.

statistical significance in qSOFA score and ICU admission rates. Secondly, we did not compare cystoscopic D-J stent indwelling and PCN insertion in these analyses. As PCN insertion is more frequently performed in our institution, only 51 cases of cystoscopic D-J stent indwelling were reported, which was insufficient for a comparative study. Future studies with access to large sample sizes will be needed to compare these procedures and their effectiveness. In addition, further studies can analyze qSOFA score with timing of both PCN insertion and cystoscopic D-J stent placement, focusing on renal decompression itself, resulting in more variable outcomes. Third, we did not compare the times of the first antibiotic injection or the initial consultation with a urologist upon arrival at the ED. There can be prognostic benefits to shortening both of these times as earlier treatments for infection and faster clinical decision-making can reduce the time to other interventions, such as PCN insertion. Furthermore, we only examined the total LOS as a prognostic factor. Further studies of these patients should focus on other variables, including the re-admission rate after discharge, whether the patients could maintain their previous lifestyles, and QoL assessments.

CONCLUSIONS

Patients with obstructive uropathy and a high risk of sepsis are likely to experience shorter hospital stay if an earlier PCN insertion is performed. Future screenings using the qSOFA score should be widely applied to cases of urolithiasis with sepsis upon presentation at the ED to facilitate prompt enable faster interventions and achieve this outcome. Future studies involving these patients should be multicentered and large-scale to improve the accuracy and wider applicability of the find-

ings.

NOTES

- **Author Contribution:** Conceptualization: JEY; Data curation: HWK; Formal analysis: JBK; Methodology: YSC; Project administration: HJK; Visualization: DHK; Writing - original draft: JEY; Writing - review & editing: DHK.
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