Comparison of the One-Step Prone Split-Leg Position to the Traditional Prone Position for Percutaneous Nephrolithotomy: A Single-Center Retrospective Study

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Purpose: To evaluate the one-step prone split-leg position compared to the traditional prone position for percutaneous nephrolithotomy (PCNL).

Materials and Methods: This study retrospectively analyzed the clinical data for 102 patients with upper urinary tract calculi who underwent PCNL at our hospital from April 2019 to December 2022. All PCNL procedures were performed by the same senior urologist. According to different surgical positions, the patients were divided into a one-step prone split-leg position group (observation group, n = 39) and a traditional bladder lithotomy position followed by prone position group (control group, n = 63). Then, the two groups were compared regarding the time of catheter insertion and channel establishment, channel size, time required for double-J stent placement, total operative time, postoperative hospital stay, stone removal rate, secondary operation rate and postoperative complications.

Results: There was no significant difference in the preoperative baseline characteristics of the patients between the two groups (all $P > .05$). Patients in the observation group had shorter total operative times, higher stone removal rates (76.9% [30/39] vs. 57.1% [36/63], $P = .042$), and lower secondary operation rates (10.3% [4/39] vs. 28.6% [18/63], $P = .029$) than those in the control group. There were no significant differences in the time of working channel establishment, channel size, postoperative hospital stay, or postoperative complications between the two groups (all $P > .05$).

Conclusion: The one-step prone split-leg position is a safe and reliable surgical posture for treating upper urinary calculi in PCNL patients. It can not only shorten the overall operation time of PCNL but also improve the stone removal rate of the operation, thus reducing the secondary operation rate of multiple renal stones.

Keywords: position; prone; percutaneous nephrolithotomy; renal calculus; ureteral calculus

INTRODUCTION

With the rapid development of urological endoscopic techniques and lithotripsy equipment, percutaneous nephrolithotomy (PCNL) has become the first-line treatment for renal stones larger than 2 cm in diameter and complex upper urinary tract stones.[1] The prone position is the most common patient position for PCNL procedures when lithotripsy is performed through the working channel.[2,3] Most urologists perform PCNL by positioning the patient in the lithotomy position and inserting a ureteral catheter retrogradely through the urethra to create artificial hydronephrosis. Then, the patient's position is changed to the prone position, and the urologist uses ultrasound or X-ray guidance to percutaneously puncture the kidney stone or hydronephrosis. Finally, under the guidance of the guide wire, the channel is dilated, and the working channel for lithotripsy is established. These are the main procedures of the PCNL protocol. In addition, there are a few cases where the patient needs to be placed in the lithotomy position again at the end of PCNL to facilitate the placement of the double-J stent. During the operation, the patient's body position is changed repeatedly, and the sterile treatment towel has to be laid repeatedly, which brings great inconvenience to the clinical work of surgeons, nurses and anesthesiologists. This may increase the surgical risk of PCNL, especially in patients with poor cardiorespiratory function or obesity and in elderly individuals.

Thus, it is of great clinical value to develop a method for reducing changes in the patient's position and conveniently complete all PCNL procedures. Therefore, we adopted the prone position with legs apart for some patients undergoing PCNL. In this scheme, the patient's position does not need to be changed during the operation, and the urologist can complete the whole PCNL procedure. In combination with the literature and our clinical practice, this position is referred to as the one-step prone split-leg position (OPSP).[4,5] We conducted a retrospective case–control study to evaluate the efficacy and feasibility of the OPSP applied to PCNL.

MATERIALS AND METHODS

Between April 2019 and December 2022, 102 patients who underwent PCNL in our department at the First

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Table 1. Baseline characteristics of the patients

Variable	OPSP group (n=39)	TPP group (n=63)	*P* value	OR	95% CI
Age (years), mean ± SD	56.4 ± 11.4	54.5 ± 11.1	.402[a]		-2.612-6.468
Sex, n (%)			.818[b]	.909	.406-2.039
Male	22 (56.4)	37 (58.7)			
Female	17 (43.6)	26 (41.3)			
Side, n (%)			.365[b]	1.455	.645-3.279
Left	24 (61.5)	33 (52.4)			
Right	15 (38.5)	30 (47.6)			
Stone location, n (%)			.383[b]		
Kidney	28 (71.8)	52 (82.5)			
Upper ureteral	4 (10.3)	5 (7.9)			
Kidney and upper ureteral	7 (17.9)	6 (9.5)			
Stone burden (mm), M (IQR)	25 (22-30)	26 (22-30)	.565[a]		-3.498-1.920
S.T.O.N.E. score, M (IQR)	9 (8-10)	9 (8-9)	.775[a]		-.434-.580
History of urolithiasis surgery, n (%)			.988[b]	.993	.369-2.666
Yes	8 (20.5)	13 (20.6)			
No	31 (79.5)	50 (79.4)			
Preoperative comorbidities, n (%)			.932[b]	.960	.374-2.467
Yes	9 (23.1)	15 (23.8)			
No	30 (76.9)	48 (76.2)			

Abbreviations: OPSP, one-step prone split-leg position; TPP, traditional prone position; SD, standard deviation; OR, odds ratio; M, median; IQR, interquartile range; CI, confidence interval.
[a]Continuous variables were compared by independent samples t test or Mann–Whitney test.
[b]Categorical variables were compared by Pearson's chi-square test.

Affiliated Hospital of Wannan Medical College were retrospectively reviewed and analyzed. The study was approved by the Research Ethics Committee at First Affiliated Hospital of Wannan Medical College. All experiments were performed in accordance with the European Association of Urology (EAU) guidelines.[6] The inclusion criteria included cases of PCNL performed in the prone split-leg position or traditional position by the same senior urologist and cases with complete clinical data. The indications for PCNL were as follows: (1) kidney stones with a diameter > 2 cm or staghorn stones; (2) renal calculi requiring surgical intervention and with failed extracorporeal shock wave lithotripsy (ESWL) or retrograde intrarenal surgery (RIRS); (3) severe hydronephrosis, upper ureteral calculi with a diameter > 1.5 cm or calculi at the pyeloureteral junction; and (4) multiple upper urinary calculi with moderate and severe hydronephrosis. The exclusion criteria were as follows: (1) the PCNL procedure performed by a different surgeon and (2) incomplete clinical data records.

According to different surgical positions, patients were divided into the OPSP group (observation group) and the traditional bladder lithotomy position followed by the prone position group (control group). Each patient underwent preoperative ultrasonography, urological plain film (KUB) and computed tomography (CT) scans.

The PCNL surgical procedure for the observation group is described below. After general anesthesia, the patient was placed in a prone position; the lower limb of the patient on one side of the urinary tract stone and the leg plate of the operating table were slightly abducted by approximately 0°~10°, and the leg plate of the operating table on the contralateral side of the patient was abducted by approximately 45°~60°, so that the hip and knee joints of the healthy side limb of the patient were flexed and expanded outward (**Figure 1**). A ureteroscope was inserted retrogradely into the patient's urethra, followed by a 5-7 French (Fr) ureteral catheter to assist in creating artificial hydronephrosis. Ureteroscopic lithotripsy was performed before percutaneous renal puncture in patients with middle and lower ureteral calculi. The urologist determined the percutaneous puncture point by B-ultrasound examination of the patient's 11th intercostal space or below the 12th rib, which is located in the posterior axillary line and scapular line area, and then punctured the target calyx under ultrasound

Table 2. Intraoperative clinical outcomes of the patients

Variable	OPSP group (n=39)	TPP group (n=63)	P value	OR	95% CI
Total procedure time (min), M (IQR)	105 (90-115)	120 (105-130)	.001[a]		-21.395--6.041
Time of ureteral catheter intubation (min), M (IQR)	6 (5-8)	5 (4-7)	.016[a]		.183-1.709
Time of working channel establishment (min), M (IQR)	10 (8-11)	9 (8-11)	.445[a]		-.462-1.043
Channel size, n (%)			.879[b]	.917	.299-2.810
Standard channel	33 (84.6)	54 (85.7)			
Mini-channel	6 (15.4)	9 (14.3)			
Time of double-J ureteral stenting (min), M (IQR)	6 (4-8)	8 (6-9)	.003[a]		-2.567--.561

Abbreviations: OPSP, one-step prone split-leg position; TPP, traditional prone position; OR, odds ratio; M, median; IQR, interquartile range; CI, confidence interval.
[a]Continuous variables were compared by the Mann–Whitney test.
[b]Categorical variables were compared by Pearson's chi-square test.

Table 3. Postoperative clinical outcomes of the patients

Variable	OPSP group (n=39)	TPP group (n=63)	*P* value	OR	95% CI
Stone removal, n (%)			.042[b]	2.500	1.020-6.128
Complete	30 (76.9)	36 (57.1)			
Incomplete	9 (23.1)	27 (42.9)			
Secondary surgery, n (%)			.029[b]	.286	.089-.921
Yes	4 (10.3)	18 (28.6)			
No	35 (89.7)	45 (71.4)			
Postoperative complications, n (%)			.774[b]	.686	.196-2.399
Yes	4 (10.3)	9 (14.3)			
No	35 (89.7)	54 (85.7)			
Clavien–Dindo classification, n (%)			1.000[b]		
Grade I	2(5.1)	5 (7.9)			
Postoperative pain	1(2.6)	2(3.2)			
Low-to-moderate fever	1(2.6)	2(3.2)			
Vomiting	0(0)	1(1.6)			
Grade II	1 (2.6)	3 (4.8)			
Blood transfusion	1(2.6)	3(4.8)			
Grade III	1 (2.6)	1 (1.6)			
Pleural effusion	1(2.6)	0(0)			
Double J-tube retraction	0(0)	1(1.6)			
Postoperative hospital stay (d), M (IQR)	7 (6-7)	7 (7-8)	.113[a]		-.602-.065

Abbreviations: OPSP, one-step prone split-leg position; TPP, traditional prone position; OR, odds ratio; M, median; IQR, interquartile range; CI, confidence interval.
[a]Continuous variables were compared by the Mann–Whitney test.
[b]Categorical variables were compared by Pearson's chi-square test or Fisher's exact test.

guidance. When the 18G coaxial needle pierced the properly targeted renal calyx, urine flowed out, and a flexible tip guidewire was introduced into the targeted calyx. Sequential Amplatz dilators were used to dilate the tract between the skin and renal papilla, establishing a 16-18 Fr mini-channel (mini-PCNL) or 24 Fr standard channel. The urologist selectively used an ultrasonic lithotripter, pneumatic lithotripter, or holmium laser lithotripter to perform lithotripsy and stone removal under nephroscopy. Then, each calyx, the renal pelvis and the upper ureter were carefully examined for residual stones. Transurethral ureteroscopy was necessary in patients with suspected stone migration to the ureter. Percutaneous nephroscopy and transurethral ureteroscopy were performed simultaneously or sequentially by the senior urologist and the assistant during the patient position of OPSP. A 5 Fr double-J stent was placed after no residual stones were confirmed. Nephrostomy tubes were not usually indwelled except in cases of hydronephrosis with infection, severe hydronephrosis or obvious bleeding in the renal channel. During the entire surgical procedure, the patient's prone and leg-separated position was maintained unchanged until the patient was turned over and moved to the transfer bed to wait

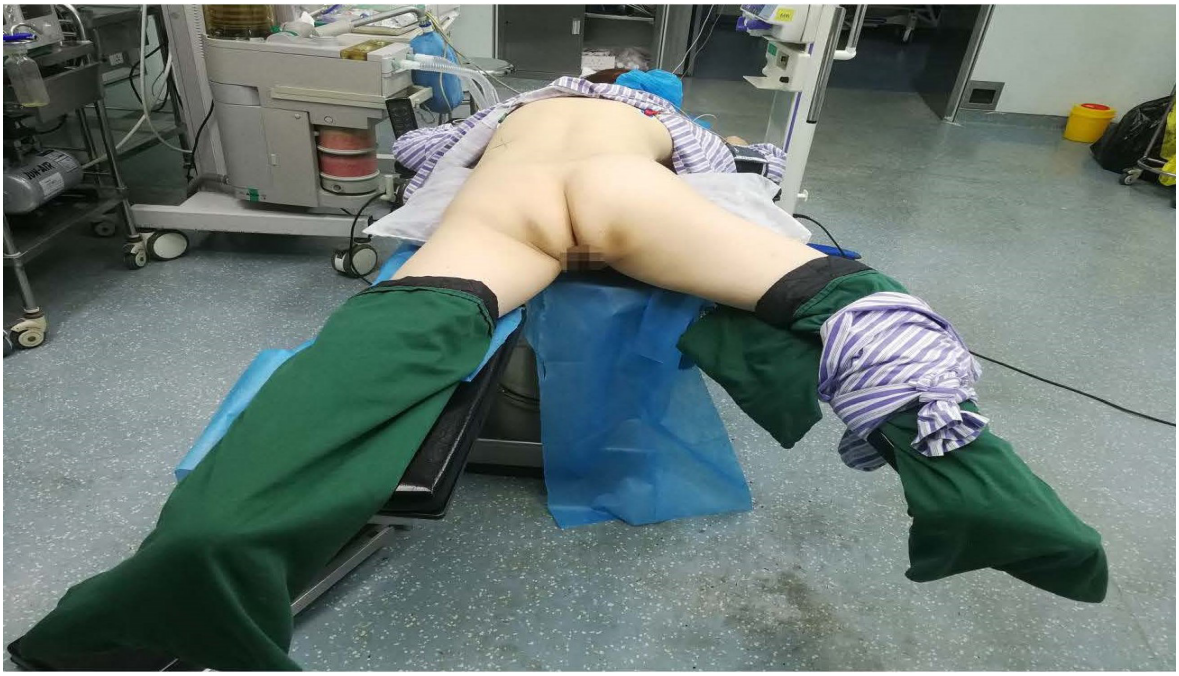

Figure 1. The one-step prone split-leg position for PCNL

Table 4. Multivariable analysis of secondary surgery after PCNL in patients

Variables	*P* value	OR	95% CI
Sex	.550	.704	.223-2.222
Age (years)	.477	.980	.926-1.037
Stone side	.208	.477	.151-1.508
S.T.O.N.E. score	.005	.533	.345-.824
History of urolithiasis surgery	.142	.346	.084-1.426
Preoperative comorbidities	.742	.781	.179-3.401
Surgical position (OPSP)	.015	5.073	1.376-18.704

Abbreviations: OPSP, one-step prone split-leg position; OR, odds ratio; CI, confidence interval.

for anesthesia recovery after the operation.

Unlike the observation group, patients in the control group underwent surgery with a traditional two-step positioning method. After general anesthesia, the patient was placed in the lithotomy position for insertion of a ureteral catheter or ureteroscopy, and then the patient was turned to the prone position for renal puncture, dilatation, establishment of a working channel and lithotripsy. Nephrostomy tubes were also generally not indwelled, which was similar to the observation group.

Baseline characteristics of the two groups, including age, sex, stone side, stone location (kidney or upper ureteral), S.T.O.N.E. score, history of urolithiasis surgery, and preoperative comorbidities (e.g., hypertension, coronary heart disease, diabetes mellitus and cerebral infarction) were collected. Intraoperative and postoperative clinical data for patients in both groups, including total procedure time, ureteral catheter intubation time, working channel establishment time, channel size, double-J ureteral stenting time, stone removal rate, secondary surgery rate, postoperative hospital stay, complications, and Clavien–Dindo classification, were subsequently recorded for group comparisons. The total procedure time was defined as the time from surgical disinfection after the patient was successfully anesthetized to the time when the double-J stent was placed and the patient was returned to the normal position. Ureteral catheter intubation time was referred to as the time elapsed from the time of indwelling a guidewire into the ureter via transurethral endoscope to the time of inserting the catheter under the guidewire. Working channel establishment time was defined as the time from B-ultrasound-guided percutaneous puncture of renal calyces or stones, insertion of a safety guidewire and gradual dilation of the channel under its guidance to the final placement of the working sheath. Secondary surgery referred to the presence of residual stones on imaging after PCNL and the need for endoscopic lithotripsy again. Complete stone removal was defined as fragments less than 4 mm in diameter or small residual stones requiring no surgical intervention on KUB or CT scan at 1-3 months after surgery.

The data were analyzed using the statistical software SPSS version 22.0 (IBM, USA) to compare the baseline characteristics and postoperative clinical data of the two groups. Continuous data are presented as the mean ± SD or median (interquartile range), while categorical data are presented as percentages. The two-sided independent sample t test or Mann–Whitney test was used to compare continuous variables, and the chi-square test or Fisher's exact test was applied for categorical variables. The significance threshold was set at P <.05. Multivariable logistic regression analysis was conducted to explore the role of risk factors for secondary surgery after PCNL in patients, and the method of independent variables accessing the regression model was Enter.

RESULTS

A total of 102 patients were included in this study. Patients in the observation group were aged 28 to 79 years, while those in the control group were aged 27 to 85 years. History of urolithiasis open surgery, including ureteroscopy and PCNL. Some cases in both groups had preoperative comorbidities such as hypertension, coronary heart disease, diabetes mellitus and cerebral infarction. There was no significant difference in the preoperative baseline characteristics of the patients between the two groups (P >.05) (**Table** 1).

The total operation time and the catheterization time of the double-J stent after the operation in the OPSP group were significantly less than those in the TPP group (P <.05), while the intraoperative catheterization time of the ureteral catheter was longer than that in the TPP group (P <.05). All patients in the OPSP group had only one position (prone split leg). In the TPP group, most patients were in two positions (lithotomy, then prone), and 2 cases were in three positions (lithotomy, then prone, and finally lithotomy for double-J ureteral stenting). There were no significant differences in intraoperative working channel establishment time or the size of channels between the two groups (P >.05) (**Table 2**).

The stone removal rate of the OPSP group was higher than that of the TPP group, and the secondary surgery rate was lower than that of the TPP group (P < .05). There were no significant differences in the incidence of postoperative complications or postoperative hospital stay between the two groups (P >.05) (Table 3). There was 1 Clavien–Dindo grade III postoperative complication in each of the two groups (pleural effusion requiring puncture drainage in the OPSP group and double J-tube retraction requiring endoscopic adjustment).

The secondary operations included re-PCNL and ureteroscopic lithotripsy, in which flexible ureteroscopic laser lithotripsy was the main procedure. In the multivariable logistic regression analysis, the S.T.O.N.E. score and surgical position (OPSP) were independent risk factors for secondary surgery after PCNL in patients (P < .05) (**Table 4**).

DISCUSSION

At present, most urologists are accustomed to performing PCNL with patients in the bladder lithotomy position first and then the prone position.[7,8] However, this traditional position has a series of disadvantages for the PCNL procedure. Repeatedly changing the patient's surgical posture not only requires additional consumption of sterile surgical kits, increases surgical time, and makes the surgical process cumbersome and inconvenient but also may cause adverse events during the process of changing the position (such as blood pressure dropping, tracheal tube displacement, increased intraocular pressure and even cardiac arrest).[9-12] This is especially true for elderly patients or patients with underlying diseases. Changing the patient's posture requires the close cooperation of the operating room nurse specialist, anesthesiologist and surgeon.

Because the patient is in a state of general anesthesia, the medical staff pay attention to protecting the patient's head, cervical vertebra, arm, tracheal intubation, infusion tube, ureteral catheter and urinary catheter. Slight carelessness in the process of moving the patient may lead to joint injury of the patient, falling off or pollution of various tubes, which will increase accidents and risks during surgery or anesthesia. In addition, it is often difficult to reach the bladder when placing a double-J stent if the surgeon notices stones or fragments moving down the patient's middle or lower ureter at the end of the PCNL procedure. Such ureteral obstruction predisposes patients to the failure of antegrade ureteral stent placement. In this situation, the patient needs to be repositioned to the lithotomy position for ureteroscopic lithotripsy, stone removal, and catheter placement. In our study, 2 cases in the TPP group showed this postural change. The patient's surgical position changed three times from the lithotomy position to the prone position and back again, highlighting the inconvenience of the traditional position for PCNL.

In recent years, urological clinicians have been constantly exploring new patient positions for PCNL, such as the supine position, oblique lateral position, waist-costal suspended supine position, oblique supine lithotomy position, oblique low arch position, waist-costal suspended half-lithotomy position, frog-like position with prone split-leg position, and other modified prone positions.[2,13-19] They are all modified postures or hybrid postures based on the prone position, supine position and lithotomy position. Each of these positions has its own characteristics, but the optimal position is still inconclusive.[20-22] Modified supine PCNL is simple and easy to perform through the urethra, but percutaneous renal operation is still difficult and challenging.[23-26] Percutaneous renal puncture, dilation and working channel establishment in the prone position are safer and easier for surgeons to learn and perform.

To optimize the PCNL process and compensate for the defects of the traditional surgical position, we modified the patient's posture for PCNL by using a prone position with legs apart based on previous literature studies.[4,5] In this patient position (OPSP), the physician can perform not only transurethral ureteroscopy and insertion of a catheter or stent but also percutaneous renal puncture and dilation and establish a working channel for lithotripsy. In addition, the urologist can combine nephroscopy and ureteroscopy to completely treat the patient's renal stones and ureteral calculi. Moreover, the patient position is particularly convenient for the transfer of the patient. After the patient is wheeled into the operating room (OR), the anesthesiologist anesthetizes the patient directly on the transfer bed and then adjusts the bed to be slightly higher than the OR table. The OR nurse prearranges the pillow for raising the head and abdomen on the operating table. The staff align the lower limbs and perineum of the patient to the corresponding position of the operating bed. While the two beds are close together, the medical staff cooperate to move the patient to the operating bed coaxially and finally adjust the lower limbs of the patient and the leg plate of the operating bed to present the posture of the separated legs. After the PCNL procedure is completed, the leg separation position is withdrawn, and the patient is coaxially transferred back to the transfer bed. The "coaxial steering" method of transferring the patient saves time and labor and is convenient and safe.

The OPSP in this study is a modified prone position that has achieved satisfactory clinical results in PCNL surgery. Compared with the TPP group, the OPSP group had a shorter total procedure time for PCNL, a higher stone removal rate and a lower secondary surgery rate, while the complications were similar in both groups. The comparison of these clinical data suggests that OPSP has obvious advantages over the traditional position for PCNL. This is also similar to the conclusions reported by some clinical scholars.[5,13,15,27,28] We realized that the advantages mentioned above were related to some characteristics of the OPSP posture during PCNL. Since the patient is placed in a one-step surgical position, the medical staff participating in PCNL are not required to change the patient's position during the operation, nor is it necessary to repeatedly disinfect the patient and lay a sterile surgical towel, which greatly reduces the overall procedure time of PCNL. Transurethral ureteroscopy can also be performed in the prone position with the legs apart. Not only can the urologist freely switch between nephroscopy and ureteroscopy but also PCNL and ureteroscopy can be performed simultaneously by two groups of surgeons to easily realize the combined operation of two scopes. In addition, the OPSP protocol ensures successful placement of a double-J stent at the end of the PCNL procedure. Urologists sometimes fail to place a double-J stent antegrade through the percutaneous working channel, which may be due to subjective error of judgment or obstruction by ureteral stones.[29] The traditional two-step patient position (from lithotomy to prone position) may require a change back to lithotomy for ureteroscopy and placement of the stent, which inevitably prolongs the ureteral stent placement time and the overall procedure time. PCNL in the OPSP does not require a change in patient position throughout the procedure; the physician can view the renal pelvis through the nephroscope and the bladder through the ureteroscope to ensure that both ends of the double J stent are in a satisfactory position, and there is no need to place the ureteral internal drainage tube under X-ray supervision.[30] In this study, the indwelling double-J stent time in the OPSP group was significantly less than that in the TPP group.

The results of this study suggest that OPSP is beneficial for improving the stone removal rate of PCNL, thereby reducing residual stones and preventing secondary surgery. This is different from the literature, which has reported that both the prone split-leg group and the traditional prone group had similar stone-free rates.[5] We believe that this is related to the simultaneous or sequential performance of percutaneous nephrolithotomy and ureteroscopic lithotripsy during one patient position. The "two-scope combination" approach allows for the simultaneous management of both renal and ureteral calculi, especially when some of the stones or fragments descending into the ureter can be easily removed, thereby increasing the stone clearance rate. Multivariable logistic regression analysis in this study showed that in addition to the S.T.O.N.E. score, surgical position (OPSP) was also an independent risk factor for secondary surgery after PCNL. When PCNL is performed in patients with complex or multiple kidney stones with high S.T.O.N.E. scores, the adoption of the OPSP protocol may avoid stone residue, and therefore, no reoperation is needed.

Transurethral ureteroscopy for patients in the OPSP re-

quires a certain amount of learning and experience accumulation of the surgeon. As suggested by the results of this study, the intubation time of the transurethral ureteral catheter is slightly longer in this position. This position is opposite to the view angle for transurethral endoscopic operation in the lithotomy position. The interureteric ridge is similar to the "ceiling" of the bladder near the neck orifice, and the bilateral ureteral orifices are approximately located at 11 o'clock and 1 o'clock. Generally, after finding the ureteral orifice, a guide wire can be used to guide the endoscope. However, in a small number of patients with ectopic ureteral orifices, orifice stenosis or deviation to one side, ureteroscopy requires more experience and skills for the operator.[31,32] We also encountered some initial difficulties in PCNL with the OPSP. With the increase in the number of cases and the accumulation of experience, we completed this clinical study, and the results showed that OPSP-PCNL had excellent outcomes and safety.

Although this study had some valuable findings, it was limited by its retrospective nature. OPSP requires the surgeon to have some experience in the PCNL procedure, which needs to be further optimized in the future for better promotion. In addition, the sample size of this study was relatively small. Future studies should expand the sample size and carry out prospective multicenter studies to further improve the safety and effectiveness of PCNL, which is also conducive to the rapid postoperative rehabilitation of patients and the reduction of postoperative residual stones.

CONCLUSIONS

This study strongly suggests that OPSP-PCNL is safe and reliable with excellent clinical results, including shortening the total procedure time, improving the stone removal rate and reducing the secondary surgery rate. The OPSP is a valuable patient position for PCNL, especially in patients with renal and ureteral stones. Nevertheless, prospective randomized controlled studies should be conducted in the future to evaluate whether an optimized OPSP-PCNL protocol may better improve outcomes.

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CONFLICT OF INTEREST

The authors report no conflicts of interest.

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