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Analysis of risk factors for stone remnants and recurrence after lateral decubitus percutaneous nephrolithotomy

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Abstract. – OBJECTIVE: This study aims to explore the risk factors for stone remnants and recurrence after lateral decubitus percutaneous nephrolithotomy (PCNL), providing insights to enhance the stone-free rate and reduce the stone recurrence rate.

PATIENTS AND METHODS: A retrospective analysis was conducted on 356 patients with renal or upper ureteral stones who underwent lateral decubitus PCNL from January 2015 to August 2022. Among them, 271 patients had complete clinical and follow-up data. General clinical information, perioperative data, and follow-up data were collected. Univariate and multivariate logistic regression analyses were performed to identify risk factors for stone remnants and recurrence after lateral decubitus PCNL.

RESULTS: The stone-free rate after lateral decubitus PCNL was 88.6% (195/271), and the stone recurrence rate within three years was 28.1% (76/271). Stone size ($p<0.001$) and stone co-infection ($p=0.047$) were identified as independent risk factors for stone remnants after lateral decubitus PCNL. Multiple stones ($p=0.003$) were an independent risk factor for stone recurrence after lateral decubitus PCNL.

CONCLUSIONS: Stone size and stone co-infection are independent risk factors for stone remnants after lateral decubitus PCNL. Multiple stones are an independent risk factor for stone recurrence after lateral decubitus PCNL.

Key Words:
Lateral decubitus, Percutaneous nephrolithotomy, Stone-free rate, Stone recurrence rate, Risk factors.

Introduction

The incidence of renal stones is on the rise worldwide[1,2]. It is estimated that the recurrence rate of urinary stones averages around 50%[1,3]. Currently, common methods for treating stones include extracorporeal shock wave lithotripsy (ESWL), ureteroscopy (URS), percutaneous nephrolithotomy (PCNL), and, to a lesser extent, open surgery[4-6]. PCNL is the preferred surgical method for treating large, multiple, complex, and lower pole renal stones as well as upper ureteral stones due to its excellent stone-free rate[7-9].

While PCNL is effective in treating renal and upper ureteral stones, there is still a certain rate of stone remnants and the potential for stone recurrence after the procedure[10,11]. Reducing stone remnants and stone recurrence is a key focus in clinical practice. The stone-free rate of PCNL for renal stones and upper ureteral stones ranges from 83% to 98.04%[12-14]. The lifetime recurrence rate of renal stones is between 10% and 75%[11,15]. Investigating the risk factors for stone remnants and recurrence after percutaneous nephrolithotomy allows for the implementation of proactive measures based on a clear understanding of these factors. This, in turn, can enhance the stone-free rate while reducing the recurrence rate, providing valuable insights for clinicians in diagnosis and treatment.

Patients and Methods

A total of 356 patients with renal stones and upper ureteral stones underwent percutaneous nephrolithotomy (PCNL) at the Department of Urology, Miyun Hospital, Peking University First Hospital, from January 2015 to August 2022. Among them, 271 patients had complete baseline and follow-up data, with 231 cases undergoing microchannel-guided lateral decubitus PCNL and

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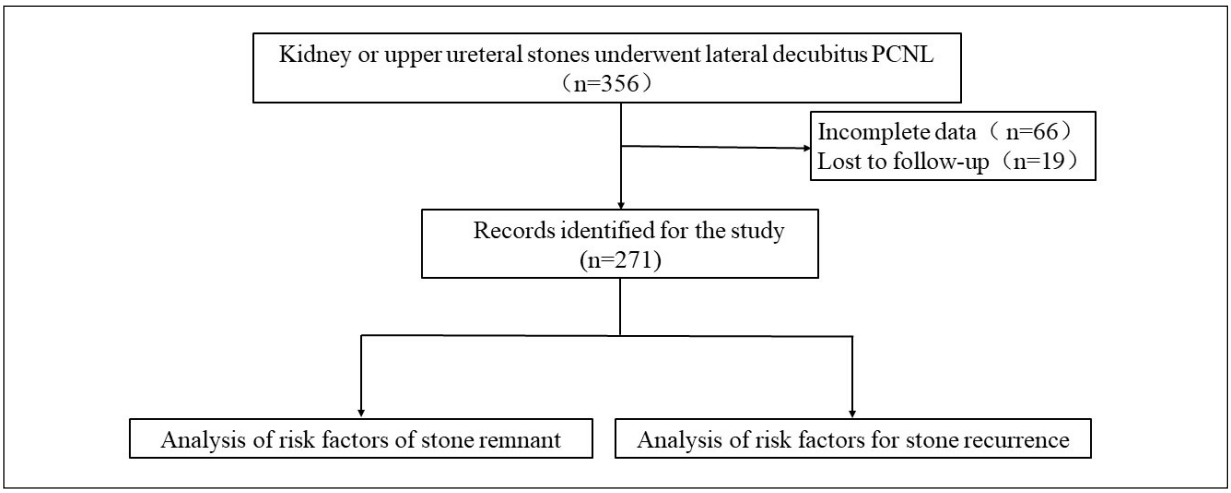

Figure 1. Flow diagram of the study.

40 cases undergoing standard channel PCNL. Clinical data, including general information, perioperative data, stone characteristics, postoperative stone-free rate, and 3-year stone recurrence rates, were collected (Figure 1).

Stone-free was defined as the absence of stones or the presence of asymptomatic, non-infectious, non-obstructive stone remnants measuring ≤4 mm on ultrasound, intravenous urography, or CT one month after the removal of the ureteral stent and completion of the surgery[7,16]. Stone remnants refer to stones that do not remain stone-free.

Stone recurrence was defined as the clear recurrence of stones, identified through ultrasound or CT, either by the appearance of new stones or an increase in the size of pre-existing stones[17].

Inclusion criteria were as follows: 1. Patients with confirmed renal or upper ureteral stones based on preoperative ultrasound, intravenous urography, or CT; 2. PCNL performed in the lateral decubitus position; 3. Complete baseline and follow-up data.

Exclusion criteria were: 1. Abnormal coagulation function; 2. Cardiovascular or pulmonary dysfunction preventing surgery; 3. Inability to comply with the study requirements.

Clinical variables in this study included gender, age, body mass index (BMI), diabetes, hypertension, coronary heart disease (CHD), stone size, lesion side, stone location, multiple stones, puncture site, channel type, number of channels, surgical time, intraoperative blood loss, mode of anesthesia, number of operations, stone co-infection, and days in hospital. The study aimed to explore the risk factors for stone remnants and recurrence in patients undergoing lateral decubitus PCNL for renal and upper ureteral stones, with postoperative stone remnants and recurrence as outcomes.

Stone size refers to the diameter of a single stone and the maximum diameter among multiple stones. Surgical time is the duration from the patient entering the operating room to the completion of the surgery. The number of operations refers to the number of stone fragmentation procedures. Patients with preoperative stone co-infection are those with positive urine cultures before surgery who turned negative after antibiotic treatment. In the context of channel types, a standard channel is defined as having an outer sheath diameter ≥24 F, while a microchannel has an outer sheath diameter ≤22 F.

This study adhered to the principles of the Helsinki Declaration (2013 revision) and received approval from the Ethics Committee of Miyun Hospital, Peking University First Hospital. The retrospective analysis of this study waived individual consent.

Surgical Technique

The preferred lithotomy position was adopted, and a cystoscopy was performed to examine the bladder mucosa and bilateral ureteral orifices. Using a guidewire, an F6 ureteral catheter was

inserted into the affected side's ureter, and physiological saline was externally connected to create an "artificial renal pelvis dilatation". Subsequently, the patient's position was changed to the lateral decubitus position. Under ultrasound guidance, a disposable puncture needle was used to puncture into the renal calyx. A safety guidewire was left in place, the skin was incised, and using the fascial dilator from the dilation tube set, the fascia was gradually dilated, and a peel-away sheath was left in place. A nephroscope was introduced into the renal cavity for observation. Upon identifying the stones, stone fragmentation and retrieval were performed, followed by the placement of a nephrostomy tube.

Follow-Up

One month postoperatively, the ureteral stent was removed from the patient. Stone clearance status after lithotripsy and stent removal was confirmed through a query of the hospital records system and telephone follow-up. Stone recurrence within three years was assessed through telephone follow-up. Stone residual and recurrence were taken as outcomes to investigate the risk factors for stone remnants and stone recurrence after lateral decubitus percutaneous nephrolithotomy.

Statistical Analysis

SPSS version 22.0 (IBM Corp., Armonk, NY, USA) was utilized for statistical analysis. Quantitative variables included age, BMI, stone size, surgical time, intraoperative blood loss, number of operations, and days in hospital. Qualitative variables encompassed gender, presence of diabetes, presence of hypertension, presence of coronary heart disease, lesion side, stone location, multiple stones, puncture site, channel type, number of channels, mode of anesthesia, and whether there was preoperative stone co-infection. Normally distributed continuous data were presented as mean ± standard deviation, while non-normally distributed data were described using median (range). For continuous variables, *t*-tests were employed for normally distributed variables, and the Mann-Whitney U test was used for non-normally distributed variables. Fisher's exact probability test was applied for categorical variables. Significance values were set at $p<0.05$. Univariate and multivariate logistic regression analyses ($p<0.05$) were used to analyze independent risk factors for postoperative infection and bleeding.

Table I. Basic characteristics of the patients.

Variable	Mean (SD) or n/N
Patients	271
Mean age (years)	51.41±12.718
BMI (kg/m^2)	27.19±27.724
Gender, n (%)	
Male	172 (63.5)
Female	99 (36.5)
Hypertension, n (%)	
Yes	84 (30.9)
No	187 (69.1)
Diabetes mellitus, n (%)	
Yes	50 (18.4)
No	221 (81.6)
CHD, n (%)	
Yes	254 (93.7)
No	17 (6.3)
Lesion side, n (%)	
Unilateral	227 (83.7)
Bilateral	44 (16.3)
Stone location, n (%)	
Kidney/ureteral stones	241 (90)
Kidney and ureteral stones	30 (10)
Multiple stones, n (%)	
Yes	62 (22.8)
No	209 (77.2)
Puncture site, n (%)	
Upper/lower renal calices	33 (12.1)
Median renal calices	238 (87.9)
Channel type, n (%)	
Standard channel	40 (14.7)
Microchannel	231 (85.3)
Number of channels	1.02±0.173
Stone size (cm)	2.87±1.036
Operation time (min)	118.73±52.283
Intraoperative blood loss (ml)	19.10±22.339
Stone co-infection, n (%)	
Yes	84 (30.9)
No	187 (69.1)
Mode of anesthesia, n (%)	
General anesthesia	252 (92.9)
Combined epidural anesthesia	19 (7.1)
Stone remnant, n (%)	
Yes	31 (11.4)
No	240 (88.6)
Stone recurrence, n (%)	
Yes	76 (28.1)
No	195 (71.9)

BMI: Body mass index; CHD: coronary artery heart disease.

Results

Stone-Free Rate and Stone Recurrence Rate After Lateral Decubitus Percutaneous Nephrolithotomy

The demographic data, stone characteristics, and surgical outcomes of the patients are presented in Table I. The patients' ages ranged from 20 to 88 years, with a mean age of 51.41 years.

There were 172 male patients and 99 female patients. The average stone size was 2.87±1.036 cm. The mean surgical time was 118.73±52.283 minutes. The stone clearance rate after lateral decubitus percutaneous nephrolithotomy was 88.6% (195/271), and the stone recurrence rate within three years was 28.1% (76/271). For standard channel lateral decubitus percutaneous nephrolithotomy, the stone-free rate was 87.5% (35/40), with a 3-year stone recurrence rate of 22.5% (9/40).

The stone-free rate for microchannel lateral decubitus percutaneous nephrolithotomy was 88.7% (205/231), and the 3-year stone recurrence rate was 29% (67/231).

Analysis of Risk Factors for Stone Remnants After Lateral Decubitus Percutaneous Nephrolithotomy

Clinical data of patients in the stone-free group and stone remnant group after lateral decubitus percutaneous nephrolithotomy are shown in Table II. In the stone-free group, the average stone size was 4.07±0.874 cm, while in the stone remnant group, the average stone size was 2.73±0.96 cm, showing a statistically significant difference between the two groups ($p<0.001$). In both the stone-free and stone remnant groups, there were statistically significant differences in the presence of multiple stones ($p=0.007$) and stone co-infection ($p=0.005$). Univariate and multivariate logistic regression analyses indicated that stone size ($p<0.001$) and stone co-infection ($p=0.047$) were independent risk factors for stone remnants after lateral decubitus percutaneous nephrolithotomy (Table III).

Analysis of Risk Factors for Stone Recurrence After Lateral Decubitus Percutaneous Nephrolithotomy

Clinical data of patients in the non-recurrence group and recurrence group after lateral decubitus percutaneous nephrolithotomy are presented in Table IV. In the non-recurrence group, the average stone size was 2.78±1.025 cm, while in the recurrence group, the average stone size was 3.1±1.037 cm, indicating a statistically significant difference between the two groups ($p<0.001$). In both the non-recurrence and recurrence groups, there were statistically significant differences in the lesion side ($p<0.001$), presence of multiple stones ($p<0.001$), number of channels ($p=0.009$), surgical time ($p<0.001$), and number of operations ($p=0.003$). Univariate logistic regression and multivariate logistic regression analyses revealed that the presence of multiple stones ($p=0.003$) was an independent risk factor for stone recurrence after lateral decubitus percutaneous nephrolithotomy (Table V).

Discussion

In recent years, with the advancement of surgical techniques, minimally invasive surgical methods have rapidly evolved[18]. Percutaneous nephrolithotomy (PCNL) is a minimally invasive and efficient method for treating renal stones and upper ureteral stones[19-21]. However, it also has some stone remnants rate and stone recurrence rate. This study analyzes the risk factors for stone remnants and stone recurrence, providing a reference for reducing the stone remnants rate and stone recurrence rate.

In this study, the stone-free rate of lateral decubitus PCNL was 88.6%, the standard channel stone-free was 87.5%, and the microchannel stone-free rate was 88.7%. Previous studies[22-25] have suggested that the microchannel stone-free rate is lower than the standard channel, but it has better advantages in postoperative complications. However, in this study, there was no significant difference between the stone-free rate of the standard channel and microchannel, and it was even lower. In the study by Mishra et al[26], the free rates in the microchannel group and standard channel group were 96% and 100%, respectively. However, compared with standard PCNL, mini-percutaneous nephrolithotomy has advantages in reducing the decrease in hemoglobin, analgesic requirements, and recovery time[26]. In the study by Cheng et al[14], the stone-free rate for patients with multiple stones in the microchannel group was 85.2%, and in the standard channel group, it was 70.0%, showing a significant difference ($p<0.05$). For individual stones, there may be no significant difference in stone-free rate between the microchannel and standard channel, but for multiple stones, the microchan-

Table II. Baseline data of stone-free group and stone remnant group.

Variable	Stone remnant group	Stone-free group	*p*-value
Patients, n (%)	31 (11.4)	240 (88.6)	
Gender, n (%)			0.898
Male	20 (11.6)	152 (88.4)	
Female	11 (11.1)	88 (88.9)	
Mean age (years)	53.19±13.953	51.18±12.563	0.407
BMI (kg/m^2)	25.58±4.241	27.40±29.429	0.732
Hypertension, n (%)			0.802
No	22 (11.8)	165 (88.2)	
Yes	9 (10.7)	75 (89.3)	
Diabetes mellitus, n (%)			0.723
No	26 (11.8)	195 (88.2)	
Yes	5 (10)	45 (90)	
CHD, n (%)			0.703
No	30 (11.8)	224 (88.2)	
Yes	1 (5.9)	16 (94.1)	
Lesion side, n (%)			0.457
Unilateral	21 (16.8)	204 (83.2)	
Bilateral	10 (21.7)	36 (76.3)	
Stone location, n (%)			0.06
Kidney/ureteral stones	24 (10)	217 (90)	
Kidney and ureteral stones	7 (23.3)	23 (76.7)	
Stone size(cm)	4.07±0.874	2.73±0.96	<0.001
Multiple stones, n (%)			0.007
No	18 (8.6)	191 (91.4)	
Yes	13 (21)	49 (79)	
Puncture site, n (%)			0.651
Upper/lower renal calices	3 (9.1)	30 (90.9)	
Median renal calices	28 (11.8)	210 (88.2)	
Channel type, n (%)			0.79
Standard channel	5 (12.5)	35 (87.5)	
Microchannel	26 (11.3)	205 (88.7)	
Number of channels	1.07±0.258	1.02±0.159	0.127
Operation time (min)	133.28±91.498	116.95±45.243	0.113
Intraoperative blood loss (ml)	23.14±31.714	18.6±20.947	0.303
Number of operations	1.07±0.267	1.03±0.16	0.176
Mode of anesthesia, n (%)			0.591
General anesthesia	28 (12.1)	203 (87.9)	
Combined epidural anesthesia	3 (7.5)	37 (92.5)	
Stone co-infection, n (%)			0.005
No	11 (6.9)	148 (93.1)	
Yes	20 (17.9)	92 (82.1)	
Days in hospital	10.41±4.305	9.22±3.562	0.097

BMI: Body mass index; CHD: coronary artery heart disease.

nel may have greater advantages. This may be related to the better mobility of the microchannel, which aids in the detection and clearance of stones. Therefore, for patients with renal stones, microchannel percutaneous nephrolithotomy may be a better choice.

In this study, smaller stone size (p<0.001) and stone co-infection (p=0.047) were identified as

Table III. Univariate and multivariate logistic regression analysis for stone remnant.

Variable	Univariate			Multivariate		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Gender	0.95	0.435-2.075	0.895			
Mean age	0.987	0.958-1.017	0.405			
BMI	1.006	0.967-1.046	0.778			
Hypertension	0.931	0.407-2.13	0.866			
Diabetes mellitus	0.853	0.31-2.351	0.759			
CHD	0.478	0.061-3.743	0.482			
Lesion side	2.106	0.866-5.119	0.1			
Stone location	2.752	1.069-7.082	0.036	0.22	0.045-1.082	0.062
Stone size	0.188	0.102-0.347	<0.001	0.197	0.098-0.394	<0.001
Multiple stones	3.314	1.413-6.950	0.005	0.566	0.168-1.9	0.357
Puncture site	1.307	0.372-4.584	0.676			
Channel type	0.739	0.261-2.089	0.568			
Number of channels	0.287	0.055-1.509	0.141			
Operation time	0.995	0.989-1.001	0.118			
Intraoperative blood loss	0.993	0.979-1.007	0.311			
Number of operations	0.335	0.064-1.748	0.194			
Mode of anesthesia	0.885	0.194-4.041	0.874			
Stone co-infection	2.925	1.277-6.7	0.011	2.906	1.016-8.316	0.047
Days in hospital	0.921	0.836-1.015	0.095			

BMI: Body mass index; CHD: coronary artery heart disease.

independent risk factors for stone remnants after lateral decubitus percutaneous nephrolithotomy. Similar results were obtained in the study by El-Nahas et al[10], where they found that stone location, stone quantity, Guy's stone score, stone diameter, and the number of puncture channels could affect the stone-free rate. Balaji et al[27] discovered that multi-channel puncture is crucial for the stone-free rate, but in this study, the number of channels was not found to play a key role in the stone-free rate (p=0.127). Therefore, for patients with stone co-infection, preoperative antibiotic use may be extended appropriately, even with the placement of a DJ tube in the first stage, followed by PCNL in the second stage, to improve the stone-free rate. For smaller stones, which are prone to move during the fragmentation process, the difficulty of stone fragmentation increases. Therefore, a more targeted design of the stone fragmentation plan may further improve the stone-free rate.

In this study, the presence of multiple stones (p=0.003) was identified as an independent risk factor for stone recurrence after lateral decubitus percutaneous nephrolithotomy. Previous studies[28-30] have mostly associated factors influencing stone recurrence with dietary factors, including caffeine intake, calcium intake, oxalate intake, etc. However, there has been no clear research on the impact of stone characteristics on postoperative stone recurrence. In this study, it was found that patients with multiple stones had a higher rate of stone recurrence, which may be related to the patient's constitution. Patients with multiple stones may have a constitution that is more prone to stone formation.

Limitations

Our study has certain limitations. It is a retrospective study, and some data on indicators affecting postoperative stone remnants and recurrence are missing. Additionally, this study is

Table IV. Baseline data of non-recurrence group and recurrence group.

Variable	Non-recurrence group	Recurrence group	*p*-value
Patients, n (%)	195 (71.96)	76 (28.04)	
Gender, n (%)			0.728
Male	125 (72.7)	47 (27.3)	
Female	70 (70.7)	29 (29.3)	
Mean age (years)	51.10±12.911	52.20±12.258	0.523
BMI (kg/m^2)	25.43±4.244	31.68±51.787	0.095
Hypertension, n (%)			0.055
No	128 (68.4)	59 (31.6)	
Yes	67 (79.8)	17 (20.2)	
Diabetes mellitus, n (%)			0.481
No	157 (71)	64 (29)	
Yes	38 (76)	12 (24)	
CHD, n (%)			0.786
No	182 (71.7)	72 (28.3)	
Yes	13 (76.5)	4 (23.5)	
Lesion side, n (%)			<0.001
Unilateral	181 (79.7)	46 (20.3)	
Bilateral	14 (31.8)	30 (68.2)	
Stone location, n (%)			0.083
Kidney/ureteral stones	178 (73.9)	63 (26.1)	
Kidney and ureteral stones	17 (58.6)	12 (41.4)	
Stone size (cm)	2.78±1.025	3.1±1.037	0.028
Multiple stones, n (%)			<0.001
No	174 (83.3)	35 (16.7)	
Yes	21 (33.9)	41 (66.1)	
Puncture site, n (%)			0.178
Upper/lower renal calices	27 (81.8)	6 (18.2)	
Median renal calices	168 (70.6)	70 (29.4)	
Channel type, n (%)			0.398
Standard channel	31 (77.5)	9 (22.5)	
Microchannel	164 (71.0)	67 (29.0)	
Number of channels	1.01±0.126	1.07±0.251	0.009
Operation time (min)	109.25±39.344	142.87±70.654	<0.001
Intraoperative blood loss (ml)	18.36±23.418	20.99±19.339	0.389
Number of operations	1.02±0.127	1.07±0.254	0.03
Mode of anesthesia, n (%)			0.482
General anesthesia	180 (71.4)	72 (28.6)	
Combined epidural anesthesia	15 (78.9)	4 (21.1)	
Stone co-infection, n (%)			0.897
No	135 (72.2)	52 (27.8)	
Yes	60 (71.4)	24 (28.6)	
Days in hospital	9.15±3.759	9.86±3.361	0.154

BMI: Body mass index; CHD: coronary artery heart disease.

Table V. Univariate and multivariate logistic regression analysis for stone recurrence.

Variable	Univariate			Multivariate		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Gender	0.908	0.525-1.569	0.729			
Mean age	1.007	0.986-1.028	0.522			
BMI	1.02	0.959-1.085	0.534			
Hypertension	1.814	0.979-3.361	0.058			
Diabetes mellitus	1.295	0.636-2.641	0.476			
CHD	1.282	0.404-4.064	0.673			
Lesion side	0.12	0.059-0.245	<0.001	0.433	0.137-1.375	0.156
Stone location	0.463	0.213-1.007	0.052			
Stone size	1.351	1.03-1.771	0.03	1.161	0.826-1.632	0.391
Multiple stones	0.102	0.054-0.194	<0.001	0.217	0.080-0.592	0.003
Puncture site	0.547	0.216-1.387	0.204			
Channel type	0.692	0.312-1.536	0.366			
Number of channels	6.903	1.333-35.762	0.021	5.49	2.343-32.265	0.09
Operation time	1.013	1.007-1.019	0	1.006	0.999-1.013	0.086
Intraoperative blood loss	1.005	0.994-1.016	0.392			
Number of operations	4.436	1.032-19.069	0.045	3.113	0.554-17.495	0.197
Mode of anesthesia	1.415	0.452-4.425	0.551			
Stone co-infection	0.957	0.532-1.721	0.882			
Days in hospital	1.053	0.980-1.132	0.156			

BMI: Body mass index; CHD: coronary artery heart disease.

a single-center study, which may introduce some bias. To address these limitations, we plan to conduct a multicenter prospective study on post-PCNL stone residue and recurrence risk factors to analyze the factors influencing post-PCNL stone remnants and recurrence more accurately.

Conclusions

Stone size and stone co-infection are independent risk factors for stone remnants after lateral decubitus PCNL. Having multiple stones is an independent risk factor for stone recurrence after lateral decubitus PCNL.

Funding
None.

Ethics Approval
The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of Peking University First Hospital-Miyun Hospital (No.: 2021-04).

Informed Consent
Informed consent was waived due to the retrospective design of the study.

Conflict of Interest
The authors declare that they have no conflict of interests.

Data Availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' Contributions
Conception and design: Honglei Liu, Wenzhi Gao, Yaming Gu and Bing Wang. Administrative support: Yaming Gu and Bing Wang. Provision of study materials or patients: Honglei Liu, Wenzhi Gao, Yangjun Han, Zihui Gao,

Mingxin Diao, Chao Zuo, Minghua Zhang, Yingzhi Diao, Chunji Wang. Collection and assembly of data: Wenzhi Gao. Data analysis and interpretation: Honglei Liu, Wenzhi Gao. Manuscript writing: All authors. Final approval of manuscript: All authors.

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