Am J Transl Res 2026;18(7):6411-6420
www.ajtr.org /ISSN:1943-8141/AJTR0173559

Original Article

Intelligent pressure-guided flexible ureteroscopic lithotripsy improves stone-free rates and reduces infectious complications in upper urinary tract infectious stones

Jingyu Gao, Zhe Xu, Zijing Luo, Lei Wang

Department of Urology, The First Hospital of Hebei Medical University, Shijiazhuang 050000, Heibei, China

Received April 24, 2026; Accepted June 9, 2026; Epub July 15, 2026; Published July 30, 2026

Abstract: Background: Standard flexible ureteroscopy lithotripsy (FURL) for upper urinary tract infectious stones carries risks of high intrarenal pressure (IPP) and postoperative infection. We evaluated whether an intelligent pressure-guided system improves outcomes. Methods: This retrospective study included 269 patients with upper urinary tract infectious stones that were received by the First Hospital of Hebei Medical University from May 2022 to December 2025. Patients were divided into the Standard Group (n = 142, standard FURL) and the Intelligent Group (n = 127, intelligent pressure-guided FURL). Primary outcomes were stone-free rate (SFR) at postoperative day 1, 1, and 3 months, during key procedural stages, and complications. Secondary outcomes included operative time, hospital stay, renal function, and inflammatory markers. Results: The Intelligent Group achieved significantly higher SFRs at day 1 (87.40% vs. 73.24%, $P = 0.004$) and month 1 (93.70% vs. 81.69%, $P = 0.003$). Operative time (52.62 vs. 66.35 minutes, $P < 0.001$) and hospital stay (3.94 vs. 5.27 days, $P < 0.001$) were shorter. Mean IPP during lithotripsy was lower in the Intelligent Group. Postoperative elevations in renal function and inflammatory markers were attenuated (all $P < 0.05$). Postoperative fever was lower (4.72% vs. 16.90%, $P = 0.002$). Conclusions: Intelligent pressure-guided FURL improves stone clearance, shortens convalescence, and reduces infectious complications compared to standard FURL for upper urinary tract infectious stones.

Keywords: Urolithiasis, ureteroscopy, lithotripsy, laser, intrarenal pressure, postoperative complications

Introduction

Upper urinary tract infectious stones, primarily composed of struvite and carbonate apatite, represent a distinct clinical entity driven by urease-producing bacterial pathogens. These calculi are associated with recurrent urinary tract infections (UTIs), progressive renal functional impairment, and an elevated risk of urosepsis. Definitive management necessitates not only complete stone clearance to eradicate the nidus of infection but also the minimization of iatrogenic renal injury during intervention [1, 2].

In this context, flexible ureteroscopy lithotripsy (FURL) has become a preferred minimally invasive modality for the treatment of upper urinary tract calculi due to its favorable safety profile compared to percutaneous nephrolithotomy. However, the application of standard FURL in the setting of infectious stones introduces unique intraoperative challenges [3]. The continuous irrigation required to maintain endoscopic visualization inevitably elevates intrarenal pelvic pressure (IPP). In the setting of bacterial colonization or pre-existing pyelovenous backflow, elevated IPP facilitates the systemic translocation of bacterial endotoxins and inflammatory mediators, thereby heightening the susceptibility to postoperative systemic inflammatory response syndrome (SIRS) and urosepsis [4-6]. Furthermore, the limited outflow channel inherent to conventional ureteral access sheaths compromises surgical visibility during active bleeding or stone dust accumulation, which may prolong operative duration and compromise the achievement of a definitive stone-free state [7, 8].

https://doi.org/10.62347/KDBD1781

The control of IPP has therefore emerged as a pivotal factor in enhancing the safety profile of FURL for infectious stones. Recognizing the limitations of passive fluid egress, technological advancements have integrated real-time pressure monitoring and active negative-pressure aspiration into the ureteroscopic platform. Intelligent pressure-guided FURL employs a dedicated pressure-measuring ureteral access sheath coupled with an automated irrigation-suction console [9, 10]. This closed-loop system continuously monitors renal pelvic pressure and dynamically adjusts the irrigation inflow and vacuum suction outflow to maintain IPP within a predefined, physiologically safe range. By simultaneously aspirating irrigation fluid and stone fragments, the system is posited to maintain a clearer endoscopic field and mitigate the cyclical pressure spikes typically observed during manual syringe irrigation or holmium laser activation. The potential clinical benefits of this approach-namely, reduced postoperative infectious complications, improved immediate stone-free rates, and preservation of renal function-have garnered increasing interest in the urological community [11, 12].

While the feasibility and general safety of intelligent pressure-guided FURL have been described in previous cohorts with mixed stone compositions, a dedicated comparative analysis focusing specifically on the high-risk subgroup of patients with upper urinary tract infectious stones remains limited. The distinct pathophysiological milieu of infection stones-characterized by fragile, purulent mucosa and a higher bacterial bioburden-demands a more rigorous evaluation of this technology's ability to mitigate pressure-related morbidity and enhance stone evacuation efficiency [13]. This study therefore aimed to retrospectively compare the clinical outcomes of intelligent pressure-guided FURL versus standard FURL in patients with confirmed upper urinary tract infectious stones, with a specific focus on perioperative IPP dynamics, stone clearance efficacy, inflammatory biomarker trajectories, and complication rates.

Materials and methods

Inclusion of patients

A retrospective analysis was conducted on 269 patients with upper urinary tract infectious stones admitted to The First Hospital of Hebei Medical University from May 2022 to December 2025. Inclusion criteria were: (1) age ≥ 18 years; (2) met the diagnostic criteria for upper urinary tract infectious stones [14]; (3) received treatment with FURL; (4) clear consciousness and cognition; (5) complete medical records. Exclusion criteria were: (1) severe uncontrolled systemic infection, defined as meeting any of the following: ① sepsis requiring vasopressor support or septic shock prior to surgery; ② imaging evidence of pyonephrosis necessitating emergency percutaneous nephrostomy; ③ persistent fever (≥ 38.5°C) or unresolved SIRS despite 48 hours of appropriate antibiotic therapy guided by culture and sensitivity results; (2) concurrent active malignancy; (3) major surgery within the last 3 months; (4) coagulation dysfunction or uncontrolled bleeding tendency; (5) concurrent psychiatric episode; (6) pregnant or breastfeeding women; (7) anatomical abnormalities of the upper urinary tract affecting flexible ureteroscopy procedures; (8) severe renal insufficiency.

According to different surgery methods, the 269 patients were defined into the Standard Group (n = 142) and the Intelligent Group (n = 127). Patients in the Standard Group underwent standard FURL, while those in the Intelligent Group received intelligent pressure-guided FURL. This study strictly adhered to the Declaration of Helsinki, and the research protocol was reviewed and approved by the Medical Ethics Committee of the First Hospital of Hebei Medical University.

Surgical method

Standard group: Patients were placed under general anesthesia in the lithotomy position. After routine disinfection and draping, an 8.0/9.8 F rigid ureteroscope (Richard Wolf GmbH, Germany) was inserted through the urethra into the bladder to observe the intravesical conditions and identify the affected ureteral orifice. Under direct vision, a 0.035-inch hydrophilic guidewire was inserted into the affected ureter. Guided by the wire, the rigid ureteroscope was advanced retrogradely to the renal pelvis or stone location to assess the degree of ureteral patency and the condition of the stone. The guidewire was left in place, and the rigid ureteroscope was withdrawn. A 12/14 F ureteral access sheath (Cook Medical, USA) was then inserted along the guidewire and positioned approximately 1-2 cm below the ureteropelvic junction under fluoroscopic or endoscopic guidance. A 7.5 F flexible ureteroscope (URF-V, Olympus, Japan) was introduced through the access sheath, and the renal pelvis and calyces were explored under flexible scope visualization to confirm the stone's location. A 200 μm holmium laser fiber (SRM-H3B, Shanghai Ruike En Medical Technology Co., Ltd., China) was used with a "dusting" lithotripsy strategy, setting the energy at 0.6-1.0 J and frequency at 20-30 Hz to fragment the stones into pieces ≤ 2 mm. After lithotripsy, another ureteroscopy was performed to ensure no significant residual stones remained. A 4.7 F or 6 F double-J stent was placed along the guidewire, and the scope was withdrawn after confirming satisfactory positioning.

Intelligent group: Patients were placed under general anesthesia in the lithotomy position. After routine disinfection and draping, an 8.0/9.8 F rigid ureteroscope was inserted through the urethra into the bladder to locate the affected ureteral orifice. Under direct vision, a hydrophilic guidewire (0.035 inches) was inserted into the affected ureter. Guided by the wire, the rigid ureteroscope was advanced retrogradely to the level of the ureteropelvic junction to assess the condition of the ureter. The guidewire was left in place, and the rigid ureteroscope was withdrawn. A 12/14 F pressure-measuring ureteral access sheath (compatible with the intelligent pressure control system) was then inserted along the guidewire and positioned approximately 1-2 cm below the ureteropelvic junction under fluoroscopic or endoscopic guidance to ensure proper placement. The suction port at the proximal end of the access sheath was connected to the negative pressure suction device of the medical irrigation-suction platform (IVT-IS01-A, Jiangxi Yiweite Technology Co., Ltd., China), and the pressure-measuring port was connected to the pressure monitoring module of the platform. The intelligent pressure control system was activated and set to fully automatic mode. System parameters were set as follows: negative pressure suction range -15 to -5 mmHg (1 mmHg = 0.133 kPa relative to atmospheric pressure); intracavitary pressure warning value 20 mmHg, limit value 30 mmHg; irrigation flow rate 50-150 ml/min (adjusted dynamically based on real-time pressure feedback). After setting the parameters, a 7.5 F flexible ureteroscope was introduced through the access sheath to explore the renal pelvis and calyces and confirm the stone's location. A 200 μm holmium laser fiber was used for lithotripsy, with energy settings of 0.6-1.0 J and frequency of 20-30 Hz. The stones were fragmented and simultaneously suctioned out. After lithotripsy, another ureteroscopy was performed to ensure no significant residual stones remained. A 4.7 F or 6 F double-J stent was placed along the guidewire, and the scope was withdrawn after confirming satisfactory positioning.

Observation indicators

The primary outcome measures were stone-free rate (SFR), IPP, and the incidence of postoperative complications. Secondary outcome measures included operative time, hospital length of stay, renal function parameters, and inflammatory markers.

Stone free rate: Non-contrast computed tomography (NCCT) (Revolution Apex, GE Healthcare, USA) was performed at 1 day, 1 month, and 3 months postoperatively to assess the residual stone status. The SFR was defined as no residual stones or a residual stone with a maximum diameter of ≤ 4 mm [15].

Surgical treatment conditions: Operative time was defined as the interval from the completion of anesthesia induction and initiation of ureteroscopic procedures to the completion of all surgical steps (including stone fragmentation, double-J stent placement, and withdrawal of the flexible ureteroscope from the urethra). Hospital stay was defined as the total number of days from admission to discharge.

Intrarenal pelvic pressure: Mean IPP was measured at each of the following time points: (1) at the time of guidewire insertion; (2) during lithotripsy; (3) during flushing lithotripsy; (4) at the end of the procedure. The Intelligent Group used the intelligent pressure control system's pressure-measuring ureteral access sheath for real-time IPP monitoring. The Standard Group used an F5 ureteral catheter (Cook Medical, USA) connected to a pressure sensor (TruWave, Edwards Lifesciences, USA) for pressure measurement.

Renal function: Serum creatinine (Scr), blood urea nitrogen (BUN), and β2-microglobulin (β2-MG) levels were measured preoperatively and

Table 1. Comparison of demographic characteristics between the two groups

Parameter	Standard group (n = 142)	Intelligent group (n = 127)	t/χ^2	*P*
Age (years)	48.25 ± 12.37	47.89 ± 11.92	0.237	0.813
Gender [n (%)]			0.132	0.716
Male	68 (47.89%)	58 (45.67%)		
Female	74 (52.11%)	69 (54.33%)		
BMI (kg/m^2)	25.31 ± 3.16	25.63 ± 3.44	0.794	0.428
Diabetes mellitus [n (%)]			0.078	0.780
Yes	23 (16.20%)	19 (14.96%)		
No	119 (83.80%)	108 (85.04%)		
Hypertension [n (%)]			0.122	0.727
Yes	35 (24.65%)	29 (22.83%)		
No	107 (75.35%)	98 (77.17%)		
History of recurrent UTI [n (%)]			0.125	0.724
Yes	51 (35.92%)	43 (33.86%)		
No	91 (64.08%)	84 (66.14%)		

BMI, body mass index; UTI, urinary tract infection.

1 day postoperatively using an automated chemiluminescence immunoassay analyzer (AU5800, Beckman Coulter, USA).

Inflammatory factor levels: C-reactive protein (CRP), interleukin-6 (IL-6), and procalcitonin (PCT) levels were measured preoperatively and 1 day postoperatively using enzyme-linked immunosorbent assay kits (ab260058, ab178013, ab221828, Abcam, China).

Complications: Complications occurring during hospitalization were recorded for both groups, including fever (postoperative temperature > 38.0°C on two consecutive measurement days or any postoperative day temperature > 39.0°C [excluding transient post-anesthesia or absorption-induced temperature increases within 24 hours]), sepsis (life-threatening organ dysfunction caused by a dysregulated host response to infection, characterized by an increase in the Sequential Organ Failure Assessment (SOFA) score ≥ 2 points) [16], hematuria (gross hematuria [urine appears red or meat wash-like] requiring clinical intervention [such as increased bladder irrigation, use of hemostatic drugs, or blood transfusion]), and back pain (new or worsening postoperative back pain with a visual analog scale [VAS] score ≥ 4 requiring analgesic treatment).

Statistical analysis

Statistical analysis was performed using R software version 4.3.3 (R Foundation for Statistical Computing, Vienna, Austria). Categorical variables were expressed as frequencies and percentages [n (%)], compared between groups using the chi-square (χ^2) test. Continuous variables were expressed as mean ± standard deviation (M±SD). Comparisons between two groups at a single or two time points were performed using the independent-sample t-test. For the IPP measured at four procedural stages, a two-way mixed repeated measures analysis of variance (ANOVA) was conducted. When a significant group × time interaction was detected, post-hoc pairwise comparisons were performed using Bonferroni-corrected independent t-tests for between-group comparisons at each time point. A *p*-value < 0.05 was considered statistically significant.

Results

Baseline characteristics

The demographic and clinical characteristics of the two cohorts were analyzed to ensure comparability at baseline (**Table 1**). No significant differences were observed between the Standard Group and the Intelligent Group regarding demographic parameters including age (P = 0.813), gender distribution (P = 0.716), body mass index (P = 0.428), or the prevalence of comorbidities such as diabetes mellitus (P = 0.780), hypertension (P = 0.727), and history of recurrent urinary tract infection (P = 0.724).

Table 2. Comparison of clinical characteristics between the two groups

Parameter	Standard group (n = 142)	Intelligent group (n = 127)	t/χ^2	*P*
Largest stone diameter (cm)	2.15 ± 0.58	2.08 ± 0.62	0.946	0.345
Stone location [n (%)]			0.101	0.951
Upper ureter	38 (26.76%)	32 (25.20%)		
Renal pelvis	67 (47.18%)	62 (48.82%)		
Renal calyx	37 (26.06%)	33 (25.98%)		
Stone density (Hu)	632.46 ± 112.39	618.92 ± 108.64	1.002	0.317
Stone composition [n (%)]			0.112	0.946
Struvite	45 (31.69%)	38 (29.92%)		
Calcium carbonate apatite	28 (19.72%)	25 (19.69%)		
Mixed	69 (48.59%)	64 (50.39%)		
Preoperative DJ stent placement [n (%)]			0.057	0.811
Yes	41 (28.87%)	35 (27.56%)		
No	101 (71.13%)	92 (72.44%)		
Preoperative PCN [n (%)]			0.047	0.829
Yes	18 (12.68%)	15 (11.81%)		
No	124 (87.32%)	112 (88.19%)		

DJ, double-J; PCN, percutaneous nephrostomy.

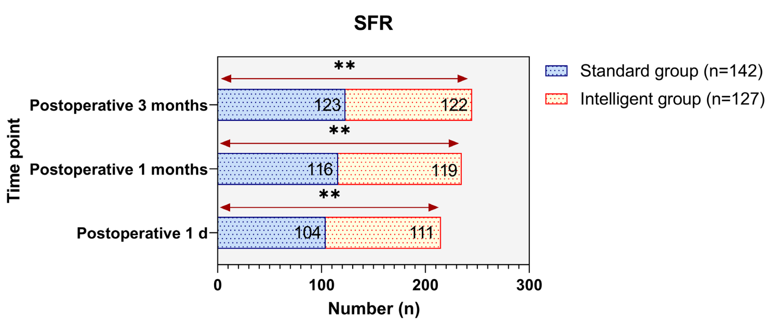

Figure 1. Comparison of SFR between the two groups [n (%)]. SFR, stone free rate; **: P < 0.01, intergroup comparison.

Furthermore, preoperative stone-related characteristics were well-matched (**Table 2**). There were no significant disparities in the largest stone diameter (*P* = 0.345), stone location distribution (*P* = 0.951), stone density as measured in Hounsfield units (*P* = 0.317), or stone composition profiles (*P* = 0.946). The rates of preoperative double-J stent placement (*P* = 0.811) and percutaneous nephrostomy (*P* = 0.829) were also comparable between the two groups.

Stone free rate

The evaluation of SFR at sequential postoperative time points demonstrated consistently superior outcomes for the Intelligent Group (**Figure 1**). The SFR on postoperative day 1 was significantly higher with the use of intelligent pressure-guided technology (χ^2 = 8.380, *P* = 0.004). This advantage in stone clearance was maintained and remained statistically significant at the one-month follow-up (χ^2 = 8.759, *P* = 0.003) and at the three-month follow-up assessment (χ^2 = 7.357, *P* = 0.007).

Surgical treatment conditions

Significant differences in operative efficiency and length of hospitalization were observed favoring the Intelligent Group (**Figure 2**). The mean operative time was substantially shorter when the intelligent pressure control system was utilized (t = 8.146, *P* < 0.001). Additionally, the duration of postoperative hospital stay was significantly reduced in the Intelligent Group compared to the Standard Group (t = 9.127, *P* < 0.001).

Intrarenal pelvic pressure

Monitoring of IPP revealed distinct pressure profiles between the two surgical approaches

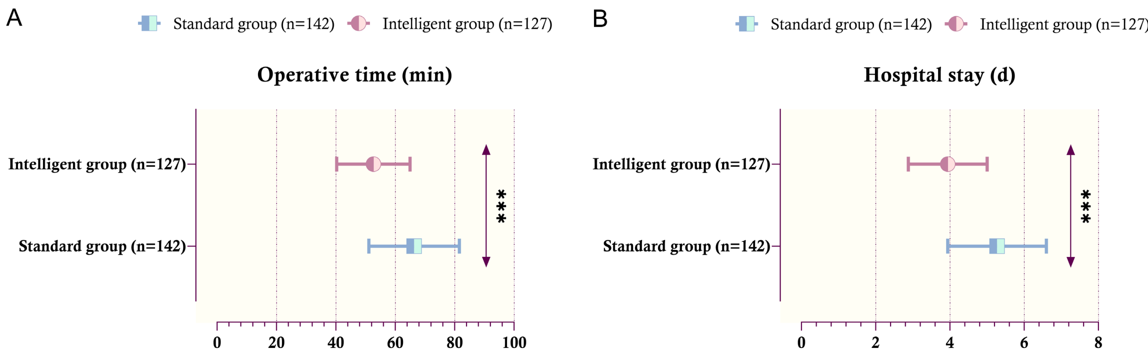

Figure 2. Comparison of surgical treatment conditions between the two groups. A. Operative time (min). B. Hospital stay (d); ***: *P* < 0.001, intergroup comparison.

Table 3. Comparison of IPP between the two groups (mmHg)

Parameter	Standard group (n = 142)	Intelligent group (n = 127)	t	*P*
At the time of guidewire insertion	16.48 ± 5.92	15.82 ± 4.27	1.056	0.292
During lithotripsy	35.46 ± 10.31	16.35 ± 3.88	20.510	< 0.001
During flushing lithotripsy	32.72 ± 9.15	15.49 ± 3.52	20.793	< 0.001
At the end of the procedure	26.13 ± 7.64	14.67 ± 3.21	16.342	< 0.001

IPP, intrarenal pelvic pressure.

Table 4. Comparison of renal function between the two groups

Parameter	Standard group (n = 142)	Intelligent group (n = 127)	t	*P*
Scr (μmol/L)				
Preoperative	87.35 ± 6.18	86.72 ± 5.93	0.844	0.399
Postoperative 1 d	93.28 ± 8.04*	90.84 ± 6.15*	2.811	0.005
BUN (mmol/L)				
Preoperative	5.36 ± 0.42	5.31 ± 0.38	0.914	0.362
Postoperative 1 d	6.02 ± 0.55*	5.84 ± 0.43*	3.138	0.002
β2-MG (mg/L)				
Preoperative	2.48 ± 0.39	2.43 ± 0.36	1.120	0.264
Postoperative 1 d	2.85 ± 0.51*	2.68 ± 0.44*	2.928	0.004

Scr, serum creatinine; BUN, urea nitrogen; β2-MG, β2-microglobulin; *, *P* < 0.05 compared to preoperative value within the same group.

(**Table 3**). At the initial stage of guidewire insertion, no significant difference in IPP was detected between the groups (*P* = 0.292). However, during the active phases of the procedure, the Intelligent Group maintained significantly lower pressures. This was evident during lithotripsy (*P* < 0.001), during flushing lithotripsy maneuvers (*P* < 0.001), and at the conclusion of the endoscopic procedure (*P* < 0.001).

Renal function

Preoperative renal function was comparable between the two groups, with no significant differences observed in Scr, BUN, and β2-MG (*P* = 0.399, *P* = 0.362, and *P* = 0.264, respectively) (**Table 4**). On postoperative day 1, the Intelligent Group demonstrated significantly better preservation of renal function compared to the Standard Group. Specifically, postoperative levels of Scr (t = 2.811, *P* = 0.005), BUN (t = 3.138, *P* = 0.002), and β2-MG (t = 2.928, *P* = 0.004) were all significantly lower in the Intelligent Group than in the Standard Group.

Inflammatory factor levels

Preoperative baseline levels of inflammatory biomarkers, including CRP, IL-6, and PCT, were comparable between the groups (*P* = 0.518, *P* = 0.790, and *P* = 0.269, respectively) (**Table 5**). On the first postoperative day, a systemic inflammatory response was observed in both cohorts; nonetheless, the magnitude of this response was significantly attenuated in the Intelligent Group. Postoperative levels of CRP (t = 5.753, *P* < 0.001), IL-6 (t = 9.446, *P* < 0.001), and PCT (t = 2.989, *P* = 0.003) were all mark-

Table 5. Comparison of inflammatory factor levels between the two groups

Parameter	Standard group (n = 142)	Intelligent group (n = 127)	T	*P*
CRP (mg/L)				
Preoperative	10.58 ± 3.42	10.87 ± 3.96	0.648	0.518
Postoperative 1 d	16.42 ± 5.13*	13.25 ± 3.88*	5.753	< 0.001
IL-6 (pg/mL)				
Preoperative	8.24 ± 1.85	8.18 ± 1.73	0.267	0.790
Postoperative 1 d	12.38 ± 2.24*	9.89 ± 2.05*	9.446	< 0.001
PCT (ng/mL)				
Preoperative	0.54 ± 0.16	0.52 ± 0.13	1.107	0.269
Postoperative 1 d	0.75 ± 0.27*	0.67 ± 0.14*	2.989	0.003

CRP, C-reactive protein; IL-6, interleukin 6; PCT, procalcitonin; *, $P < 0.05$ compared to preoperative value within the same group.

Table 6. Comparison of complications between the two groups [n (%)]

Parameter	Standard group (n = 142)	Intelligent group (n = 127)	χ^2	*P*
Fever	24 (16.90%)	6 (4.72%)	10.032	0.002
Sepsis	6 (4.23%)	1 (0.79%)	1.917	0.166
Hematuria	8 (5.63%)	4 (3.15%)	0.971	0.324
Back pain	5 (3.52%)	2 (1.57%)	0.381	0.537

edly lower in the group treated with intelligent pressure-guided ureteroscopy.

Complications

Compared to the Standard Group, the incidence of postoperative fever was significantly lower in the Intelligent Group (χ^2 = 10.032, P = 0.002) (**Table 6**). While the rate of sepsis trended lower in the Intelligent Group, this difference did not reach statistical significance (P = 0.166). Similarly, the occurrence of postoperative hematuria (P = 0.324) and back pain requiring intervention (P = 0.537) did not differ significantly between the two surgical modalities.

Discussion

This retrospective analysis compared clinical outcomes between intelligent pressure-guided FURL and standard FURL in patients with upper urinary tract infectious stones. The findings indicate that integrating real-time IPP monitoring with active negative-pressure aspiration confers measurable advantages across several domains, including stone clearance efficiency, operative efficiency, inflammatory response attenuation, and complication reduction.

Baseline characteristics of the two groups were well matched, supporting the validity of the observed differences. The management of infectious stones presents unique challenges owing to bacterial colonization within the stone matrix and the friable nature of the surrounding urothelium. These factors increase susceptibility to postoperative infectious complications when IPP becomes elevated during standard ureteroscopic procedures [3, 17].

The higher SFR achieved with the intelligent pressure-guided system at all postoperative time points can be attributed to the synergistic effect of continuous suction and optimized irrigation. During standard FURL, stone dust and small fragments remain suspended in the collecting system, obscuring visualization and necessitating repeated manual flushing. These pauses prolong operative time and allow fragments to migrate into dependent calyces [18, 19]. The intelligent system simultaneously aspirates the dust cloud and evacuates fragmented debris through the specialized access sheath. This maintains a clear endoscopic field, enabling more precise and uninterrupted lithotripsy. For infection stones, residual fragments can serve as a nidus for bacterial recolonization and recurrent stone formation. Superior early clearance may therefore translate into reduced future infectious episodes, although longer-term surveillance would be required to confirm this benefit [20, 21].

The reductions in operative time and hospital stay observed in the intelligent group reflect improved procedural workflow and perioperative recovery. Shorter operative duration results from elimination of manual irrigation cycles and from reduced time spent retrieving migrated fragments. Integration of suction converts the access sheath into a conduit for simultaneous visualization and evacuation. The corresponding decrease in hospitalization length aligns with the attenuation of postoperative inflammatory response and the lower incidence of febrile morbidity. Patients experiencing fewer complications are eligible for earlier discharge, which may reduce nosocomial infection risk and healthcare resource utilization [22].

IPP dynamics are central to the safety of ureteroscopy for infectious stones. Standard FURL, even with a conventional ureteral access sheath, permits intermittent pressure elevations exceeding the physiological threshold for pyelovenous and pyelolymphatic backflow. The data indicate that standard procedures are associated with sustained pressure surges during lithotripsy and irrigation. Such elevations facilitate translocation of bacterial endotoxins and pro-inflammatory cytokines into the systemic circulation. The intelligent pressure control system maintained IPP at a substantially lower plateau throughout active procedural phases. This was achieved through automated balancing of irrigation inflow and suction outflow [23, 24]. By preventing harmful pressure spikes, the intelligent system appears to limit systemic absorption of infectious material and reduce renal barotrauma. This finding aligns with prior clinical and experimental work demonstrating a correlation between mean IPP during ureteroscopy and the risk of SIRS [25, 26].

The differential impact on renal function markers on the first postoperative day provides further evidence of the renal protective effect conferred by the intelligent pressure-guided approach. While the changes in Scr, BUN, and β2-MG were modest in both groups, the magnitude of postoperative elevation was clearly greater following standard ureteroscopy. In the context of infection stones, the renal parenchyma is often already compromised by chronic inflammation and edema. The addition of sustained high-pressure irrigation can induce transient renal tubular dysfunction or interstitial edema, which manifests as a slight reduction in glomerular filtration rate and impaired tubular reabsorption. The pressure-controlled environment created by the intelligent system likely minimizes this hydrostatic insult to the nephrons, resulting in better preservation of renal functional reserve in the immediate postoperative period. This advantage is particularly relevant for patients with pre-existing renal insufficiency or those with a solitary functioning kidney [27, 28].

The evaluation of inflammatory cytokines provided a biochemical correlate to the clinical observation of reduced febrile morbidity. CRP and IL-6 are sensitive markers of the acute-phase response to surgical trauma and infection. PCT serves as a more specific indicator of bacterial infection burden. The blunted postoperative rise in these markers within the intelligent group substantiates the hypothesis that controlling IPP reduces the microbial and endotoxic load delivered to the systemic circulation [29]. Although the incidence of overt sepsis was too low in this cohort to draw definitive statistical conclusions, the trend toward fewer severe infectious events in the intelligent group is clinically noteworthy. The significant reduction in postoperative fever, a common and costly complication following the manipulation of infectious stones, underscores the practical value of this technology in improving patient comfort and reducing the need for escalation of antibiotic therapy [30, 31].

This study has several limitations. Its retrospective, single-center design introduces potential selection bias, and allocation to surgical modality was not randomized. Although baseline characteristics were comparable, unmeasured confounders related to surgeon preference or subtle variations in stone complexity could influence outcomes. The follow-up period of three months precludes assessment of long-term stone recurrence rates or durability of renal functional preservation. Future research should focus on prospective randomized trials to validate these findings. Cost-effectiveness analyses comparing capital investment in the intelligent pressure platform against savings from reduced hospital stays and fewer readmissions would be valuable. Investigations in patients with larger stone burdens or more severe baseline renal impairment are also warranted to define populations most likely to derive maximum benefit.

Conclusion

Intelligent pressure-guided FURL offers superior intraoperative pressure regulation, enhanced immediate stone clearance, and a reduction in postoperative inflammatory response compared to standard techniques in the management of upper urinary tract infectious stones. This approach represents a clinically valuable advancement for mitigating infection-related morbidity in this high-risk patient population.

Acknowledgements

This study was supported by the Central Government-guided Local Science and Technology Development Fund (Regional Science and Technology Innovation System Project), Grant No. 254Z7703G.

Disclosure of conflict of interest

None.

Address correspondence to: Lei Wang, Department of Urology, The First Hospital of Hebei Medical University, No. 89 Donggang Road, Yuhua District, Shijiazhuang 050000, Heibei, China. E-mail: Wlei99@163.com

References

[1] Pattou M, Yonneau L, de Gouvello A, Almeras C, Saussine C, Hoznek A, Denis E, Chabannes E, Lechevallier E, Abid N, Hubert J, Estrade V and Meria P. Urosepsis after ureterorenoscopy, intraoperative recognition of type-IV stones could change clinical practice. World J Urol 2024; 42: 534.

[2] Prywer J and Olszynski M. Bacterially induced formation of infectious urinary stones: recent developments and future challenges. Curr Med Chem 2017; 24: 292-311.

[3] Cui D, Ma Q, Wang G, Luo J and Chen G. Safety and efficacy of flexible and navigable suction combined with retrograde flexible ureteroscopy in the management of infectious stones. BMC Infect Dis 2025; 25: 1079.

[4] Dassanayake SN, Harrison NL, Traxer O, Gauhar V, Yuen SKK and Somani BK. Mortality from ureteroscopy for kidney stone disease: systematic review of literature from the section of EAU endourology. World J Urol 2025; 43: 432.

[5] Pischetola A, Hughes T, Geraghty R, Boulmani M and Somani BK. Incidence of urinary infections and urosepsis after ureteroscopy for stone disease: a systematic review of literature. Ther Adv Urol 2026; 18: 17562872251412050.

[6] Zhu P, Hua X, Teng X and Wang R. Beyond the sheath: unmasking true predictors of PostfURS fever through propensitymatched precision. World J Urol 2025; 43: 595.

[7] Crisafi D, Santucci J, Hong A, Sii S, Bolton D and Jack G. Complication rates and outcomes of suction devices in ureteroscopy and retrograde intrarenal surgery: a systematic review. BJU Int 2026; 137 Suppl 3: S6-18.

[8] Gauhar V, Castellani D, Tsaturyan A, Taguchi K, Herrmann T, Somani B and Yuen SKK. Does the existing evidence on flexible and navigable suction ureteral access sheath indicate a potential paradigm shift in the management of kidney and ureteral stones with flexible ureteroscopy? An overview from EAU endourology. Curr Opin Urol 2026; 36: 35-41.

[9] Ding T, Xu Z, Huang Z, Hu W, Xiao B and Li J. Optimizing aspiration efficiency in RIRS: the impact of ratio of endoscope-sheath diameter, irrigation flow, and negative pressure in an vitro study. Urolithiasis 2025; 53: 102.

[10] Uy M, Moryousef J, Wang L, Guo Y, Matsumoto ED, Daignault-Newton S, Sui W, Roberts WW, Dauw CA and Ghani KR. Flexible and navigable suction ureteral access sheaths for the treatment of urolithiasis: systematic review and meta-analysis. Eur Urol Focus 2025; [Epub ahead of print].

[11] Cormio A, Castellani D, Yuen SKK, Fong KY, Ragoori D, Dragos L, Omar M, Cormio L, Zeng G, Zhu W, Liu S, Herrmann TRW, Somani BK, Ng CF, Elshazly M and Gauhar V. Elective flexible ureteroscopy with suction sheaths for infectious stones in prior UTI patients. BJUI Compass 2026; 7: e70151.

[12] Huang Q, Ding M, Lian X, Huang Y, Wang T, Chen B and Chen Y. Efficacy and safety of flexible and navigable suction ureteral access sheath combined with flexible ureteroscopic lithotripsy versus flexible ureteroscopic lithotripsy alone for infected upper urinary tract stones: a retrospective cohort study. World J Urol 2026; 44: 167.

[13] Yuen SKK, Zhong W, Chan YS, Castellani D, Bhojani N, Agarwal MS, Tokas T, Croghan S, Jung H, Herrmann T, Somani B and Gauhar V; Global Research on Intra-renal Pressure Collaborative Group. Current utility, instruments, and future directions for intra-renal pressure management during ureteroscopy: scoping review by global research in intra-renal pressure collaborative group initiative. Ther Adv Urol 2025; 17: 17562872251314809.

[14] Skolarikos A, Geraghty R, Somani B, Tailly T, Jung H, Neisius A, Petřík A, Kamphuis GM, Davis N, Bezuidenhout C, Lardas M, Gambaro G, Sayer JA, Lombardo R and Tzelves L. European association of urology guidelines on the diagnosis and treatment of urolithiasis. Eur Urol 2025; 88: 64-75.

[15] Panthier F, Gauhar V, Ventimiglia E, Kwok JL, Keller EX and Traxer O. Rethinking stone-free

rates and surgical outcomes in endourology: a point of view from pearls members. Eur Urol 2024; 86: 198-199.
[16] Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, Bellomo R, Bernard GR, Chiche JD, Coopersmith CM, Hotchkiss RS, Levy MM, Marshall JC, Martin GS, Opal SM, Rubenfeld GD, van der Poll T, Vincent JL and Angus DC. The third international consensus definitions for sepsis and septic shock (sepsis-3). JAMA 2016; 315: 801-810.
[17] Dai L, Xiang J, Liu X, Wen X, Tan L and Zhang J. Risk factors for urosepsis following ureteroscopic lithotripsy: a systematic review and meta-analysis. Front Surg 2025; 12: 1603311.
[18] Cui D, Ma Q, Xie S, Wang G, Li G and Chen G. Comparison of the effectiveness of two adjustable negative pressure ureteral access sheaths combined with flex ureteroscopy for ≤ 2 cm renal stones. Sci Rep 2024; 14: 4745.
[19] Zhao J, Wang J, Yang S, Liu J, Xia J, Gu X and Long J. A novel bendable suction sheath in flexible ureteroscopy for renal calculi. J Int Med Res 2025; 53: 3000605251386570.
[20] Wang L, Luo Z, Huang W and Jia Q. Efficacy and safety of the flexible negative-pressure ureteral sheath in retrograde intrarenal surgery: a systematic review and meta-analysis. Front Surg 2025; 12: 1649574.
[21] Duan H, Xu B and Xie T. Flexible negative pressure suction ureteral access sheath combined with ureteroscopy in the treatment of upper urinary tract calculi: a meta-analysis. Medicine (Baltimore) 2025; 104: e45933.
[22] Wu C, Yin C, Chen J, Mei Q, Sun Y, Mei H and Liao X. Retrospective analysis of flexible ureteroscopic lithotripsy using end-fire, flexible negative-pressure ureteral access sheath for the management of 2-3-cm kidney stones. J Int Med Res 2025; 53: 3000605251381472.
[23] Lykkegaard EG and Jung H. Intrarenal pressure during ureteroscopy. Eur Urol Focus 2025; 11: 709-711.
[24] Hong A, Browne C, Jack G and Bolton D. Intrarenal pressures during flexible ureteroscopy: an insight into safer endourology. BJU Int 2024; 133 Suppl 3: 18-24.
[25] Hong A, Leroi M, Alberto M, Bolton D and Jack G. The exponential relationship between raised intrarenal pressure and bacteraemia. BJU Int 2026; 137 Suppl 3: S78-S85.
[26] Hong A, du Plessis J, Browne C, Jack G and Bolton D. Mechanism of urosepsis: relationship between intrarenal pressures and pyelovenous backflow. BJU Int 2023; 132: 512-519.
[27] Fulla J, Larenas F, Saldivia D, Ibañez H, Elorrieta V, Sanchez C and Salvadó JA. Automated intrarenal pressure control in flexible ureteroscopy using an integrated ureteroscope pressure measurement and fluid management system: first-in-human use. World J Urol 2025; 44: 45.
[28] Lei Y, Xin H, Jin K, Leming S and Xiaolin D. Effects of flow rate on pressure and nephrons during flexible ureteroscopy with intelligent control of renal pelvic pressure: an in-vivo pig model. BMC Urol 2025; 25: 175.
[29] Ahmed R, Hamdy O, Alatawi A, Alhowidi A, Al-Dahshan N, Alkadah AN, Adnan S, Alali AM, Alwabisi YHO, Alruwaili S, Binmohaiya MB, Soliman AA and Elbakary M. The role of inflammatory biomarkers in predicting postoperative fever following flexible ureteroscopy. Medicina (Kaunas) 2025; 61: 1366.
[30] Bhojani N, Miller LE, Bhattacharyya SK, Chua WJ, Tailly T, Eisner B and Chew BH. Continuous intrarenal pressure monitoring during endourological procedures for stone disease: a canary in the coalmine for optimizing patient safety. Urol Int 2025; 109: 641-647.
[31] Bhojani N, Morris K, White J, Rojanasarot S, Tran ED and Monga M. Post-operative infection with a single-use ureteroscope with real-time intrarenal pressure monitoring vs. all other single-use ureteroscopes. Expert Rev Med Devices 2025; 22: 1135-1143.