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ORIGINAL RESEARCH

Comparison of the effects of different lithotripsy protocols under ureteroscope on ureteral calculi and their effects on stress status and renal function of patients

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Abstract

In order to explore the therapeutic effect of holmium laser and pneumatic lithotripsy on ureteric stones, as well as their effects on stress status and renal function, 100 patients with ureteral calculi admitted to the hospital from January 2021 to January 2023 were selected into a pneumatic lithotripsy group (n = 50) and a holmium laser lithotripsy group (n = 50). The results showed that Holmium laser lithotripsy had a significantly higher primary lithotripsy success rate (92.00%) than pneumatic lithotripsy (76.00%) ($p < 0.05$). However, a slightly higher postoperative stone clearance rate was observed in the pneumatic lithotripsy group with no significant differences between both groups. Significantly shorter operation time and average hospital stays were observed in the holmium laser lithotripsy group than in the pneumatic lithotripsy group. 3 days after surgery, C-reactive protein (CRP) and interleukin-6 (IL-6) levels in the holmium laser lithotripsy group were evidently lower than the pneumatic lithotripsy group. Holmium laser lithotripsy produced significantly lower malondialdehyde (MDA) levels ($p < 0.05$) and significantly higher superoxide dismutase (SOD) levels than pneumatic lithotripsy ($p < 0.05$). Both groups had similar preoperative renal function indexes (serum creatinine (Scr) and blood urea nitrogen (BUN)) ($p > 0.05$). Lastly, holmium laser lithotripsy had a considerably lower incidence of complications at 6.00% than pneumatic lithotripsy at 26.00% ($p < 0.05$). The results indicate that, compared with pneumatic ballistic lithotripsy, holmium laser lithotripsy can effectively improve the lithotripsy effect of ureteral stones, shorten the operation and hospitalization time, effectively reduce the inflammatory and oxidative stress status of the body, and effectively reduce the risk of postoperative complications.

Keywords

Ureteral calculi; Pneumatic lithotripsy; Holmium laser lithotripsy; Lithotripsy effect

1. Introduction

Ureteral calculi are very common diseases in urology, mainly affecting male populations south of the Yangtze River and coastal areas. The disease has also been growing in the north year by year in recent years [1]. There is a high risk of this disease among people aged 20 to 40 years with more males than females. In most cases, this disease is accompanied by low back pain, hematuria, lower abdominal pain, and renal colic [2, 3]. Patients' ureter stones should be treated according to their size. Studies have found that stones are $\leq$5 mm in diameter, and even without no drug intervention, self-exclusion rates are very high. A medical expulsive treatment can be chosen for patients with stones of 5–10 mm, such as α-blockers and calcium channel antagonists in western medicine, or traditional Chinese medicine syndrome differentiation treatment. If stones are large, surgical stone extraction is required [4]. Clinical ureteral stones are mainly treated with holmium laser lithotripsy. It converts the energy into vapor, which forms tiny vacuoles, which are transferred to the stone and smash it into powder. Water absorbs a large amount of energy and reduces the damage to the surrounding tissue. At the same time, holmium laser penetration into human tissues is shallow, only 0.4 mm. The lithotripsy technique can therefore create minimal damage to the surrounding tissues and is highly safe, and is widely used in clinical practice [5]. Barometric ballistic lithotripsy is a method that uses the energy produced by compressed air to push the bullet body in the gravel handle, and transfers the energy to the probe in the trajectory. The probe head repeatedly impacts the stone. By exceeding the stone tension, the energy causes the stone to disintegrate and achieve the purpose of lithotripsy. There is still controversy about the clinical effects of holmium laser lithotripsy and pneumatic lithotripsy in ureteral calculi surgery, especially when it comes to triggering the body stress state [6]. Therefore, this study compares the lithotripsy effects of the two groups, particularly the effects of the two lithotripsy protocols on inflammatory stress, oxidative stress and renal function.

2. General data and methods

2.1 Clinical data

100 patients with ureteral calculi admitted to our hospital between January 2021 to January 2023 were selected and randomly divided into a pneumatic lithotripsy group (n = 50) and a holmium laser lithotripsy group (n = 50).

Inclusion criteria: (1) Meet the diagnostic criteria for ureteral calculi by imaging examination. (2) Stone diameter of 1 to 2 cm. (3) No surgery history and planned surgical treatment. (4) Complete clinical data. (5) Signed informed consent.

Exclusion criteria: (1) Aged under 18. (2) Uncontrollable systemic bleeding disorders, severe cardiopulmonary (or cardiovascular function) insufficiency. (3) Unable to tolerate surgical treatment. (4) Urinary tract infection, severe urethral stricture or ureteral malformations, or severe kidney stones in addition to ureteral calculi, preoperative urinary tract infection not effectively controlled. The study complied with the standards of hospital ethics committee and was performed after obtaining the study permission.

2.2 Study methods

Devices and equipment: ureteroscope (German Richard-Wolf Wolf 7326071, Baoshan District, Shanghai, China), high frequency holmium laser machine (Lumenis Pulse 50H, Medical Laser Equipment Trading (Beijing) Co., LTD., Beijing, China), pneumatic ballistic lithotomy machine, holmium laser fiber (Medical Laser Equipment Trading (Beijing) Co., LTD., Beijing, China) 200 μm, disposable ureter stent tube (788626, Bard Medical Technology Shanghai Co., Ltd., Shanghai, China).

Both groups received epidural anesthesia and were placed in a lithotomy position. Upon conventional draping disinfection, the affected ureter was inserted with a guide wire and ureteroscopy was performed, while a continuous flow of normal saline was administered. The same lithotripsy physician performed all procedures. The pneumatic lithotripsy group received pneumatic lithotripsy. An ureteroscope was swung to the stone location, and a pneumatic device was placed under direct vision to perform pneumatic lithotripsy. With a pneumatic lithotripter operating at 0.4 mPa, the stone suction diameter was $\leq$0.3 cm after lithotripsy. The stone forceps could be removed if the diameter was 0.3–0.5 cm. Patients in the holmium laser lithotripsy group received holmium laser lithotripsy and were also placed in a lithotomy position. Ureteroscopy was used in the same way as pneumatic lithotripsy. The difference was that the holmium laser fiber was effectively introduced through the ureteroscopic channel, and the holmium laser lithotripter was used. The parameters were set. Power: 25 W, lithotripsy energy: 0.21–1.5 J, frequency: 10–15 Hz, and lithotripsy diameter: 0.2–0.3 cm. After surgery, both groups were examined by a ureteroscope to observe whether there were residual stones. The ureteroscope was withdrawn if no residual stones were found after lithotripsy. A ureteral stent (double-J tube) was placed along the guide wire under direct vision for approximately 2 weeks to ensure ureteral patency. Generally, the indwelling catheter is removed after 1–3 days, and conventional antibiotics are given for 1–3 days for anti-infection after surgery.

2.3 Outcome measures

2.3.1 Comparison of lithotripsy effect

In both groups, abdominal plain films, ultrasonography and Computed Tomography (CT) for K.U.B (kidney, ureter and bladder) were performed 3 days after surgery. Evaluation criteria for primary lithotripsy success rate: Complete exclusion of stones was considered to be a marked response, while a few residual stones with a diameter $\leq$2.5 mm were considered moderate. Primary lithotripsy success rate was the sum of marked and moderate responses. Criteria for postoperative assessment of stone clearance: Urinary B-ultrasound or CT was reexamined 1 week after surgery. Imaging results could be judged without stones, low back pain or urinary irritation symptoms.

2.3.2 Comparison of operation time and hospital stay

Statistical analysis and comparison of operation time and hospital stay were carried out between both groups. In general, ureteral calculi surgery requires a hospital stay of 3 to 7 days. Physical condition and severity of illness determine the specific time frame.

2.3.3 Comparison of serological parameters

Fasting cubital venous blood sample was collected before treatment and in the morning 3 days after operation to determine the levels of serum inflammatory factors, oxidative stress factors and renal function-related parameters. Inflammatory factors include C-reactive protein (CRP) and interleukin-6 (IL-6). Oxidative stress involves malondialdehyde (MDA) and superoxide dismutase (SOD). Renal function includes serum creatinine (Scr) and blood urea nitrogen (BUN). Enzyme-linked immunosorbent assay was used to detect CRP, IL-6 and Scr. MDA was detected by thiobarbituric acid method, SOD by oxidase method, and BUN by micromethod kit. All Clinical laboratory results and detection processes were provided by our hospital. Normal range: CRP $<$5 mg/L IL-6: 0.373–0.463 pg/mL, MDA: (4.06 $\pm$ 0.6) nmol/mL, SOD: 129–216 pg/mL, Scr: 53–106 μmol/L (in men), 44–97 μmol/L (in women), 88.4–176.8 μmol/L (in whole blood), BUN: 3.2–7.1 mmol/L.

2.3.4 Comparison of complications

We analyzed and compared the incidence of perioperative complications such as ureteral injury, ureteral stricture and urinary system infection between both groups. Urinary system infection: The next day after surgery, patients were required to submit 50 mL of midstream urine within 2 hours to avoid urea decomposition by bacteria. It could be diagnosed when microscopic bacteria >1/field or urine bacterial culture count $\geq 10^5$/mL.

Personnel and inspectors involved in this study were all clinically experienced and skilled.

2.4 Statistical methods

After quantitative processing, all data were analyzed using Statistical Package Social Sciences (SPSS) Version 23.0 (IBM SPSS, Chicago, IL, USA). Enumeration data were expressed as the number of cases (percentage). Chi-square test was used for comparison. Measurement data were expressed as means. Independent t-test was used for comparison. $p < 0.05$ shows statistically significant difference.

3. Results

3.1 General data of patients

General data such as mean age, disease duration, stone diameter, and stone location did not differ significantly between both groups ($p > 0.05$) (Table 1).

3.2 Comparison of lithotripsy effect

Pneumatic lithotripsy group had a primary lithotripsy success rate of 76.0% (38/50), and a postoperative stone clearance rate of 86.00% (43/50). Holmium laser lithotripsy group had a primary lithotripsy success rate of 92.00% (46/50), and postoperative stone clearance rate of 96.00% (48/50). Holmium laser lithotripsy had a significantly higher success rate than pneumatic lithotripsy (χ^2 value = 4.762, p value = 0.029). However, a slightly higher postoperative stone clearance rate was observed in the pneumatic lithotripsy group with no significant differences between both groups (χ^2 value = 3.053, p value = 0.081).

3.3 Comparison of operation time and hospital stay

Significantly shorter operation time and average hospital stays were observed in the holmium laser lithotripsy group than in the pneumatic lithotripsy group ($p < 0.05$) (Table 2).

3.4 Comparison of inflammatory factor levels

Preoperative pneumatic lithotripsy and holmium laser lithotripsy did not differ significantly in the levels of inflammatory cytokines CRP and IL-6 ($p > 0.05$). Compared with the preoperative pneumatic lithotripsy group, the levels of both factors were differently elevated in the postoperative patients, while the levels of CRP and IL-6 were significantly lower in the holmium laser lithotripsy group than in the pneumatic lithotripsy group ($p < 0.05$) (Table 3).

3.5 Comparison of levels of oxidative stress hormone

Preoperative oxidative stress hormones levels (MDA and SOD) did not differ significantly between both groups ($p > 0.05$). Both groups showed an increase in MDA levels after surgery, while SOD levels decreased. Holmium laser lithotripsy produced significantly lower MDA levels ($p < 0.05$) and significantly higher SOD levels than pneumatic lithotripsy ($p < 0.05$) (Table 4).

3.6 Comparison of renal function index levels

Both groups had similar preoperative renal function indexes (Scr and BUN) ($p > 0.05$). The postoperative Scr and BUN of both groups were reduced, while the index levels of the holmium laser lithotripsy group were slightly lower than the pneumatic lithotripsy group, but there was no significant difference between both groups ($p > 0.05$) (Table 5).

3.7 Comparison of complications

1 patient developed ureteral stricture and 2 patients developed urinary tract infection after holmium laser lithotripsy. Holmium laser lithotripsy had a significantly lower incidence of complications at 6.00% ($p < 0.05$) (Table 6).

4. Discussion

In recent years, minimally invasive techniques have changed the clinical treatment of ureteral calculi has changed from traditional incisions to minimally invasive treatment. There has been a shift towards minimally invasive ureteroscopic lithotripsy as the treatment of ureteral calculi [7, 8]. Ureteral stones can be treated minimally invasively with pneumatic lithotripsy and holmium laser lithotripsy. A lithotripter is driven primarily by compressed gas, which drives the bullet body to impulse the stone and break it apart [9]. Holmium laser lithotripsy, on the other hand, uses the laser energy to transmit the energy to the stone, so that it is powdered and excreted with urine [10].

An assessment of the effect of lithotripsy on ureteral calculi requires not only clarification of the lithotripsy effect, but also comprehensive consideration of the physical stress response and complications that lithotripsy can cause [11]. This study suggest that the stone clearance rate was 86% in the pneumatic lithotripsy group and 96% in the holmium laser lithotripsy group. Despite no significant differences between the groups, the results still confirmed that both regimens were effective regimens for treating ureteral calculi, and holmium laser lithotripsy was significantly more successful than pneumatic lithotripsy in achieving primary lithotripsy. Compared with previous studies, our findings confirm that the high clearance of holmium laser lithotripsy, which be attributed to its precision lithotripsy and clear ureteroscopic [12]. Significantly shorter operation time and average hospital stays were observed in the holmium laser lithotripsy group than in the pneumatic lithotripsy group, revealing the efficiency and accuracy of the holmium laser lithotripsy program.

Serum inflammatory factors and body oxidative stress-related factors are important assessment indicators of surgical trauma in patients [13]. Minimally invasive surgery reduces inflammatory stress and oxidative stress more effectively than traditional lithotomy, which is beneficial for postoperative rehabilitation of patients [14]. Pneumatic lithotripsy and

TABLE 1. General data of 100 subjects.

Group	Case	Mean age (yr)	Mean disease duration (d)	Stone diameter (cm)	Stone location		
					Upper stones	Middle stones	Lower stones
Pneumatic lithotripsy group	50	48.13 ± 5.83	3.97 ± 0.31	1.45 ± 0.32	13	20	17
Holmium laser lithotripsy group	50	49.29 ± 6.05	4.07 ± 0.24	1.39 ± 0.33	11	19	20
t/χ^2		0.975	1.825	0.874		0.436	
p		0.332	0.071	0.384		0.804	

TABLE 2. Comparison of operation time and hospital stay ($\bar{x} \pm s$).

Group	Case	Operation time (min)	Hospital stay (d)
Pneumatic lithotripsy group	50	59.50 ± 9.03	4.97 ± 1.51
Holmium laser lithotripsy group	50	47.41 ± 8.38	4.01 ± 1.39
t value		6.943	3.321
p value		<0.001	0.001

TABLE 3. Comparison of inflammatory factor levels ($\bar{x} \pm s$).

Group	Case	CRP (mg/L)		IL-6 (pg/mL)	
		Before surgery	After surgery	Before surgery	After surgery
Pneumatic lithotripsy group	50	8.07 ± 2.82	15.45 ± 2.95	6.95 ± 1.09	13.21 ± 1.61
Holmium laser lithotripsy group	50	7.08 ± 4.16	11.00 ± 2.72	6.76 ± 0.91	10.19 ± 1.58
t value		1.405	7.501	0.932	9.461
p value		0.163	0.001	0.354	0.001

Note: CRP: C-reactive protein; IL-6: interleukin-6.

TABLE 4. Comparison of levels of oxidative stress hormone ($\bar{x} \pm s$).

Group	Case	MDA (nmol/mL)		SOD (pg/mL)	
		Before surgery	After surgery	Before surgery	After surgery
Pneumatic lithotripsy group	50	4.37 ± 0.75	12.12 ± 1.30	85.13 ± 4.22	59.72 ± 5.17
Holmium laser lithotripsy group	50	4.39 ± 0.78	8.68 ± 1.12	86.02 ± 5.03	68.00 ± 5.32
t value		0.146	14.193	0.951	7.901
p value		0.884	<0.001	0.344	<0.001

Note: MDA: malondialdehyde; SOD: superoxide dismutase.

TABLE 5. Comparison of renal function index levels ($\bar{x} \pm s$).

Group	Case	Scr (mol/L)		BUN (mmol/L)	
		Before surgery	After surgery	Before surgery	After surgery
Pneumatic lithotripsy group	50	216.83 ± 49.86	120.47 ± 36.92	10.49 ± 2.35	6.23 ± 2.66
Holmium laser lithotripsy group	50	217.25 ± 57.30	110.76 ± 33.07	10.33 ± 3.04	5.99 ± 1.72
t value		0.039	1.384	0.280	0.519
p value		0.969	0.169	0.780	0.605

Note: Scr: serum creatinine; BUN: blood urea nitrogen.

TABLE 6. Comparison of complications.

Group	Case	Ureteric perforation	Ureteric stricture	Urinary tract infection	Overall incidence
Pneumatic lithotripsy group	50	5 (10.00)	3 (6.00)	5 (10.00)	26.00%
Holmium laser lithotripsy group	50	0	1 (2.00)	2 (4.00)	6.00%
χ^2					7.44
p value					0.006

holmium laser lithotripsy however, are still controversial. To clarify the effects of the two regimens, we analyzed and compared inflammatory and oxidative stress factors before and after surgery. Both groups had significantly higher CRP, IL-6 and MDA levels than before operation. Holmium laser lithotripsy significantly reduced the levels of the three indicators compared with pneumatic lithotripsy. SOD levels in patients after surgery decreased compared to preoperative levels. However, the greater the decrease in SOD levels, the greater the rise in free radical levels, which may damage the body [15]. Holmium laser lithotripsy showed a significant downward trend of index level compared to pneumatic lithotripsy. According to the comparison results, both minimally invasive lithotripsy techniques caused some damage to patients, but holmium laser lithotripsy caused less damage. This may be because of the mechanism of holmium laser lithotripsy, which uses holmium laser that penetrate tissue to precisely locate and cut the tissue, causing minimal damage to surrounding tissues. This can reduce body stress response caused by minimally invasive surgery.

Whenever ureteral calculi form, they block the ureter and will negatively affect the patient's renal function. Having a blocked ureter will cause ureteral dilatation and hydronephrosis, since urine cannot be expelled from the kidney into the bladder. This damage be exacerbated with the presence of stones [16]. To investigate the effects of both lithotripsy procedures, this study also compared the changes in renal function indicators between both groups. After surgery, Scr and BUN of the patients were significantly decreased, indicating that both regimens contributed to restoring renal function. However, postoperative indicator levels did not differ significantly between both groups. A comparison of postoperative complications was also conducted between the two groups. Holmium laser lithotripsy induced significantly fewer complications than pneumatic lithotripsy, perhaps due to higher primary lithotripsy success rate in holmium laser lithotripsy. Pneumatic lithotripsy, on the other hand, has a large shock wave and can cause more damage to surrounding tissues.

5. Conclusions

In summary, holmium laser lithotripsy is more effective than pneumatic lithotripsy in primary lithotripsy, causes less damage to the patient, resulting in a lower degree of inflammatory and oxidative stress responses, thereby promoting renal function recovery with fewer complications and safety assurances. This study compares the lithotripsy effect of both regimens, especially in the degree of stress response. Ureteral calculi, however, is prone to recurrence. In this study, the number of samples and time constraints limited the investigation of the recurrence rate. The subsequent study will investigate in-depth content and explore further.

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

RJL—designed the study and carried them out. RJL and ZMC—prepared the manuscript for publication and reviewed the draft of the manuscript. RJL, ZMC, FBC, YLL, BMZ, YSQ and ZC—supervised the data collection. RJL, ZMC, FBC, YLL and BMZ—analyzed the data. RJL, ZMC and FBC—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 Wuzhou People's Hospital (Approval no. 2024035). 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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