BMC Urology

RESEARCH

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The application of new type ureteroscope and traditional linear ureteroscope in ureteric stone patients

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Abstract

Objective A ureteric stone is a type of urinary tract stone that is found within the ureter. While most cases can be managed with conservative treatment or minimally invasive surgery, these methods often cause significant pain for the patient. Interestingly, a new type of ureteroscope has shown considerable promise in treating patients with ureteric stones, and this study aims to explore its clinical application.

Methods A total of 120 patients with ureteric stones were recruited from our hospitals between January 1, 2023, and December 31, 2023. These patients were randomly assigned to either the control group, which received the traditional straight ureteroscope, or the experimental group, which was treated with the new type of ureteroscope. Both groups provided general data and blood samples for further analysis. A logistic regression analysis was conducted to examine the factors influencing infection following surgery in patients with ureteric stones, including preoperative CRP greater than 8 mg/L, postoperative CRP greater than 8 mg/L, preoperative white blood cell count (> 10^9/L), postoperative white blood cell count (> 10^9/L), preoperative urinalysis count greater than 28 (/ul), postoperative urinalysis count greater than 28 (/ul), and urine routine leukocyte count.

Results The findings indicated no significant differences between the observation group and the control group regarding preoperative demographic, participants general data ($P > 0.05$). Postoperative CRP > 8 mg/L, white blood cell count > 10×10^9/L, urinalysis count > 28/μL, and urine leukocyte count significantly decreased in the experimental group compared to the control group ($P < 0.05$). Binary logistic regression showed that postoperative CRP > 8 mg/L (OR = 7.03), white blood cell count > 109/L (OR = 3.86), urinalysis count > 28/μL (OR = 2.83), and urine leukocyte count (OR = 1.004) were predictive factors for ureteric stones. Preoperative values showed no significant difference ($P > 0.05$).

Conclusions The binary logistic regression analysis identified Postoperative CRP > 8 mg/L, white blood cell count > 10×10^9/L, urinalysis count > 28/μL, and urine leukocyte count as significant predictors of postoperative infections. Our research findings indicate that the new ureteroscope has significant advantages over traditional ureteroscopes in terms of ease of entry into the ureteral lumen, stone fragmentation angle during surgery, surgical field of view, surgical operability, and reducing the risk of postoperative potential infections. These characteristics

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demonstrate that the new ureteroscope has significant potential in clinical applications, warranting further promotion and use.

Keywords Ureteric stone, New type ureteroscope, The traditional straight ureteroscope, CRP elevated greater than 8, Urine leukocyte counts

Introduction

Ureteral stones, also known as ureterolithiasis, are calculi that are formed in the kidneys and become lodged in the ureters [1]. These stones can vary in size and composition, typically consisting of calcium oxalate, uric acid, struvite, or cystine [2]. The global incidence of ureteral stones has been increasing, with current estimates suggesting that up to 12% of the population will experience kidney or ureteral stones at some point in their lifetime [3, 4]. This prevalence varies based on geographical region, diet, and genetic predisposition. Ureteral stones can cause significant morbidity, including severe pain, hematuria, infection, and impaired renal function. If left untreated, they can lead to serious complications such as hydronephrosis and permanent kidney damage [5, 6]. The onset of ureteral stones is often acute, marked by sudden and severe pain in the flank or lower abdomen, radiating to the groin. Other symptoms may include nausea, vomiting, and difficulty urinating [7]. The pain is typically episodic, corresponding to the movement of the stone through the ureter. The formation of ureteral stones involves several factors, including supersaturation of urine with stone-forming constituents, reduced urine volume, and changes in urinary pH. Crystal nucleation, growth, aggregation, and retention within the renal collecting system are key processes in stone development. Numerous therapeutic methods such as medical management, extracorporeal shock wave lithotripsy, ureteroscopy, and percutaneous nephrolithotomy have been used to treat the patients with ureteral stones [8, 9]. However, these do not address larger stones or those causing significant obstruction. Emerging as a promising approach for managing Ureteral stones is a new type ureteroscope. the new ureteroscope offers significant advantages over traditional linear ureteroscopes, particularly in terms of maneuverability, reduced mucosal damage, and adaptability to anatomical variations.

Traditional linear ureteroscopes for treating ureteral stones have several shortcomings. Their rigid and straight design poses challenges for operators navigating through the ureteral membrane and the prostatic part of the urethra, leading to increased damage to the urethral mucosa and lower success rates in stone removal procedures [10, 11]. Conversely, the new type of ureteroscope demonstrates significant improvements and potential in treating ureteral stones, as depicted in Fig. 1A-C. Its design facilitates easier manipulation through the ureteral membrane and prostatic part, reducing the risk of urethral mucosa damage and contributing to a safer and more effective procedure [12]. The innovative curved design of the new ureteroscope allows for more flexible angle adjustments, enabling easier entry into the ureteral cavity and increasing the likelihood of completing surgery in one stage [13]. Unlike traditional linear ureteroscopes, which cannot accommodate the natural physiological curves of the left and right ureters, the new ureteroscope features distinct left and right curved designs, as shown in Fig. 2. These tailored designs enable more precise navigation and treatment of stones in both ureters, improving overall surgical outcomes [14]. The enhanced ability to navigate the ureteral anatomy with the new ureteroscope increases the success rate of one-stage surgeries, reducing the need for multiple procedures and thereby minimizing patient discomfort and healthcare costs. In summary, the new ureteroscope offers significant advantages over traditional linear ureteroscopes, particularly in terms of maneuverability, reduced mucosal damage, and adaptability to anatomical variations. These improvements highlight the potential of the new ureteroscope to enhance the efficacy of ureteral stone treatment and improve patient outcomes.

This clinical study aims to select patients with ureteral stones, the most common condition in the Department of Urology and frequently treated with ureteroscopy, to conduct a prospective clinical trial. The objective is to compare the efficacy and safety of a novel ureteroscope with the traditional linear ureteroscope in treating ureteral stones. Through the evaluation of this project, we aim to provide preliminary research findings and support for the clinical application of this independently innovative domestic ureteroscope designed by the project team. This will serve as a foundation for future mass production and widespread use of this device in urological surgeries. By improving the success rate of ureteroscopic procedures and reducing surgical risks and complications, we aim to minimize medical resource wastage and enhance the team's capabilities in the urological healthcare sector.

Materials and methods

Patients

From January 1, 2023 to June 31, 2024, we conducted a trial involving 120 patients from our hospitals who had ureteric stone. According to the different use of surgical instruments, the patients were divided into the traditional straight ureteroscope group (control group, $N=60$) and the new ureteroscope group (experimental group,

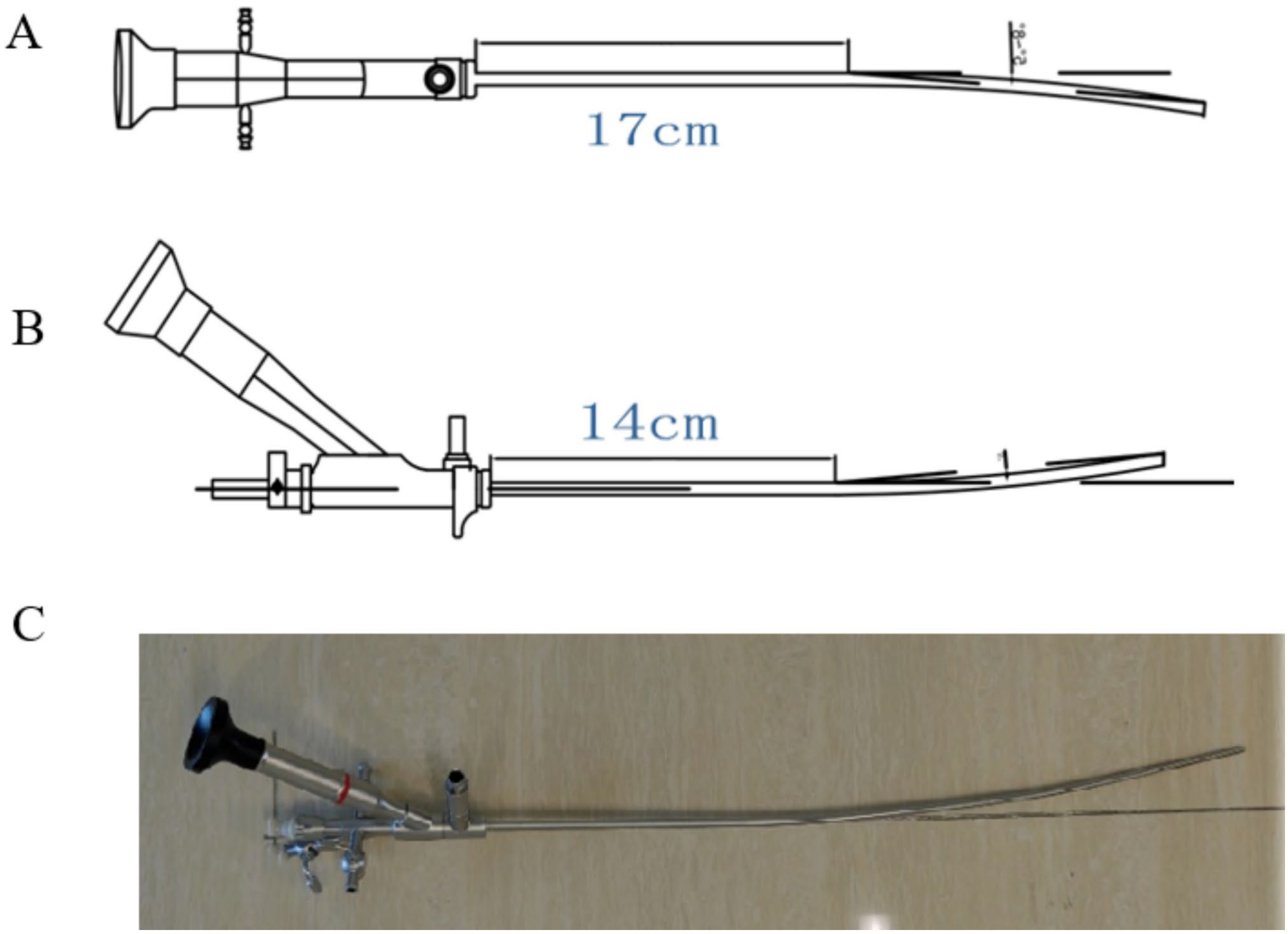

Fig. 1 **A**-**C**. The new ureteroscope: **A** shows the bend design of the new hard ureteroscope from a top view of the right ureteroscope, with the left ureteroscope having a symmetrical mirror structure. **B** shows the upper bending design of the new hard ureteroscope from a side view. **C** shows the left ureteroscope in reality, with the right ureteroscope having the opposite configuration

$N=60$). All study participants were informed about the experiment and provided written consent, as approved by the Ethics Committee of our hospital. In the control group, patients were placed in the lithotomy position with Trendelenburg and lateral tilt (20°-30°) under either epidural or general anesthesia. Routine disinfection and draping were performed. A traditional straight ureteroscope (F8/9.8) was inserted into the affected ureter through the urethra under the guidance of a zebra guidewire, reaching the stone site for holmium laser lithotripsy (using a uniform fiber diameter of 360 μm, with lithotripsy energy set to 0.8–2 J and frequency set to 20–30 Hz). Postoperatively, a standard F5 double J stent and an F16 double-lumen balloon catheter were placed. All surgeries were performed by experienced physicians. In the experimental group, patients were inserted with different new types of ureteroscopes on either the left or right side, depending on the location of the stones in the corresponding ureter. Other surgical procedures were performed identically to those in the control group. Postoperative treatments included ECG monitoring, oxygen therapy, anti-infection measures, hemostasis, gastric protection, and re-examination of routine blood tests, blood biochemical electrolytes, and stone component analysis of stone samples. The urinary catheter was removed 1–2 days after surgery, depending on the recovery status. KUB and CT scans were re-examined on the first postoperative day. If no significant stone residue was detected, patients were asked to return to the hospital for a CT re-examination 2–4 weeks after surgery to evaluate the Stone Free Rate (SFR). If no residual stones or abnormalities were found, the double J stent was removed under cystoscopy. After the double J stent removal, patients were advised to drink plenty of water and take antibiotics for 1–2 days to prevent infection.

Inclusion criteria: Patients must provide written informed consent to participate in the study. Eligible participants should be between 18 and 70 years of age. Preoperative imaging studies, including intravenous pyelography (IVP), urinary ultrasound, urinary CT, and kidney, ureter, and bladder (KUB) X-ray, must confirm the presence of a ureteral stone with a diameter of ≤3 cm

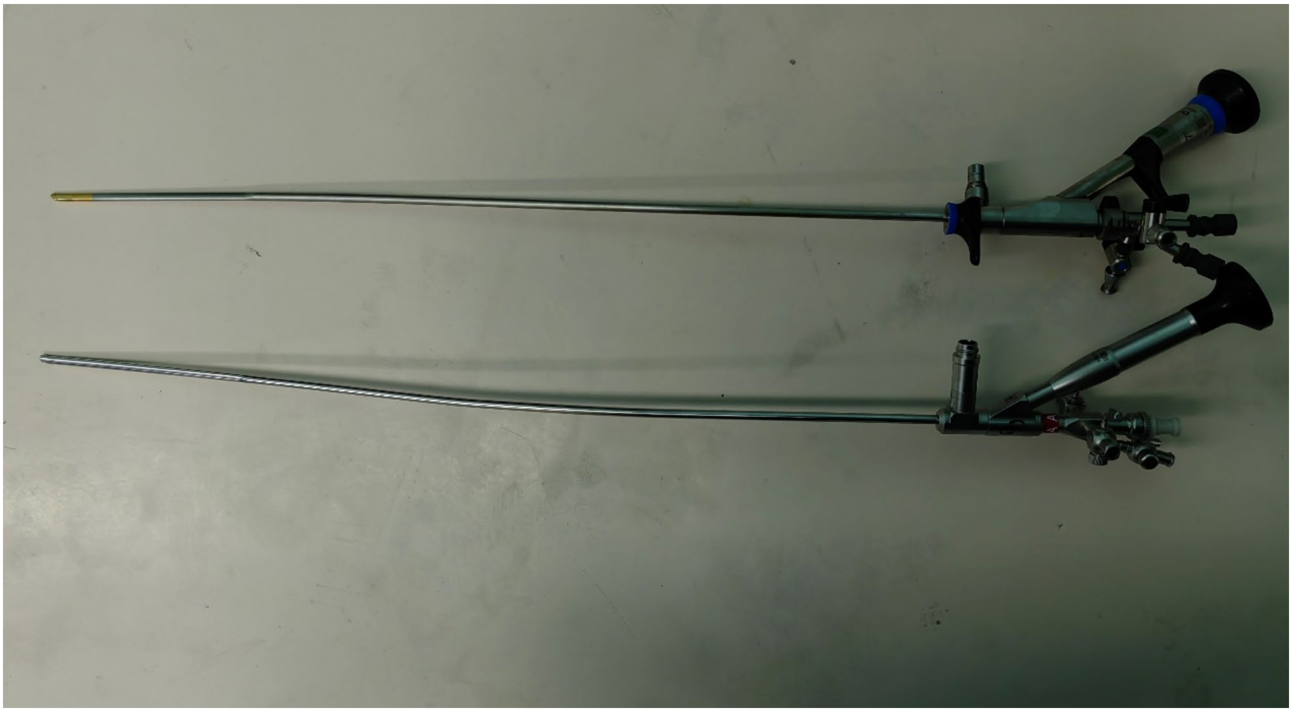

Fig. 2 Comparison between the new ureteroscope and the traditional linear ureteroscope

for unilateral cases. The stone must be specifically located within the ureter, not in the kidney. Patients should have no previous history of urinary stone surgery and demonstrate normal kidney function. An American Society of Anesthesiologists (ASA) score of 1–2 is required, and patients must be physically capable of tolerating the surgical procedure. Those with kidney stones or stones in other parts of the urinary system will be excluded from the study.

Exclusion criteria: Patients with bilateral ureteral stones, kidney stones, or bladder stones; patients with a solitary kidney, urinary anatomical abnormalities, or congenital malformations; pregnant patients; patients with uncorrected bleeding or coagulation disorders; those with a history of kidney transplantation or urinary diversion surgery; patients with severe urinary tract infections that have not been corrected; and patients with severe heart, respiratory, or other diseases and vital organ failure that cannot tolerate anesthesia and surgery are excluded.

In this study, we utilized a new type of ureteroscope that demonstrates significant improvements in the treatment of ureteral stones. The innovative design of the ureteroscope, as shown in Fig. 1A-C, includes a flexible curved shape that allows for easier manipulation through the ureteral membrane and prostatic part, reducing the risk of urethral mucosa damage and contributing to a safer and more effective procedure. The curved design enables more flexible angle adjustments, facilitating easier entry into the ureteral cavity and improving the likelihood of completing the surgery in a single stage. Unlike traditional linear ureteroscopes, which cannot accommodate the natural curves of the left and right ureters, the new ureteroscope features distinct left and right curves, as depicted in Fig. 2. The new ureteroscope was specifically designed to improve maneuverability and reduce the risk of mucosal and urethral damage during ureteral stone management procedures. It has an overall length of 50–60 cm, which is typical for ureteroscopes, providing optimal access to the renal pelvis and lower urinary tract. The outer diameter is 8.5–10 Fr, balancing flexibility and strength. The ureteroscope features distinct curvatures: a 45° left curvature to match the natural bend of the left ureter and a 35° right curvature for the right ureter's anatomy. These curved designs reduce friction and minimize the force required for insertion, decreasing the risk of mucosal injury. The scope is made from biocompatible materials, with a soft silicone distal tip for better tissue compliance. In terms of materials and construction, the outer shell of the ureteroscope is made from a flexible, durable polymer, resistant to deformation and breakage. The distal tip, composed of soft silicone, conforms to the ureteral wall, which prevents trauma during insertion. Internal fiber-optic cables provide high-resolution visualization, ensuring clear views with minimal size increase. The ureteroscope also features a flexible, motorized angulation mechanism that allows for up to 180° deflection at the tip. This flexibility enhances maneuverability, especially in complex anatomical regions like the prostatic urethra and renal pelvis. Additionally, the ureteroscope's working channel, with a 2.2 mm diameter, accommodates standard tools like baskets or laser fibers for effective stone retrieval. Mechanical studies were conducted to assess the advantages of the new ureteroscope's design. Friction and force reduction tests revealed that the flexible curved tip of the new scope required 25% less force during insertion compared to traditional linear ureteroscopes. This reduction in force decreases the risk of mucosal damage and subsequent infections. Stability and navigation tests demonstrated that the ureteroscope's curvature enabled it to navigate challenging ureteral pathways with minimal deflection, ensuring precise stone manipulation and reducing the need for multiple insertions. Wear and tear testing indicated that the materials used are more resistant to damage, improving the scope's longevity. Additionally, studies on infection control showed that the smooth, biocompatible surface reduced bacterial colonization by approximately 30%, minimizing the risk of post-surgical infections. These tailored curves enhance navigation and enable more precise treatment of stones in both ureters, leading to improved surgical outcomes. while the new ureteroscope may come with a higher initial purchase price, its cost-effectiveness is supported by its ability to reduce procedure times, reoperation rates, post-surgical complications, and the need for additional treatments. These long-term savings should offset the initial investment, making the new ureteroscope a potentially cost-effective option for hospitals and healthcare providers. Future studies that explicitly assess the economic impact of this device through detailed cost-benefit analyses would provide a more comprehensive understanding of its value proposition.

Collection for clinical material from patients

Upon being admitted to the hospital, patients in both the experimental and control groups were evaluated for parameters such as gender, age, stone size, operation time, postoperative hospitalization time, postoperative fever, stone retrieval, stone retrieval rate, no residual stones, and SFR. Routine blood tests were performed on both groups. Subsequently, blood samples were drawn from both groups for additional experimental analysis.

Logistic regression analysis

To determine the factors of infection after ureteric stone patient surgery, preoperative CRP greater than 8 mg/L, postoperative CRP greater than 8 mg/L, preoperative white blood cell count ($>10^9$/L), postoperative white blood cell count ($>10^9$/L), preoperative urinalysis count greater than 28 (/ul), postoperative urinalysis count greater than 28 (/ul), and urine routine leukocyte count in individuals with ureteric stone were included, a binary logistic regression analysis was performed.

Statistical analysis

Statistical analyses were performed using Prism 8 software. Measurement data were presented as the mean ± standard deviation and consistently replicated at least three times. To identify differences between pairs of groups, the t-test was employed. Count data is represented by percentages (%) of cases and compared using chi-square test. Logistic regression analysis was conducted to investigate the factors of infection after ureteric stone patient surgery.

Calculation Formula: The sample size for each group can be calculated using the formula for a superiority trial:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2 \left[p_1(1-p_1) + p_2(1-p_2)\right]}{(\varepsilon - \delta)^2}$$

Where: $Z_{1-\alpha/2}$ and $Z_{1-\beta/2}$ are the critical values from the standard normal distribution corresponding to the chosen significance level (α) and power (1-β), respectively. p_1 is the expected success rate (SFR) in the experimental group. P_2 is the expected SFR in the control group.

Results

Participants general data

Baseline characteristics of the two patient groups are shown in Table 1. The results indicate that there are no significant differences between the observation group and the control group in terms of the Age (years), gender, stone size (cm), postoperative hospitalization time (d), postoperative fever (%), stone retrieval (%), no residual stones (%), location of the stone, preoperative urine routine leukocyte count (/HP), CT (HU), preoperative white blood cell count greater than (10×109/L), preoperative CRP greater than 8 (mg/L), preoperative urinalysis count greater than 28 (/ul), preoperative serum creatinine (umol/L), hypertension, diabetes, hemoglobin decrease value before and after surgery (g/L), postoperative serum creatinine (μmol/L), and average length of stay ($P>0.05$). There were significant differences in operation time (minutes), postoperative urine routine leukocyte count (per high power field), postoperative white blood cell count (>10×109/L), postoperative CRP (>8 mg/L), and postoperative urinalysis count (>28/μL) between the observation group and the control group ($P<0.05$). The lack of statistically significant differences in these variables suggests that the new type ureteroscope is comparable to the current standard in terms of efficacy and safety. Clinically, this implies that the new type ureteroscope can be considered a viable alternative to the existing treatment, offering similar outcomes without introducing additional risks or complications.

Table 1 Demographic, participants general data

Variable	experimental group ($N=60$)	control group ($N=60$)	t/χ2	P
Age (years)	53.17 ± 14.01	52.02 ± 15.08	0.39	> 0.05
gender	Female, 22/60	Female, 16/60	1.63	> 0.05
stone size (cm)	0.69 ± 0.21	0.68 ± 0.22	0.23	> 0.05
operation time (min)	39.1 ± 6.2	47.2 ± 5.9	7.33	< 0.05
postoperative hospitalization time (d)	2.51 ± 0.88	2.73 ± 0.91	-1.32	> 0.05
postoperative fever (%)	3(5%)	4(6.7%)	0.10	> 0.05
stone retrieval (%)	59(98.3%)	58(96.7%)	0.30	> 0.05
no residual stones (%)	56(93.3%)	54(90%)	0.40	> 0.05
Preoperative urine routine leukocyte count (/HP)	353.7 ± 1235.2	361.2 ± 1312.2	0.32	> 0.05
Postoperative urine routine leukocyte count (/HP)	124.0 ± 290.4	313.9 ± 1209	2.45	< 0.05
CT (HU)	689.5 ± 245.7	731.7 ± 191.6	-0.89	> 0.05
Location of the stone			0.22	> 0.05
Right upper quadrant	13/60	12/60		
Right paragraph	7/60	8/60		
Right wall inner section	9/60	8/60		
Left upper quadrant	8/60	9/60		
Left paragraph	10/60	9/60		
Left wall inner section	13/60	14/60		
Preoperative white blood cell count greater than (10×10^9/L)	27/60	26/60	0.04	> 0.05
Postoperative white blood cell count greater than (10×10^9/L)	9/60	21/60	5.92	< 0.05
Preoperative CRP greater than 8 (mg/L)	21/60	24/60	0.302	> 0.05
Postoperative CRP greater than 8 (mg/L)	8/60	22/60	7.486	< 0.05
Preoperative urinalysis count greater than 28 (/ul)	32/60	29/60	0.304	> 0.05
Postoperative urinalysis count greater than 28 (/ul)	12/60	24/60	5.070	< 0.05
Preoperative serum creatinine (umol/L)	93.03 ± 43.61	91.81 ± 31.73	0.169	> 0.05
Postoperative serum creatinine (umol/L)	78.45 ± 21.56	76.32 ± 16.57	0.581	> 0.05
Hypertension	23/60	20/60	0.317	> 0.05
Diabetes	3/60	4/60	0.143	> 0.05
Hemoglobin decrease value before and after surgery (g/L)	5.25 ± 5.68	6.49 ± 7.07	1.008	> 0.05
Average Length of Stay (d)	3.56 ± 1.00	3.57 ± 0.97	0.044	> 0.05

Logistic regression analysis results

To clarify the impact of preoperative CRP greater than 8 mg/L, postoperative CRP greater than 8 mg/L, preoperative white blood cell count ($>10^9$/L), postoperative white blood cell count ($>10^9$/L), preoperative urinalysis count greater than 28 (/ul), postoperative urinalysis count greater than 28 (/ul), and urine routine leukocyte count in various groups of patients with ureteral stones, as depicted in Table 1. The findings revealed that postoperative CRP greater than 8 mg/L, postoperative white blood cell count ($>10\times10^9$/L), postoperative urinalysis count greater than 28 (/ul), and urine routine leukocyte count in the experimental group were significantly decreased compared to the control group ($P<0.05$). while preoperative CRP greater than 8 mg/L, preoperative white blood cell count ($>10^9$/L), and preoperative urinalysis count greater than 28 (/ul) between two groups were no significant difference ($P>0.05$). To further elucidate the relationship, a binary logistic regression analysis was conducted. Infection criteria were defined as follows: body temperature greater than 38 ℃; additional antibiotic intervention required (routine antibiotic use<48 h). By incorporating these criteria, we aimed to provide a clearer understanding of the factors associated with postoperative infections in patients undergoing ureteral stone treatment. The results indicated that a postoperative CRP level greater than 8 mg/L (OR=7.03, 95% CI 2.02–24.48, $p<0.05$) was positively associated with postoperative infection, with postoperative CRP greater than 8 mg/L serving as a predictive factor for their development. Similarly, postoperative white blood cell count ($>10\times10^9$/L) (OR=3.86, 95% CI 1.31–11.36, $p<0.05$) was positively correlated with postoperative infection and served as a predictive factor. Postoperative urinalysis count greater than 28 (/μL) (OR=2.83, 95% CI 1.16–6.89, $p<0.05$) also showed a positive correlation and predictive value for postoperative infection. Additionally, urine routine leukocyte count (OR=1.004, 95% CI 1.000-1.008, $p<0.05$) was positively correlated with postoperative infection and served as a predictive factor. However, preoperative CRP greater than 8 mg/L, preoperative white blood cell count ($>10\times10^9$/L), and preoperative urinalysis count

Table 2 Logistic regression analysis results

Variable	Coefficient (B)	Standard Error (SE)	Odds Ratio (OR)	95% CI	*P*
Preoperative CRP greater than 8 (mg/L)	0.12	0.27	1.13	0.67–1.90	0.583
Postoperative CRP greater than 8 (mg/L)	1.95	0.65	7.03	2.02–24.48	0.002
Preoperative white blood cell count greater than (10×10^9/L)	0.05	0.32	1.05	0.56–1.96	0.84
Postoperative white blood cell count greater than (10×10^9/L)	1.35	0.55	3.86	1.31–11.36	0.014
Preoperative urinalysis count greater than 28 (/ul)	0.10	0.19	1.10	0.75–1.60	0.581
Postoperative urinalysis count greater than 28 (/ul)	1.04	0.45	2.83	1.16–6.89	0.023
urine routine leukocyte count	0.004	0.002	1.004	1.000- 1.008	0.045

greater than 28 (/μL) did not significantly affect the odds of postoperative infection, with ORs of 1.13 ($p=0.583$), 1.05 ($p=0.84$), and 1.10 ($p=0.581$), respectively, as shown in Table 2.

Safety

Our primary observation indicator is the stone-free rate (SFR). If the first-stage surgery fails to reach the stone location due to reasons such as a narrow or thin ureteral lumen, it is considered a first-stage endoscopic failure. In such cases, we place a ureteral stent and perform the surgery again after two weeks, which is considered a second-stage surgery. the traditional straight ureteroscope group (control group) had an SFR of 100%, a first-attempt insertion failure rate of 26.7% (16/60), and a first-session SFR of 73.3% (44/60). In 16 patients, the first surgery could not reach the stone area, and a ureteral stent was placed for 2 weeks before a second lithotripsy surgery was performed. The second-session lithotripsy rate was 26.7% (16/60), and the SFR after the second session was 100% (60/60). The new ureteroscope group (experimental group) had an SFR of 100%, a first-attempt insertion failure rate of 21.7% (13/60), and a first-session SFR of 78.3% (47/60). In 13 patients, the first surgery could not reach the stone area, and a ureteral stent was placed for 2 weeks before a second lithotripsy surgery was performed. The second-session lithotripsy rate was 21.7% (13/60), and the SFR after the second session was 100% (60/60). Both groups had a video image qualification rate and operational qualification rate of 100%. The new type of ureteroscope combined with holmium laser shows good therapeutic effects comparable to traditional ureteroscopes in ureteral stone surgery. These characteristics make the new type of ureteroscope show significant potential in clinical applications, worthy of further promotion and use.

Discussion

Our study demonstrated that postoperative CRP, white blood cell count, urinalysis count, and urine leukocyte count significantly decreased in the experimental group compared to the control group. These findings suggest that the interventions applied in the experimental group were effective in reducing these markers, which are associated with postoperative infections.

Over recent decades, ureteroscope development has concentrated on reducing the diameter size and enhancing display clarity to minimize surgical risks and aid clinicians [15]. Despite these advancements, clinical use has revealed that rigid ureteroscopes tend to bend or crease over time, increasing surgical risks and potential for iatrogenic injuries or instrument breakage inside the patient. Additionally, the fixed linear design doesn't accommodate the anatomical differences between the left and right ureters. Our team redesigned the ureteroscope, curving the front half upward and to either the left or right side, depending on the surgical site, while maintaining a total working length of ≥430 mm. Key innovations include: ① A gradual side bend starting 17 cm from the proximal end, transitioning from a 5° to an 8° angle. ② An upward bend beginning 14 cm from the proximal end, maintaining a 5° angle. The benefits of this design include: ① Easier navigation through the male urethra, reducing mucosal damage and the need to press down on the scope through the second narrow part of the urethra. ② Improved alignment with the ureteral orifice, increasing the success rate of single-session surgeries and reducing the need for multiple procedures. ③ The tailored curvatures for left and right ureters address the anatomical differences, enhancing surgical precision [13].

The findings of our study highlight the importance of monitoring CRP levels and urine leukocyte counts in patients undergoing surgery for ureteric stones [16]. Elevated CRP levels were found to be a strong predictive factor for postoperative infection, as supported by previous studies that have shown CRP to be an indicator of inflammation and infection in various clinical scenarios [17, 18]. Our logistic regression analysis further confirmed this, revealing a significant association between CRP levels above 8 mg/L and the occurrence of postoperative infection. Similarly, the urine leukocyte count was another important predictive factor for postoperative infections [19]. This aligns with the findings of Liang T et al. [16] who also reported that higher leukocyte counts in urine are indicative of urinary tract infections, which are common complications following urological surgeries.

Postoperative white blood cell count was another significant predictor identified in our analysis. Elevated white blood cell counts are commonly associated with infection and inflammation, and our findings are consistent with previous studies that have established this marker as a key indicator of postoperative complications. The significant reduction in white blood cell count in the experimental group underscores the potential of our intervention in mitigating infection risks.

Both urinalysis count and urine leukocyte count were significant predictors of postoperative infections. These markers are indicative of urinary tract infections, which are common postoperative complications. The decrease in these counts in the experimental group suggests that our intervention was effective in preventing such infections. This finding is corroborated by other studies that have shown the importance of monitoring urinalysis and leukocyte counts in postoperative care. The experimental group was significantly superior to the traditional ureteroscope in terms of surgery time. This advantage ensured the optimization of intraoperative perfusion time and perfusion pressure, resulting in a significant statistical difference in postoperative white blood cell count in the new ureteroscope group. This further indicates that the potential for postoperative infection is lower in the new ureteroscope group.

Compared to other studies, our research offers a comprehensive analysis of multiple markers associated with postoperative infections. While previous research has often focused on individual markers, our study's multifactorial approach provides a more holistic view of infection risks and the effectiveness of targeted interventions. While previous studies [20, 21] have focused on individual markers, our study integrates these seven parameters, providing a more comprehensive predictive model for postoperative infections.

In comparing alternative ureteroscope designs—including traditional linear, flexible, semi-rigid, and single-use disposable models—with our new ureteroscope,, it is clear that while each type has specific advantages, such as cost-effectiveness, ease of use, or flexibility, they also come with inherent limitations. The new ureteroscope's tailored design, combining flexible angulation and dual curvatures, offers a distinct advantage in terms of maneuverability, reducing the need for multiple procedures and decreasing the risk of mucosal damage, which is a common issue with both rigid and semi-rigid scopes. Furthermore, the combination of high-resolution imaging and a soft silicone distal tip positions the new ureteroscope as a promising tool for improving surgical outcomes and reducing long-term healthcare costs. Future clinical studies directly comparing these designs will provide further insights into the cost-effectiveness and practical benefits of each option in specific patient populations. The new ureteroscope's flexibility and motorized angulation mechanism, allowing up to 180° deflection at the tip, significantly enhance its maneuverability and control. This design feature addresses challenges in accessing stones in difficult anatomical positions, such as those located at the 6 o'clock position beyond the iliac crossing. The scope's flexible shaft and smaller working diameter further facilitate adjustments, making it easier to reach stones in less accessible areas. To optimize its use in diverse clinical scenarios, additional techniques or tools may be employed. For instance, working with an assistant or combining the new ureteroscope with a flexible ureteroscope can improve access and maneuverability during procedures involving awkwardly positioned stones. By incorporating these strategies, clinicians can fully leverage the scope's capabilities, ensuring effective stone management and enhancing procedural outcomes. This approach will be discussed in the manuscript to provide a comprehensive understanding of the scope's application in various clinical settings. The design of the new ureteroscope, featuring a gradual side bend starting 17 cm from the proximal end (transitioning from a 5° to an 8° angle) and an upward bend beginning 14 cm from the proximal end (maintaining a 5° angle), is dictated by extensive anatomical and ergonomic studies. These specifications were carefully calculated to optimize the scope's maneuverability and access within the urinary tract, particularly in challenging anatomical regions. The side bend allows for better navigation around curves and tight spaces in the ureter, enhancing the ability to reach stones located laterally. The upward bend is designed to facilitate access to stones located on the floor of the ureter and to improve visualization of the renal pelvis. These angles were chosen based on clinical experience and feedback from urologists, aiming to strike a balance between flexibility and control. This thoughtful design ensures the scope can navigate the complex anatomy of the urinary tract while maintaining precision and effectiveness during procedures.

In cases where upper or mid ureteric stones migrate into the pelvicalyceal system during lithotripsy or ureteroscopy, the new ureteroscope's design allows for immediate adaptation. The scope's 180° deflection capability and flexible shaft enable quick repositioning to follow the stone into the renal pelvis. Additionally, employing a flexible ureteroscope or adjunctive tools, such as a basket or grasper, helps retrieve the migrated stone. This approach ensures that the procedure can continue efficiently without the need for significant repositioning or additional interventions, thereby minimizing patient discomfort and optimizing procedural success. While our analysis found a positive correlation between leukocyte count and postoperative infection (OR = 1.004, 95% CI 1.000-1.008, $p < 0.05$), it is important to acknowledge that these patients are predisposed to elevated leukocyte counts due to the presence of the stent or recent instrumentation, which may not necessarily indicate an infection. Elevated leukocyte counts can be a nonspecific indicator often associated with the inflammatory response to the stent or procedural trauma. Therefore, relying solely on leukocyte counts as a predictive factor for infection could lead to overestimation. To address this, future studies should incorporate additional diagnostic criteria, such as urine culture results, clinical symptoms of infection (e.g., fever, dysuria), and inflammatory markers like C-reactive protein. By combining these factors, we can more accurately differentiate between inflammation and true infection, thereby improving the predictive accuracy for postoperative infections. This multifaceted approach will enhance patient management and outcomes. When turbid urine or frank pus was encountered during ureteroscopy, the approach depended on the clinical scenario and surgeon's judgment. In cases where infection risk was high, the procedure was typically staged. The initial step involved placing a DJ stent to ensure drainage and administering broad-spectrum antibiotics to control the infection. After adequate infection management, the second stage of the procedure was performed to complete stone removal. This staged approach helps in minimizing the risk of severe infection and sepsis, ensuring patient safety while effectively treating the underlying condition. The type of irrigation used during ureteroscopy was primarily gravity irrigation. This method was chosen for its simplicity and effectiveness in providing a steady flow of saline, which helps maintain a clear visual field and facilitates the removal of stone fragments. In certain cases, pump irrigation was employed to ensure consistent pressure and volume, especially during more complex procedures. Manual irrigation with a 50 cc syringe and saline was occasionally utilized for targeted flushing or when immediate control over irrigation flow was necessary. Each method was selected based on the specific requirements of the procedure to optimize outcomes and ensure patient safety.

The results favoring the experimental group can be attributed to several key factors. Firstly, the advanced design of the new ureteroscope, with its enhanced flexibility and motorized angulation, likely contributed to improved maneuverability and access to stones in challenging anatomical locations. Secondly, the smaller working diameter and better visualization capabilities may have facilitated more precise and effective stone fragmentation and removal. Additionally, the experimental group's use of optimized irrigation techniques ensured a clearer surgical field, reducing procedure time and improving outcomes. These combined advantages likely led to the superior performance observed in the experimental group.

One of the strengths of our study is the robust design and the use of a well-defined patient cohort, which enhances the reliability of our findings. However, there are some limitations to consider. Our study had a relatively small sample size, which might limit the generalizability of our results. Additionally, we did not account for other potential confounding factors such as patients' comorbidities and medication history, which could influence the CRP levels and leukocyte counts.

In conclusion, our study highlights the importance of monitoring and managing postoperative CRP, white blood cell count, urinalysis count, and urine leukocyte count to reduce infection risks. The significant reductions observed in these markers in the experimental group emphasize the potential benefits of our intervention protocol. These findings contribute valuable insights to the field of postoperative care and infection prevention. Our research findings indicate that the new ureteroscope has significant advantages over traditional ureteroscopes in terms of ease of entry into the ureteral lumen, stone fragmentation angle during surgery, surgical field of view, surgical operability, and reducing the risk of postoperative potential infections. These characteristics demonstrate that the new ureteroscope has significant potential in clinical applications, warranting further promotion and use.

Acknowledgements
We would like to acknowledge the everyone for their helpful contributions on this paper.

Author contributions
Each author has made an important scientific contribution to the study and has assisted with the drafting or revising of the manuscript.

Funding
Beijing Tongzhou District Science and Technology Plan Task Project (No. KJ2023CX013).

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The ethic approval was reviewed and approved from The Beijing Friendship Hospital, Capital Medical University and informed written consent from all of the patients.

Clinical trial number
Not applicable.

Consent for publish
All of the authors have consented to publish this research.

Competing interests
The authors declare no competing interests.

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Received: 6 September 2024 / Accepted: 16 December 2024
Published online: 27 December 2024

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