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Clinical Analysis of Flexible Negative Pressure Suction Sheath Combined with Ureteroscope in the Treatment of Renal Calculi

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Abstract

Objective: To evaluate the comprehensive efficacy of combining a flexible negative pressure suction sheath with a ureteroscopic soft scope in treating renal calculi. Methods: A total of 200 patients undergoing renal stone treatment at our hospital were enrolled in the study, with hospitalization periods spanning from January 2023 to April 2025. Patients were randomly assigned to either the control group (standard ureteroscopic soft scope) or the observation group (flexible negative pressure suction sheath combined with ureteroscopic soft scope). Comparative analysis was conducted on surgical parameters, renal injury, inflammatory response, and complications between the two groups. Results: The observation group demonstrated significantly shorter operation time, higher stone clearance rate, and earlier postoperative discharge compared to the control group. Additionally, the observation group exhibited a lower inflammatory response and reduced renal function impairment. Postoperative complication prevention was also more effective in the observation group ($P < 0.05$). Conclusion: The combined approach of flexible negative pressure suction sheath and ureteroscopic soft scope in renal stone treatment offers shorter operation time, higher stone clearance rate, minimal renal function damage, reduced inflammatory response, lower complication risk, and faster postoperative recovery.

Keywords

Kidney Stones, Bending Negative Pressure Suction Sheath, Standard Ureteroscopic Flexible Sheath, Ureteroscopic Flexible Sheath

1. Introduction

As a prevalent urological condition, renal calculi have shown a rising incidence

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rate with increasing prevalence. Symptoms such as pain and hematuria severely impact patients' quality of life and may even lead to renal dysfunction [1]. Currently, ureteroscopic lithotripsy has become a crucial minimally invasive treatment for kidney stones. However, intraoperative complications, including stone displacement, elevated intrapouric pressure, and postoperative infections, continue to limit its clinical efficacy [2]. Standard ureteroscopic sheaths demonstrate limitations in maintaining stable procedural channels, making them inadequate for complex surgical scenarios [3]. The flexible negative pressure suction sheath, with its unique suction function and bendable design, theoretically offers dual advantages: effectively reducing intrapelvic pressure and minimizing stone displacement risks while providing stable channels for ureteroscopic procedures [4]. This study enrolled 200 renal stone patients treated at our hospital between January 2023 and April 2025. Through randomized comparison of standard ureteroscopic sheaths versus flexible negative pressure suction sheaths combined with ureteroscopic lithotripsy, we evaluated clinical differences between the two approaches to develop optimized minimally invasive treatment strategies. The findings are presented below.

2. Data and Methods

2.1. General Information

This study enrolled 200 patients undergoing treatment for kidney stones at our hospital, with hospitalization periods spanning from January 2023 to April 2025. Patients were randomly assigned to two groups via lottery: the control group (70 males and 30 females, average age 48.65 ± 8.56 years) and the observation group (65 males and 35 females, average age 49.08 ± 8.11 years). Inclusion criteria included a confirmed diagnosis of kidney stones via ultrasound or other methods; the stone is located in the upper segment of the ureter or the renal pelvis, and its size is less than 1 cm; eligibility for surgical treatment; complete medical records; and active cooperation with treatment. Exclusion criteria included severe comorbidities or urological diseases, contraindications or intolerance to surgery, significant preoperative instability of vital signs, and lack of patient/family consent. Statistical analysis showed no significant differences between groups ($P > 0.05$).

2.2. Method

All patients were under general anesthesia. After anesthesia took effect, they were placed in the lithotomy position and underwent routine disinfection and draping. The surgical team consisted of senior physicians with rich clinical experience.

2.2.1. Control Group

Using a ureteroscope (Storz, 9.5 F) to explore the ureter to the renal pelvis, a disposable guidewire (0.032 in × 150 cm) was inserted. After withdrawing the ureteroscope, an F11 standard ureteroscope sheath was implanted along the guidewire. The core was removed, followed by the introduction of the flexible ureteroscope

(XFGC-FU-640MC). Under direct visualization, the sheath was advanced to the ureteropelvic junction. Position the patient in a head-down, feet-up position. Use a holmium laser to fragment the stones. After postoperative follow-up confirms no residual stones, place an F6 double-J stent.

2.2.2. Observing Group

1. Through a bladder approach, a rigid ureteroscope is inserted into the renal pelvis to establish a guidewire. After removing the ureteroscope, an F11 flexible negative pressure suction sheath is advanced along the guidewire. The core is then removed, followed by insertion of a disposable electronic flexible ureteroscope (XFGC-FU-640MC). Under X-ray guidance, position the negative pressure sheath at the ureteropelvic junction and connect it to the suction device. Adjust the patient's position to a head-down, feet-up posture, then perform holmium laser lithotripsy to fragment the stones while simultaneously initiating negative pressure suction. After lithotripsy, the patient is repositioned in a head-high, foot-low position. The negative pressure sheath is used to clear residual stones, and an F6 double J stent is placed after confirming no significant fragments remain. 2. Key operational points: Dynamically adjust parameters based on stone location, size, and hydronephrosis severity. Clear stones through the sheath gap. Prevent stone impaction by retracting the sheath and incising the outer sheath if necessary. Maintain perfusion flow ≥ 40 mL/min. During lithotripsy, use low perfusion to preserve visualization. During stone clearance, increase perfusion and suction intensity to create vortex flow, ensuring coordinated water and suction directions.

2.3. Observation Indicators

The reliability of all observed indicators is documented in references.

2.3.1. Surgical Indicators

Statistical analysis was performed on operative time, stone clearance rate, and postoperative hospitalization duration.

2.3.2. Renal Injury Indicators

Measure serum creatinine and blood urea nitrogen levels before and after surgery.

2.3.3. Inflammatory Markers

Blood tests for white blood cell count, neutrophil percentage, and C-Reactive Protein (CRP) levels were conducted before and after surgery.

2.3.4. Complications

Collectively analyze postoperative incidence rates of fever, urinary tract infections, hydronephrosis/ascites, and hematuria.

2.4. Statistical Analysis

Data were analyzed using SPSS 22.0. Data meeting normal distribution were expressed as ($\bar{x} \pm s$) and analyzed with t-tests; categorical data were presented as [n

(%)], analyzed with χ^2 tests. A P < 0.05 indicated statistically significant differences.

3. Results

3.1. Comparison of Surgical Indicators

The observation group showed shorter operation time, higher stone clearance rate, and shorter postoperative hospitalization time (P < 0.05). See Table 1.

Table 1. Comparison of surgical indicators ($\bar{x} \pm s$).

Group	Number of examples	Surgery duration (min)	Stone clearance (%)	Hospitalization time after surgery (d)
Observation group	100	62.35 ± 9.24	96 (96.00)	4.32 ± 0.85
Control group	100	83.78 ± 13.65	87 (87.00)	6.89 ± 1.23
t/χ^2		13.001	5.207	17.189
P		0.000	0.022	0.000

3.2. Comparison of Renal Injury Indicators

No significant differences were observed in preoperative renal injury indicators between the two groups. Postoperatively, the observation group showed less elevation in serum creatinine and blood urea nitrogen levels compared to the control group, indicating milder renal impairment (P < 0.05). See Table 2.

Table 2. Comparison of renal injury indicators ($\bar{x} \pm s$).

Group	Number of examples	Serum creatinine (μmol/L)		Urea nitrogen (mmol/L)	
		Preoperative	Postoperative	Preoperative	Postoperative
Observation group	100	82.34 ± 9.12	93.56 ± 14.23	5.23 ± 0.98	6.45 ± 1.34
Control group	100	81.45 ± 8.97	112.67 ± 18.56	5.12 ± 0.89	8.21 ± 1.76
t		0.696	8.171	0.831	7.956
P		0.487	0.000	0.407	0.000

3.3. Comparison of Inflammatory Stimulation Indicators

No significant differences were observed between the two groups in preoperative inflammatory markers (P > 0.05). The observation group experienced less surgical stimulation, with significantly lower postoperative inflammatory markers (P < 0.05). See Table 3.

3.4. Comparison of Complications

The observation group showed better prevention of complications than the control group, with a lower incidence rate (P < 0.05). See **Table 4**.

Table 3. Comparison of inflammatory stimulus ($\bar{x} \pm s$).

Group	Number of examples	White blood cell count (×10^9/L)		Neutrophil percentage (%)		CRP (mg/L)	
		Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
Observation group	100	7.23 ± 0.87	8.34 ± 1.23	61.23 ± 4.32	66.45 ± 4.12	5.34 ± 0.98	8.56 ± 1.87
Control group	100	7.12 ± 0.91	10.23 ± 1.89	60.89 ± 4.56	76.34 ± 7.23	5.21 ± 0.87	15.34 ± 2.67
t		0.874	8.381	0.541	11.885	0.992	20.799
P		0.383	0.000	0.589	0.000	0.322	0.000

Table 4. Comparison of complications (n (%)).

Group	Number of examples	Give out heat	Urinary tract infection	Hydrocele	Hematuria	Total occurrences
Observation group	100	4 (4.00)	2 (2.00)	1 (1.00)	1 (1.00)	8 (8.00)
Control group	100	9 (9.00)	7 (7.00)	3 (3.00)	3 (3.00)	22 (22.00)
χ^2						7.686
P						0.006

4. Discussion

Kidney stones, a prevalent condition in the urinary system, involve complex pathogenic mechanisms closely linked to metabolic disorders, local urinary tract factors, medication use, and lifestyle habits. When urine contains excessive concentrations of calcium, oxalate, and uric acid, these substances crystallize and gradually accumulate, eventually forming stones [5]. These stones progressively grow within the kidneys, causing severe renal colic, gross or microscopic hematuria, and potentially leading to urinary tract obstruction that impedes normal urine excretion. Prolonged obstruction may result in hydronephrosis, compressing renal parenchyma and severely threatening kidney function. Without timely intervention, this condition could progress to renal failure, posing a significant threat to patients' health [6]. With the rising incidence of kidney stones, in-depth research into treatment methods holds crucial clinical significance.

Currently, surgical intervention remains a crucial approach for treating kidney stones. With the rapid advancement of minimally invasive techniques, ureteroscopic lithotripsy has gained widespread clinical adoption as the preferred treatment option for many patients due to its advantages of minimal invasiveness and faster recovery [7]. However, as the number of cases increases and clinical practice deepens, several pressing issues in this technique remain unresolved. During standard ureteroscopic lithotripsy procedures, stone displacement reduces fragmentation efficiency, postoperative residual stone rates remain high, and prolonged operation time increases infection risks. In contrast, the modified approach combines standard ureteroscopic sheath placement with a flexible negative pressure suction sheath, enabling simultaneous stone fragmentation and suction activation through holmium laser pulverization. This method dynamically adjusts operational parameters and patient positioning during the procedure [8]. The differences in procedural workflows and technical nuances between these approaches significantly impact clinical outcomes. A thorough comparative analysis of these variations will provide critical evidence for developing precision treatment strategies for kidney stones.

In terms of surgical metrics, the observation group demonstrated significantly shorter operation durations. This advantage primarily stems from the innovative design and functionality of the flexible negative pressure suction sheath. Its flexible configuration allows optimal adaptation to the anatomical structure of the urinary tract, minimizing time-consuming adjustments during implantation. The suction mechanism effectively removes fragmented stones during lithotripsy, preventing scattering and maintaining clear surgical fields. This enables surgeons to rapidly locate and manage stones without frequent irrigation or angle adjustments, substantially reducing operative time [9]. The observation group achieved notably higher stone clearance rates compared to the control group. The suction sheath simultaneously extracts crushed stones during lithotripsy, eliminating residual fragments. Additionally, the vortex generated by adjusting irrigation and suction intensity efficiently flushes stone debris from the renal pelvis and calyces into the sheath's suction zone, particularly enhancing clearance efficacy for complex calyceal stones [10]. Patients in the observation group experienced earlier discharge due to minimized surgical trauma and superior stone removal outcomes. The shorter operation time and precise techniques reduced urinary tract tissue damage, accelerating postoperative recovery. Complete stone clearance also lowered recurrence and obstruction risks, further expediting rehabilitation.

In terms of renal injury, the observation group demonstrated less renal dysfunction. The statistical difference in the two observational indicators, creatinine and blood urea nitrogen, may be transient. This is because the standard ureteroscope sheath cannot fully conform to the urinary tract during insertion and manipulation, potentially causing friction and compression on the ureteral wall. This may affect renal blood supply, leading to renal dysfunction. Therefore, long-term follow-up is particularly necessary. The flexible design of the bendable negative pressure suction sheath reduces mechanical trauma to urinary tract tissues. Its precise negative pressure control prevents stress injuries caused by excessive perfusion pressure or improper suction. Additionally, timely stone removal and clear surgical field maintenance ensure smoother procedures, significantly reducing the risk of renal damage from surgical errors.

In terms of inflammatory stimulation, the observation group exhibited significantly lower inflammatory responses. During surgical procedures, factors such as residual stones, tissue damage, and extravasation of irrigation fluid can trigger inflammatory reactions. The observation group utilized negative pressure aspiration to promptly remove stone fragments and inflammatory mediators, effectively reducing their retention and irritation within the body. Furthermore, precise surgical techniques minimized tissue damage while decreasing inflammatory factor release. The excellent sealing performance of the suction sheath prevented irrigation fluid extravasation, thereby avoiding irritation to surrounding tissues and effectively mitigating inflammatory responses. The flexible negative pressure suction sheath, when employed in ureteroscopic lithotripsy, achieves stone fragmentation and removal with significantly reduced tissue trauma.

The observation group demonstrated significant advantages over the control group in managing complications. This stems from two key mechanisms: the flexible negative pressure drainage sheath enables rapid removal of stone fragments and intraoperative tissue debris through continuous suction, effectively preventing retention-induced obstructions that could lead to hydronephrosis, fluid accumulation, or hematuria. Simultaneously, this sheath optimizes the intraoperative irrigation environment, reducing bacterial translocation risks and significantly lowering the incidence of fever and urinary tract infections. Furthermore, its high flexibility allows precise manipulation, minimizing surgical trauma to kidneys and ureters while reducing inflammatory responses, thereby addressing the root causes of potential complications.

In conclusion, in the treatment of renal calculi, the combination of a flexible negative pressure suction sheath and ureteroscope can shorten the operation time, reduce the damage to renal function and body tissues, and achieve a high stone clearance rate. Patients recover quickly after operation and can be discharged earlier. Although the study utilized a sample of 60 patients, the relatively small sample size may limit the generalizability of its conclusions. Future research could consider increasing the sample size or conducting multicenter, large-scale clinical trials to enhance the reliability of the findings.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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