Ureteroscopic Lithotripsy in Reverse Trendelenburg Position and Intraoperative Furosemide

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Purpose: Upward stone migration is a significant problem during ureteroscopic lithotripsy (URSL) for upper ureteral stone, especially in absence of a ureteral occlusion device. In this study, we evaluated the novel strategy of reverse Trendelenburg position (RTP) and intraoperative diuresis for URSL without ureteral occlusion devices to avoid upward migration.

Materials and Methods: From March 2018 to May 2020, a total of 119 URSLs were performed for upper ureteral stone (6-15 mm) with 67 procedures in RTP and 52 procedures in conventional lithotomy position (CLP). 20 mg of intravenous furosemide was administered prior to stone fragmentation with holmium laser only in RTP group. Patient demographics, stone side, stone size and operative characteristics were recorded and compared between the two groups.

Results: Patient data, stone side and size were similar in the two groups. All procedures were complete without conversion to open surgery and major complications. There was no significant difference in the mean operative time (47.9 ± 7.7 min vs 45.3 ± 7.0 min, $P = .062$) and mean hospital stay (3.9 ± 0.9 d vs 4.0 ± 1.0 d, $P = .336$) between the RTP and CLP group. Stone upward migration was significantly less in RTP group (3.0%, 2/67) than in CLP group (19.2%, 10/52) ($P = .005$). Stone-free rate at one month after initial treatment was 92.5% in RTP group and 73.1% in CLP group ($P = .004$).

Conclusion: The strategy of placing the patient in RTP and intraoperative administration of intravenous furosemide is simple, feasible and cost-effective in preventing stone upward migration during URSL with holmium laser in absence of a ureteral occlusion device for upper ureteral stone.

Keywords: diuresis; position; upward migration; ureteral stone; ureteroscopic lithotripsy

INTRODUCTION

The surgical management of urinary calculi has changed considerably from the open approach to the minimally invasive approach over the past three decades. Four minimally invasive treatment modalities, including extracorporeal shockwave lithotripsy (SWL), ureteroscopic lithotripsy (URSL), laparoscopic lithotomy and percutaneous nephrolithotomy, are now available for ureteral stone. URSL is one of the preferred treatments for ureteral stone in many urologic centers, as it renders low cost and significantly great stone-free rate[1-4]. The quick technological advances in laser and miniaturization of endoscopic devices have permitted to use URSL in larger and complex stones.

Stone migration during URSL is always the major problem, especially for the upper ureteral stone. The migrating stones may necessitate additional procedures including intraoperative use of the flexible ureteroscope and ureteral stenting, or secondary procedures such as postoperative SWL and reoperation, which result in an increase in operative time and medical expenses. Several devices have been used to prevent stone migration and achieved a high success rate[5]. However, these commercial devices may be expensive and unavailable in many countries. In our center, a novel strategy of reverse Trendelenburg position (RTP) and intraoperative administration of intravenous furosemide is introduced to prevent stone migration during URSL for upper ureteral stone. We here describe our experience and the efficacy of this method.

MATERIALS AND METHODS

Study design and patients

Between March 2018 and May 2020, 112 patients with upper ureteral stone (6-15 mm) underwent URSLs with holmium laser in our center, in which 67 procedures were performed in RTP and 52 procedures were performed in conventional lithotomy position (CLP). The patients enrolled in this retrospective study were adult patients with radiological evidence of ureteral stone on plain X-ray film of the kidneys, ureter, and bladder (KUB) and/or noncontrast computed tomography (CT) scan. Stone location was defined as upper ureter if the stone was located cranial to the sacroiliac joint according to the preoperative imaging. The radiological size of the stone was determined by measuring the longest

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Table 1. Demographic data and SWL success rate comparisons between PCN and no PCN groups

	RTP Group	CLP Group	*P* value
Procedures, n	67	52	
Gender, n (%)			0.673
Male	45 (67.2)	33 (63.5)	
Female	22 (32.8)	19 (36.5)	
Age (yr)	43.6 ± 10.4	41.4 ± 12.1	0.283
Body mass index (kg/m^2)	23.3 ± 3.0	22.2 ± 3.2	0.067
Stone size (mm)	11.1 ± 1.8	10.5 ± 2.1	0.108
Stone side, n (%)			0.713
Left	39 (58.2)	32 (61.5)	
Right	28 (41.8)	20 (38.5)	
Hydronephrosis, n (%)			0.772
Mild	50 (74.6)	40 (76.9)	
Moderate	17 (25.4)	12 (23.1)	

Abbreviations: RTP, Reverse Trendelenburg Position; CLP, Conventional Lithotomy Position.

diameter of the stone. The included patients were adult patients with solitary stone with size ≤ 15 mm in the upper ureter. Exclusion criteria included a history of any intervention on the corresponding ureter, urinary tract abnormalities, recent active infection, coagulopathy, pregnancy, radiolucent stone, hypokalemia, serum creatinine levels ≥ 1.5 mg/dL, and severe hydronephrosis. Severe hydronephrosis was defined as the presence of renal pelvis dilation along with all calyces dilatation and thinning of the renal parenchyma in imaging.

The study was approved by the institutional review board of the Affiliated Hospital of Xuzhou Medical University (No: XYFY2017012). All patients were informed of related complications and the possibility of conversion to other procedures preoperatively.

Surgical procedures

In the RTP group, the patients were initially placed in the lithotomy position under general anaesthesia. A 6/7.5 F rigid ureteroscope (Richard Wolf, Knittlingen, Germany) was inserted into the bladder through the urethra under visual guidance and then introduced into ureter orifice with the guidance of a flexible 0.035-in guidewire (Zebra, Boston Scientific, USA). Advancement of the ureteroscope within the ureter was performed with low irrigation pressure. A safety guide wire was inserted beyond the target stone once the stone was endoscopically identified in the ureter. Then, the ureteroscope was reintroduced into the ureter beside the safety guide wire and the irrigation was discontinued. 20 mg of intravenous furosemide with simultaneous intravenous fluid infusion was given to obtain a high urine flow. During the onset of action about five minutes after intravenous administration, the 550-um laser fibre was placed on stone through the ureteroscope and the operating table was tilted to 30° of RTP. The holmium laser generator (VersaPulse PowerSuite 100W, Lumenis, Israel) was applied as an energy source set at 0.8-1.0 J and a rate of 6-10 Hz. With the minimum irrigation pressure to maintain a clear vision, the stone was fragmented using laser lithotripsy into particles less than 3 mm in size, which would spontaneously pass. A stent was placed at the end of the procedure for 2 weeks, unless there were complications, a solitary kidney or ureter stricture, where internal stent remained for 4-12 weeks.

URSL in the CLP group was performed in the same way as in the RTP group, except that patients were placed in lithotomy position and without use of intravenous furosemide throughout lithotripsy procedure.

Outcome analysis

All patients underwent KUB for detection of stone upward migration at one day and noncontrast CT for determination of stone-free rate at one month after URSL respectively. Stone-free was defined as absence of residual fragments being visible in the imaging studies, whereas stone upward migration was defined as a stone fragment measuring > 3 mm pushed back into the pelvicalyceal system. Patient demographics, stone side, stone size and operative characteristics were recorded. The unpaired t-test was used for comparison of consecutive variables. Chi-square test was used for comparison of categorical data and fisher's exact test was performed when the expected cell count in more than 25% of cases was less than 5. Binary logistic regression analysis was applied to estimate the effect of novel strategy of position and diuresis on stone migration. A value of $P < .05$ was accepted as statistically significant.

RESULTS

67 URSLs performed on 63 patients in RTP group and 52 URSLs performed on 49 patients in CLP group were included in this study. Bilateral procedures on the same occasion were performed on 4 patients in RTP group and 3 patients in CLP group respectively. Patient data, stone side and size were similar in the two groups. (**Table 1**)

All procedures were complete without conversion to open surgery and major complications. The mean operative time for RTP group (47.9 ± 7.7 min) was slightly longer than for CLP group (45.3 ± 7.0 min) ($P = .062$). There was no significant difference in mean hospital stay (3.9 ± 0.9 d vs 4.0 ± 1.0 d) between the RTP and CLP group ($P = .336$). Stone-free rate at one month after initial treatment was 92.5% in RTP group and 73.1% in CLP group ($P = .004$). (**Table 2**)

Postoperative complications were graded according to the modified Clavien classification[6]. Stone upward migration (grade III) was significantly less in RTP group (3.0%, 2/67) than in CLP group (19.2%, 10/52) ($P = .005$) (**Table 2**). The binary logistic regression analysis showed a significant association between the novel strategy and stone migration (95% confidence interval:

Table 2. Demographic data and SWL success rate comparisons between PCN and no PCN groups for propensity-score matching

	RTP Group	CLP Group	*P* value
Operative time (min)	47.9 ± 7.7	45.3 ± 7.0	0.062
Hospital stay (d)	3.9 ± 0.9	4.0 ± 1.0	0.336
Stone-free, No. (%)	62 (92.5)	38 (73.1)	0.004
Complications, No. (%)			
Upward migration (grade III[a])	2 (3.0)	10 (19.2)	0.005
Hematuria (grade I[a])	6 (9.0)	3 (5.8)	0.730
Fever (grade I[a])	3 (4.5)	4 (7.7)	0.698
Perforation (grade III[a])	2 (3.0)	1 (1.9)	1.000

Abbreviations: RTP, Reverse Trendelenburg Position; CLP, Conventional Lithotomy Position.
[a]Modified clavien classification[6].

1.7-37.0, odds ratio = 7.7, *P* = .01). Auxiliary treatment was performed at one month postoperatively. Of the two patients with migrating stones in RTP group, one was rendered stone-free with an adjuvant SWL procedure, while the remaining one patient underwent flexible ureteroscopy after SWL failure. Six cases of migrating stone were successfully managed with the auxiliary SWL and the remaining four cases were fragmented to dust using the holmium laser with flexible ureteroscopy in CLP group.

Other complications in this study included hematuria, fever and ureteral perforation. No significant differences were found in these complications between the two groups. In 9.0% (6/67) of procedures in RTP group and 5.8% (3/52) of procedures in CLP group (*P* = .730), mild gross hematuria (grade I) developed intraoperatively and disappeared in postoperative 2-3 days. Transient fever (grade I) was seen in 4.5% (3/67) of procedures in RTP group and 7.7% (4/52) of procedures in CLP group (*P* = .698), which resolved with conservative treatment. Ureteral perforation (grade III) was encountered in 3.0% (2/67) of procedures in the RTP group and 1.9% (1/52) in the CLP group (*P* = 1.000). The perforation was minor and was managed by indwelling a ureteral stent for 12 weeks without discontinuing the lithotripsy. No ureteral avulsion occurred in this study. (**Table 2**)

DISCUSSION

URSL can be performed more safely and with a higher success rate due to the advent of progressively smaller ureteroscopes and more efficient lithotripsy modalities [(1)]. Continuous high-pressure irrigation for obtaining a clear operative visual field may result in an ascending stone, which may complicate the procedure. Stone migration is also influenced by the type of lithotripter, the site and size of ureteral stone, and degree of hydronephrosis and proximal ureteral dilation.

Upward migration of ureteral stone is the leading cause of URSL treatment failure and the reported rate of occurrence ranges from 28% to 60% [(7)]. The more proximal to the renal pelvis the ureteral stone is located, the higher is the risk of upward migration. In an early study, Knispel et al reported that the migration rate was 40% for proximal ureteral stone and 5% for distal ureteral stone respectively[(8)]. Thus, extensive efforts have been made to minimize the risk of upward migration during URSL.

Various ureteral occlusion devices have been created specially to prevent upward stone migration and assist with fragment extraction. The Stone Cone was used by Maislos and colleagues in 19 consecutive cases of proximal-ureteral stones with 100% success, and no need for additional procedures[(9)]. In a randomized trial for proximal-ureteral stones by Wang and associates, NT trap group achieved no cases of stone migration and a 100% of stone-free rate one week after operation in the studied group of 56 cases[(10)]. Other occlusion devices, such as Accordion, Lithocatch and BackStop, have also been introduced into the market in recent years. Although clinical studies have indicated significant reduction in stone migration, every device has its limitations and equipment costs that preclude its routine utilization during URSL. More importantly, the occlusion devices are not always available in some urologic center.

Several strategies have been employed to reduce upward stone migration. The holmium laser can be selected as energy source for URSL as it presents a significant reduction in upward stone migration when compared with other lithotripter types [(11,12)]. Yoo and associates introduced anterograde irrigation-assisted URSL with reduced risk of stone migration into kidney and decreased operation time[(13)]. However, this strategy with the requirement of preoperative percutaneous nephrostomy is an appropriate option only for those patients with complicated urinary tract infection.

Controlling irrigation pressure and altering patients' position are simple procedure modifications to minimize upward stone migration. Lowering irrigation pressure for visibility maintenance and placing the patient in RTP optimizing the gravity has been tried[(14-16)]. Yoo and associates' study supports that increasing pressure beyond the stone can reduce the risk of upward stone migration[(13)]. Intravenous administration of furosemide is a noninvasive and fast method to increase intrapelvic pressure. To our knowledge, the effect of RTP with administration of furosemide on upward stone migration has not been evaluated in URSL.

Using gravity by alterations in the angle of inclination effectively reduced stone retropulsion during URSL in an in vitro model[(17)]. To utilize gravity and negative pressure during URSL, Canguven and colleagues placed the patients in RTP and decreased the pressure below the ureteral stone by pulling back the ureteroscope[(18)]. In this study, 20 mg of intravenous furosemide was used to increase the pressure beyond the ureteral stone in patients placed in RTP. Stone upward migration was significantly less in RTP group than in CLP group, suggesting that the maneuver aided decreasing the upward stone migration during URSL. Achieving a stone-free status is important, since small residual stone fragments may act as a nidus for growth. The stone-free rate was significantly higher in RTP group than in CLP group. The difference should be associated with decreased stone upward migration and increased stone

dust expulsion. It was in agreement with a study conducted by Ziaee and colleagues, in which the position and diuresis had been used to enhance stone-free rate after SWL for renal stone[19].

There were no major complications in this study. The upward migration rate was 3.0% for the upper ureteral stone in RTP group. The rate was lower than most of previously reported rates for URSL without use of an occlusive device[15,20]. A decision analysis by Ursiny and Eisner showed that it became cost-effective to use an anti-retropulsion device at a retropulsion rate of more than 6.3% [21]. Urologists may assess retropulsion rates to determine whether an anti-retropulsion device would be beneficial in clinical setting. The migration rate of 3.0% in this study suggests that this strategy could be considered in absence of an anti-retropulsion device.

There are several limitations in this study. First, this is a retrospective study with small sample size and confined to a single center. Second, there is lack of stone composition in this study, which may influence the stone migration. Third, the results may be affected by renal function because of demand for use of furosemide. It would have been interesting if patients in CLP also underwent intravenous furosemide. Thus, further studies are needed to confirm our results.

CONCLUSIONS

The results of this study show that position and diuresis can be used to reduce upward stone migration in the absence of a ureteral occlusion device during URSL for upper ureteral stone. The strategy of placing the patient in RTP and intraoperative administration of intravenous furosemide is simple, feasible and cost-effective in preventing ureteral stone upward migration during URSL with holmium laser.

CONFLICT OF INTEREST

The authors report no conflict of interest.

REFERENCES

1. Lam JS, Greene TD, Gupta M. Treatment of proximal ureteral calculi: holmium:YAG laser ureterolithotripsy versus extracorporeal shock wave lithotripsy. J Urol. 2002; 167:1972-6.
2. Hollenbeck BK, Schuster TG, Faerber GJ, Wolf JS Jr. Comparison of outcomes of ureteroscopy for ureteral calculi located above and below the pelvic brim. Urology. 2001; 58:351-6.
3. Hendrikx AJ, Strijbos WE, de Knijff DW, Kums JJ, Doesburg WH, Lemmens WA. Treatment for extended-mid and distal ureteral stones: SWL or ureteroscopy? Results of a multicenter study. J Endourol. 1999; 13:727-33.
4. Bagley DH. Expanding role of ureteroscopy and laser lithotripsy for treatment of proximal ureteral and intrarenal calculi. Curr Opin Urol. 2002; 12:277-80.
5. Bastawisy M, Gameel T, Radwan M, Ramadan A, Alkathiri M, Omar A. A comparison of Stone Cone versus lidocaine jelly in the prevention of ureteral stone migration during ureteroscopic lithotripsy. Ther Adv Urol. 2011; 3:203-10.
6. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004; 240:205-13.
7. Chow GK, Patterson DE, Blute ML, Segura JW. Ureteroscopy: effect of technology and technique on clinical practice. J Urol. 2003; 170:99-102.
8. Knispel HH, Klän R, Heicappell R, Miller K. Pneumatic lithotripsy applied through deflected working channel of miniureteroscope: results in 143 patients. J Endourol. 1998; 12:513-5.
9. Maislos SD, Volpe M, Albert PS, Raboy A. Efficacy of the Stone Cone for treatment of proximal ureteral stones. J Endourol. 2004; 18:862-4.
10. Wang CJ, Huang SW, Chang CH. Randomized trial of NTrap for proximal ureteral stones. Urology. 2011; 77:553-7.
11. Marguet CG, Sung JC, Springhart WP, et al. In vitro comparison of stone retropulsion and fragmentation of the frequency doubled, double pulse nd:yag laser and the holmium:yag laser. J Urol. 2005; 173:1797-800.
12. Yu W, Cheng F, Zhang X, et al. Retrograde ureteroscopic treatment for upper ureteral stones: a 5-year retrospective study. J Endourol. 2010; 24:1753-7.
13. Yoo J, Lee SJ, Choe HS, Kim HY, Lee JH, Lee DS. Anterograde irrigation - assisted ureteroscopic lithotripsy in patients with percutaneous nephrostomy. Int Braz J Urol. 2019; 45:406-7.
14. Dretler SP. Ureteroscopy for proximal ureteral calculi: prevention of stone migration. J Endourol. 2000; 14:565-7.
15. Feng C, Ding Q, Jiang H, et al. Use of NTrap during ureteroscopic Holmium:YAG laser lithotripsy of upper ureteral calculi. Minim Invasive Ther Allied Technol. 2012; 21:78-82.
16. 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; 22:1213-7.
17. Patel RM, Walia AS, Grohs E, Okhunov Z, Landman J, Clayman RV. Effect of positioning on ureteric stone retropulsion: 'gravity works'. BJU Int. 2019; 123:113-7.
18. Canguven O, Boz M, Bulbul M, Selimoglu A, Albayrak S. Withdraw of the ureteroscope causes fragmented ureter stones to disperse. Int Braz J Urol. 2013; 39:756-7.
19. Ziaee SA, Hosseini SR, Kashi AH, Samzadeh M. Impact of sleep position on stone clearance after shock wave lithotripsy in renal calculi. Urol Int. 2011; 87:70-4.
20. Jiang H, Wu Z, Ding Q, Zhang Y. Ureteroscopic treatment of ureteral calculi with holmium: YAG laser lithotripsy. J Endourol. 2007; 21:151-4.
21. Ursiny M, Eisner BH. Cost-effectiveness of anti-retropulsion devices for ureteroscopic lithotripsy. J Urol. 2013; 189:1762-6.