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Original Article

Efficacy and safety of flexible ureteroscopy assisted by a flexible-tip negative pressure suction sheath for 2-4 cm renal calculi

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Abstract: Objective: To investigate the efficacy and safety of flexible ureteroscopy assisted by a flexible-tip negative-pressure suction sheath for the treatment of 2-4 cm renal calculi. Methods: We retrospectively analyzed clinical data from 103 patients with 2-4 cm renal calculi who underwent flexible ureteroscopic holmium laser lithotripsy. Patients were divided into a flexible-tip suction sheath group (n=52) and a conventional sheath group (n=51) according to the type of ureteral access sheath used during surgery. Perioperative findings and surgical complications were compared between the two groups. Results: The stone-free rate was significantly higher in the flexible-tip suction sheath group (92.31%) than in the conventional sheath group (76.47%), and hospital stay was significantly shorter (both $P < 0.05$). The incidences of postoperative fever and steinstrasse in the flexible-tip suction sheath group were 3.85% and 1.92%, respectively, which were significantly lower than the 17.65% and 15.67% observed in the conventional sheath group (both $P < 0.05$). Postoperatively, serum levels of TNF-α, IL-1β, IL-6, CRP, cortisol, norepinephrine, and adrenocorticotropic hormone increased in both groups; however, the magnitude of elevation was significantly smaller in the flexible-tip suction sheath group (all $P < 0.05$). In addition, postoperative levels of serum creatinine, cystatin C, blood urea nitrogen, and neutrophil gelatinase-associated lipocalin, as well as 6-month postoperative quality-of-life scores, were significantly better in the flexible-tip suction sheath group than in the conventional sheath group (all $P < 0.05$). Conclusion: The application of flexible-tip negative-pressure suction sheath-assisted flexible ureteroscopy in patients with 2-4 cm renal calculi was associated with a higher stone-free rate, reduced incidences of specific postoperative complications, and more favorable short-term recovery outcome. This suggests its clinical value. Nevertheless, prospective randomized controlled trials are warranted for further validation.

Keywords: Flexible-tip negative pressure suction sheath, flexible ureteroscopy, renal calculi, stone-free rate, complications

Introduction

Renal calculi are among the most prevalent urologic diseases. They form as solid deposits from the crystallization and accumulation of urinary minerals in the kidneys, and may present with clinical manifestations such as voiding dysfunction, renal colic, and secondary infection. Without timely treatment, they can lead to urinary tract obstruction, chronic kidney injury, and other complications that severely impair patient health [1]. Currently, extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), and flexible ureteroscopic lithotripsy are the mainstay treatments for renal stones 2-4 cm in diameter [2, 3]. Although ESWL is minimally invasive, it yields unsatisfactory stone-free rates for larger or harder stones and often requires repeated sessions, increasing patient discomfort and economic burden [4]. PCNL achieves high stone clearance efficiency but carries risks of bleeding and infection, and its use is limited in patients with complex renal anatomy or underlying comorbidities [5].

In recent years, flexible ureteroscopic holmium laser lithotripsy has emerged as a first-line treatment for 2-4 cm renal stones owing to its minimally invasive nature, favorable safety profile, and rapid recovery [6, 7]. However, it remains associated with challenges such as elevated intrapelvic pressure during surgery, incomplete clearance of stone fragments, post-

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operative fever, and steinstrasse, which may compromise surgical efficacy and negatively affect patient prognosis [8]. The flexible-tip negative-pressure suction sheath enables efficient aspiration of stone fragments using negative pressure, thereby reducing intrapelvic pressure, lowering infection-related complications, and improving stone clearance efficiency [9]. Although several studies have reported the application of this sheath in flexible ureteroscopy, most have been limited by small sample sizes or short follow-up periods, and its efficacy for 2-4 cm stones requires further validation. Therefore, this study retrospectively analyzed clinical data from 103 patients with 2-4 cm renal calculi to evaluate the efficacy and safety of this technique, to provide evidence to support clinical decision-making for this patient population.

Materials and methods

Study population

We performed a retrospective analysis of 103 consecutive patients with 2-4 cm renal calculi who underwent flexible ureteroscopic holmium laser lithotripsy at the Department of Urology, Hebei Yanda Hospital, between January 2022 and January 2025. Based on the type of ureteral access sheath used, patients were assigned to either the flexible-tip suction sheath group (n=52) or the conventional sheath group (n=51).

The final sample comprised all eligible patients admitted during the study period who met the inclusion and exclusion criteria.

This study was approved by the Ethics Committee of Hebei Yanda Hospital and conducted in accordance with the principles of the Declaration of Helsinki. Given the retrospective design using de-identified existing clinical data with no additional patient interventions, the requirement for informed consent was waived.

Inclusion and exclusion criteria

Inclusion criteria: (1) confirmed diagnosis of renal calculi per established diagnostic criteria [10]; (2) complete baseline, treatment, and follow-up data, or availability for postoperative follow-up (including assessments at 1 week and 6 months postoperatively); (3) stone diameter of 2-4 cm; (4) solitary renal calculus.

Exclusion criteria: (1) pregnancy or lactation; (2) surgical intolerance or contraindications to surgery; (3) coagulation disorders, severe cardiac, hepatic, or renal dysfunction, or malignancy; (4) urinary tract stricture, congenital malformation, or active infection; (5) concurrent ureteral or bladder calculi; (6) incomplete follow-up data or loss to follow-up.

Sample size source and post hoc sufficiency assessment

The final sample size was determined by all eligible patients with complete clinical data who met the inclusion and exclusion criteria during the study period. A total of 103 patients were enrolled, including 52 in the flexible-tip suction sheath group and 51 in the conventional sheath group.

Since this study was not a prospective randomized controlled trial, no sample size estimation was conducted prior to study initiation. To evaluate whether the available sample size generally met the statistical requirements for comparison of the primary outcome, the stone-free rate was selected as the primary endpoint. Based on published literature, the stone-free rate was estimated at approximately 75% in the conventional ureteral sheath group and 90% in the flexible-tip negative-pressure suction sheath group. With a two-sided significance level of $\alpha=0.05$ and a statistical power of $1-\beta=0.80$, a *post hoc* sample size sufficiency assessment was performed using PASS software, which indicated a minimum requirement of 49 patients per group.

The actual enrollment of 52 patients in the flexible-tip suction sheath group and 51 in the conventional sheath group generally satisfies the sample size requirement for comparison of this primary outcome. However, this analysis constituted a *post hoc* assessment and cannot replace *a priori* sample size calculation in prospective studies. Accordingly, the findings of this study should be interpreted as retrospective exploratory evidence.

Surgical procedure

All patients underwent comprehensive preoperative evaluation to confirm stone location and size. Epidural or general anesthesia was administered, and patients were placed in the lithotomy position.

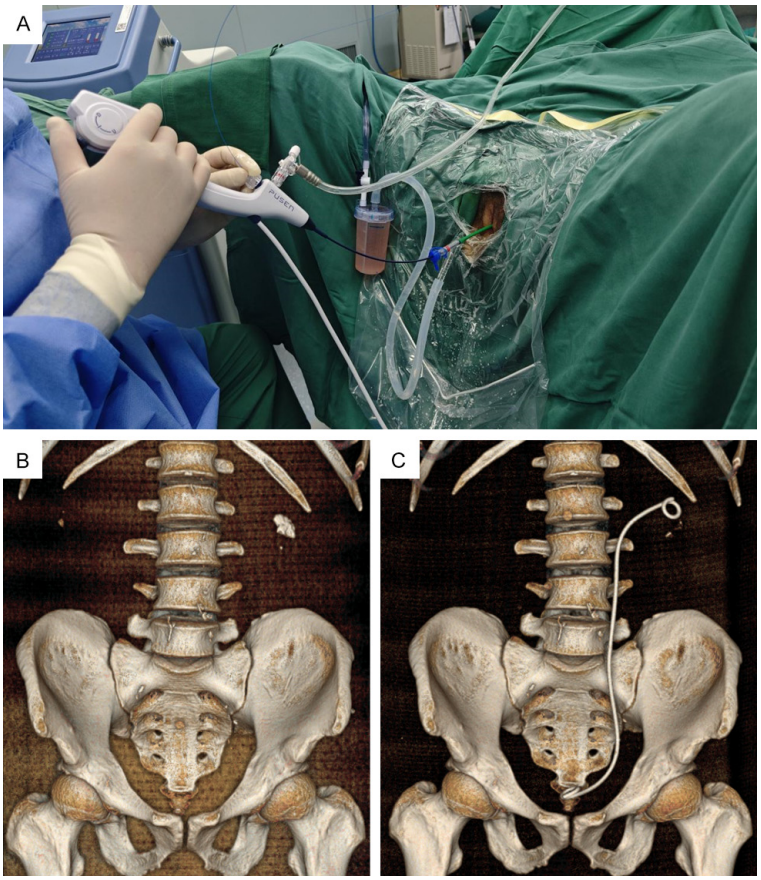

Figure 1. Schematic diagram of flexible-tip suction sheath assisted flexible ureteroscopy for 2-4 cm renal calculi. A. Intraoperative view showing the flexible-tip suction sheath inserted through the ureteral route into the renal collecting system, with flexible ureteroscopy for lithotripsy and negative-pressure suction to remove stone fragments. B. Preoperative three-dimensional reconstructed CT image showing the anatomic relationship among the kidney, ureter, and bony structures. C. Postoperative three-dimensional reconstructed CT image illustrating the position of the flexible-tip suction sheath inserted through the ureteral route into the renal collecting system.

Conventional sheath group: A rigid ureteroscope was inserted transurethrally to rule out significant ureteral stenosis or anatomical abnormalities. A zebra guidewire was advanced through the rigid ureteroscope with its tip positioned in the renal pelvis. After withdrawing the rigid ureteroscope, a 12 F conventional ureteral access sheath was advanced over the guidewire to the ureteropelvic junction. An electronic flexible ureteroscope was passed through the sheath and connected to an irrigation pump for intermittent irrigation to maintain a clear operative field. The renal pelvis and calyces were systematically inspected. After stone localization, holmium laser lithotripsy was performed to fragment the calculus into pieces ≤2 mm. Stone fragments were flushed out by irrigation fluid and expected to pass spontaneously postoperatively, with no active negative-pressure suction applied. A double-J ureteral stent was placed routinely at the end of the procedure.

Flexible-tip suction sheath group: A rigid ureteroscope was first inserted transurethrally to rule out significant ureteral stenosis, after which a guidewire was advanced into the renal pelvis. A 14F flexible-tip negative-pressure suction sheath was placed over the guidewire in appropriate position and connected to a negative-pressure suction device to maintain stable suction. An electronic flexible ureteroscope was advanced through the suction sheath and connected to an irrigation pump for intermittent irrigation to maintain a clear operative field. The renal pelvis and calyces were systematically explored, and holmium laser lithotripsy was performed after stone localization. During lithotripsy, stone fragments >2 mm were directly aspirated and removed through the suction sheath, while fragments ≤2 mm were either evacuated with negative-pressure assistance or allowed to pass spontaneously postoperatively. A double-J ureteral stent was placed routinely after the procedure (**Figure 1**).

Postoperatively, both groups received symptomatic treatment including prophylactic anti-infective therapy, fluid supplementation, and antispasmodic and analgesic medications. Quinolones were used as an alternative for patients with antibiotic allergies.

Outcome measures

Perioperative findings: Operative time, intraoperative blood loss, stone-free rate, and length of hospital stay were recorded for both groups.

Table 1. Comparison of baseline data between the two groups

Data	Flexible-tip suction sheath group (n=52)	Conventional sheath group (n=51)	χ^2/t	*P*
Gender (Male/Female)	35/17	32/19	0.236	0.627
Age (Years)	48.25±6.32	48.73±5.93	0.397	0.692
Duration of illness (Months)	6.35±1.65	6.54±1.62	0.590	0.557
Stone diameter (cm)	3.17±0.58	3.09±0.56	0.712	0.478
Stone location (Left/Right)	28/24	26/25	0.085	0.771
ASA classification (Class I/Class II)	20/32	22/29	0.233	0.629
Body mass index (kg/m^2)	22.75±2.13	22.64±2.05	0.267	0.790
RUSS score (Points)	4.33±0.63	4.46±0.59	1.081	0.283

Note: ASA: American Society of Anesthesiologists classification; BMI: body mass index; RUSS: Resorlu-Unsal Stone score.

Complications: The incidences of postoperative fever, steinstrasse, and infection were documented in both groups.

Inflammatory markers: Serum tumor necrosis factor-α (TNF-α), interleukin-1β (IL-1β), interleukin-6 (IL-6), and C-reactive protein (CRP) were measured by enzyme-linked immunosorbent assay (ELISA). Measurements were performed as part of routine clinical practice, and only patients with complete data for these markers were included in the final analysis. Blood samples (4 mL) were collected preoperatively and on postoperative day 1. Samples were centrifuged at 3000 r/min for 10 min (radius 6 cm). Serum was separated and stored at -80°C.

Stress response indicators: Serum cortisol (Cor), norepinephrine (NE), and adrenocorticotropic hormone (ACTH) levels were measured preoperatively and on postoperative day 1 by radioimmunoassay.

Renal injury indicators: Serum creatinine (SCr), cystatin C (Cys-C), blood urea nitrogen (BUN), and neutrophil gelatinase-associated lipocalin (NGAL) levels were measured preoperatively and at 1 week postoperatively using an automatic biochemical analyzer.

Quality of life: The World Health Organization Quality of Life-BREF (WHOQOL-BREF) questionnaire was used to evaluate patients preoperatively and at 6 months postoperatively. The scale covers four domains: physical, psychological, social relationships, and environment. Each domain was scored from 0 to 100, with lower scores indicating poorer quality of life. Postoperative renal function testing at 1 week and quality-of-life assessment at 6 months were completed via a combination of outpatient follow-up and telephone interviews. Dedicated personnel were responsible for follow-up management and data recording to maximize follow-up rates. Only patients with complete follow-up data were included in the final analysis.

Statistical analysis

Statistical analysis was performed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation ($\bar{x}$ ± SD) and compared using the independent-samples t test. Categorical variables were expressed as percentages and compared using the chi-square test. Fisher's exact test was used when expected frequencies were small or the assumptions for the chi-square (χ^2) test were not met. A *P* value < 0.05 was considered significant.

Results

Comparison of baseline characteristics

No significant differences were observed between the two groups in baseline characteristics, including sex, age, disease duration, stone diameter, stone location, American Society of Anesthesiologists classification, body mass index (BMI), or Resorlu-Unsal Stone score (all P > 0.05), confirming good comparability between groups (**Table 1**).

Comparison of perioperative outcomes

No significant differences were found between the two groups in operative time or intraoperative blood loss (both P > 0.05). A higher stone-

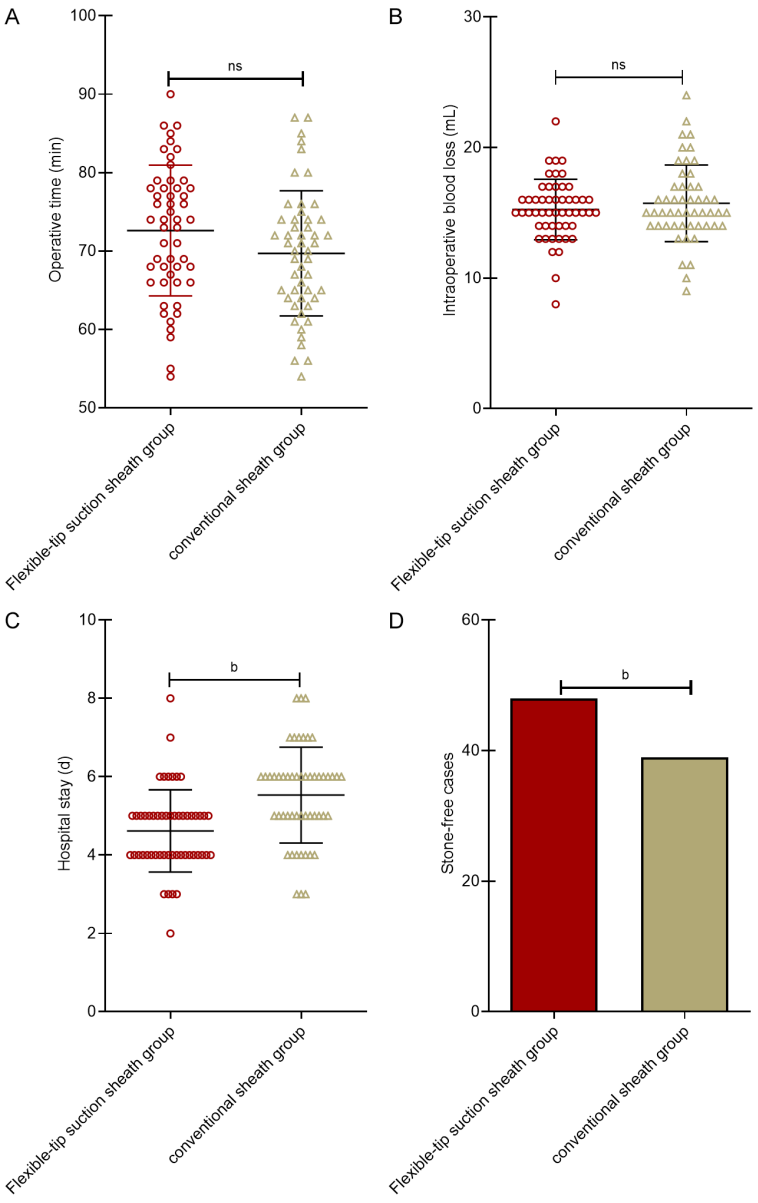

Figure 2. Comparison of perioperative outcomes between the flexible-tip suction sheath group (n=52) and the conventional sheath group (n=51). Each scatter dot represents an individual patient. A. Operation time (min). B. Intraoperative blood loss (mL). C. Hospital stay (d). D. Stone-free cases. Note: Compared to the Conventional Sheath Group, $^{b}P < 0.05$.

free rate and shorter hospital stay were observed in the flexible-tip suction sheath group compared with the conventional sheath group (both P < 0.05) (**Figure 2**).

Comparison of complications

Lower incidences of postoperative fever and steinstrasse were observed in the flexible-tip suction sheath group compared to the conventional sheath group (both P < 0.05). No significant difference was observed in the incidence of infection between the two groups (P > 0.05) (**Table 2**).

Comparison of inflammatory markers

There were no significant differences in preoperative inflammatory marker levels between the two groups (all P > 0.05). On postoperative day 1, serum levels of TNF-α, IL-1β, IL-6, and CRP were significantly increased in both groups compared to baseline; however, the magnitude of increase was significantly smaller in the flexible-tip suction sheath group (all P < 0.05) (**Figure 3**).

Comparison of stress response indicators

No significant differences were observed in preoperative serum levels of Cor, NE, or ACTH between the two groups (all P > 0.05). On postoperative day 1, all stress response indicators increased markedly in both groups; however, the degree of elevation was significantly lower in the flexible-tip suction sheath group (all P < 0.001) (**Table 3**).

Comparison of renal injury indicators

There were no significant differences between the two groups in preoperative levels of SCr, Cys-C, BUN, or NGAL (all P > 0.05). At 1 week postoperatively, all four indicators increased to varying degrees in both groups; however, levels were significantly lower in the flexible-tip suction sheath group (all P < 0.001) (**Table 4**).

Comparison of quality of life

No significant difference was observed in preoperative quality-of-life scores between the two groups (all P > 0.05). At 6 months postopera-

Table 2. Comparison of complications between the two groups [n (%)]

Group	Fever	Formation of Steinstrasse	Infection
Flexible-tip suction sheath group (n=52)	2 (3.85)	1 (1.92)	1 (1.92)
Conventional sheath group (n=51)	9 (17.65)	8 (15.67)	3 (5.88)
*P	0.028	0.031	0.617

*Fisher's exact test.

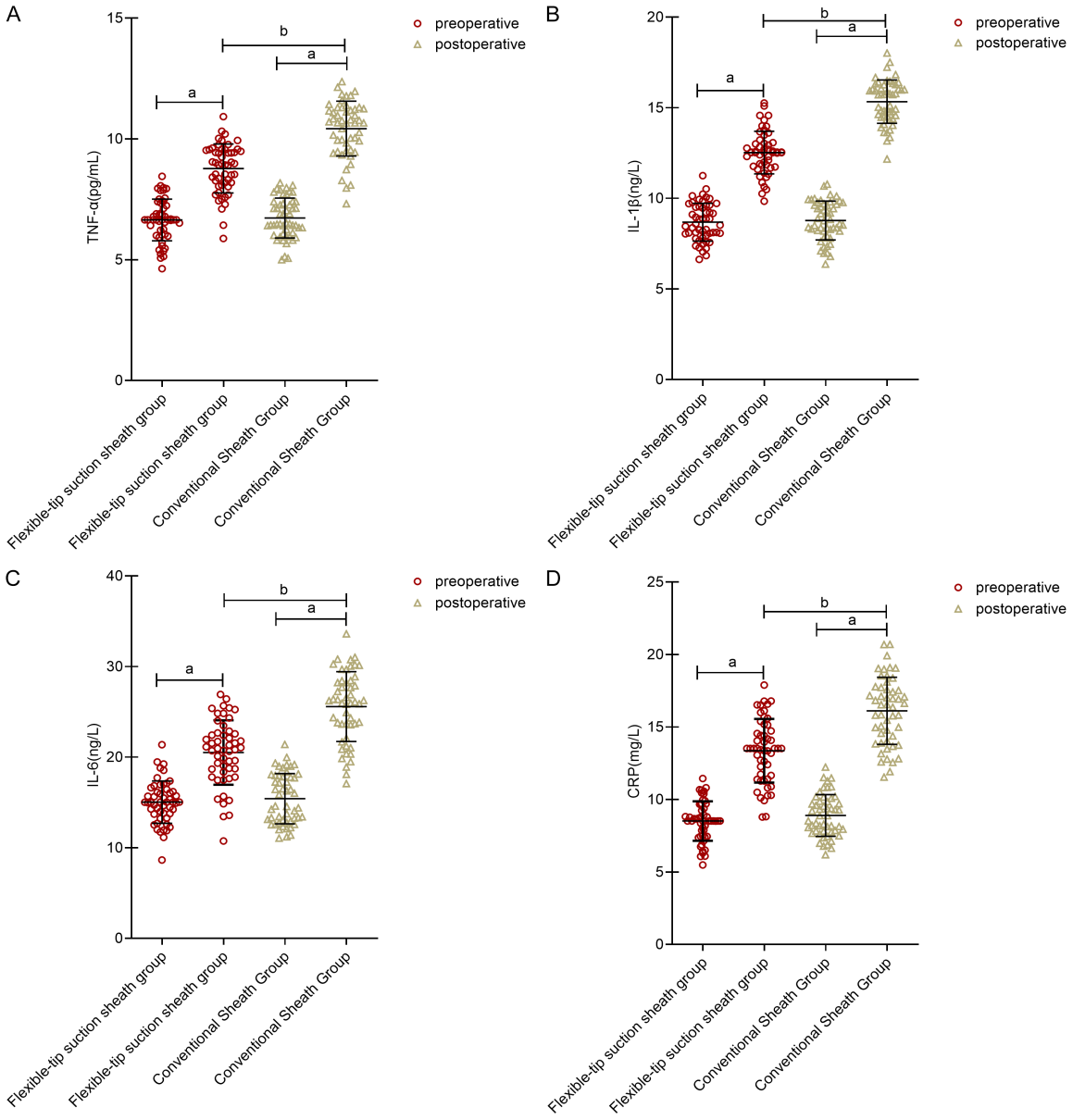

Figure 3. Comparison of serum inflammatory marker levels before surgery and on the first postoperative day between the flexible-tip suction sheath group (n=52) and the conventional sheath group (n=51). Each scatter dot represents an individual patient. A. Tumor Necrosis Factor-α (TNF-α). B. Interleukin-1β (IL-1β). C. Interleukin-6 (IL-6). D. C-reactive protein (CRP). Note: Compared to the preoperative levels in this group, $^{a}P < 0.05$; compared to the Conventional Sheath Group, $^{b}P < 0.05$.

tively, scores in all domains improved significantly in both groups compared to baseline; moreover, the flexible-tip suction sheath group had significantly higher scores across all

Table 3. Comparison of stress response indicators between the two groups (χ±S)

Indicator	Time	Flexible-tip suction sheath group (n=52)	Conventional sheath group (n=51)	*t*	*P*
Cor (μg/L)	Before the operation	140.32±12.25	142.26±14.06	0.747	0.457
	One day after the operation	160.85±13.74*	187.65±16.05*	9.110	< 0.001
NE (μg/L)	Before the operation	223.54±18.72	221.85±17.67	0.471	0.639
	One day after the operation	254.39±20.73*	278.69±22.06*	5.910	< 0.001
ACTH (ng/L)	Before the operation	25.55±2.16	25.89±2.27	0.779	0.438
	One day after the operation	30.17±2.58*	35.36±3.13*	9.190	< 0.001

Note: Compared to the before surgery within the group, *P < 0.05. Serum cortisol (Cor), norepinephrine (NE), and adrenocorticotropic hormone (ACTH).

Table 4. Comparison of renal function damage indicators between the two groups ($\bar{x}$±S)

Indicator	Time	Flexible-tip suction sheath group (n=52)	Conventional sheath group (n=51)	*t*	*P*
SCr (μmol/L)	Before the operation	92.36±5.69	93.05±5.92	0.603	0.548
	One week after the operation	102.11±8.74*	113.05±9.64*	6.036	< 0.001
Cys-C (mg/L)	Before the operation	1.36±0.68	1.41±0.71	0.365	0.716
	One week after the operation	2.26±0.75*	3.13±0.80*	5.695	< 0.001
BUN (mmol/L)	Before the operation	9.04±1.20	9.12±1.28	0.327	0.744
	One week after the operation	11.52±1.55*	14.83±1.39*	11.403	< 0.001
NGAL (μg/L)	Before the operation	6.78±1.16	6.53±1.22	1.066	0.289
	One week after the operation	8.33±1.37*	10.22±1.35*	7.051	< 0.001

Note: Compared to the before surgery within the group, *P < 0.05. Serum creatinine (SCr), cystatin C (Cys-C), blood urea nitrogen (BUN), and neutrophil gelatinase-associated lipocalin (NGAL).

Table 5. Comparison of quality of life between the two groups (χ±S, score)

Indicator	Time	Flexible-tip suction sheath group (n=52)	Conventional sheath group (n=51)	*t*	*P*
Physical domain	Before the operation	50.39±4.77	51.03±4.92	0.670	0.504
	6 months after the operation	72.05±6.05*	63.39±5.26*	7.757	< 0.001
Psychological domain	Before the operation	53.46±4.39	53.89±4.25	0.505	0.615
	6 months after the operation	73.27±5.87*	65.52±5.19*	7.102	< 0.001
Social relationships domain	Before the operation	55.68±4.47	55.22±4.80	0.378	0.706
	6 months after the operation	72.08±5.64*	65.58±5.37*	5.991	< 0.001
Environmental domain	Before the operation	57.05±4.51	56.39±4.62	0.734	0.465
	6 months after the operation	75.05±6.33*	67.28±5.43*	6.691	< 0.001

Note: Compared to the before surgery within the group, *P < 0.05.

domains than the conventional sheath group (all P < 0.001) (**Table 5**).

Discussion

Renal calculi are one of the most common urological disorders, and conventional treatment strategies have notable limitations for stones 2-4 cm in diameter [11, 12]. With the rapid advancement of endoscopic technology, flexible ureteroscopy has become the mainstream treatment for stones of this size. Using the natural urinary tract as the surgical access, this approach offers minimal trauma, rapid postoperative recovery, straightforward operability, and a relatively gentle learning curve. Nevertheless, conventional ureteral access sheaths lack a negative-pressure suction function, which frequently leads to elevated renal pelvic pressure and inadequate evacuation of stone fragments, ultimately compromising surgical outcome [13, 14].

The flexible-tip suction sheath is indicated primarily for patients undergoing flexible ureteroscopy for renal calculi, particularly those with a large stone burden who require real-time fragment clearance during lithotripsy or strict intraoperative control of renal pelvic pressure. Typical applicable scenarios include 2-4 cm renal stones, lower calyceal calculi, multiple renal calculi, and cases with a large expected intraoperative fragment volume. While facilitating smooth passage of the flexible ureteroscope into the renal collecting system, this device enables negative-pressure-assisted stone clearance, optimizes the operative field, and reduces risks associated with intrapelvic hypertension. It yields greater clinical benefit in patients with favorable ureteral anatomy without severe stricture or tortuosity. In contrast, its use should be considered cautiously or avoided in patients with ureteral stricture, marked anatomic anomalies, or conditions precluding safe sheath placement.

In this retrospective cohort study, patients treated with flexible-tip negative-pressure suction sheath-assisted flexible ureteroscopy exhibited a higher stone-free rate, shorter hospital stay, and lower incidences of postoperative fever and steinstrasse. These findings suggest that application of this technique may be associated with favorable perioperative outcome. However, given the non-randomized design of this study, factors including surgeon preference, patient anatomic conditions, stone characteristics, and disparities in perioperative management may have confounded the results. Accordingly, these findings should be interpreted as evidence of association rather than direct causation.

The underlying mechanisms may be explained as follows. Conventional straight-tip sheaths serve only as a passage for the endoscope, and stone fragments are cleared primarily by irrigation flushing. This approach has low efficiency for relatively large stones and tends to cause fragment deposition in the renal calyces, increasing the risk of steinstrasse formation [15, 16]. In contrast, the flexible-tip suction sheath enables active aspiration to directly remove fragments larger than 2 mm, substantially reducing residual stone burden and improving stone-free efficacy [17]. Furthermore, active negative-pressure decompression alleviates intraoperative renal pelvic hypertension and reduces retrograde reflux of infectious substances into the circulation, which contributes to a lower incidence of postoperative fever [18]. Improved stone clearance also reduces the likelihood of reoperation, and the reduced complication burden further shortens hospital stay.

As a novel auxiliary device for flexible ureteroscopy, the flexible-tip suction sheath has prominent clinical advantages. Its negative-pressure function allows real-time removal of stone debris, enhances stone clearance efficiency, mitigates renal pelvic pressure elevation, and reduces retrograde flow of bacteria and endotoxins, thereby lowering the risk of postoperative fever and infection. Additionally, its deflectable tip improves accessibility to the renal calyces, optimizes lithotripsy routes, and increases surgical efficiency. However, this technique still has certain limitations. First, it requires proficient surgical skills to balance suction efficacy and avoid mucosal injury caused by excessive negative pressure. Second, the higher device cost may impose an additional economic burden on patients. Third, safe sheath placement remains challenging in patients with poor ureteral anatomy or severe stricture. Therefore, surgical strategies and device selection should be individualized according to patient conditions to achieve optimal therapeutic outcomes.

Inflammatory and stress biomarkers are critical indicators for evaluating surgical trauma. In this study, postoperative levels of TNF-α, IL-1β, IL-6, CRP, Cor, NE, and ACTH were elevated in both groups, yet the magnitude of elevation was markedly lower in the flexible-tip suction sheath group. This indicates that adjunctive use of the flexible-tip suction sheath can effectively mitigate perioperative inflammatory and stress responses. The intraoperative reduction of renal pelvic hypertension by continuous suction may be the core mechanism. Renal pelvic hypertension impairs renal microcirculation and triggers excessive release of inflammatory mediators; negative-pressure suction can effectively reverse this pathologic process. Additionally, retained fragments and inadequate evacuation in conventional procedures may irritate local urothelial tissue and aggravate inflammation. The reduced residual stone volume in the flexible-tip suction sheath group lessens mechanical stimulation of the urinary

tract and decreases systemic inflammatory stress [19, 20]. The milder stress response is closely associated with minimized surgical trauma and fewer complications. Smoother intraoperative manipulation and lower postoperative morbidity collectively blunt the elevation of stress hormones such as Cor, NE, and ACTH [21].

Renal protection and quality of life improvement are core therapeutic goals for renal calculi treatment. Postoperative levels of SCr, Cys-C, BUN, and NGAL were significantly lower, and 6-month quality-of-life scores were remarkably higher, in the flexible-tip suction sheath group. These results suggest that application of this suction sheath can alleviate postoperative renal injury and enhance long-term quality of life. Intraoperative renal pelvic hypertension is a major contributor to postoperative renal functional damage. The decompression effect of the flexible-tip suction sheath relieves renal parenchymal compression as well as ischemia-hypoxia injury, resulting in milder elevation of renal injury biomarkers. Moreover, improved quality of life is a comprehensive benefit derived from a higher stone-free rate, fewer complications, and better renal protection. Removal of residual stones relieves lumbago, abdominal distension, and hematuria; reduced postoperative discomfort and preserved renal function further optimize patients' long-term life status.

Several limitations of this study should be acknowledged. First, as a single-center retrospective investigation, patients were not randomly allocated but grouped according to the type of ureteral access sheath used in routine clinical practice, which inevitably introduces selection bias, indication bias, and potential confounding factors. Although no significant differences in baseline characteristics were observed between the two groups, the influence of factors including stone hardness, calyceal anatomy, surgeon experience, and disparities in perioperative management on study outcomes cannot be completely ruled out. Second, this study has a relatively limited sample size and short follow-up duration, and long-term outcomes such as stone recurrence, sustained renal function changes, and reintervention rates have not been systematically evaluated.

Therefore, the results of this study should be interpreted as exploratory evidence. Future multicenter, large-sample, prospective randomized controlled trials incorporating propensity score matching or multivariate regression analysis are warranted to further verify the efficacy and safety of this technique.

In conclusion, this retrospective study demonstrates that in patients with 2-4 cm renal calculi, the application of flexible-tip negative-pressure suction sheath-assisted flexible ureteroscopy is associated with a higher stone-free rate, reduced incidences of select postoperative complications, and more favorable short-term recovery outcomes, suggesting the clinical utility of this technique.

Disclosure of conflict of interest

None.

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