Compare the Clinical Application of Ureteroscopic Occluder and Stone Retrieval Basket During Holmium Laser Treatment for Upper Ureteral Calculi

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Purpose: To explore the clinical efficacy of ureteroscopic occluder and stone retrieval basket combined with holmium laser in the treatment of upper ureteral calculi.

Materials and Methods: This retrospective study included 103 patients treated with ureteroscopic holmium laser lithotripsy for upper ureteral stones. Patients were divided into two groups based on the device applied during lithotripsy: group 1 for the occluders (52 cases), and group 2 for the stone retrieval baskets (51 cases). The stone upward migration rate, stone-free rate, and complication rate during or after surgery were compared.

Results: The operation time was 45 ± 7 min in the occluder group and 43 ± 5 min in the basket group (P = .111). There was no significant difference between the stone retropulsion rate (13% vs. 16%, P = .787). The successful one-time stone-free rate was 92% vs. 94% (P = .999) respectively. Furthermore, there was no significant difference in the hospitalization time (P = .581) and postoperative complication rate (P = .715) between 2 groups.

Conclusion: The treatment of upper ureteral calculi with ureteroscopic occluder and stone retrieval basket combined with holmium laser lithotripsy can both effectively prevent intraoperative stone retropulsion, improve the success rate of one-time lithotrips. The occluder was more cost-effective than the stone retrieval basket, yet it was a more desired choice for over dilated ureters.

Keywords: holmium laser lithotripsy; occluder; stone migration; stone retrieval basket; upper ureteral calculi

INTRODUCTION

Ureteral calculus is one of the most common urologic diseases worldwide and the prevalence is still growing. Ureteroscopic holmium laser lithotripsy (URL) is currently first-line therapy for ureteral stones[1] because of several favorable characteristics (i.e., low invasiveness, high stone-free rate, and relatively low risk of intra- and post-operative complications[2, 3]). However, there are still drawbacks when holmium laser lithotripsy is used alone in the setting of upper ureteral calculi, such as insufficient lithotripsy, low success rate (35% ~ 87%[4]) and upward migration of stone fragments[5]. With the emergence of a variety of auxiliary stone occlusion devices and stone retrieval baskets, more and more occlusion devices are being applied in the treatment of upper ureteral calculi, such as Stone cone[6], N-Trap[7], PercSys Accordion[8], Escape basket[9], INNOVEX TMIVX-SC10[10] and so forth. We treated 103 upper ureteral stone patients with holmium laser lithotripsy combined with either occluder or stone retrieval basket, both of which can effectively prevent the stone from migrating into the pelvis and improve stone-free rate.

PATIENTS AND METHODS

General Information

We reviewed a total of 103 upper ureteral calculi cases aged 19-82 years who underwent holmium laser lithotripsy combined with the occluder or the stone retrieval basket from Mar 2018 to Jan 2019. The diagnosis of upper ureteral calculi was confirmed by ultrasonography or direct X-ray plus CT scan in all cases. Upper ureteral calculi were defined as those located between the ureteropelvic junction and the upper ureter (the segment above the upper edge of the iliac crest). The maximum diameter on CT scan measured the size of the stones. If there were multiple stones in the same area, the length of the largest stone was measured. The patients who had a history of ureteral stricture or previous ipsilateral ureteroscopic lithotripsy history in one year were not included in this study. All the operations were performed by two surgeons of comparable skill and experience. The occluder group was composed of 52 cases, including 30 males and 22 females, 26 stones on the left and 26 right, with the stone diameter ranging from 4.2 to

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Table 1. the comparison of clinical parameters between the occluder group and Stone retrieval basket group

	Occluder Group (N=52)	Stone Retrieval Basket (N=51)	*P*-Value
Gender	Male: 30 Female:22	Male: 28 Female:23	.775
Age	39.15 ± 15.20	38.53 ± 14.85	.833
Stone position	Left: 26 Right: 26	Left: 27 Right: 24	.765
Stone diameter (mm)	10.91 ± 1.92	10.78 ± 1.74	.731
Stone retropulsion rate	7/52 (13%)	8/51 (16%)	.787
Flexible ureterscope rate	3/52 (6%)	5/51 (10%)	.488
One-time stone-free rate	48/52 (92%)	48/51 (94%)	.999
Operation time (min)	45.19 ± 6.91	43.25 ± 5.23	.111
Hospitalization time (day)	4.28 ± 0.74	4.20 ± 0.78	.581
Postoperative fever	4/52 (8%)	3/51 (6%)	.715
Severe hematuria	2/52 (4%)	1/51 (2%)	.569

15.4 mm; the stone retrieval basket group had 51 cases, including 28 males and 23 females, 27 stones on the left and 24 right, with the stone diameter ranging from 7.6 to 13.4mm.

Instruments

Innovex TMIVX ~ SC10 (Innovex Medical Co. Ltd, Shanghai, China) is a ureteral tube occluder made of thermoplastic urethane (TPU), 145 cm long, outer sheath 2.6 Fr with a 10 mm diameter occluder leave. The nitinol stone retrieval basket (Cook Medical, Bloomington, IN) is 120 cm long, outer sheath 1.9 Fr. The diameter of the open basket is 15 mm. The rigid ureteroscope used in our medical center was Wolf 8.0/9.8F rigid ureteroscope (Richard Wolf GmbH, Knittlingen, Germany). 60w holmium laser (Lumenis GmbH, Dreieich, Germany) with the 550 um fiber was used with the settings of 10-30 Hz and 1.0-2.0 J.

Surgical Method

Occluder group: The patient was placed in the lithotomy position after spinal anesthesia or general anesthesia, Wolf 8/9.8 Fr ureteroscope was sent up along the HiWire guidewire (Cook Medical, Bloomington, IN) up to the stone in the ureter. Then the guidewire was taken out and the occluder was inserted into the working channel of the ureteroscope. When the occluder leaf completely went beyond the stone, we pulled the handle to tighten the occluder leaf and it transformed into a ball shape that blocked the ureteral cavity above the stone and prevented retropulsion (**Figure 1A**). Next, the holmium laser fiber was inserted into the working channel with the setting of 1.0 ~ 2.0 J, 10 ~ 30 Hz to dust the stone into powder or fragments smaller than 2mm. The handle was then half loosened slowly to ensure that the leaf could be dragged through the ureteral lumen after the stone being completely crushed. Then the occluder was taken out slowly to "sweep" the fragments out of the ureter into the bladder under the observation of the endoscope, then a D-J Tube was indwelled along the guidewire. In cases when larger fragments moved to the renal pelvis, ureteral dilatation sheath was placed along the guidewire, and a stone retrieval basket was used under the flexible ureteroscope to grasp the escaped fragments. The D-J tube was generally pulled out about 4 weeks later if there was no stenosis or inflammatory polyp in the ureter.

Stone Retrieval Basket Group: The lithotomy position and anesthesia method were the same. Closed stone retrieval basket was directly inserted through the gap between the stone and ureter. Then the basket was opened, rotated and adjusted to an appropriate state before tightening to ensure holding the stone by at least a corner (**Figure 1B**). Then the laser fiber was carefully inserted and stones fragmented without damaging the basket. The position of the basket was sometimes adjusted during the process of fragmentation if necessary. Flexible

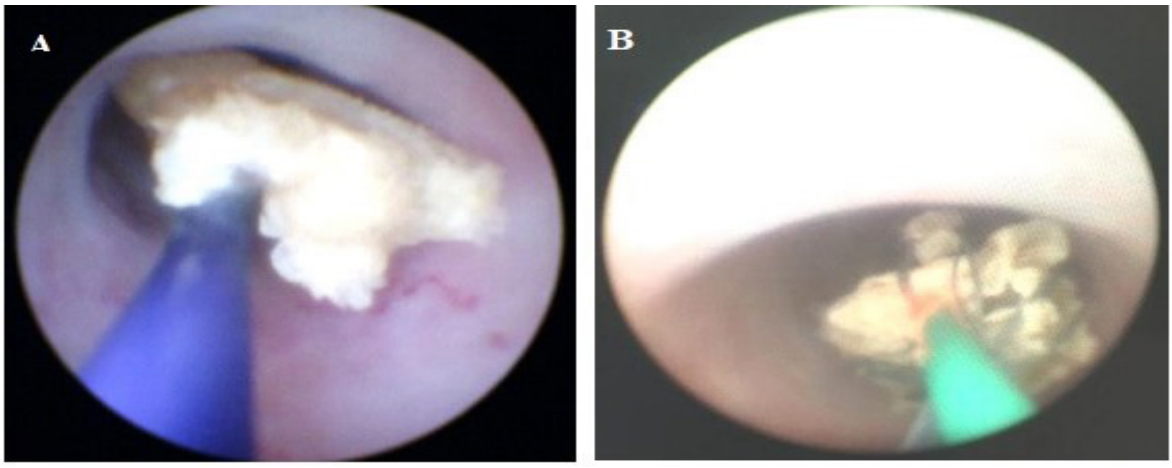

Figure 1. the application of occluder and stone retrieval basket during the operation. A: the occluder leaf had completely gone beyond the stone and tightened to block the ureteral cavity above calculi to prevent retropulsion. B: the stone had been grasped by the stone retrieval basket and the laser has been inserted.

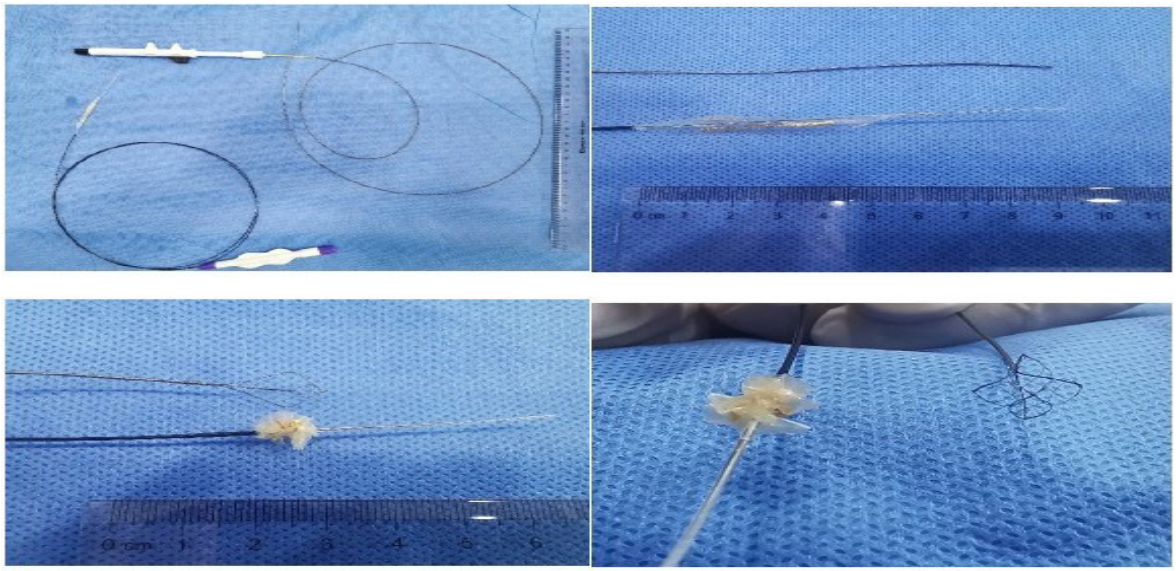

Figure 2. Comparison of the occluder and the basket

ureteroscope was also used in cases of large fragments escaping into the renal pelvis. The D-J tube was also indwelled and taken out in the 4 weeks follow-up.

Criteria

Stone retropulsion: the whole preoperative stones or large intraoperative fragments (≥ 4 mm) moved upward to the renal pelvis or calyx.

Successful lithotripsy: the stones were utterly fragmented without visible residue, including those that were moving upward to the renal pelvis or calyx.

Stone residue: Stone debris with a diameter ≥ 4 mm assessed by X-ray or CT scan carried out four weeks postoperatively.

The Ethics Committee of the hospital approved this retrospective study and permitted the waiver of written informed consent from patients. The study protocol is also following the Declaration of Helsinki.

Statistical Analysis

The data were analyzed through the software package Statistical Package for Social Sciences, Version 17.0 (SPSS 17.0), and expressed as mean ± standard deviation (x ± SD). The one-time success rate, postoperative complication rate, stone residue rate etc. were compared by the chi-square test, while the size of the stone, operation time and length of hospital stay were compared by *t*-test.

RESULTS

There were 48 successful cases out of a total of 52 (with a one-time lithotripsy success rate of 92%) in the occluder group. In seven cases, stone fragments migrated upward to the renal pelvis, 2 of which occurred before using laser and flexible ureteroscope was used for three times for fetching migrated stone debris. The stone retrieval basket group successfully fragmented 48 out of 51 (with a one-time lithotripsy success rate of 94%), In eight cases stone fragments migrated upward, four of which occurred before using laser before the lithotripsy. A flexible ureteroscope was subsequently used in five cases. The mean operation time was 45 ± 7 vs. 43 ± 5 min (P = .111), and the average hospitalization time was almost the same (4 ± 1 d, P = .581). There was no significant difference in the stone retropulsion rate (P = .787) or one-time stone-free rate (P = .999) between the two groups given the flexible ureteroscope usage were similar (**Table 1**).

There was no severe complication such as ureteral perforation or avulsion. Four patients had postoperative fever (> 38°C) and two patients had severe hematuria in the occlusion group, while three and one patients in the basket group respectively (P = .715). After giving antibiotic treatment, the temperature of all fever patients returned to normal within 3 days. Hematuria gradually disappeared after taking hemostatic medicine.

DISCUSSION

Ureteroscopic laser lithotripsy is used commonly for lower and middle ureteral stone treatment, it is sometimes a challenge for upper ureteral stones, demanding to remove all the fragments which might migrate to the renal pelvis[11]. The retropulsion depends on dilatation of the proximal ureter, irrigation pressure, energy and type of lithotripsy tools and the condition of the calculi. Compared to pneumatic lithotripsy and ultrasonic lithotripsy, holmium laser has advantages of lower migration rate, better efficacy and lower complication rate. High-power holmium laser further improves the efficiency of lithotripsy, but at the same time, it increases the calculus migration rate[12], especially in cases with significantly dilated ureter .

To prevent ureteral calculi retropulsion, techniques like head-high/feet-low position, keep the holmium laser energy low and diuretics[13] were used. And we found controlling water irrigation intermittently and avoiding high irrigation pressure, which also had been effective. With the development of new occlusion devices, such as various types of ureteral pipeline blocking devices such as Stone Cone, N-Trap and PercSys Accordion, ureteral stone retropulsion rate are significantly reduced[14, 15]. Feng et al. reported for the first time the application of the Innovex TMIVX-SC10 occluder in patients with upper ureteral calculi in 2012[14]. We carried out this study to further compare the clinical efficacy of

ureteroscopic occluder and stone retrieval basket during holmium laser treatment for upper ureteral calculi.

The Innovex TMIVX-SC10 occluder consists of a handle, an outer sheath, a guide-wire, and a leaf at the top. The leaf is made of TPU material with an ultra-smooth hydrophilic layer and can be lubricated in water to reduce resistance and friction between the device and stone. The friction is the primary cause that rubs the stone and induces retropulsion, especially at the ureteropelvic junction (UPJ) with the upper ureteral lumen dilated. The device can pass through the ureteroscope with a working channel higher than F3 due to its small diameter. During the operation, the occluder is placed through the working channel under direct observation. After insertion, the handle is pulled and the leaf transforms into aff ometimes even surrounded by inflammatory spherical shape and blocks the ureter above the stone. No ureter perforation or avulsion occurred in our center, yet the tip isn't soft enough. Sometimes there could be ureteral or mucosal damage during occluder insertion and placement. When dealing with incarcerated stone, the stone could be tightly clogged in the lumen of ureter, sometimes even surrounded by an inflammatory polyp, then the occluder or even the guidewire can not pass through, we usually choose to open a channel in the stone by holmium laser and then place the occluder through the channel. Sometimes the upper ureter is dilated so greatly and the occluder leaf could hardly block the ureter. Although the occluder can prevent stones from retropulsion, there are still chances of fragments migrating to the renal pelvis through the crack between ureter and occluder so fragmenting the stones into large pieces should be avoided at first, and instead use dusting "erosion" method, by which we mean start fragmenting the stone from the edges with high frequency (30Hz) and low energy (1.0J) setting. And after lithotripsy, occluder is gradually loosened and pulled out, and the stone fragments could be "swept" out along the half-open leaf. Although the leaf of the Innovex TMIVX-SC10 occluder is quite soft yet if being clogged with fragmented stone debris in the ureter and dragged too harshly, it could possibly cause ureter mucosal avulsion or rupture.

Our stone retrieval basket is a stone grasping device made of nickel-titanium alloy.

The idea of using basket as a anti-retropulsion tool comes from the inability of the occluder to completely block the stones in significantly dilated upper ureter. In that situation we found the basket very helpful to keep the stone in its original position. Open the basket when approaching to the distal end of stone so that the stone can fall into the basket and be caught by adjusting the basket gently. If the stones are large or incarcerated, open a channel by eroding the edge of the stone with holmium laser and inserting the closed basket through the gap. After grasping the stone, preferably by one corner, aim the laser fiber at the stone and carefully fragment the stone gradually. Meanwhile, the laser fiber should stay a certain distance from the basket to avoid damaging the metal mesh of the basket during the laser lithotripsy process. If the basket was damaged accidentally during the process, the stone retrieving function would be hampered.

During our study, we found that when the calculi were close to the pelvis with severe hydronephrosis, the limited diameter of the occluder could not match the relatively wide space. As a result, the occluder could not provide sufficient occlusion to prevent the stone from migrating[16]. Compared with the occluder, the basket can play a more effective role under these circumstances. Regardless of the dilatation degree of ureteral and pelvic, stones could be entrapped and fragmented in situ. However, the basket also has some limitations. One of the drawbacks is that the metal mesh on the basket could be damaged by laser[17]. In the narrow ureteral operating space, working laser fiber and the metal mesh sometimes get too close and the laser energy inevitably damage the mesh of the basket, resulting in its inability to hold the stone firmly. This accident does not influence the process of following fragmentation, but the damaged basket sometimes can not retrieve the residual stone correctly. Then either a new basket another form of lithotripsy is demanded to avoid the potential of ureteral injury[9,18,19]. The damaged mesh could fall off and be left in the ureter, which is very dangerous and warrant high attention. Furthermore, the stone retrieval basket cost was two times higher than the occluder, which means the patients need to pay more when the doctor selects the stone retrieval basket for operation.

CONCLUSIONS

Our data suggest that ureteroscopic occluder and stone retrieval basket combined with holmium laser lithotripsy can both effectively prevent intraoperative stone retropulsion in the treatment of upper ureteral calculi, improve the success rate of one-time lithotripsy, and reduce postoperative stone residual rate. The efficacy and safety of ureteroscopic occluder and stone retrieval basket have no significant difference. In severely dilated ureter, the basket could probably hold the stone in a position, which is challenging to be entirely blocked by the occluder, however, be careful in the laser lithotripsy process to avoid damaging the metal mesh of the basket.

CONFLICT ON INTEREST

The authors report no conflict of interest.

REFERENCES

1. Turk C, Petrik A, Sarica K, et al. EAU Guidelines on Interventional Treatment for Urolithiasis. Eur Urol. 2016;69:475-482.
2. Stamatelou KK, Francis ME, Jones CA, Nyberg LM, Curhan GC. Time trends in reported prevalence of kidney stones in the United States: 1976-1994. Kidney Int. 2003;63:1817-1823.
3. Ordon M, Urbach D, Mamdani M, Saskin R, Honey RJ, Pace KT. A population based study of the changing demographics of patients undergoing definitive treatment for kidney stone disease. J Urol. 2015;193:869-874.
4. Lee YH, Tsai JY, Jiaan BP, Wu T, Yu CC. Prospective randomized trial comparing shock wave lithotripsy and ureteroscopic lithotripsy for management of large upper third ureteral stones. Urology. 2006;67:480-484.
5. Gupta PK. Is the holmium:YAG laser the best intracorporeal lithotripter for the ureter? A 3-year retrospective study. J Endourol.

2007;21:305-309.

6. Eisner BH, Dretler SP. Use of the Stone Cone for prevention of calculus retropulsion during holmium:YAG laser lithotripsy: case series and review of the literature. Urol Int. 2009;82:356-360.
7. Ding H, Wang Z, Du W, Zhang H. NTrap in prevention of stone migration during ureteroscopic lithotripsy for proximal ureteral stones: a meta-analysis. J Endourol. 2012;26:130-134.
8. Eisner BH, Pengune W, Stoller ML. Use of an antiretropulsion device to prevent stone retropulsion significantly increases the efficiency of pneumatic lithotripsy: an in vitro study. BJU Int. 2009;104:858-861.
9. Kesler SS, Pierre SA, Brison DI, Preminger GM, Munver R. Use of the Escape nitinol stone retrieval basket facilitates fragmentation and extraction of ureteral and renal calculi: a pilot study. J Endourol. 2008;22:1213-1217.
10. Feng CC, Wu Z, Jiang HW, Ding Q. A new stone occlusion device for upper ureteral calculi: preliminary clinical outcomes. Minim Invasive Ther Allied Technol. 2012;21:351-354.
11. Teichman JM, Rao RD, Rogenes VJ, Harris JM. Ureteroscopic management of ureteral calculi: electrohydraulic versus holmium:YAG lithotripsy. J Urol. 1997;158:1357-1361.
12. White MD, Moran ME, Calvano CJ, Borhan-Manesh A, Mehlhaff BA. Evaluation of retropulsion caused by holmium:YAG laser with various power settings and fibers. J Endourol. 1998;12:183-186.
13. Honeck P, Wendt-Nordahl G, Hacker A, Alken P, Knoll T. Risk of collateral damage to endourologic tools by holmium:YAG laser energy. J Endourol. 2006;20:495-497.
14. Ahmed M, Pedro RN, Kieley S, Akornor JW, Durfee WK, Monga M. Systematic evaluation of ureteral occlusion devices: insertion, deployment, stone migration, and extraction. Urology. 2009;73:976-980.
15. Saussine C, Andonian S, Pacik D, et al. Worldwide Use of Antiretropulsive Techniques: Observations from the Clinical Research Office of the Endourological Society Ureteroscopy Global Study. J Endourol. 2018;32:297-303.
16. Qi S, Li Y, Liu X, et al. Clinical efficacy, safety, and costs of percutaneous occlusive balloon catheter-assisted ureteroscopic lithotripsy for large impacted proximal ureteral calculi: a prospective, randomized study. J Endourol. 2014;28:1064-1070.
17. Kroczak T, Ghiculete D, Sowerby R, et al. Dual usage of a stone basket: Stone capture and retropulsion prevention. Can Urol Assoc J. 2018;12:280-283.
18. Farahat YA, Elbahnasy AE, Elashry OM. A randomized prospective controlled study for assessment of different ureteral occlusion devices in prevention of stone migration during pneumatic lithotripsy. Urology. 2011;77:30-35.
19. Bagbanci S. Holmium:Yttrium Aluminum Garnet Laser and Guidewires: Is There a Durability Difference Among Guidewires Against Laser Energy? An In Vitro Experimental Study. J Endourol. 2017;31:528-532.