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Original Article

Risk factors and interventions for post-percutaneous nephrolithotomy urinary tract infection in diabetic patients with renal calculi

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Abstract: Objective: To investigate risk factors and interventions for post-percutaneous nephrolithotomy (PCNL) urinary tract infection (UTI) in patients with renal calculi and diabetes mellitus (DM). Methods: Clinical data of 210 DM patients with renal calculi who underwent PCNL at Hu Zhou Central Hospital between January 2018 and October 2024 were retrospectively analyzed. Patients were divided into infection and non-infection groups based on post-PCNL UTI occurrence. Univariate and multivariate logistic regression analyses was performed to identify risk factors. Negative emotions (Self-Rating Anxiety/Depression Scale [SAS]/[SDS]), pain intensity (Visual Analogue Scale [VAS]), sleep quality (Pittsburgh Sleep Quality Index [PSQI]), and quality of life level (Short-Form 36-Item Health Survey [SF-36]) were also assessed. Results: Among the 210 patients, 33 (15.71%) developed post-PCNL UTI, with 27 (67.50%) Gram-negative bacterial strains identified. Univariate analysis revealed that age, operation time (OT), number of renal calculi, fasting blood glucose (FBG), and preoperative UTI were significantly associated with post-PCNL UTI. Multivariate analysis identified age ≥60 years (P=0.001), OT ≥90 min (P=0.031), FBG ≥10 mmol/L (P<0.001), and preoperative UTI (P=0.013) as independent risk factors. Patients with UTI exhibited significantly higher SAS, SDS, VAS, and PSQI scores, along with lower SF-36 scores compared to non-infected patients. Conclusions: Age ≥60 years, OT ≥90 min, FBG ≥10 mmol/L, and preoperative UTI are risk factors for post-PCNL UTI. Patients with these risk factors require enhanced perioperative nursing and targeted preventive measures. Furthermore, tailored interventions should be implemented to address their negative emotions, pain, sleep quality, and quality of life.

Keywords: Renal calculi, diabetes mellitus, percutaneous nephrolithotomy, urinary tract infection, risk factors, interventions

Introduction

Renal calculi are mineral deposits that form in the calyces and renal pelvis, often attached to the renal papillae, resulting from supersaturation of urinary minerals [1]. The prevalence of renal calculi is about 15.0%, with a rising trend and a recurrence rate of up to 50% within five years of the initial episode [2]. Their development is associated with insufficient dietary calcium and fluid intake, as well as systemic diseases such as obesity, diabetes mellitus (DM), and cardiovascular diseases. Additionally, global variations in geographical, socioeconomic, and climatic factors influence their occurrence [3, 4]. Percutaneous nephrolithotomy (PCNL) is a commonly used treatment for renal calculi, offering the advantages of minimal invasiveness, favorable safety, high therapeutic efficacy, and preserved renal function. It is particularly effective for patients with a heavy or complex stone burden, achieving a stone clearance rate of no less than 90%. Despite its high clinical efficacy, PCNL carries an inevitable risk of perioperative complications [5, 6], which can compromise surgical outcomes and adversely affect postoperative recovery and quality of life, especially in patients with renal calculi complicated by DM [7].

Urinary tract infection (UTI) is one of the most common perioperative complications of PCNL, with an incidence of approximately 40%, and nearly 10% of these patients are at risk of developing life-threatening sepsis [8-10]. Moreover, many patients with renal calculi also

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have DM. DM-related elevations in urine glucose and uric acid levels can alter the microbial environment of the renal pelvis, potentially increasing the risk of postoperative UTI [11, 12]. In DM patients undergoing PCNL, inadequate management of postoperative UTI may lead to infection aggravation, resulting in sepsis, postoperative hemorrhage, systemic inflammatory response syndrome, and other serious complications. These adverse events increase treatment difficulty and pose significant threats to patient health and survival [13-15]. Therefore, identifying the risk factors for post-PCNL UTI and implementing effective interventions are crucial to ensuring optimal surgical outcomes and reducing postoperative complications in patients with renal calculi and DM.

Materials and methods

Patient characteristics

This retrospective study was approved by the Ethics Committee of Hu Zhou Central Hospital. A total of 210 patients with renal calculi and DM who received treatment at Hu Zhou Central Hospital between January 2018 and October 2024 were included. All patients underwent PCNL. The cohort comprised 131 males and 79 females, with a mean age of 53.85±11.78 years.

Inclusion and exclusion criteria

Inclusion criteria: Diagnosis of renal calculi confirmed by ultrasound, computed tomography, or plain radiography of the urinary tract [16]; presence of primary unilateral or bilateral urinary calculi; symptoms of lower UTI, such as frequent urination, urgency, or dysuria; symptoms such as renal pain or fever; confirmed diagnosis of DM; complete medical records.

Exclusion criteria: Congenital urinary tract malformations, including ureteropelvic junction stenosis, horseshoe kidney, or vesicoureteral reflux; presence of infectious diseases or malignant tumors; other infections besides UTI; pregnancy or lactation; poor compliance and cognitive dysfunction.

Postoperative UTI data collection and diagnostic criteria

Data Collection: Data on sex, age, operation time (OT), hospital length of stay (HLOS), number of renal calculi, fasting blood glucose (FBG), preoperative UTI, preoperative urinary tract obstruction, and underlying diseases were collected from the hospital's electronic medical record system.

Diagnostic criteria for postoperative UTI [17]: Presence of significant urinary tract irritation symptoms after PCNL, such as frequent urination and dysuria, accompanied by fever and renal percussion tenderness; postoperative urinalysis showing leukocyte counts ≥5 per high-power field (HPF) in males and ≥10/HPF in females; postoperative urine culture indicating bacterial growth $\geq 10^4$ colony forming unit (CFU)/ml for Gram-positive bacteria or $\geq 10^5$ CFU/ml for Gram-negative bacteria.

Assessment indicators

Negative emotions in patients with post-PCNL UTI were assessed using the Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS), each ranging from 20 to 80 points, with higher scores indicating more severe anxiety or depression. Pain intensity was evaluated using the Visual Analogue Scale (VAS), which ranges from 0 to 10 points, where higher scores indicate greater pain intensity. Sleep quality was assessed using the Pittsburgh Sleep Quality Index, which ranges from 0 to 10 points, with higher scores implying poorer sleep quality. Quality of life was measured using the Short-Form 36-Item Health Survey (SF-36), focusing on role, emotional, social, and physical functioning. SF-36 scores range from 0 to 100 points, with higher scores reflecting better quality of life.

Statistical analysis

Data were analyzed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables with a normal distribution were expressed as mean ± standard deviation, and inter-group comparisons were performed using independent sample t-tests, while intra-group (pre- and post-treatment) comparisons were conducted using paired t-tests. Categorical variables were presented as frequencies and percentages [n (%)], and inter-group comparisons were performed using the χ^2 test. Significant variables in univariate analysis were subsequently entered into a multivariate logistic regression model for further analysis. A two-

Table 1. Baseline characteristics of patients with renal calculi and DM

Factors	n=210
Sex	
Male	131 (62.38)
Female	79 (37.62)
Age (years old)	
<60	137 (65.24)
≥60	73 (34.76)
OT (min)	
<90	112 (53.33)
≥90	98 (46.67)
HLOS (d)	
<7	157 (74.76)
≥7	53 (25.24)
Number of renal calculi	
Single	125 (59.52)
Multiple	85 (40.48)
FBG (mmol/L)	
<10	126 (60.00)
≥10	84 (40.00)
Preoperative UTI	
Without	101 (48.10)
With	109 (51.90)
Preoperative urinary tract obstruction	
Without	77 (36.67)
With	133 (63.33)
Underlying diseases	
Without	61 (29.05)
With	149 (70.95)

Note: DM, diabetes mellitus; OT, operation time; HLOS, hospital length of stay; FBG, fasting blood glucose; UTI, urinary tract infection.

tailed *P*-value of <0.05 was considered statistically significant.

Results

Baseline characteristics of patients with renal calculi and DM

Among the 210 patients with renal calculi and DM, the majority were male (62.38%) and under 60 years of age (65.24%). Additionally, 53.33% had an OT of less than 90 minutes, 74.76% had a HLOS of less than 7 days, and 59.52% had a single stone. Furthermore, 60% had FBG levels below 10 mmol/L, 51.90% had preoperative UTI, 63.33% had preoperative urinary tract obstruction, and 70.95% had underlying diseases (**Table 1**).

Table 2. Pathogen distribution in patients with post-PCNL UTI

Factors	Number of stains (n=40)
Gram-negative bacteria	27 (67.50)
Escherichia coli	16 (40.00)
Pseudomonas aeruginosa	6 (15.00)
Klebsiella pneumoniae	1 (2.50)
Others	4 (10.00)
Gram-positive bacteria	13 (32.50)
Staphylococcus aureus	5 (12.50)
Coagulase-negative staphylococci	4 (10.00)
Enterococcus faecalis	2 (5.00)
Others	2 (5.00)

Note: post-PCNL UTI, post-percutaneous nephrolithotomy urinary tract infection.

Pathogen distribution in patients with post-PCNL UTI

Among the 33 patients who developed UTI after PCNL, a total of 40 strains of pathogenic bacteria were isolated from urine samples. Of these, 27 strains (67.50%) were Gram-negative bacteria, with Escherichia coli being the most common (16 strains, 40.00%), followed by Pseudomonas aeruginosa (6 strains, 15.00%). Additionally, 13 strains (32.50%) were Gram-positive bacteria, with Staphylococcus aureus as the predominant species (5 strains, 12.50%), followed by coagulase-negative staphylococci (4 strains, 10.00%) (**Table 2**).

Univariate analysis of risk factors for post-PCNL UTI

The 210 patients were analyzed based on the occurrence of post-PCNL UTI, with 33 cases (15.71%) in the infection group and 177 cases (84.29%) in the non-infection group. Univariate analysis showed that post-PCNL UTI was not significantly associated with sex, HLOS, or underlying diseases (all P>0.05), but was strongly associated with age, OT, number of renal calculi, FBG, and preoperative UTI (all P<0.05) (**Table 3**).

Multivariate analysis of risk factors for post-PCNL UTI

Factors found to be significantly associated with post-PCNL UTI in the univariate analysis were entered into a multivariate logistic regres-

Table 3. Univariate analysis of risk factors for post-PCNL UTI

Factors	n	Infection group (n=33)	Non-infection group (n=177)	χ^2	P
Sex				0.053	0.819
Male	131	20 (60.61)	111 (62.71)		
Female	79	13 (39.39)	66 (37.29)		
Age (years old)				14.394	<0.001
<60	137	12 (36.36)	125 (70.62)		
≥60	73	21 (63.64)	52 (29.38)		
OT (min)				6.292	0.012
<90	112	11 (33.33)	101 (57.06)		
≥90	98	22 (66.67)	76 (42.94)		
HLOS (d)				0.532	0.466
<7	157	23 (69.70)	134 (75.71)		
≥7	53	10 (30.30)	43 (24.29)		
Number of renal calculi				6.585	0.010
Single	125	13 (39.39)	112 (63.28)		
Multiple	85	20 (60.61)	65 (36.72)		
FBG (mmol/L)				14.387	<0.001
<10	126	10 (30.30)	116 (65.54)		
≥10	84	23 (69.70)	61 (34.46)		
Preoperative UTI				8.923	0.003
Without	101	8 (24.24)	93 (52.54)		
With	109	25 (75.76)	84 (47.46)		
Preoperative urinary tract obstruction				5.761	0.016
Without	77	6 (18.18)	71 (40.11)		
With	133	27 (81.82)	106 (59.89)		
Underlying diseases				2.034	0.154
Without	61	13 (39.39)	48 (27.12)		
With	149	20 (60.61)	129 (72.88)		

Note: post-PCNL UTI, post-percutaneous nephrolithotomy urinary tract infection; OT, operation time; HLOS, hospital length of stay; FBG, fasting blood glucose.

Table 4. Variable assignment of risk factors for Post-PCNL UTI

Variable	Assignment
Age (years old)	<60 =0, ≥60 =1
OT (min)	<90 =0, ≥90 =1
Number of renal calculi	Single =0, multiple =1
FBG (mmol/L)	<10 =0, ≥10 =1
Preoperative UTI	Without =0, with =1
Preoperative urinary tract obstruction	Without =0, with =1

Note: post-PCNL UTI, post-percutaneous nephrolithotomy urinary tract infection; OT, operation time; FBG, fasting blood glucose.

sion model. The analysis revealed that, age ≥60 years (P=0.001), OT ≥90 min (P=0.031), FBG ≥10 mmol/L (P<0.001), and preoperative UTI (P=0.013) were independent risk factors for post-PCNL UTI (**Tables 4**, **5**).

Analysis of negative emotions in patients with post-PCNL UTI

Patients in the infection group had significantly higher SAS and SDS scores compared to those in the non-infection group (both P<0.001) (**Table 6**).

Analysis of pain intensity and sleep quality in patients with post-PCNL UTI

Pain intensity and sleep quality were assessed using VAS and the Pittsburgh Sleep Quality Index, respectively. The results revealed that patients in the infection group had markedly higher scores on both scales compared to those in the non-infection group (both P<0.001) (**Table 7**).

Table 5. Multivariate analysis of risk factors for Post-PCNL UTI

Factors	β	SE	Wald	P	OR	95% CI
Age ≥60 years old	1.490	0.459	10.539	0.001	4.439	1.805-10.915
OT ≥90 min	1.023	0.475	4.640	0.031	2.781	1.097-7.053
Multiple stones	0.881	0.456	3.741	0.053	2.414	0.988-5.897
FBG ≥10 mmol/L	1.755	0.476	13.607	<0.001	5.786	2.277-14.703
Preoperative UTI	1.211	0.489	6.127	0.013	3.358	1.287-8.763
Preoperative urinary tract obstruction	0.879	0.540	2.646	0.104	2.408	0.835-6.944

Note: post-PCNL UTI, post-percutaneous nephrolithotomy urinary tract infection; SE, standard error; OR, Odds Ratio; CI, confidence interval; OT, operation time; FBG, fasting blood glucose.

Table 6. Analysis of negative emotions in patients with post-PCNL UTI

Indicators	Infection group (n=33)	Non-infection group (n=177)	t	P
SAS (points)	43.73±5.83	37.11±4.56	7.308	<0.001
SDS (points)	40.48±4.52	35.88±4.26	5.641	<0.001

Note: post-PCNL UTI, post-percutaneous nephrolithotomy urinary tract infection; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale.

Analysis of quality of life in patients with post-PCNL UTI

Assessment of quality of life using the SF-36 revealed that patients in the infection group had significantly lower scores in role, emotional, social, and physical functioning compared to those in the non-infection group (all P<0.001) (**Table 8**).

Intervention measures for post-PCNL UTI

Based on the above findings, preventive strategies for post-PCNL UTI should prioritize nursing care in the following aspects: preoperative blood glucose control, thorough preoperative urinary system evaluation, intraoperative adherence to strict aseptic techniques and shortening of operation duration, postoperative catheter and urethral orifice hygiene, guidance on fluid intake and medication adherence, nutritional support, and close monitoring. These measures will be further analyzed in detail in the discussion section.

Discussion

Renal function deterioration may occur within six months after PCNL in patients with renal calculi and DM, and as early as one month postoperatively in those with preoperative UTI [18]. This may be attributed to structural changes in blood vessels, which impair local blood supply, induce inflammation, and disrupt metabolic imbalances, ultimately leading to worsened renal function [19, 20]. Therefore, effective prevention of UTI is crucial for delaying disease progression in patients with renal calculi and DM after PCNL [21].

This study included 210 patients with renal calculi and DM, all of whom underwent PCNL. Among them, 33 patients (15.71%) developed postoperative UTI. The occurrence of post-PCNL UTI may be attributed to bacterial release during surgical manipulation or stone fragmentation, as well as bacterial introduction through the nephrostomy tract [22]. Several previous studies have reported that certain clinical or surgical factors, such as female sex, prolonged OT, use of a nephrostomy tube, preoperative positive urine culture, and prior PCNL, may increase the risk of postoperative infection. However, conflicting evidence also exists, with some studies suggesting no significant association between these factors and post-PCNL UTI risk [10, 23]. In light of these inconsistencies, further clinical investigation is warranted to identify reliable risk factors, which is essential for the targeted prevention of post-PCNL UTI in patients with renal calculi and DM. In our study, a total of 40 pathogenic strains were isolated from 33 patients who developed postoperative UTI, the majority of which were Gram-negative bacteria (27 strains, 67.50%). Escherichia coli was the most frequently detected organism (16 strains, 40.00%), consistent with findings from previous research [24]. Similarly, Gutierrez et al. [10] reported that patients infected with Gram-negative bacteria were more likely to develop UTI-related

Table 7. Analysis of pain intensity and sleep quality in patients with post-PCNL UTI

Indicators	Infection group (n=33)	Non-infection group (n=177)	t	P
VAS (points)	3.27±0.72	2.19±0.70	8.101	<0.001
Pittsburgh Sleep Quality Index (points)	2.21±0.74	1.39±0.49	8.067	<0.001

Note: post-PCNL UTI, post-percutaneous nephrolithotomy urinary tract infection; VAS, Visual Analogue Scale.

Table 8. Analysis of quality of life in patients with post-PCNL UTI

Indicators	Infection group (n=33)	Non-infection group (n=177)	t	P
Role functioning (points)	60.09±6.34	64.22±5.87	3.664	<0.001
Emotional functioning (points)	51.39±4.93	60.54±6.97	7.206	<0.001
Social functioning (points)	55.67±6.90	63.03±7.09	5.497	<0.001
Physical functioning (points)	57.48±5.94	65.68±6.76	6.513	<0.001

Note: post-PCNL UTI, post-percutaneous nephrolithotomy urinary tract infection.

fever compared to those with Gram-positive infections, in line with our findings.

Univariate analysis identified age, OT, number of renal calculi, FBG, and preoperative UTI as factors associated with post-PCNL UTI. Subsequent multivariate logistic regression analysis confirmed that age ≥60 years (P=0.001), OT ≥90 min (P=0.031), FBG ≥10 mmol/L (P<0.001), and preoperative UTI (P=0.013) were independent risk factors. In contrast, the number of renal calculi was not independently associated with the occurrence of post-PCNL UTI. This may be attributed to the fact that advanced age (≥60 years) usually indicates poorer baseline physical conditions in patients with renal calculi and DM, which can impair systemic immunity or local immune defenses at the lesion site, thereby increasing the risk of postoperative UTI [14]. In addition, prolonged OT during PCNL increases the volume of perfusate used. This perfusate may facilitate the translocation of bacteria or toxins into the bloodstream via the renal pelvis during lithotripsy, thereby increasing the risk of postoperative infection [25]. Furthermore, preoperative hyperglycemia impairs the function of leukocytes and monocytes, increases the risk of systemic inflammatory response syndrome, and places the body in a state of inflammation-related stress [26]. Preoperative UTI can disrupt the local inflammatory microenvironment, triggering immune stress responses in various organs, which in turn weakens urinary tract defense mechanisms and increases the risk of postoperative infection [27]. Zhu et al. [28] reported that preoperative UTI, DM, and prolonged OT (≥60 min) were associated with varying degrees of increased risk of post-PCNL infection, consistent with our findings. Similarly, Wang et al. [29] identified prolonged OT as an independent risk factor for postoperative urinary sepsis in patients with preoperative UTI, further supporting our results. Additional studies have also indicated that factors, such as female sex, positive urine culture, infected stones, elevated peripheral leukocyte counts, prolonged OT, and residual stones, are significant risk factors for post-PCNL infection, in line with our observations [30]. Moreover, patients who developed UTI following PCNL were more likely to exhibit pronounced negative emotions, greater pain intensity, poorer sleep quality, and lower quality of life. Targeted nursing interventions for this patient population may help improve their overall treatment experience and enhance patient satisfaction.

Based on the above analysis, targeted interventions can be developed for patients with renal calculi and DM to effectively prevent post-PCNL UTI. First, effective blood glucose control, achieved through dietary management, physical activity, and pharmacological treatment (e.g., insulin), can mitigate the immunosuppressive effects of hyperglycemia, thereby reducing the risk of postoperative infection. Second, a comprehensive preoperative assessment of the urinary system should be conducted. This includes urine culture and antibiotic susceptibility testing to identify potential pathogens in advance and facilitate targeted prophylactic antibiotic use. During the procedure,

strict adherence to aseptic technique is essential to minimize the risk of bacterial contamination. Third, OT should be carefully controlled, and efforts should be made to minimize the duration of the procedure to reduce the risk of infection. Last, comprehensive postoperative care is also essential. Key measures include maintaining the patency of the nephrostomy tube and urinary catheter, conducting proper cleaning and care of the urethral orifice, encouraging adequate fluid intake, rational use of antibiotics, providing nutritional support, and closely monitoring for signs of infection to enable timely intervention.

This study has several limitations that warrant consideration. First, the underlying mechanisms of post-PCNL UTI in patients with renal calculi and DM were not explored. Second, the effectiveness of clinical intervention measures was not validated. Third, the association between glycemic control and infection risk was not specifically assessed. These limitations restrict the ability to draw mechanistic conclusions and to evaluate the clinical utility of targeted preventive strategies. Future research should incorporate fundamental experimental studies to elucidate the biological mechanisms contributing to post-PCNL UTI in this high-risk population, thereby enhancing our understanding of disease pathogenesis. In addition, clinical trials are needed to verify the efficacy of proposed nursing and preventive interventions. Finally, prospective studies examining the impact of glycemic control on infection risk could help clarify its regulatory role and guide individualized management in diabetic patients undergoing PCNL.

Conclusion

The incidence of post-PCNL UTI in patients with renal calculi and DM was 15.71%. Age ≥60 years, OT ≥90 min, FBG ≥10 mmol/L, and preoperative UTI were identified as significant risk factors. Patients presenting with these risk factors require heightened clinical attention and targeted preventive strategies to reduce the likelihood of postoperative UTI and to ensure optimal surgical outcomes following PCNL. Furthermore, for patients who develop postoperative UTI, it is recommended to implement comprehensive and individualized care plans that address psychological well-being, pain management, sleep quality, and daily functional support. Such interventions may help mitigate the multidimensional physical and psychological burden associated with post-PCNL UTI, thereby improving overall patient recovery and satisfaction.

Disclosure of conflict of interest

None.

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