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Clinical Application Study of Super-Mini Percutaneous Nephrolithotomy in the Treatment of Kidney Stones

Zehong You*, **Wenyong Lian**

Third Division General Hospital of Xinjiang Production and Construction Corps, Kashi 843900, Xinjiang Province, China

Corresponding author: Zehong You, 18799910072@163.com

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Abstract: *Objective:* To observe the clinical efficacy and complication rates of different stone fragmentation techniques in the treatment of kidney stones. *Methods:* This study selected 100 patients with urinary stones treated at the Third Division General Hospital from 2021 to November 2023 as subjects. The control group ($n = 50$) received conventional percutaneous nephrolithotomy (PCNL) for stone fragmentation, while the research group ($n = 50$) received super-mini percutaneous nephrolithotomy (SMP) treatment. Surgical parameters, stone clearance rates, recurrence rates, and complication rates were compared between the two groups. *Results:* After treatment, the surgical parameters in the research group were significantly better than those in the control group. The research group had a higher stone clearance rate and lower rates of stone recurrence and complications ($P < 0.05$). *Conclusion:* Compared with conventional PCNL, SMP shows better clinical outcomes for patients with kidney stones. It improves surgical parameters, increases stone clearance rates, and reduces both stone recurrence and complication rates, making it a valuable technique for clinical reference.

Keywords: Super-mini percutaneous nephrolithotomy; Kidney stones; Stone clearance; Clinical application

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1. Introduction

Kidney stones are a common surgical condition, primarily referring to stones located in the renal pelvis and calyces [1]. These stones are usually composed of calcium oxalate, calcium phosphate, and other compounds. Kidney stones are a prevalent condition, often associated with metabolic dysfunction, chronic nephritis, and the long-term consumption of high-calcium foods [2]. Clinically, patients present with severe lower back pain, soreness, and in some cases, stones that have migrated to the ureter may cause intense renal colic, greatly affecting the patient's daily life.

Currently, the primary treatment for kidney stones is surgical, aimed at alleviating symptoms and improving quality of life. With the advent of EMS ultrasonic lithotripsy, percutaneous nephrolithotomy (PCNL) has established a standard 20–24 F access channel, which is suitable for treating larger individual stones.

However, for more complex staghorn calculi, conventional access may not meet the practical requirements for lithotripsy [3]. Super-mini percutaneous nephrolithotomy (SMP) is a method that involves accessing the kidney through a small incision to visually locate and fragment the stones. This technique has demonstrated favorable outcomes in clinical practice [4].

This study selected 100 patients with urinary stones treated at the Third Division General Hospital from 2021 to November 2023 to explore the clinical efficacy of different nephroscopy techniques for kidney stone treatment. The results may provide useful insights for future clinical practice.

2. Materials and methods

2.1. General information

The study selected 100 patients with urinary stones who were treated at the Third Division General Hospital between 2021 and November 2023. Based on the different treatment methods, the patients were divided into a control group (n = 50) and a research group (n = 50). There were no statistically significant differences in the general data between the two groups (P > 0.05), making them comparable (see **Table 1**).

Table 1. Comparison of general data between the two groups

Groups	Number of cases	Gender		Age (years)	Average age (years)	Stone type (cases)	
		Male	Female			Left-sided stones	Right-sided stones
Control group	50	26	24	19–70	51.25 ± 3.15	27	23
Research group	50	25	25	20–70	51.27 ± 3.14	26	24
χ^2 / t		0.040		-	0.032	0.040	
P		0.841		-	0.975	0.841	

Inclusion criteria: (1) All patients met the relevant diagnostic criteria for kidney stones; (2) The American Society of Anesthesiologists (ASA) score [5] was between grades 1–2; (3) Patients had surgical indications; (4) Age < 70 years; (5) All surgeries were assisted by medical staff from the Third Division General Hospital.

Exclusion criteria: (1) Patients with severe renal insufficiency; (2) Those with contraindications to surgery; (3) Patients undergoing immunotherapy or with hematological disorders; (4) Patients with concurrent renal tuberculosis; (5) Patients with mental disorders.

2.2. Methods

The control group received conventional PCNL. After preoperative preparations, patients were placed in the lithotomy position. A ureteroscope was inserted into the bladder through the urethra, and a 0.35 mm ultra-smooth guide wire was placed into the ureter of the affected side. An F5 ureteral catheter was inserted into the renal pelvis along the guide wire, and a urethral catheter was fixed in place. The patient was then placed in the prone position, and ultrasound was used to determine the puncture site. An 18G interventional needle was used to puncture the target renal calyx. After a successful puncture, a zebra guide wire was placed into the renal pelvis, and the tract was dilated to F20. The nephroscope was then introduced into the renal pelvis along the tract, and a holmium laser lithotripsy system was used to completely remove the stones. After surgery, an F5 double-J stent and a nephrostomy tube were routinely placed.

The research group received treatment with SMP. After intubation anesthesia, a rigid ureteroscope was used to place a 5 F ureteral catheter, and a 16 F urinary catheter was inserted into the bladder. After confirming no abnormalities, 10 mL of 0.9% saline was injected into the catheter, and the ureteral catheter was secured in place. The patient was placed in the prone position, and after disinfection and draping, the location of the stones was determined using X-ray and ultrasound. A contrast agent (iohexol) was injected into the renal pelvis and calyces, and based on the imaging results, a puncture point was selected, and a zebra guide wire was inserted into the renal collecting system. After confirming the position of the guide wire with an X-ray, a fascial dilator was used to expand the tract to F12. An F12 metal sheath was then placed, followed by a 3.3/7 F SMP nephroscope. The renal calyces and pelvis were inspected for stones, and a 200μm–365μm holmium laser fiber was used for lithotripsy, adjusting the frequency to 20–40 Hz and energy to 0.5–2.0 J. Stones were fragmented starting from the edges to avoid damage to the renal pelvis mucosa. The stones were pulverized into particles smaller than 3 mm and promptly suctioned out. After successful lithotripsy, an F5 double-J stent was placed.

2.3. Observation indexes

(1) Comparison of surgical indicators: The two groups were compared in terms of operative time, intraoperative blood loss, and length of hospital stay;

(2) Comparison of stone clearance rates: Bilateral kidney CT scans were used to observe stone clearance. If residual stones were found, the surgery was deemed unsuccessful; otherwise, it was considered successful. Secondary stone clearance success rate: If the first stone removal was unsuccessful, and medication proved ineffective, any residual stones during the second stone removal attempt would result in a failed outcome, while complete removal was deemed successful;

(3) Comparison of recurrence rates: The two groups were followed for 6 months postoperatively, and the recurrence rates were recorded;

(4) Comparison of complication rates: Complications included ureteral injury, infection, and others. The total complication rate was calculated as (ureteral injury + infection + others) / total cases × 100%.

2.4. Statistical analysis

Data processing was conducted using SPSS 25.00 software. Continuous variables were described using the mean ± standard deviation (SD), and intergroup comparisons were conducted using the *t*-test. Categorical variables were described using [*n* (%)], and comparisons were made using the chi-squared (χ^2) test. A P value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of surgical indicators between the two groups

Table 2 shows that the research group had significantly shorter operative time and length of hospital stay as well as lesser intraoperative hemorrhage as compared to the control group ($P < 0.05$).

Table 2. Comparison of surgical indicators between the two groups (mean ± SD)

Groups	*n*	Operative time (min)	Intraoperative hemorrhage (mL)	Length of hospital stay (d)
Control group	25	80.25 ± 12.15	53.25 ± 5.92	10.25 ± 2.33
Research group	25	60.03 ± 10.18	39.43 ± 4.28	6.62 ± 1.21
t		9.020	13.377	9.777
P		< 0.001	< 0.001	< 0.001

3.2. Comparison of stone clearance rates between the two groups

After treatment, the stone clearance rate in the control group was 80.0% (20/25), while the stone clearance rate in the study group was 96.0% (24/25). The study group had a higher stone clearance rate than the control group ($\chi^2 = 12.121$, $P < 0.05$).

3.3. Comparison of recurrence rates between two groups

After treatment, the recurrence rate in the control group was 20.0% (5/25), while the recurrence rate in the study group was 4.0% (1/25). The recurrence rate in the study group was lower than that of the control group ($\chi^2 = 10.653$, $P < 0.05$).

3.4. Comparison of complication rates between the two groups

As shown in **Table 3**, the research group had only one adverse event (infection), which is significantly lower than the control group, which had 8 adverse events (2 ureteral injuries, 2 infections, and 1 other; $P < 0.05$).

Table 3. Comparison of complication rates between the two groups [*n* (%)]

Groups	*n*	Ureteral injury	Infection	Other	Total incidence
Control group	25	2 (8.0)	2 (8.0)	1 (4.0)	5 (20.0)
Research group	25	0 (0.0)	1 (4.0)	0 (0.0)	1 (4.0)
χ^2		-	-	-	10.653
P		-	-	-	< 0.001

4. Discussion

Kidney stones are a common clinical disease, and once the kidney becomes diseased, urine abnormalities often occur. Studies have shown that calcium plaques exist within the renal papilla, and 19.6% of 1,154 patients had calcium plaques, 65 of which showed plaque growth, indicating that calcium plaques are the foundation of kidney stones [6]. When the stone moves within the kidney or enters the ureter, it can cause symptoms such as severe pain in the lower rib area, radiating pain to the lower abdomen and groin, difficulty urinating, pink-colored urine, frequent urination, as well as symptoms of infection such as high fever and chills, and acute renal failure symptoms like oliguria or anuria, severely impacting the patient's daily life. Therefore, performing timely surgical treatment is crucial for improving the patient's clinical symptoms and enhancing their quality of life.

With the continuous development and maturation of PCNL technology in China, it has been widely used in kidney stone treatment and has become one of the primary methods for treating urinary stones. SMP, guided by ultrasound, allows real-time observation of the layers being punctured, achieving precise puncturing. The use of a micro nephroscope facilitates intraoperative handling without the need for large tract dilation, which reduces surgical trauma and blood loss [7]. Related research [8] shows that compared to traditional lithotripsy techniques, applying SMP in lithotripsy for kidney stone patients achieves better outcomes, which is consistent with the results of this study. The results of this study showed that, after treatment, the surgical indicators in the study group were significantly better than those in the control group, and the stone clearance rate was higher in the study group. This indicates that SMP has less impact on the patient's kidney function. During the procedure, guided by ultrasound, a 10–12 F peel-away sheath with suction functionality can be used. The advantage of this peel-away sheath is that it can remove the stone from the body in the shortest time, improving the stone clearance rate [9]. The results of this study also indicate that the complication rate in the study group was significantly lower than that in the control group, suggesting that SMP can significantly reduce postoperative infections and other complications. For patients with larger stones, the nephroscope can be used to clear the stones, overcoming the problem of frequent postoperative complications associated with traditional lithotripsy techniques [10].

In conclusion, applying SMP in the clinical treatment of kidney stone patients provides excellent results, improving surgical indicators, increasing stone clearance rates, reducing stone recurrence, and lowering the incidence of complications, making it worthy of clinical application.

Disclosure statement

The authors declare no conflict of interest.

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