Evaluation of the Efficacy and Safety of Split Leg Prone Position and Standard Prone Position In the Treatment of Patients Undergoing Percutaneous Nephrolithotripsy

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Introduction. For percutaneous nephrolithotripsy, body position directly affects lithotripsy method and success rate.

Aim: To evaluate the efficacy and safety of treating patients undergoing percutaneous nephrolithotripsy with split leg prone position and traditional posture.

Methods. Sixty patients with kidney stones admitted to our hospital from November 2018 to August 2022 were selected as the study subjects for a prospective study, all of whom were treated with percutaneous nephrolithotripsy (PCNL). They were divided into two groups, A and B, with 30 patients in each group, based on different surgical positions. Group A were given Split Leg Prone Position and group B were given Standard Prone Position. Compare patient surgical indicators, intraoperative comfort, stone clearance indicators, stress indicators[mean arterial pressuree (MAP), heart rate (HR), and blood oxygen saturation (SpO2) levels], and postoperative complication rates.

Results. The channel establishment time, surgical time, and hospitalization time of Group A patients were significantly shorter than those of Group B, and the intraoperative bleeding volume, HR and hospitalization cost were significantly lower than those of Group B. The MAP, intraoperative posture comfort score, intraoperative posture comfort rate, and stone clearance rate of Group A patients were significantly higher than those of Group B ($P<0.05$). There was no significant difference in the success rate of SpO2 levels, puncture and the incidence of postoperative complications between the two groups ($P>0.05$).

Conclusion. The split leg prone position can simplify the surgical procedure of PCNL, ensuring the effectiveness and safety of PCNL. It is recommended in clinical practice that the split leg prone position can replace the traditional prone position as the commonly used position for PCNL.

Keywords. Split leg prone position; Traditional posture; Percutaneous nephrolithotripsy; Efficacy; Security

INTRODUCTION

Renal calculi represent a common affliction within the urinary system. Recent epidemiological studies studies indicate a prevalence ranging from 1.7 to 14.8%, and is still on the rise [1,2]. Clinical manifestations primarily include renal colic and hematuria, which, in severe cases, may escalate to systemic inflammatory responses, concurrent urinary tract infections, or even urosepsis. Prolonged mucosal stimulation by stones can potentially lead to the development of urinary system tumors [3,4]. In cases where pharmacological relief proves ineffective or the stone burden is significant, clinical practice favors surgical interventions such as PCNL and transurethral ureteroscopic lithotripsy, contingent upon the size of the stones [5,6].

At present, PCNL has developed several postures including traditional prone position and split leg prone position. The conventional prone position is the most commonly used position for PCNL, which has the advantages of wide practical range and high safety, providing a wider operating space for the operator, easy positioning and establishment of a short and straight percutaneous renal channel, easy entry into the renal calices after puncture, and reduced bleeding [7]. However, the drainage tube in PCNL needs to be retained, which may cause rejection. and using chest and abdominal pillows to maintain a prone position for a long time can increase abdominal pressure, which can easily lead to abnormal blood circulation and ventilation function in patients, followed by symptoms such as chest tightness and respiratory discomfort, which limits intraoperative anesthesia monitoring [8,9].

Moreover, in clinical practice, the location of most patients' stones is different, and the clinical treatment plan suitable for the patient needs to be constantly changed during the operation. Choosing a suitable body position for puncture can reduce the wound area, shorten the patient's bedtime, and be more easily accepted by the patient [10]. The split leg prone position is a new type of posture that has been applied in PCNL in recent years, which is beneficial for improving surgical results and has received attention and attention. Split Leg Prone Position is a modified standard prone position, which can simplify the surgical process, shorten the surgical time, avoid the occurrence of rejection reactions, reduce the rate of residual stone and reduce the medical cost of patients. However, its effectiveness in treating kidney stones in PCNL still needs to be explored.

The purpose of this study is to confirm the efficacy and safety of using two different postures, the split leg prone position and the traditional position, for patients undergoing PCNL surgery. The following report is presented.

1. MATERIALS AND METHODS

1.1 Materials

Sixty patients with kidney stones admitted to our hospital from November 2018 to August 2022 were selected as the study subjects, all of whom underwent PCNL treatment. Divide into two groups according to the different postures during surgery, A and B, with 30 cases each. And basic information such as gender, age, BMI, specific location and type of kidney stones were compared between the two groups of patients.

1.2 Eligibility Criteria

The inclusion criteria were as follows: (1) Diagnosis of kidney stones confirmed through imaging techniques, including urinary tract X-rays, CT scans, ultrasounds, and excretory urography. (2) Absence of any prior urological or related surgical interventions. (3) Normal cognitive and communicative functions. Conversely, the exclusion criteria included: (1) Presence of coexisting malignant tumors, urinary system inflammatory conditions, or any other diseases impairing renal functionality. (2) Severe dysfunction of critical organs, namely the heart, brain, and liver. (3) Abnormal coagulation profiles, bleeding disorders, or current use of anticoagulant therapy. (4) Known contraindications or intolerances to surgical procedures. Ethical approval for this study was granted by the hospital's ethics committee. Informed consent was meticulously obtained from all participants and their families, ensuring their agreement was well-documented through signed consent forms.

1.3 Method

1.3.1 Routine Diagnostic and Laboratory Examination: Upon admission, patients subjected to the study received standard diagnostic and therapeutic management for kidney stones, which included regulation of fluid intake, adherence to a low-salt diet, analgesia, and infection control measures. Prior to the surgical intervention, routine laboratory evaluations were conducted for all participants, encompassing venous blood cell counts, urinalysis via dry chemical analysis, and assessments of liver and kidney function.

1.3.2 Group A: The PCNL procedure was executed with the patients in a split-leg prone position. Following endotracheal intubation and the induction of general anesthesia, the positioning of the patient entailed aligning the pubic symphysis approximately 2 cm beyond the operating table's backplate edge. The legs were extended naturally, forming an angle between 40° and 60°. To elevate the waist and prevent movement, a soft cushion was positioned beneath the chest and abdomen, and the abdominal area was secured. Standard disinfection protocols were applied to the perineal and dorsal surgical sites, which were then draped. The placement of a F6 ureteral stent into the renal pelvis via the ureter was achieved under ureteroscopic guidance, accompanied by the insertion of a urinary catheter to maintain the stent's position. The creation of "artificial renal hydronephrosis" was facilitated by the infusion of 0.9% saline through the ureteral catheter into the renal pelvis. B-ultrasound was utilized to ascertain the hydronephrosis's characteristics, location, quantity, and size, in the affected kidney, enabling precise puncture site determination. Successful entry into the calculous renal calyx and pelvis was indicated by the emergence of clear urine upon needle core withdrawal. A mixture of contrast medium and saline was injected in equal parts into the puncture site,

revealing distinct imaging and confirming puncture success. A guide wire introduction followed by a 1cm incision to extend the needle sheath preceded the dilation of the puncture track in 2F increments up to 18F, after which the guide wire was removed. Following the establishment of the access tract, a percutaneous nephroscope sheath was introduced to examine the stones on the affected side. Lithotripsy was then conducted using either the pneumatic ballistic lithotripsy system or holmium laser lithotripsy technology. Subsequent to the fragmentation process, any remaining stone fragments were evacuated using irrigation fluid under pressure. In the event of residual stones or bleeding within any renal calyx, prompt intervention was undertaken. Completion of the procedure involved the placement of a 5F double J tube and a 16F nephrostomy tube in the ureter on the affected side, followed by suturing and securing of the insertion sites. These steps mark the completion of all surgical interventions[11-12] As shown in Figure 1 Group A.

1.3.3 Group B: In the traditional positioning for PCNL treatment, patients initially assumed the lithotomy position following general anesthesia and endotracheal intubation. A routine sterile drape was applied subsequent to positioning. The placement of an F6 ureteral stent was achieved retrogradely through the affected ureter into the renal pelvis, secured with a urinary catheter to prevent displacement. The patient was then repositioned prone, with a soft pad under the chest and abdomen, elevating the abdominal kidney level by approximately 20 cm. The surgical area on the back was disinfected prior to the application of a sterile surgical towel[13] The procedural steps thereafter mirrored those of Group A, as depicted in Figure 1, Group B.

1.4 Observation Indicators

The study observed and compared various surgical parameters between the two patient groups, including the time required to establish the surgical channel, duration of surgery, volume of intraoperative bleeding, length of hospital stay, and associated costs. Postural comfort was evaluated using the Kolcaba Comfort Assessment Scale, which assesses psychological, environmental, physiological, and socio-cultural comfort across 12 items. A higher score indicates a greater level of patient comfort [11]: Surgical efficacy was also assessed, focusing on the puncture success rate and stone clearance rate [12](Evaluation was conducted one month after surgery using Kidneys, Ureters, and Bladder (KUB) imaging or CT scans. The total stone load was calculated by summing the loads of all stones, with a stone diameter exceeding 5 mm classified as residual. Successful stone removal was defined by a failure to meet this diameter criterion and an average stone load reduction exceeding 100 mm^2). Comparative analysis extended to hemodynamic stress indicators, including MAP, HR, and blood oxygen saturation (SpO_2) before anesthesia and post-operatively, using electronic monitoring. The incidence of complications such as infections, fever, bleeding, pleural effusion, kidney injury, perirenal hematoma, and intestinal injury was also examined.

1.5 Statistical Processing: Data analysis was performed using SPSS version 23.0. Measurement data were presented as mean ± standard deviation ($\bar{x} \pm s$) and analyzed using the t-test; count data were expressed as number (n) and percentage (%) and analyzed using the Chi-square (X^2) test. A paired sample t-test was employed for comparing pre-treatment and after treatment indices within groups. A P-value of less than 0.05 was considered indicative of statistical significance.

2. RESULTS

2.1 Comparison of two groups of basic information

There was no statistically significant difference (P>0.05) in the general data of gender, age, and body mass index (BMI) between the two groups of patients, indicating comparability. Moreover, the p-values for the location, size, and type of kidney stones in both groups were greater than 0.05, and there was no statistically significant difference between the two groups, indicating comparability between the two groups of kidney stone patients. And in the comparison of basic information, there was no difference between the two groups of patients, indicating equivalence. See Table 1.

Table 1 Comparison of General Information between Two Groups

	Group A (n=30)	Group B (n=30)	F/X^2	P
Male	17(56.67)	18(60.00)	0.262	0.793
Female	13(43.33)	12(40.00)	0.262	0.793
Age (years)	51.27±8.28	51.33±8.46	0.028	0.978
BMI(kg/m2)	24.01±3.12	23.99±3.29	0.024	0.981
Stone location				
unilateral	20(66.67)	21(70.00)	0.278	0.781
Bilateral	10(33.33)	9(30.00)	0.334	0.740
Stone diameter(cm)	3.33±0.30	3.30±0.39	0.176	0.561
Stone type				
Multiple stones	11(36.67)	12(70.00)	0.409	0.982
Right angle stone	10(33.33)	8(26.67)	0.409	0.982
Solitary stone	3(10.00)	4(13.33)	0.409	0.982
Horseshoe kidney stone	4(13.33)	4(13.33)	0.409	0.982
Calculus in renal calyceal diverticulum	2(6.67)	2(6.67)	0.409	0.982

2.2 Comparison of surgical indicators between two groups of patients

Patients in Group A experienced significantly shorter times in channel establishment, surgery duration, and hospitalization compared to Group B. Furthermore, Group A exhibited substantially lower volumes of intraoperative bleeding and reduced hospitalization costs, with these differences achieving statistical significance (P<0.05). These findings are summarized in Table 2

Table 2 Comparison of Surgical Indicators Between Two Groups

	Group A (n=30)	Group B (n=30)	t	P
Channel establishment time(min)	6.19±0.92	7.71±0.96	6.261	<0.001
Operative time(min)	79.35±7.26	86.09±7.39	3.564	0.001
Intraoperative bleeding volume(mL)	82.56±31.26	118.00±59.53	2.887	0.006
Hospital stay(d)	6.30±0.52	7.18±0.82	10.280	<0.001
Hospitalization expenses(w)	2.03±0.12	2.77±0.21	16.760	<0.001

2.3 Comparison of intraoperative comfort between two groups of patients

The intraoperative comfort, assessed by posture comfort scores and rates, was significantly higher in Group A than in Group B ($P<0.05$). The comparative results are presented in Table 3.

Table 3 Comparison of Intraoperative Comfort Scores Between Two Groups

	Group A (n=30)	Group B (n=30)	t/X^2	P
Comfort rating (points)	105.09±8.89	90.75±9.38	6.078	<0.001
Intraoperative posture comfort rate (%)	29(96.67%)	22(73.33%)	2.531	0.011

2.4 Comparison of Stone Clearance Rates Between Two Groups

No significant difference was observed in the puncture success rates between the two groups ($P>0.05$). The Stone Free Rate (SFR), an essential metric for evaluating the success of kidney stone removal surgeries, reflects the percentage of patients with either no detectable stones or insignificant stone fragments on postoperative imaging. The SFR for Group A was significantly higher at 96.67% compared to 76.67% in Group B ($P<0.05$), indicating a superior stone clearance outcome. Refer to Table 4 for detailed comparisons.

Table 4 Comparison of Stone Clearance Rates Between Two Groups [n(%)]

	Group A (n=30)	Group B (n=30)	X^2	P
Puncture success rate	28(93.33%)	29(96.67%)	0.351	0.554
Stone clearance rate/Stone free rate (SFR)	29(96.67%)	23(76.67%)	5.192	0.023

2.5 Comparison of Comparison of Hemodynamic Indicators Between Two Groups

After surgery, the MAP in both groups was significantly reduced from pre-anesthesia levels, with Group A demonstrating higher MAP than Group B. The HR increased significantly postoperatively in both groups, with Group A showing a lower increase compared to Group B (both $P<0.05$). However, there were no statistically significant differences in SpO2 levels between the two groups at any time point before or after surgery (all P>0.05). See Table 5 for a comprehensive comparison.

Table 5 Comparison of Hemodynamic Indicators Between Two Groups (x±s)

	Group A (n=30)	Group B (n=30)	t	P
MAP(mmHg)				
Before anesthesia	108.06±4.82	108.04±4.86	0.016	0.987
Before anesthesia	98.40±3.67*	92.14±4.12*	6.214	<0.001
HR(times/min)				
Before anesthesia	98.40±3.67*	73.16±3.10	0.049	0.961
Postoperative completion	76.21±2.99*	82.29±4.24*	6.419	<0.001
SpO2(%)				
Before anesthesia	98.45±0.85	98.32±1.02	0.536	0.594
Postoperative completion	98.40±0.91	98.18±0.89	0.947	0.348

Note: Compared to before anesthesia, * P<0.05. MAP: Mean arterial pressure; HR: Heart rate; SpO_2: Blood oxygen saturation.

2.6 Comparison of the Comparison of Hemodynamic Indicators Between Two Groups

The occurrence of postoperative complications, including infection, fever, bleeding, pleural effusion, renal injury, perirenal hematoma, and intestinal injury, did not significantly differ between the two groups (P>0.05). Refer to Table 6 for detailed data.

Table 6 Comparison of the Incidence of Complications Between Two Groups[n(%)]

	Group A (n=30)	Group B (n=30)	X^2	P
Infection fever	1(3.33)	1(3.33)	-	-
Bleeding	1(3.33)	1(3.33)	-	-
Pleural effusion	0	1(3.33)	-	-
Renal injury	1(3.33)	1(3.33)	-	-
Perirenal hematoma	0	1(3.33)	-	-
Intestinal injury	1(3.33)	1(3.33)	-	-
Total occurrence rate	4(13.33%)	6(20.00%)	0.480	0.488

3 DISCUSSION

The etiology of kidney stones remains under investigation, with potential factors including obesity, elevated levels of blood lipids and glucose, changes in intestinal inflammation, genetic mutations, and the formation of nanoparticle calcium [13,14]. Clinically, kidney stones significantly disrupt individuals' quality of life and health, necessitating prompt and effective treatment to relieve patient discomfort. Percutaneous Nephrolithotomy (PCNL) has emerged as the gold standard for the management of urinary tract stones following percutaneous nephrostomy for kidney stone removal [15]. The principal procedure in PCNL involves creating a direct channel from the skin to the kidney. The use of ultrasound facilitates the detailed visualization of the renal pelvis and calyces, allowing for the precise placement of a nephroscope to identify stone locations. Stone removal is accomplished through holmium laser or pneumatic ballistic methods, with larger residual fragments being extracted via lithotomy forceps [16,17]. It is crucial to minimize the risk of damage to surrounding organs during the channel creation and puncture processes. The choice of surgical position plays a pivotal role in the successful execution of the procedure and significantly influences patient outcomes. [18].

The findings of this study revealed that patients in Group A, who were positioned in the Split Leg Prone Position during PCNL, experienced shorter channel establishment times, reduced total surgical durations, and earlier discharge times compared to those in Group B, who underwent surgery in the traditional position. Moreover, Group A exhibited lower intraoperative bleeding, decreased hospitalization costs, enhanced intraoperative posture comfort, and superior stone clearance rates. Traditional PCNL necessitates multiple positional adjustments during the procedure, initially requiring the lithotomy position followed by a transition to a prone position for the catheter placement. These frequent positional changes not only escalate the workload but also compound the complexity of intraoperative tasks such as channel formation and puncture. Conversely, the Split Leg Prone Position eliminates the need for position alterations during catheter placement, simplifying the surgical setup and reducing procedural complexity. This ease of operation facilitates shorter surgical times, optimizes resource use, and minimizes the likelihood of iatrogenic injuries, including increased intraoperative bleeding due to positional shifts[19,20]. In addition, patients with PCNL usually need to have nephrostomy tubes retained for 3-5 days after surgery, resulting in a relatively long hospital stay after surgery. Combined with literature analysis, the relatively small changes in the prone position of the split leg during surgery can significantly improve the efficiency of the completion of the operation process and reduce the risk of surgery, mainly related to the reasonable positioning during the operation to shorten the establishment of the channel and the total operation time, and avoid rebleeding in the injured wounds of the shifted position, and the pain and discomfort of patients in perioperative period are also relieved.

The puncture success rate for both positions examined in this study was high, with no significant difference observed. Research [21] that the prone position can cushion a soft pillow under the chest and abdomen to temporarily shift the kidney backwards and downwards, providing the surgeon with a wider field of view for percutaneous kidney puncture, reducing the difficulty of puncture, dilation, and manipulation of the endoscope and stone crusher, and making it easier to complete operations such as low renal calyx puncture or multi-channel establishment. Monitoring of hemodynamic indicators in patients revealed that after surgery, MAP in Group A was higher than that in Group B, while HR was lower than that in Group B; However, there was no significant change in Sp O2 levels between pre anesthesia and postoperative inclusion in patients. There are research reports [22,23] that frequent changes in patient positions after anesthesia can lead to abnormal hemodynamic indicators, which are not conducive to the normal operation and increase the risk of accidents. Changes in chest pressure during prone position can also affect hemodynamic indicators deviating from the normal range. The Split Leg Prone Position minimizes risks associated with repeated positional adjustments, obviates the need for repositioning for stone removal, decreases the likelihood of lower limb venous thrombosis during surgery, and reduces variations in blood flow indicators caused by body position adjustments, offering a safer alternative for patients at high risk of thrombosis due to high blood viscosity[24]. In this study, the fluctuation amplitude of postoperative MAP and HR in Group A patients was smaller than that in Group B, indicating that PCNL surgery in a split leg prone position can maintain stable blood flow rate and pressure in patients with kidney stones. In the follow-up statistics of postoperative complications in patients in this study, it was found that there was no significant difference in the total probability of complications between the two groups of patients. Some studies have shown [25] that when PCNL surgery is performed in a traditional position, attention should be paid to the damage to the cervical nerve when transitioning to a prone position during surgery. And an increase in abdominal pressure changes blood flow trends, increases the burden on the heart and lungs, and may cause cardiovascular harm and pulmonary ventilation dysfunction.

In conclusion, PCNL surgery utilizing the Split Leg Prone Position, as opposed to the traditional prone position, has been shown to enhance surgical efficiency and mitigate risks for patients with kidney stones. This approach not only improves the rate of stone removal and overall patient comfort but also facilitates the maintenance of stable hemodynamic balance. Nevertheless, this study acknowledges areas needing refinement. The limited sample selection could introduce bias into the research findings. Despite no significant differences in the baseline data of participants, the potential variability attributable to the wide range of anatomical conditions was not thoroughly investigated due to sample constraints. Future studies should aim for a broader sample base and incorporate multi-center research to address this limitation. Additionally, the timing of hemodynamic monitoring presented inconsistencies, lacking fixed intervals between measurements. Ongoing research will seek to address these issues, continuing to refine and advance surgical methodologies for the treatment of patients with kidney stones.

DECLARATIONS

FUNDING
No funding was received

AVAILABILITY OF DATA AND MATERIALS
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHORS' CONTRIBUTIONS
KZ and ZZY conducted the experiments. YF and HBX participated in the sequence alignment. KZ and ZZY participated in the design of the study and performed the statistical analysis. KZ conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

CONSENT FOR PUBLICATION
Not applicable.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE
This study was approved by the Second Affiliated Hospital Committee of Bengbu Medical College(JD-HG-2023-70). Written informed consent was obtained from all participants for this study. All methods were performed according to relevant guideline and regulations.

CONFLICT OF INTEREST
declare that they have no conflict of interest

AUTHORS DECLARE
that they have no conflicts of interest with respect to the research, authorship, and/or publication of this manuscript. No financial or personal relationships with individuals or organizations have influenced or could be perceived to have influenced the work presented in this paper

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