Flexible Ureteroscopic Lithotripsy Based on the Concept of Enhanced Recovery After Surgery

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ABSTRACT

Background: To evaluate the efficacy of flexible ureteroscopic lithotripsy (FURSL) based on the concept of enhanced recovery after surgery (ERAS).

Methods: 435 patients with upper urinary calculi between 2017-2020 were retrospectively analysed and assigned to ERAS group (ERAS management) and control group (traditional management). Operative time, postoperative ambulation time, postoperative hospital stay, total cost of hospitalization, postoperative complications and stone removal were compared.

Results: 427 cases were successfully performed FURSL procedure with 4 cases of ERAS group (n = 216) and 4 cases of control group (n = 219) failed respectively. No postoperative complications occurred in either group except for fever and hematuria. There were no significant difference in postoperative fever and stone removal between the two groups (all $p > 0.05$). The patients in ERAS group had shorter operative time, shorter postoperative ambulation time, less postoperative severe hematuria, shorter postoperative hospital stay and lower total cost of hospitalization than those in control group (all $p < 0.05$).

Conclusions: FURSL based on the concept of ERAS for the treatment of upper urinary tract calculi is safe and reliable, with rapid postoperative recovery, low cost of hospitalization and worthy of clinical promotion.

Keywords: Flexible ureteroscopy; Lithotripsy; Laser; Enhanced recovery after surgery; ERAS

Background

ERAS was first advocated by Kehlet Henrik in the field of colorectal surgery at the end of the last century [1]. Since then, the concept has become increasingly popular with surgical staff. According to existing evidence-based medical practice, the main connotation of ERAS refers to using multimodal strategies to optimize perioperative related treatments, reducing the stress response of body and avoiding complications, while actively adopting minimally invasive techniques to improve the safety of surgery and patient satisfaction, so as to achieve the purpose of accelerating patients' recovery and shortening hospital stay [2]. Studies have shown that ERAS can reduce hospital stay by approximately 30% after surgery, thereby reducing medical costs without increasing the risk of postoperative complications and readmission rates [3-6]. Although the ERAS concept has been gradually popularized in the field of general surgery in recent years, it is relatively rare in urology. On the other hand, the awareness and application of ERAS by Chinese surgeons and patients are also in the process of continuous improvement and development with some traditional concepts needing to be updated and changed.

Urinary calculi are common and frequently occurring diseases in Chinese people's daily lives. The overall prevalence of kidney stones is about 5.88% in China with higher in southern area of the Yangtze River [7]. The surgical treatment of urolithiasis was mainly based on open surgery in which the postoperative recovery process was quite slow in the past. In recent years, with the rapid development of minimally invasive techniques in urology, the vast majority of urinary stones can be removed by endoscopic surgery. FURSL has been widely performed in the treatment of upper urinary tract stones with safety and effectiveness, which is a typical representative of minimally invasive surgery in the urinary system and exactly conforms to the core strategy of ERAS [2, 8]. To date, there are few reports about the application of ERAS in the perioperative period of FURSL.

To evaluate the clinical effectiveness of ERAS managements during the perioperative period of FURSL, a retrospective case-control study was carried out.

Methods

Patients

Between January 2017 and April 2020, patients with upper urinary tract calculi who were treated with FURSL precedure at the department of urology were enrolled in this study. All cases underwent the preoperative examination including B-ultrasonography, plain abdominal radiography for kidney-ureter-bladder (KUB), computed tomography (CT) scan or dual-source CT to confirm the diagnosis of urinary stones. Those with normal renal function were examined for intravenous pyelography (IVP), and magnetic resonance urography (MRU) or computed tomography urography (CTU) was performed if necessary.

Inclusion and exclusion criteria

The inclusion criteria for cases included the following aspects: (1) kidney or upper ureteral calculi with stone diameter less than 30 millimeter (mm); (2) calculi with unsatisfactory outcome of extracorporeal shockwave lithotripsy (SWL) or percutaneous nephrolithotomy (PCNL); (3) renal calculi not suitable for PCNL because of obesity, scoliosis or patient's wishes. The exclusion criteria were as follow: some urinary diseases e.g., excessive hydronephrosis, renal empyema, and severe urethral or ureteral stricture.

Grouping

According to the management measures during the perioperative period of FURSL, all patients were assigned to different group: ERAS group (undergoing perioperative management based on the concept of ERAS) or control group (undergoing traditional perioperative management). Patients were enrolled and divided into the two groups based on the different responsible doctors.

Perioperative management measures

Preoperative routine urine test and urine culture were implemented in both groups. If patients were found to have obvious evidence of urinary tract infection (UTI) (e.g., positive urine culture, negative urine culture but more than two urine tests showing increased leukocyte count), the anti-infective treatment was actively carried out (e.g., selecting sensitive antibiotics with guidance of drug susceptibility test, prescribing antibiotics empirically when urine culture was negative). After the results of laboratory urinalysis improved significantly, FURSL procedure was performed. Perioperative management measures of the two groups are shown in Table 1.

Table 1. Summary of perioperative management measures.

	ERAS group	Control group
Before surgery	Preoperative double-J stent indwelling 0-2 weeks	Preoperative double-J stent indwelling 2-4 weeks
	Individualized preoperative education using multimedia	Traditional preoperative education with paper materials
	Surgeons, nurses, and anesthetists formed a multidisciplinary team for preoperative visits	Surgeons, nurses or anesthetists performed preoperative visits respectively
	A list of rehabilitation plans	No
	No preoperative bowel preparation	No preoperative bowel preparation except for patients with constipation
	Normal oral solid nutrition until 6 hours before surgery	Normal oral solid nutrition until 10 hours before surgery
	Normal drinking water until 2 hours before surgery	Normal drinking water until 10 hours before surgery
	250-400 ml carbohydrate drinks for non-diabetic patients 2 hours before surgery	No
During surgery	Combining laryngeal mask ventilation with general anesthesia	Combining tracheal intubation with general anesthesia
	Selecting short-acting anesthetics as much as possible	No
	Strengthen monitoring of intraoperative body temperature	No
	Increasing the operating room temperature (24-26 ℃)	General operating room temperature (22-24 ℃)
	Warming intravenous fluids and surgical infusion fluids	No
	Goal-directed fluid therapy for intraoperative fluid administration	Standard intraoperative fluid regimen
	Using syringes for saline infusion of FURSL by the assistant with hands	An irrigation pump for saline infusion of FURSL
After surgery	Selecting non-opioids based on patients' postoperative analgesia needs	Not deliberately avoiding opioids for analgesia
	Drinking water 6 hours after surgery and then gradually resuming diet	Receiving oral intake after gastrointestinal function was recovered
	Mobilization out of bed 6 hours after surgery	Mobilization out of bed 12-24 hours after surgery
	Removing urinary catheter 12-24 hours after surgery	Removing urinary catheter 24-48 hours after surgery
Discharge and follow-up	Discharging based on the criteria, returning for KUB X-ray or CT scan 2 weeks later and removing double-J stent	Discharging based on the criteria, returning to KUB X-ray or CT scan 4 weeks later and removing double-J stent

ERAS, enhanced recovery after surgery

Discharge criteria included normal temperature, normal diet, normal mobilization, no urinary catheter, no serious gross hematuria, no severe flank pain or abdominal pain, no serious dysuria, and agreeing to be discharged.

Surgical methods

The main surgical instruments and accessory tools including digital flexible ureteroscope (URF-V, Olympus; Shinjuku-ku, Tokyo, Japan), modular flexible ureteroscope (PD-PS-0094, PolyDiagnost; Hallbergmoos, Freistaat Bayern, Germany), fiberoptic flexible ureteroscope (11278A1, Karl Storz; Tuttlingen, Baden-Württemberg, Germany), rigid ureteroscope (8/9.8F, Richard Wolf; Knittlingen, Baden-Württemberg, Germany), ureteral access sheath (12/14F, Cook; West Lafayette, Indiana, USA), holmium laser (PowerSuite 100W, Lumenis; Yokneam, HaZafon, Israel) and nitinol stone baskets (2.2F, Cook; West Lafayette, Indiana, USA) were chosen for utilization in the surgery.

All FURSL procedures were performed by senior urologists as follows. After general anesthesia, patients were placed on operating table in the lithotomy-Trendelenburg position. Preoperative double-J stent was removed by rigid ureteroscope, and then a 0.035 inch guidewire was retrogradely placed for the guidance of ureteral access sheath. Along the sheath, a flexible ureteroscope was inserted to explore renal pelvis and calyxes for stones. Subsequently, fragmenting stones were conducted under holmium laser with a 200-μm fiber and appropriate parameters (energy 0.8-1.2 J, frequency 15-20 Hz). At the end of the lithotripsy, a nitinol stone basket was inserted to grab larger fragments for analyzing stone composition. The final step was to indwell 5-6F double-J stent and 16-18F catheter.

Outcome measures

Patients' age, gender, stone location (kidney or upper ureteral), stone side, stone size (maximum diameter), underlying diseases (e.g., hypertension, diabetes mellitus, gout, chronic kidney disease), history of urinary stone and type of flexible ureteroscope were collected as baseline characteristics in ERAS group and control group. Postoperative clinical data including operative time, ambulation time, hospital stay, total cost of hospitalization, complications and stone removal rate were recorded for comparing between the two groups.

Operative time means the time from rigid ureteroscope insertion to double-J stent placement. The main complications included postoperative fever and hemorrhage. Fever was defined as the axillary temperature higher than 37.3 °C, which was divided into low-grade fever (37.3-38.0 °C), moderate fever (38.1-39.0 °C) and high-grade fever (≥ 39.1 °C). If the gross hematuria lasted more than 24 hours after surgery, it was considered as postoperative severe hematuria. Complete removal of stones was evaluated by KUB X-ray or CT scan 2-4 weeks after surgery with the definition of no residual stones being found or fragments smaller than 4mm in diameter.

Statistical analysis

SPSS version 22.0 (IBM, USA) was used for statistical analysis to compare the baseline characteristics and postoperative clinical data between the two groups. Continuous data were expressed in the form of mean ± SD while categorical data were expressed as percentages. Independent sample *t*-test and Chi-squared test were performed with two-sided *p* values smaller than 0.05 being regarded as statistically significant.

Results

From January 2017 to April 2020, 435 patients participated in this trial after obtaining informed consent. 8 patients were withdrawn due to the failure of FURSL procedure. 4 failed FURSL cases in ERAS group included 1 case with flexible ureteroscope being unable to pass the ureteral stricture, 1 case with stricture of renal calyx neck, 1 case of no calculi by flexible ureteroscopy and 1 case with lower calyceal calculus being changed to SWL due to the restricted angle for FURSL. There were also 4 cases of failed FURSL surgery in control group, including 1 case of no stones by flexible ureteroscopy, 1 case with lower calyceal calculus being changed to PCNL owing to the angle limitation and 2 cases with hard texture of stones being changed to PCNL. 427

patients completed the trial and they were assigned to the two groups: 212 patients in ERAS group and 215 patients in control group.

There was no significant difference between ERAS group and control group in terms of age, gender, stone location, stone side, stone size, underlying diseases, history of urinary stone and type of flexible ureteroscope ($p > 0.05$) (Table 2).

Table 2. Baseline characteristics of the patients.

Variables	ERAS group ($n = 216$)	Control group ($n = 219$)	P
Age in years	50.38 ± 13.19	52.67 ± 12.62	0.064[a]
Gender			0.335[b]
Male	136 (63.0)	128 (58.4)	
Female	80 (37.0)	91 (41.6)	
Stone location			0.483[b]
Kidney	185 (85.6)	195 (89.0)	
Upper ureteral	14 (6.5)	9 (4.1)	
Kidney and upper ureteral	17 (7.9)	15 (6.9)	
Stone side			0.677[b]
Left	99 (45.8)	109 (49.8)	
Right	106 (49.1)	101 (46.1)	
Bilateral	11 (5.1)	9 (4.1)	
Stone size (mm)	18.78 ± 4.50	19.26 ± 4.56	0.272[a]
Underlying diseases			0.198[b]
Yes	107 (49.5)	95 (43.4)	
No	109 (50.5)	124 (56.6)	
History of urolithiasis surgery			0.221[b]
Yes	18 (8.3)	26 (11.9)	
No	198 (91.7)	193 (88.1)	
Type of flexible ureteroscope			0.514[b]
Digital	86 (39.8)	77 (35.2)	
Modular	107 (49.5)	113 (51.6)	
Fiberoptic	23 (10.6)	29 (13.2)	

Continuous data are shown as mean ± SD.

Categorical data are shown as *n* (%).

[a]Independent samples *t*-test.

[b]Pearson Chi-square test.

ERAS, enhanced recovery after surgery; SD, standard deviation.

No postoperative complications occurred in either group except for fever and hematuria. There was no significant difference in postoperative fever or stone removal between the two groups ($p > 0.05$) (Tables 3 and 4). However, there were still some differences in postoperative clinical data between the two groups. The patients in ERAS group had shorter operative time, shorter postoperative ambulation time, less postoperative severe hematuria, shorter postoperative hospital stay and lower total cost of hospitalization than those in control group ($p < 0.05$) (Table 3). The majority of the postoperative fever cases in the 2 groups were low to moderate fever (Table 4). In control group, there was 1 case of postoperative hematuria with repeated hemorrhage which was finally cured by super-selective renal artery embolization for hemostasis.

Table 3. Postoperative clinical outcomes.

Variables	ERAS group (*n* = 212)	Control group (*n* = 215)	*P*
Operative time (min)	80.59 ± 36.84	91.26 ± 36.56	0.003[a]
Postoperative ambulation time (h)	11.23 ± 5.13	21.08 ± 4.68	< 0.001[a]
Postoperative hospital stays (d)	2.33 ± 1.18	3.00 ± 1.74	< 0.001[a]
Total cost of hospitalization (USD)	2723.9 ± 549.9	2867.8 ± 661.0	0.015[a]
Postoperative fever			0.579[b]
Yes	57 (26.9)	63 (29.3)	
No	155 (73.1)	152 (70.7)	
Postoperative severe hematuria			0.015[b]
Yes	18 (8.5)	35 (16.3)	
No	194 (91.5)	180 (83.7)	
Stone removal			0.541[b]
Complete	166 (78.3)	163 (75.8)	
Incomplete	46 (21.7)	52 (24.2)	

Continuous data are shown as mean ± SD.

Categorical data are shown as *n* (%).

[a]Independent samples *t*-test.

[b]Pearson Chi-square test.

ERAS, enhanced recovery after surgery; SD, standard deviation; USD, United States dollar (Converted from CNY at the exchange rate on November 14, 2019).

Table 4. Distribution of the patients with postoperative fever.

Variables	ERAS group (*n* = 57)	Control group (*n* = 63)	*P*
Postoperative fever			0.220[a]
Low-grade	42 (73.7)	38 (60.3)	
Moderate	13 (22.8)	19 (30.2)	
High-grade	2 (3.5)	6 (9.5)	

Data are shown as *n* (%).

[a]Pearson Chi-square test.

ERAS, enhanced recovery after surgery.

Discussion

The proportion of minimally invasive surgery in urinary system currently has reached more than 90% in many regional medical institutions, which is in line with the requirements of ERAS. Some studies have demonstrated the satisfactory outcomes of ERAS program in laparoscopic radical prostatectomy, radical cystectomy and laparoscopic radical nephrectomy [5, 9-12]. However, there are few reports about ERAS application in ureteroscopy, especially a lack of specialist guidance similar to that in general surgery. From the minimally invasive point of view, ERAS will has broad application prospects in the perioperative period of FURSL. As a consequence, this study which combined ERAS with FURSL was of great meaningful, specifically for patients. The purpose of the trial was to evaluate the clinical application of ERAS in FURSL with exploring the optimization and implementation of ERAS measures.

The results of this study indicate that compared with the traditional perioperative management measures, the ERAS measures have significant advantages in shortening operative time, decreasing postoperative hematuria, promoting recovery and reducing hospital cost. In ERAS group, experienced assistant used a 50ml syringe for saline infusion by hands instead of irrigation pump during FURSL procedure , which contributed to flexibly control the infusion speed and timing. We believe that such measure can be beneficial to shorten operative time and be more effective in avoiding the risk of kidney injury or infection caused by excessive intrarenal pressure.

The increase of hydrostatic pressure in the renal collecting system caused by fluids infusion during ureteroscopy may result in harmful effects at the early term [13]. Intraoperative renal pelvic pressure may increase substantially, which is related to the irrigation pressure [14]. Studies have shown that excessive intrarenal pressure may lead to serious infection, especially in patients with preoperative uncontrolled UTI who are prone to urosepsis [15-17]. In addition, continuous high pressure in renal pelvis may also lead to renal injury or even hematoma [18]. The ureteral access sheath in place may drain the majority of fluids to maintain a low intrarenal pressure in FURSL procedure [19]. The application of intelligent pressure-controlled devices may also be beneficial for maintenance of low pressure, which increases hospital costs for patients [20, 21]. In this study, the 12/14F ureteral access sheath was placed for great drainage effect. With the utilization of inexpensive artificial irrigation in which the irrigant could be timely adjusted for more suitable flow in ERAS group, the excessive intrarenal pelvic pressure was effectively avoided and that was conducive to the safety of surgery.

Studies have indicated that ERAS intervention could alleviate the postoperative stress response in patients and accelerate the recovery [22-24]. This trial has the similar conclusion. The severity of postoperative hematuria in ERAS group was lower than that in control group, which may be related to a milder stress response. Although the patients started ambulating out of bed early, the incidence of severe hematuria was not increased in ERAS group. Shorter postoperative hospital stays were also a reason for lower total hospital costs, which may improve patients' satisfaction.

Through this study, we believe that the key to implement ERAS measures during the perioperative period of FURSL is to change some traditional and backward medical concepts. A few medical staff, patients and their families are convinced of some traditional concepts which are currently out of date in China, such as long-term fasting before surgery, preoperative bowel preparation, postoperative oral intake after the recovering of gastrointestinal function, lying without pillow for 6 hours or even more after surgery, rare mobilization out of bed, long-term indwelling catheter, excessive infusion and antibiotic treatment. Actually, many traditional concepts lack the support of evidence-based medicine. For example, in early stage of endoscopic surgery, catheter was retained for 3 days after ureteroscopic lithotripsy, and double-J stent was indwelt for 4 weeks before FURSL. Such seemingly safe measures increase the risk of postoperative local infection, deep vein thrombosis, backache and urination discomfort. It is reported that the appropriate amount of carbohydrate drinks and shortening the fasting time before surgery may alleviate the patients' thirst, hunger, nervousness and other discomfort, which have a positive effect on patients during and after surgery [10]. For patients without ureteral stricture, preoperative double-J stent may not ensure successful placement of the ureteral access sheath and complete removal of stones by FURSL [25]. We believe that preoperative bowel preparation are mainly suitable for patients who will undergo colorectal surgery, and enema may cause complications such as pain, bleeding and infection, especially in patients with hemorrhoids or the elderly. If the ureter is unobstructed by imaging suggestion or patients with a history of ureteroscopy, in our opinion, short-term placement of double-J stent or preparation without stent before FURSL procedure deserve to be tried. In this study, there was no preoperative bowel preparation for patients in ERAS group. Those without diabetes mellitus had a carbohydrate drink (250-400 ml, 10% glucose injection) 2 hours before surgery. And preoperative placement of the stent for 0-2 weeks is a measure of ERAS. We observed that these measures significantly relieved the negative mood, particularly in patients who were waiting for surgery in order, which did not increase the postoperative gastrointestinal discomfort and complications. Discomfort caused by the stent and lower urinary tract symptoms associated with the stent were also reduced in ERAS group.

As a retrospective trial, this study has some limitations. The ERAS program adopted was changed after referring to the colorectal surgery field, rather than the standard ERAS protocol. Some measures such as nutritionist participation, pain score and multimodal analgesia were not strictly implemented. More prospective randomized controlled trials with further optimized ERAS protocol for FURSL are needed in future.

Conclusions

The results of this trial demonstrate that the intervention of ERAS measures can shorten operative time, accelerate postoperative recovery and reduce the total hospital cost of patients with FURSL surgery. We not only ameliorated the traditional measures in perioperative period of FURSL from the aspects of patients' diet, bowel preparation, anesthesia, infusion, etc., but also strengthened the communication with anesthetists, nurses and other specialists related to comorbidities. Then the individualized ERAS measures were developed and implemented to achieve the purpose of rapid rehabilitation after surgery in the study. In conclusion, our trial indicates that FURSL based on the concept of ERAS is safe and reliable with excellent clinical results,and the ERAS program is worthy of application.

List of abbreviations

flexible ureteroscopic lithotripsy (FURSL)

enhanced recovery after surgery (ERAS)

kidney-ureter-bladder (KUB)

computed tomography (CT)

intravenous pyelography (IVP)

magnetic resonance urography (MRU)

computed tomography urography (CTU)

extracorporeal shockwave lithotripsy (SWL)

percutaneous nephrolithotomy (PCNL)

urinary tract infection (UTI)

Ethics approval and consent to participate

The research was approved by the Research Ethics Committee of The First Affiliated Hospital of Wannan Medical College. Informed consents were obtained from the participants. The leader of The First Affiliated Hospital of Wannan Medical College and the ethics committees made an agreement on this research and approved this consent procedure.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

PA, ZZ, DZ, CD, HH, AND ZW analyzed and interpreted the patient data. LS was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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