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ORIGINAL RESEARCH

The effect of transurethral flexible ureteroscopic lithotripsy on renal function and efficacy in male patients with kidney stones

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Abstract

This study investigates the effects of transurethral flexible ureteroscopic lithotripsy (FURL) on renal efficacy and function in male kidney stone patients. A retrospective analysis was conducted on clinical data from 200 male patients with kidney stones treated at our hospital between February 2022 and February 2024. Depending on the technique of therapy, the patients were split into two groups: one for extracorporeal shock wave lithotripsy (ESWL) and another for FURL. Each group had 100 cases. The ESWL group was treated with ESWL, while the FURL group received FURL. The efficacy and renal function outcomes of the two methods were compared. According to the findings, the FURL group's overall effective rate and improvement impact were considerably higher than those of the ESWL group ($p < 0.05$). Additionally, postoperative recovery time was shorter in the FURL group compared to the ESWL group ($p < 0.05$). Both groups had higher postoperative levels of blood urea nitrogen (BUN) and creatinine (Cr) than preoperative levels; however, the FURL group had lower levels of these markers than the ESWL group ($p < 0.05$). Additionally, the FURL group had lower postoperative white blood cell (WBC), and C-reactive protein (CRP) levels than the ESWL group ($p < 0.05$). Likewise, the FURL group experienced a decreased complication rate ($p < 0.05$). FURL treatment is valid in its expanded application due to its ability to increase efficacy, decrease complication rates, stabilize renal function indicators, and shorten recovery durations following surgery.

Keywords

Flexible ureteroscopic lithotripsy; Extracorporeal shock wave lithotripsy; Kidney stones

1. Introduction

Kidney stones are common urinary system illnesses that primarily affect young and middle-aged adults. There is no substantial difference in the prevalence of kidney stones between the left and right sides. They can occur in the renal calyces, renal pelvis, and the junction of the renal pelvis and ureter [1]. Approximately 40% to 75% of patients with kidney stones experience varying degrees of back pain, ranging from dull or sharp discomfort in the lumbar region to intense knife-like pain in the lumbar and abdominal regions [2]. Early identification and treatment are essential because kidney stones can cause more immediate renal damage than stones in other places, and since the kidneys are the principal site of stone production within the urinary system.

Currently, surgical interventions such as extracorporeal shock wave lithotripsy (ESWL) and transurethral flexible ureteroscopic holmium laser lithotripsy (FURL) are effective treatments for kidney stones [3, 4]. ESWL employs ultrasound or X-ray for precise localization, causing minimal bodily damage by fragmenting stones into fine particles for excretion. However, its effectiveness is limited to stones with diameters less than 20 mm, restricting its widespread clinical use [5]. In contrast, FURL safely and effectively fragments stones using pulsed near-infrared light generated by a holmium laser. This technique promotes quick recovery and excellent hemostatic effects, leading to perfect clinical outcomes [6]. Although both procedures offer relatively simple operations, less postoperative pain, and quick recovery, they still can cause certain risks of trauma and postoperative complications. Currently, there are few clinical studies on the effects of these procedures on postoperative renal function and complications. The incidence of kidney stones is higher in males than females [7]. This discrepancy is partly due to anatomical variations in the lower urinary system between the sexes; androgens in male urine promote the production of oxalate crystals, whereas estrogen in female urine enhances the excretion of citrate and inhibits the formation of kidney stones.

Other factors, such as alcohol consumption, further necessitate increased awareness and early treatment of kidney stones in males [8, 9]. Therefore, this study focuses on male patients with kidney stones to thoroughly compare the efficacy of

FURL and ESWL, thereby providing more scientific strategies for clinical practice.

Clinical retrospective studies analyze data from the past to understand current trends. Retrospective studies are comparable to follow-up studies in prospective research that were started earlier. They investigate facts from the past at present, where both exposure and disease or death are already known facts. This research method moves from "effect" to "cause". Retrospective studies have several benefits such as, ease of implementation, saving time, manpower, resources, funds and quick results acquisition. Therefore, this article adopts a retrospective study to provide reliable theoretical support for clinical practice.

2. Materials and methods

2.1 General data

A retrospective analysis was conducted on the clinical data of 200 male patients with kidney stones admitted to our hospital from February 2022 to February 2024. The patients were divided into two groups based on their treatment method: a FURL group (treated with transurethral ureteroscopic lithotripsy) and an ESWL group (treated with extracorporeal shock wave lithotripsy), each consisting of 100 cases. The patient inclusion flow chart is shown in Fig. 1. This study has been approved by the Medical Ethics Committee of our hospital.

Inclusion Criteria: (1) Diagnosed with kidney stones through ultrasound, X-rays, and other examinations; (2) Stone diameter ≤2.5 cm and meeting surgical indications; (3) Normal cognitive function; (4) First occurrence of kidney stones; (5) Signed informed consent form.

Exclusion Criteria: (1) Accompanied by renal dysfunction and anatomical abnormalities; (2) Combined with urological tumors or significant uncontrolled urinary infections; (3) Combined with ureteral stones and bladder stones; (4) Combined with severe organ dysfunction; (5) Presence of coagulation or immune system disorders; (6) Combined with hematological diseases; (7) Presence of adverse lifestyle habits such as excessive drinking; (8) Combined with various infectious diseases.

2.2 Methods

ESWL group: Anesthesia was not required for patients in this group. Patients were appropriately positioned based on the location of the stones. Localization was assisted using X-ray or ultrasound, followed by ESWL performed with a lithotripter. To treat kidney stones, the operating energy was set between 20 and 30 J, and the number of shock waves was regulated between 1500 and 1900, depending on the patient's condition. Post-lithotripsy, antibiotics were administered to prevent infection, and patients were advised to drink at least

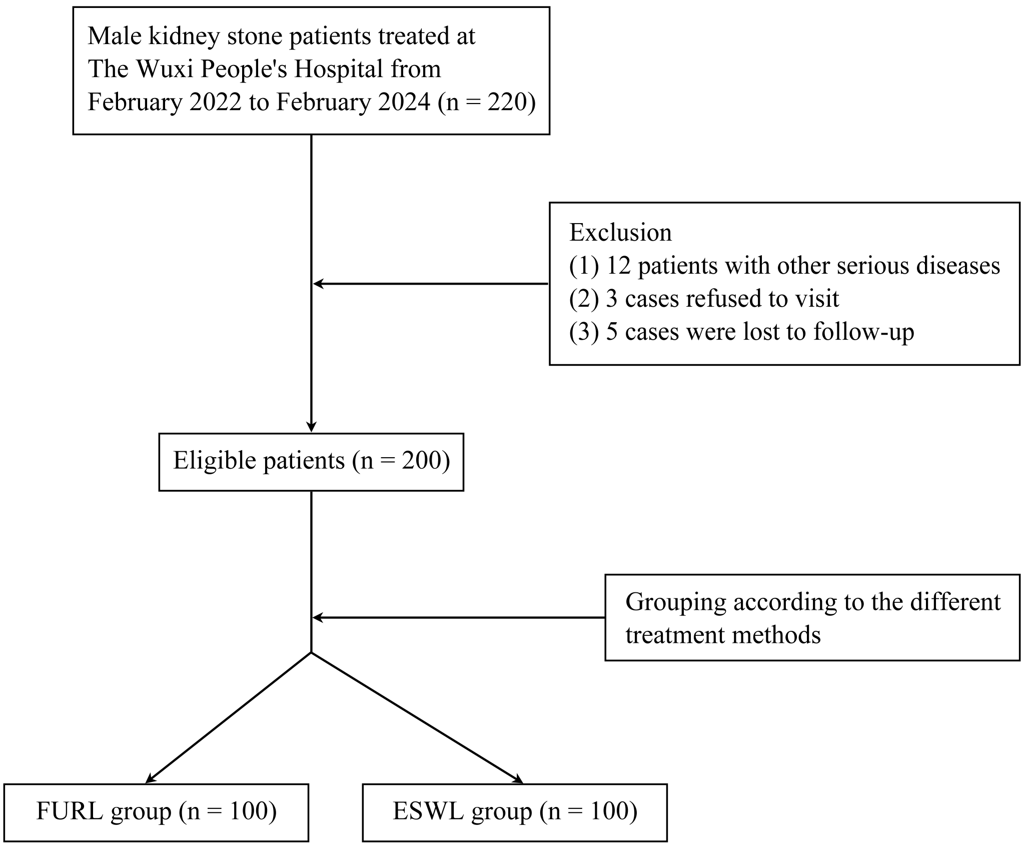

FIGURE 1. Flow chart of the included patients. FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

3000 mL/day of water. The efficacy of the lithotripsy was reaffirmed after seven days, and the outcome was used to determine whether a second session was required. The total number of treatments was limited to three.

FURL group: Patients received either epidural or general anesthesia while in the lithotomy position. Using a ureteroscope (wolf F8–9.8), the affected ureter was examined up to the renal pelvis. After placing a zebra guide wire, the scope was retracted, and a ureteral access sheath (F12–14 Boston) was inserted to an appropriate depth before removing the inner core and inserting the flexible ureteroscope (Olympus). After exploration, the position of the sheath was adjusted to gradually locate the stone. Upon locating the stone, a 200 μm laser fiber (0.8–1.2 J, 40–60 Hz) was introduced to pulverize the stone while maintaining a clear view with low-pressure irrigation. After ensuring no residual stones in the renal pelvis through repeated exploration, the zebra guide wire was left in place, and the ureteral sheath and scope were slowly withdrawn, observing the condition of the ureter. An F5 double J stent was placed. The patient could be discharged if there were no fevers post-operation, and a plain abdominal film on the first postoperative day confirmed no significant residual stones and correct positioning of the double J stent. The double J stent was then removed 4–6 weeks after the operation.

2.3 Observation indicators

(1) Clinical efficacy: Following the course of treatment, computerized tomography (CT) scans and clinical symptoms were used to evaluate the impact of the intervention on both groups of patients. Cured: Disappearance of clinical symptoms such as abdominal pain, hematuria, and renal colic, and no stones observed on CT scan; Improved: Alleviation of symptoms like abdominal pain, hematuria, and renal colic, and reduction in stone size on CT scan; Ineffective: No change in the size of the stone on a CT scan, and no improvement in clinical symptoms [10]. (2) Comparison of clinical surgical indicators: operation time and postoperative recovery time. (3) Renal function indicators: Both groups had their preoperative and 3-day postoperative serum creatinine (Cr) and blood urea nitrogen (BUN) levels tested. (4) Inflammatory Response Factors: Fasting elbow venous blood samples (5 mL) were collected from the patients in the morning before surgery and on the second postoperative day. The levels of C-reactive protein (CRP) were measured using an enzyme-linked immunosorbent assay (ELISA). The total white blood cell (WBC) count was determined using a fully automated blood cell analyzer (UniCel DxH800, Beckman Coulter, Pasadena, CA, USA). (5) Postoperative complications, including urinary tract infection, bleeding, fever and haematoma.

2.4 Statistical methods

The software SPSS 22.0 (IBM, Armonk, NY, USA) was used to statistically analyse the data. Concisely, quantitative data conforming to a normal distribution are expressed as ($\bar{x} \pm s$), and comparisons between groups were conducted using an independent samples t-test; if the data do not conform to a normal distribution, they should be presented as median ±95% confidence interval (or interquartile range) and analyzed using the Mann-Whitney U test. Count data were described in percentage (%), and were analyzed using the chi-square test for independent samples, with $p < 0.05$ indicating statistically significant differences.

3. Results

3.1 General information

Tables 1 and 2 displays the general data ($p > 0.05$) for both groups.

3.2 Comparison of treatment effectiveness

The total effective rate and improvement effect in the FURL group were significantly better than the ESWL group ($p < 0.05$) (Table 3).

3.3 Clinical indicators

There was a significant difference ($p < 0.05$) in the duration of stay, postoperative recovery time, and operation time between the FURL and ESWL groups (Table 4).

3.4 Renal function indicators

Both groups' postoperative BUN and Cr levels were greater than their preoperative values; the ESWL group's BUN and Cr levels were higher than those of the FURL group ($p < 0.05$) (Table 5).

3.5 Inflammatory factors

After three days of surgery, the FURL group had lower levels of CRP and WBC ($p < 0.05$) compared to the ESWL group (Table 6).

3.6 Complication rates

The incidence of complications in the FURL group was lower than in the ESWL group ($p < 0.05$) (Table 7). Patients who developed urinary tract infections postoperatively recovered after three days of antibiotics and other anti-infective treatments. Other patients who experienced bleeding and fever also achieved recovery following further treatment. Postoperative Hematoma Management: Patients with postoperative hematomas were treated based on the size of the hematoma. The problem is usually not severe and particular treatment is not needed for minor haematomas (<3 cm) that do not cause any discomfort. Increasing fluid intake to promote urination can aid in the absorption of the hematoma. For larger hematomas (>3 cm) accompanied by symptoms such as lower back pain or kidney pain, timely medical intervention is necessary. In such cases, surgical treatment may be required to remove the hematoma promptly to prevent significant kidney damage.

4. Discussion

Kidney stones are a common urinary system disease, closely related to factors such as metabolic abnormalities, medications, and urinary tract lesions, as well as climate and di-

TABLE 1. Comparison of general information between two groups ($\bar{x} \pm s$).

Group	N	Age (yr)	BMI (kg/m^2)	Number of stones
FURL group	100	43.60 ± 8.67	22.41 ± 1.12	4.83 ± 1.22
ESWL group	100	42.37 ± 8.18	22.38 ± 1.10	4.85 ± 1.28
t	-	1.032	0.128	0.114
p	-	0.303	0.898	0.909

Note: The quantitative data is described by ($\bar{x} \pm s$), and after an independent sample t-test, $p < 0.05$ indicates statistically significant differences. BMI: body mass index; FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

TABLE 2. Stone locations in both groups (n (%)).

Group	N	Upper calyx	Middle calyx	Pelvis	Lower calyx
FURL group	100	13	15	45	27
ESWL group	100	10	10	52	28
χ^2	-	0.442	1.143	0.981	0.025
p	-	0.506	0.285	0.322	0.874

FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

TABLE 3. Comparison of patient treatment efficacy (n (%)).

Group	N	Cured	Improved	Ineffective	Total effective rate
FURL group	100	34 (34.00)	62 (62.00)	4 (4.00)	96 (96.00)
ESWL group	100	30 (30.00)	48 (48.00)	22 (22.00)	78 (78.00)
χ^2	-	0.368	3.960	14.324	
p	-	0.544	0.047	<0.001	

Note: The count data is described as a percentage (%) and after comparison using the chi-square test, $p < 0.05$ indicates statistically significant differences. FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

TABLE 4. Comparison of clinical indicators of two groups ($\bar{x} \pm s$).

Group	N	Operation time (min)	Postoperative recovery of normal time (d)	Length of stay
FURL group	100	65.25 ± 12.52	2.20 ± 0.87	3.25 ± 1.16
ESWL group	100	31.50 ± 13.22	4.05 ± 1.14	5.84 ± 1.58
t	-	18.553	12.885	13.261
p	-	<0.001	<0.001	<0.001

FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

TABLE 5. Comparison of renal function indicators in the two groups ($\bar{x} \pm s$).

Group	N	BUN (mmol/L)		Cr (mmol/L)	
		Before surgery	3 d after surgery	Before surgery	3 d After surgery
FURL group	100	5.10 ± 1.15	6.20 ± 0.78	90.16 ± 9.51	101.38 ± 10.05
ESWL group	100	4.98 ± 1.09	6.69 ± 1.06	89.67 ± 9.35	107.16 ± 10.86
t	-	0.700	3.709	0.368	3.906
p	-	0.484	<0.001	0.713	<0.001

BUN: blood urea nitrogen; Cr: creatinine; FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

TABLE 6. Comparison of inflammatory factors in the two groups ($\bar{x} \pm s$).

Group	N	CRP (mg/L)		WBC ($\times 10^9$/L)	
		Before surgery	3 d after surgery	Before surgery	3 d after surgery
FURL group	100	13.27 ± 2.26	5.52 ± 1.25	12.04 ± 1.35	6.58 ± 0.57
ESWL group	100	13.68 ± 2.15	6.84 ± 1.32	11.96 ± 1.37	8.35 ± 0.86
t	-	1.315	7.238	0.374	17.122
p	-	0.190	<0.001	0.709	<0.001

CRP: C-reactive protein; WBC: white blood cell; FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

TABLE 7. Comparison of the complications (n (%)).

Group	N	Urinary Infection	Bleeding	Fever	Haematoma	Total
FURL group	100	2 (2.00)	1 (1.00)	1 (1.00)	1 (1.00)	5 (5.00)
ESWL group	100	6 (6.00)	4 (4.00)	7 (7.00)	3 (3.00)	20 (20.00)
χ^2	-					10.286
p	-					0.001

FURL: flexible ureteroscopic lithotripsy; ESWL: extracorporeal shock wave lithotripsy.

etary habits [11]. The treatment of kidney stones needs to be chosen based on the size and shape of the stones. Historically, open surgery was commonly used for clinical treatment, which caused significant harm to patients and often did not achieve the expected efficacy, frequently leading to renal tissue damage [12]. Due to the kidneys' retroperitoneal location, high surgical requirements are imperative, making it crucial to explore more scientific treatment measures [13].

The clinical treatment of kidney stones has seen an increased application of FURL, ESWL and percutaneous nephrolithotomy (PCNL) due to the ongoing development of minimally invasive procedures [14]. ESWL is the preferred clinical method for treating kidney stones but can easily induce complications such as infections, tissue damage, and stone street formation, resulting in a poor prognosis [15]. FURL does not produce stone displacement effects and can prevent stone migration, effectively compensating for the shortcomings of ESWL [16]. The results of this study indicate that the total effective rate and improvement effect in the FURL group were significantly higher than those in the ESWL group. This demonstrates that FURL is superior to ESWL in the treatment of kidney stones by reducing the adverse effects associated with repeated lithotripsy. In a study conducted by Geraghty Robert, a meta-analysis of randomized controlled trials compared outcomes between flexible ureteroscopy and shock wave lithotripsy (SWL) in patients with kidney stones or proximal ureteral stones <2 cm. Consistent with the findings of this investigation, the results indicated that, among 669 patients, the flexible ureteroscopy group had a considerably greater stone removal rate than the SWL group [17]. Our study's findings can be categorized as follows: Larger stones are difficult to completely fragment because of the limited energy produced by the shock waves during ESWL. Additionally, some patients experience suboptimal initial lithotripsy outcomes due to the limited space for stone dispersion within the kidney, which requires multiple repeat procedures [18]. By contrast, ureteroscopic holmium laser lithotripsy is a minimally invasive procedure that uses pulsed lasers to precisely fragment stones under the guidance of specialized endoscopes. Large-diameter stones are successfully broken up by the powerful impact forces applied to the stones by the holmium laser used in this process. During the procedure, the energy from the pulsed laser is conducted through an inserted optical fiber, which reacts with the moisture on the stone surface to create numerous bubble explosions, transferring the laser energy to the stone for precise fragmentation [19]. Flexible ureteroscopes allow for direct visualization and precise access to the location of stones, enabling complete fragmentation and removal. This method lessens the possibility of remaining stone pieces when compared to ESWL. Ureteral flexible endoscopes can utilize laser lithotripsy, which is highly effective in breaking the stones into small pieces that can be easily removed or naturally passed. During ureteroscopic surgery, surgeons can directly manipulate and position the endoscope to target stone fragments that are difficult to reach within the ureter, thereby improving the overall stone clearance rate. Unlike ESWL, which relies on transmitting energy from extracorporeal shock waves to break the stones, FURL provides a more direct and controllable method of stone fragmentation. The effectiveness of ESWL may be influenced by factors such as the patient's body habitus, stone composition and location. These factors are less likely to affect the outcomes of ureteroscopic surgery, making it a more universally applicable solution. Consequently, this surgical technique has a good stone-clearing impact and produces good lithotripsy results in a single treatment session. Overall, the total effective rate of FURL in treating kidney stones is higher. In addition, the FURL group experienced a quicker procedure and postoperative recovery period than the ESWL group. This result may be explained by the fact that, for patients whose kidney stones measure more than 20 mm in diameter, using flexible ureteroscopes during surgery maximizes the body's natural pathways, preventing direct injury to the kidneys and surrounding tissues and minimizing bleeding. Therefore, patients in the FURL group experience less physical trauma, which benefits their postoperative recovery. On the other hand, ESWL's repeated targeting of the same area with shock waves can cause damage to the kidney and surrounding pelvic tissues, leading to pronounced inflammatory and oxidative stress responses, as well as increased risks of postoperative fever and infection [20]. FURL offers clear visual fields, reducing damage to the ureter and surrounding tissues. The holmium laser used in FURL is a high-energy pulsed laser that quickly pulverizes the stones into powder, improving stone clearance rates. Additionally, the holmium laser reaches the treatment site via the body's structural channels, minimizing surgical trauma and the resultant stress response. FURL treatment utilizes flexible ureteroscopes with bendable characteristics, allowing procedures to be conducted through standard channels or retrogradely into the renal pelvis and calyces, which helps improve the success rate of stone fragmentation. The use of a flexible ureteroscope for lithotripsy greatly reduces damage to the kidney and surrounding tissues, as it eliminates the need for channel puncture. This minimally invasive procedure results in relatively less surgical trauma effectively lower intraoperative blood loss and is beneficial for postoperative recovery. Consequently, compared to ESWL, patients in the FURL group recover faster postoperatively and have shorter operation times. For instance, In Hao Xiaoqiang's study, 111 patients with kidney stones (2–3 cm) were divided into groups: 55 patients (control group) underwent minimally invasive percutaneous nephrolithotomy (PCNL), while 56 patients (research group) received FURL. The surgical outcomes were compared, revealing that the research group had longer surgery times but less bleeding, shorter postoperative recovery times, and significantly higher quality of life compared to the control group [21]. These findings demonstrate that FURL can accelerate postoperative recovery and improve the quality of life for patients with 2–3 cm kidney stones without significantly affecting renal function. For kidney stone patients, FURL is a less intrusive method of creating a puncture channel than PCNL. It also provides advantages in terms of lowering intraoperative blood loss, accelerating patient recovery, and easing discomfort [22].

After surgery, the level of BUN and Cr in the ESWL group was higher than in the FURL group, indicating that FURL has a lesser impact on renal function. Both surgical methods used in this study can potentially damage renal tubular epithelial cells, leading to impaired renal function and perfusion [23]. However, FURL causes less renal damage. One reason could be the insufficient stone fragmentation by ESWL, which fails to fully relieve ureteral obstruction. In contrast, FURL can accurately and completely remove stones of various diameters from the body, thus clearing the ureter and protecting renal function. Another explanation could be that the energy from the shock waves produced by ESWL damages the renal parenchyma to some extent, which alters the state of renal perfusion. In contrast, FURL employs short-duration laser pulses that are pulsed. Despite the fact that the laser generates vaporization, the brief heating duration inhibits significant heat transfer to nearby tissues, concentrating the tissue effect locally [24]. Therefore, FURL causes less damage to tissues near the stones. Postoperatively, many fragmented stones gradually move downward and are expelled, potentially stimulating the bladder and urethral walls, which may lead to urinary tract infections and other adverse events [25]. The penetration depth of the holmium laser during surgery is shallow, and the emission time is brief, rarely stimulating nearby ureteral mucosa [26]. The cutting action of the laser can also relieve ureteral strictures. Additionally, a 0.9% sodium chloride solution is used intraoperatively to carry away excess heat from surrounding tissues, preventing ureteral perforation, consistent with the findings of Li Z [27]. FURL treatment does not require the establishment of a renal tract and can naturally enter the kidney for stone fragmentation, thus causing relatively less damage to renal function. The flexible ureteroscope, being soft, offers superior capability to explore the renal pelvis and reduces harm to the renal parenchyma. Consequently, patients in the FURL group exhibit better renal function indicators compared to those in the ESWL group. Postoperatively, levels of CRP and WBC in the FURL group were lower than in the ESWL group, indicating that holmium laser lithotripsy under flexible ureteroscopy causes minimal damage to renal function, and reduces the inflammatory response in patients. Clinical studies have shown that CRP and WBC are sensitive markers for inflammation. WBC and CRP levels usually increase sharply following surgical trauma. The underlying reason for the results of this study is that the ureteroscope body is slender and flexible, minimizing damage when passing through the patient's ureter. Once inside the renal tissue, it has a large degree of maneuverability and comprehensive functionality. In Chen Wenpu's study involving 104 patients with upper ureteral calculi who underwent either PCNL or FURL, the results showed that postoperative inflammation markers were lower in the FURL group compared to the PCNL group [28]. This further confirms that FURL induces a smaller inflammatory response and a lesser stress reaction from the body, leading to easier recovery for patients' post-surgery. Moreover, the study results indicate that the incidence of postoperative complications in the FURL group was lower than in the ESWL group, suggesting that holmium laser lithotripsy under flexible ureteroscopy significantly reduces postoperative complications and boasts higher safety. This provides a theoretical basis for the clinical implementation of treatments for kidney stones $\leq$2.5 cm.

This study has certain limitations. Firstly, the sample size is relatively small, which may limit the robustness of the findings. The results might not be as broadly applicable to larger populations due to the single-center design. The findings' limited applicability is further attributed to the insufficient assessment of the patient's general data and baseline circumstances. Second, the recurrence rate of kidney stones $<$2.5 cm in individuals has not been thoroughly studied. Supplementing this aspect with relevant data analysis will help further understand the impact of these two surgical methods on the recurrence in such patients. Lastly, the study did not thoroughly explore risk factors influencing postoperative complications. Additional analysis is needed to understand these risk factors better and to improve surgical and clinical management strategies. Future research should be supported by larger sample sizes, including more diverse patient demographic data, and should be conducted as multi-center studies. Additionally, it is important to consider the risk factors related to postoperative complications and incorporate data and discussions on patient recurrence to enhance the accuracy and comprehensiveness of the research results.

5. Conclusions

In summary, FURL treatment has the potential to increase overall effectiveness rates, improve clinical indicators, stabilize renal function metrics, lower the incidence of complications, and merit broader implementation in clinical settings.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

YZ—designed the study and carried them out, prepared the manuscript for publication and reviewed the draft of the manuscript. YZ, WGS—supervised the data collection, analyzed the data, interpreted the data. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of Wuxi People's Hospital (Approval no. KY23006). Written informed consent was obtained from a legally authorized representative for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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