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Research Article
Flexible Ureteroscopic Holmium Laser Lithotripsy vs Percutaneous Nephrolithotomy for Renal Stones

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Abstract

Background and Objective: The incidence of kidney stones has been increasing in recent years. Percutaneous nephrolithotomy and flexible ureteroscopic holmium laser lithotripsy are common lithotripsy procedures. This study aimed to analyze the differences in the effects of flexible ureteroscopic holmium laser lithotripsy and percutaneous nephrolithotomy for the treatment of kidney stones, as a way to explore the best treatment plan. **Materials and Methods:** Clinical data of 95 patients with kidney stones admitted to our hospital from May, 2020 to September, 2022 were retrospectively selected and divided into two groups according to different treatment methods, 45 cases in the control group and 50 cases in the study group. The control group underwent percutaneous nephrolithotomy and the study group received flexible ureteroscopic holmium laser lithotripsy and the differences in indexes between the two groups after applying different surgical treatments were compared. **Results:** The study group had longer operation time, less intraoperative bleeding, shorter length of stay and higher treatment cost than the control group ($p<0.05$). After surgery, the CRP, IL-6, WBC counts, BUN, Scr and CysC in the study group were lower compared with the control group ($p<0.05$). After surgery, the GQOLI-74 scores in the study group were higher compared with the control group ($p<0.05$), but no significant difference was observed in the IIEF -5 and CIPE scores between two groups ($p>0.05$). **Conclusion:** Flexible ureteroscopic holmium laser lithotripsy and holmium laser lithotripsy with percutaneous nephrolithoscopy are both effective in kidney stone extraction, but holmium laser lithotripsy with flexible ureterorenoscopy has the advantages of less trauma, faster recovery and higher safety, but the treatment cost is relatively high and the appropriate procedure can be determined according to the actual condition of patients.

Key words: Holmium laser lithotripsy, flexible ureterorenoscopy, percutaneous nephrolithotomy, kidney stones, quality of life

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

There are many factors that affect how stones develop. Crystalline substances will become supersaturated when their solubility in urine is diminished or their concentration is too high, which will lead to precipitation and aggregation of crystalline chemicals in the kidney and finally the development of kidney stones[1]. With the improvement of quality of life, the incidence of kidney stones has increased, with men having a significantly higher risk of developing them than women. The symptoms of the disease are influenced by factors such as the location of stone formation, size, shape, infection and obstruction, among which lumbar and abdominal pain, renal colic, hematuria, nausea and abdominal distension are common symptoms that can have a serious impact on the patients' quality of life[2,3]. Renal colic, hematuria and other symptoms are frequently associated with kidney stones and in severe cases, problems including urinary sepsis and hydronephrosis can also develop. These complications should be treated as soon as they show up.

There are surgical treatment options for kidney stones and open surgery has a high stone removal rate, but it can cause more postoperative complications, produce greater surgical trauma and have an unremarkable prognosis. Minimally invasive techniques have gradually replaced traditional open stone extraction due to the advancement and development of medical science, among which holmium laser lithotripsy with flexible ureterorenoscopy and holmium laser lithotripsy with percutaneous nephrolithotomy are common stone extraction procedures[4]. Percutaneous nephrolithotomy provides the benefits of high stone removal rates, minimal trauma and quick postoperative recovery, but a follow-up study revealed that this procedure has a high surgical risk since it can significantly compromise patients' renal function. Holmium laser lithotripsy with ureteroscopy is a procedure that is performed through body orifices without significant damage to the body tissues. This treatment option is widely employed, particularly in the management of big kidney stones, with high benefits, low intraoperative bleeding and quick postoperative recovery. This is due to the accumulation of operating experience and updated technology. This study explored the effect of different surgical procedures and their effects on the treatment of kidney stones.

MATERIALS AND METHODS

General data: Clinical data of 95 patients with kidney stones admitted to The First Affiliated Hospital of Nanjing Medical University from May, 2020 to September, 2022 were according to different treatment methods, 45 cases in the control group (percutaneous nephrolithotomy) and 50 cases in the study group (flexible ureteroscopic holmium laser lithotripsy) and all patients were male. The study group aged 24-63 years, mean (43.64±4.74) years, stone diameter 1.44-2.95 cm, mean (2.09±0.42) cm; stone location: 8 cases in the lower renal calyces, 25 cases in the renal pelvis, 4 cases in the middle renal calyces and 8 cases in the upper renal calyces; the control group aged 22-64 years, mean (44.02±4.84) years, stone diameter 1.38-2.99 cm, mean (2.07±0.45) cm; stone locations: 10 cases in the infrarenal calyces, 26 cases in the renal pelvis, 6 cases in the middle renal calyces and 8 cases in renal calyces; general data of the two groups were comparable ($p>0.05$).

Inclusion criteria: (1) Kidney stones diagnosed by imaging, (2) Stones <3 cm and single stones and (3) No contraindications to surgery.

Exclusion criteria: (1) Substantial lesions of vital organs, (2) Incomplete case data, (3) Mental disorders and (4) Urinary tract infections or lesions.

Methods

Control group: Routine preoperative preparation, anesthesia method: Epidural anesthesia, position: Bladder lithotomy position; insert the F5 catheter retrogradely with the assistance of cystoscope, then change the patient's position to prone position and raise the affected kidney area to an angle of 30-45°, inject an appropriate amount of normal saline to complete the establishment of artificial hydronephrosis, observe the stones and kidney conditions under B-scan ultrasound and perform the puncture of the target renal calices under the guidance of ultrasound until urine flow is observed, then insert the zebra guide wire, percutaneously expand the renal channel and use it as a stone extraction channel. Holmium laser lithotripsy was performed, saline was continuously instilled, small lithotripsy flowed out through the channel and large lithotripsy was removed with the aid of forceps and double J tubes and nephrostomy tubes are indwelled after the operation.

In study group, the double-J tube was prepositioned on the affected side of the patient 3-4 weeks before surgery, anesthesia: General anesthesia, position: Cystotomy position and the double-J tube was removed during surgery. The ureteral rigidoscope was placed into the bladder via the urethra, the ureter was probed and dilated and after completion, the zebra guide wire was left in the renal pelvis area and the rigidoscope was withdrawn. The ureteral guide

sheath was placed, the soft ureteroscope was inserted along the guidewire to observe the stone. Holmium laser lithotripsy was performed, saline was continuously instilled, small stones flowed out through the channel, large stones were assisted to be removed and double J tubes were left in place.

The two groups received routine anti-infection treatment after surgery and the double J tube was removed according to the situation after postoperative 4th-8th week re-examination.

Outcome measurement

Comparison of operation time: The duration of different stone removal operations including upper calyx, middle calyx, lower calyx and renal pelvis position were recorded separately.

Comparison of surgical indicators: Including intraoperative bleeding, hospital stay and treatment cost.

Stone removal rate: Residual stones >3 mm in diameter by KUB examination were not removed[5].

Comparison of inflammatory factors: The C-Reactive Protein (CRP), Interleukin-6 (IL-6) and White Blood Cell count (WBC), 3 mL of peripheral elbow venous blood was collected before and 3 days after surgery and CRP was determined by immunoturbidimetric method, IL-6 by Enzyme-Linked Immunosorbent Assay (ELISA) and WBC by fully automated analyzer[6].

Renal function: Preoperative and 3 days postoperative serum Cystatin C (CysC), blood creatinine (Scr) and cysteine proteinase inhibitor C (CysC) levels were determined by fully automated analyzer[7].

Sexual function: International Index of Erectile Function (IIEF-5) and Chinese Index of Premature Ejaculation-5 (CIPE) were performed before and 3 months after surgery to assess sexual function, where IIEF-5 scored 0-25 and CIPE scored 0-50 and the scores were directly proportional to sexual function[8].

Comparison of complications: The occurrence of postoperative complications was recorded.

Quality of life: The Generic Quality of Life Inventory-74 (GQOLI-74) was performed preoperatively and 1 month postoperatively and the scores were positively correlated with quality of life.

Statistical analysis: The data were processed by SPSS25.0 software package, the measurement data was represented by ($\bar{\chi}\pm s$) and the t test was used, the count data was represented by n (%) and the χ^2 test was used and $p<0.05$ indicated that the difference was statistically significant. GraphPad Prism8 was adopted as the graphics software.

Ethical consideration

Ethical approval: This study was approved by the Medical Ethics Committee of The First Affiliated Hospital of Nanjing Medical University.

Statement of human and animal rights: All procedures in this study were conducted in accordance with the Declaration of Helsinki.

Statement of informed consent: Informed consent for patient information to be published in this article was not obtained because this is a retrospective study.

RESULTS

Comparison of operation time: There was no significant difference between two groups in the operation time of upper calyx, middle calyx and renal pelvis stones ($p>0.05$), but the operation time of lower calyx stones was longer in the study group compared with the control group ($p<0.05$) (Table 1).

Comparison of surgical indicators: Compared with the control group, the study group had less intraoperative bleeding, shorter hospital stay and higher treatment cost ($p<0.05$) (Table 2).

Comparison of stone removal rate: The total stone removal rate was 95.56 and 94.00% in the control group and study group, respectively ($p>0.05$) (Table 3).

Comparison of inflammatory factors: There was no significant difference in the comparison of inflammatory factors between the two groups before surgery ($p>0.05$) and the CRP (Fig. 1a-b), IL-6 (Fig. 1c-d) and WBC counts (Fig. 1e-f) were elevated in both groups after surgery and the levels were lower in the study group compared with the control group ($p<0.05$) (Fig. 1).

Comparison of renal function: There was no significant difference in renal function between two groups before surgery ($p>0.05$) and the levels of BUN (Fig. 2a-b), Scr (Fig. 2c-d) and CysC (Fig. 2e-f) were elevated in both groups after surgery and the levels were lower in the study group com pared with the control group ($p<0.05$) (Fig. 2).

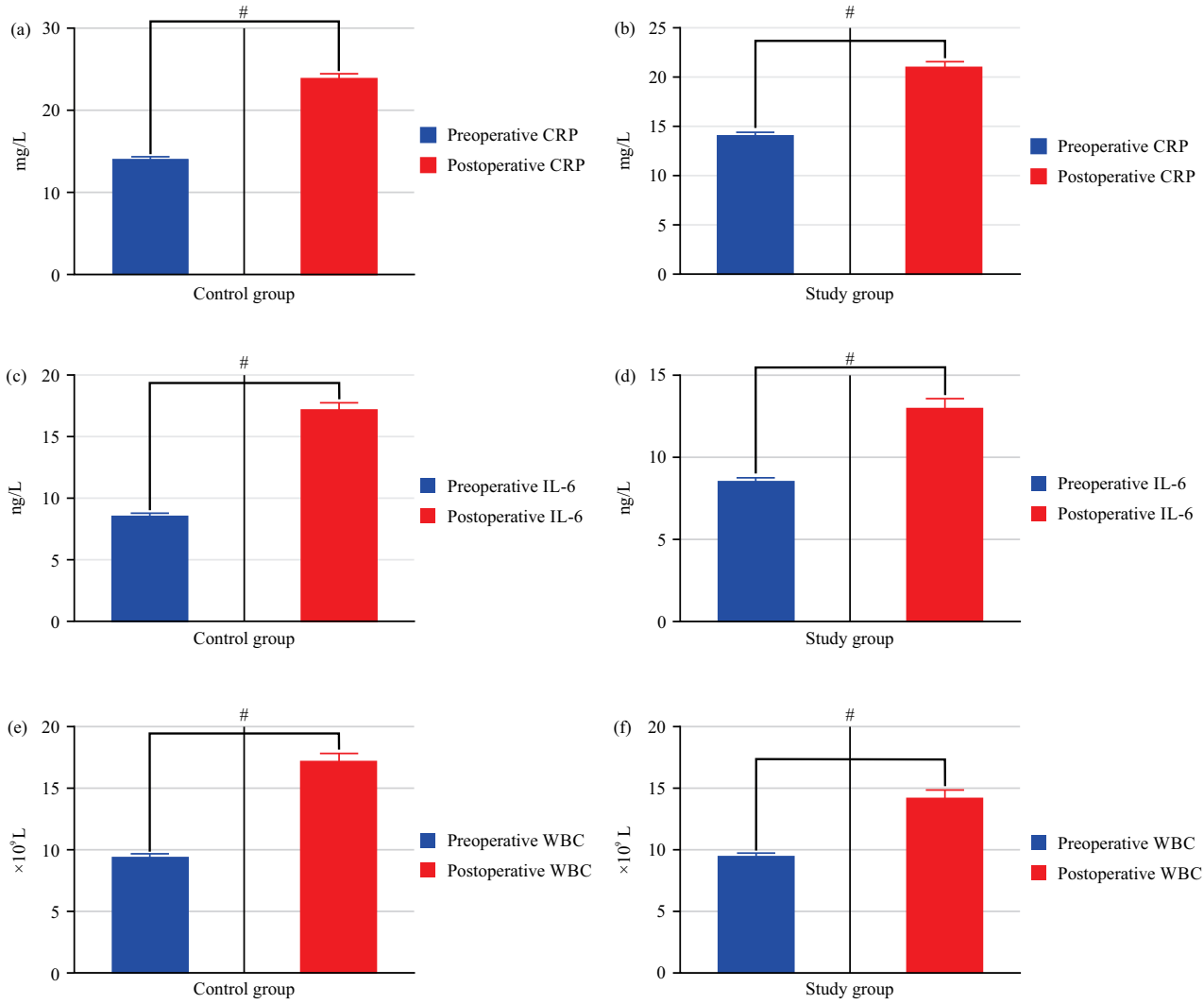

Fig. 1(a-f): Comparison of inflammatory factors

Ratio of CRP, IL-6 and WBC counts before and after treatment in the same group, #p<0.05 and the difference is statistically significant

Table 1: Comparison of surgical indicators ($\bar{\chi}\pm s$)

Group	Number of cases	Upper calyx stones	Middle calyx stones	Inferior calyx stones	Renal pelvic stones
Control group	45	61.13±10.84	58.46±14.06	55.25±10.56	52.78±10.56
Study group	50	66.84±12.84	64.25±15.63	76.84±14.46	57.57±8.95
t test	/	1.357	1.847	21.957	1.258
p-value	/	0.657	0.000	0.572	0.095

Table 2: Comparison of surgical indexes ($\bar{\chi}\pm s$)

Group	Number of cases	Operative time (d)	Intraoperative bleeding (mL)	Length of hospitalization (d)	Treatment cost (yuan)
Control group	45	53.06±5.85	50.46±5.19	7.46±0.88	19674.46±5408.45
Study group	50	63.66±7.02	28.97±4.08	4.63±0.54	41057.24±7894.35
t test	/	7.945	22.548	19.099	15.232
p-value	/	0.000	0.000	0.000	0.000

Table 3: Comparison of stone removal rate (cases, %)

Group	Number of cases	Stone diameter >2 cm	Stone diameter ≤2 cm	Total stone removal rate
Control group	45	95.00 (19/20)	96.00 (24/25)	95.56
Study group	50	95.65 22/23	92.59 25/27	94.00
χ^2 test	/	0.000	0.008	0.115
p-value	/	0.988	0.928	0.735

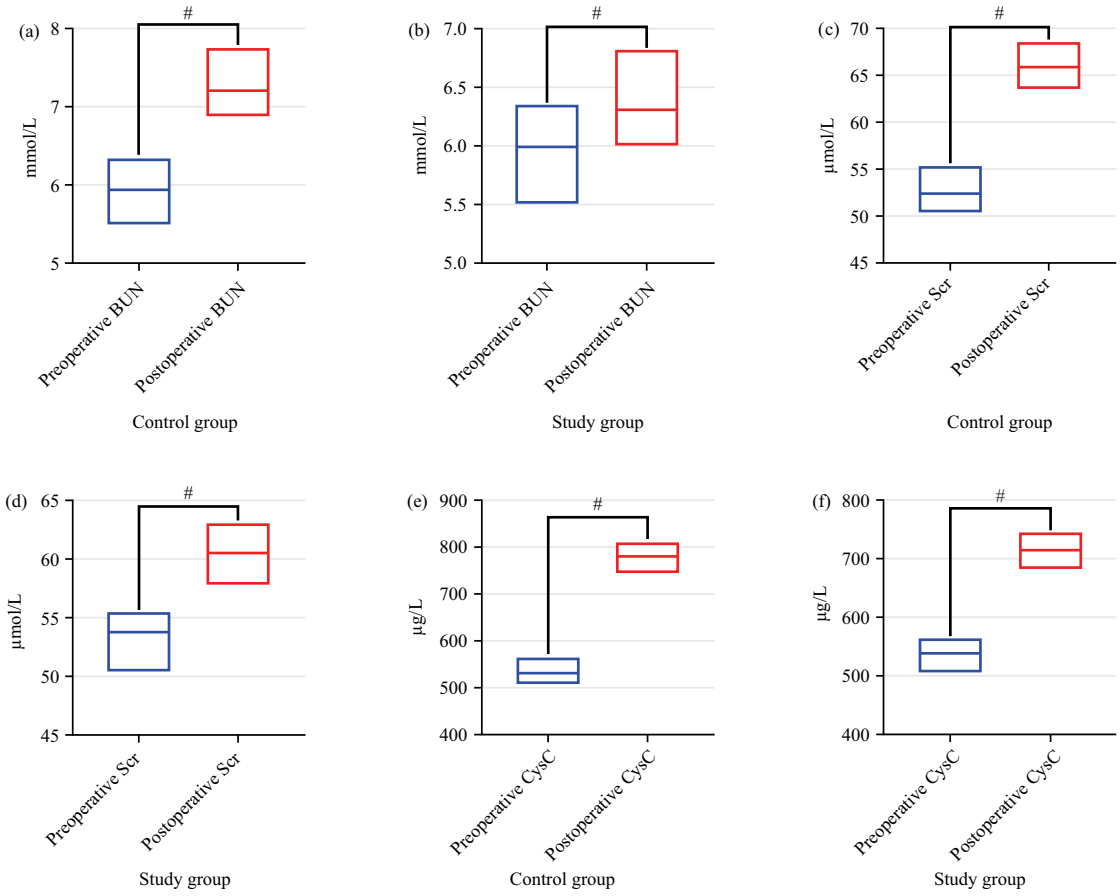

Fig. 2(a-f): Comparison of renal function

Ratio of BUN, Scr, CysC levels before and after treatment in the same group, #p<0.05 and the difference is statistically significant

Sexual function: There was no significant difference in sexual function between the two groups before surgery (p>0.05) and the IIEF-5 (Fig. 3a-b) and CIPE (Fig. 3c-d) scores increased in both groups after surgery, but there was no significant difference between two groups (p>0.05) (Fig. 3).

Complications: The incidence of complications in the control group and the study group were 28.89 and 4.00%, incidence of complications in the study group (Fig. 4b) was lower and the difference was statistically significant (p<0.05) (Fig. 4).

Comparison of quality of life: There was no significant difference in the quality of life between the two groups before surgery (p>0.05) and the GQOLI-74 scores increased in both groups after surgery and the study group had higher scores compared with the control group (p<0.05) (Table 4).

DISCUSSION

Even though kidney stones are a benign condition, it is nevertheless important to treat them properly. Kidney stones can, to a certain extent, obstruct the urinary tract, which can then result in insufficient urinary drainage and may result in complications like urinary tract infection, pain, hydronephrosis and uremia. As a result, treatment for kidney stones is currently receiving a lot of attention[9]. Kidney stones are commonly treated with surgery, including both open and minimally invasive procedures. With the advancement of medical care, minimally invasive stone extraction has proved successful in removing stones with a high rate while minimizing tissue stress. However, there are various procedures for minimally invasive surgery, which commonly include holmium laser lithotripsy with flexible ureterorenoscopy and holmium laser lithotripsy with percutaneous nephrolithotomy[10-12]. Percutaneous holmium laser lithotripsy is performed by puncturing the patient's

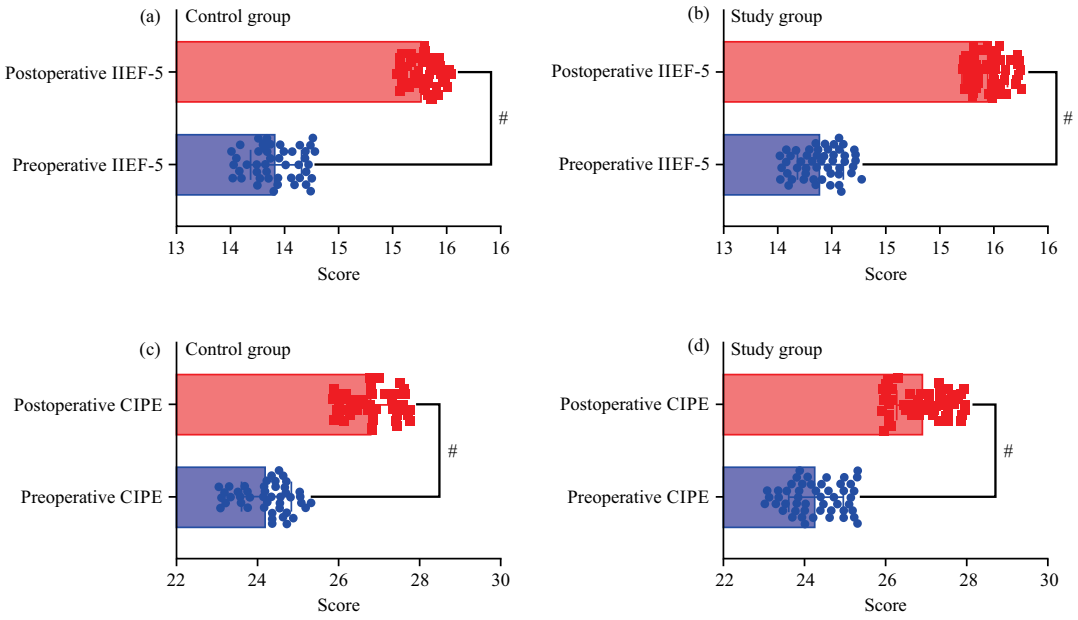

Fig. 3(a-d): Comparison of sexual function

Ratio of IIEF-5 and CIPE scores before and after treatment in the same group, #p<0.05 and the difference is statistically significant

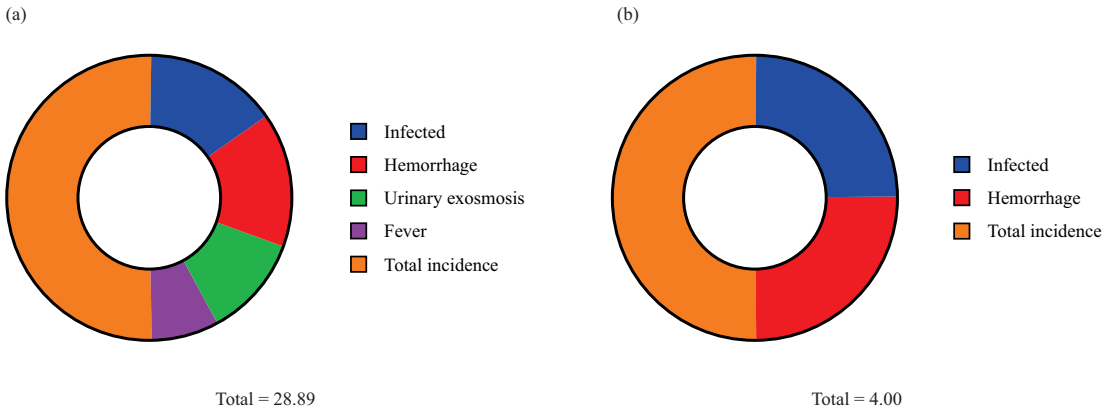

Fig. 4(a-b): Comparison of complication rates, (a) Control group and (b) Study group

Table 4: Comparison of quality of life (score, $\bar{\chi}\pm s$)

Group	Number of cases	Preoperative	Postoperative
Control group	45	148.95±15.99	198.84±25.57
Study group	50	149.02±17.34	255.78±21.84
t test	/	0.020	11.703
p-value	/	0.984	0.000

lumbar region and establishing a 1 cm channel which can directly reach the kidney, after which the nephroscope is placed in the kidney to observe the stone and the stone is crushed under the right and left of holmium excitation and the crushed stone can be discharged through the channel established in the lumbar region[13]. The insertion of the mirror body into the urethra is referred to as flexible ureteroscopic holmium laser lithotripsy. No incision is performed on the patient's body; the stones are simply removed through the natural cavity. It is a minimally invasive, "non-invasive", procedure. Due to the lack of water availability, the tiny working channel and the hazy field of view, early flexible ureteroscopy was restricted. Flexible ureteroscopy holmium laser lithotripsy has grown less intrusive in recent years

associated support equipment. Studies have shown that flexible ureterorenoscopy combined with holmium laser lithotripsy is less common and less effective than percutaneous nephrolithotomy for individuals with stones larger than 2 cm in diameter[14,15]. The results of the present study showed no significant difference in stone removal rate between two groups, suggesting that both procedures are more effective in removing kidney stones. The increased stone removal rate of holmium laser lithotripsy with flexible ureterorenoscopy is directly tied to the ongoing development of lithotripsy equipment and it is anticipated that as technology advances, the benefits of this operation will continue to grow.

Surgery is invasive and inflammatory damage cannot be avoided, which will continuously produce CRP to counteract this inflammatory damage and activate complement to improve phagocytosis[16]. The CRP is an acute phase protein, which is a sensitive inflammatory index in the early stage. While IL-6 is a pro-inflammatory factor, the body stimulates inflammatory cells to continuously secrete IL-6 following injury and it can induce the production of CRP and aggravate the inflammatory response[17]. The examination of postoperative changes in CRP, IL-6 and WBC counts can indicate to some extent the extent of damage produced by surgery because the rise of WBC is prevalent in infections, tissue injury and after surgery. In kidney stone extraction, attention should be paid to the protection of kidney function. Among them, SCr, BUN and CysC are commonly indicators for the assessment of renal function injury[18]. The results of the present study showed that the postoperative SCr, BUN, CysC, CRP, IL-6 and WBC indexes altered less in the study group compared to the preoperative ones, suggesting that flexible ureteroscopy holmium laser lithotripsy can reduce the damage to renal function, which minimize the inflammatory response. The reason may be that holmium laser lithotripsy with percutaneous nephrolithotomy requires percutaneous puncture and dilation of the renal parenchyma and damage to the kidney cannot be avoided when the stone extraction channel is established in this way[19]. In flexible ureteroscope holmium laser lithotripsy, the flexible ureteroscope is placed through the natural orifice and the mirror body is soft and the head can be bent at 180°. With the assistance of it, the operative field can be seen directly and the renal calyces and renal pelvis can be easily reached, greatly reducing the expansion of the kidney[16,20]. It was found that the postoperative complication rate was low in the study group and the reason for this may be related to the low damage caused by flexible ureteroscopy holmium laser lithotripsy. In a study, 68 patients with kidney stones were enrolled and treated with holmium laser lithotripsy (study group) and percutaneous nephrolithotomy (control group) and the results showed that there was no significant difference in stone removal rate between the two groups and the postoperative BUN, Scr and CysC levels were lower in the study group than in control group, which was consistent with the findings of this study.

In modern medical theory, it is stated that there is no direct relationship between kidney stones and sexual function, but in Chinese medical theory, it is believed that there is a close relationship between kidney and sexual function directly and the occurrence of kidney stones can affect sexual function to some extent[21]. The results of this study showed that sexual function improved in both groups after surgery, but there was no significant difference between the two groups. This suggests that the occurrence of kidney stones may affect sexual function and that sexual function can be restored after stone removal in two groups. It was found that the postoperative quality of life was higher in the study group. Flexible ureteroscopic holmium laser lithotripsy has the following advantages: (1) High safety, no thermal effect, which can effectively avoid damage to the surrounding tissues[22], (2) Procedure is less painful and uses natural orifice without puncture, incision and reduces pain, (3) Clear operative field, the head of the flexible mirror can be freely bent 180°, which facilitates multi-directional observation of the stone and kidney[23], (4) No damage to the renal papilla, which allows multiple stone extraction operations and (5) Holmium laser can crush all types of stones and there are few postoperative complications, leading to fast recovery. However, it also has some disadvantages. The price of flexible ureteroscope is relatively expensive and it is relatively easy to damage, which also leads to higher treatment costs[24].

The results of this study showed that the operation time of removing the lower calyx stone was longer in the study group and the reason for this was related to the specificity of the location of the stone in the lower calyx, when the stone was located in the lower calyx with a pelvic funnel angle <30°, this would become a blind area in the operative field and make the operation more difficult, so it would increase the operation time. Since the diameter of the holmium laser fiber is only 200 μm, lithotripsy is usually performed in a high-frequency and low-energy mode. The limited lithotripsy energy results in a low amount of lithotripsy at one time, coupled with factors such as a narrow operative field and a low range, resulting in a longer operation time for removal of lower calyceal stones. According to studies, the angle of the infundibulum of the renal pelvis is a separate risk factor that affects the success rate of the procedure, operating time and stone clearance rate in flexible ureteroscopic holmium laser

lithotripsy. At the same time, stone recurrence will rise as a result of long-term fragment retention. As a result, it's essential to continuously wash the crushed stones with isotonic solution during the procedure to ensure a clean surgical field. Therefore, the patient's condition should be evaluated in the later stages of treatment, especially in patients with lower calyceal stones and a more appropriate surgical plan should be selected. There are still many shortcomings in this study, such as the small number of samples and indicators and the short follow-up period, which may lead to some bias in the experimental data. The stones in this study were less than 3 cm, but whether it can replace holmium laser lithotripsy by percutaneous nephrolithotomy needs to be further investigated, so the above issues should be improved to improve the accuracy of the experimental data.

CONCLUSION

Flexible ureteroscopy holmium laser lithotripsy and percutaneous nephroscopic holmium laser lithotripsy have a good effect on the removal of kidney stones, but flexible ureteroscopy holmium laser lithotripsy has the advantages of less trauma, faster recovery and high safety, but the cost of treatment is relatively high and the operation time for lower calyceal calculus is relatively long, so the appropriate operation options can be selected according to the actual condition of the patient. At the same time, it still needs to be further explored whether it can completely replace holmium laser lithotripsy by percutaneous nephrolithotomy.

SIGNIFICANCE STATEMENT

The incidence of kidney stones has increased in recent years and surgery is one of the efficacious therapeutic modalities. Several studies have confirmed that percutaneous nephrolithotomy for treating kidney stones exhibits notable drawbacks, including significant trauma, prolonged postoperative recovery periods and high incidence of complications. In this study, it was found that flexible ureteroscopic holmium laser lithotripsy has the advantages of lower invasiveness, faster recovery and higher safety compared with percutaneous nephrolithotomy. This research can provide more references of surgical procedures for patients undergoing kidney stone surgery.

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