Comparison of Stone Dusting Efficiency When Using Different Energy Settings of Holmium: YAG Laser for Flexible Ureteroscopic Lithotripsy in The Treatment of Upper Urinary Tract Calculi

Shulian Chen#, Ni Fu#, Wei Cui, Zeju Zhao, Xu Luo*

Purpose: The aim of this study is to evaluate the impact of different pulse energy settings on dusting efficiency in flexible ureteroscopic lithotripsy (fURSL) for the treatment of upper urinary tract calculi.

Materials and Methods: Data of 88 consecutive patients who underwent fURSL for upper urinary tract calculi by a single surgeon in our department from August 2017 to August 2018 were reviewed retrospectively. Lumenis Power Suite 100W lithotripter with a 200 μm laser fiber was used to comminute stones. According to energy settings, patients were divided into three groups- low energy group (LE: 0.3-0.6J), middle energy group (ME: 0.7-1.0J), high energy group (HE: 1.1-1.5J). Frequency was set at 30Hz in all patients. ANOVA and Chi square tests were applied to compare the difference of the mean lithotripsy and operation time, early stone-free rate (eSFR), overall stone-free rate (oSFR) and complication rate.

Results: A total of 32, 36 and 20 patients were included in the LE, ME and HE groups, respectively. There was no difference in the age, gender distribution or in any other stone characteristics among the three groups. The mean lithotripsy time of LE, ME, HE was 10.9 ± 7.6, 16.1 ± 7.0, 23.0 ± 15.0 min respectively. The mean operation time of the three groups was 16.9 ± 7.7, 22.3±7.1, 29.2±14.9 min respectively. There were significant differences on the mean lithotripsy time ($P = 0.002$) and the mean operation time ($P = 0.001$) among the three groups. The stone-free rate was 31.8% and 87.5% respectively in eSFR and oSFR. No statistical significance was detected among the three groups in terms of the eSFR ($P = 0.89$), oSFR ($P = 0.86$), and complication rate ($P = 0.97$).

Conclusion: In fURSL with dusting, low energy (0.3-0.6J) is more efficient than middle (0.7-1.0J) and high energy (1.1-1.5J). As energy increased, dusting efficiency decreased dramatically. Consequently, we recommend low pulse energy (0.3-0.6J) as the optimal dusting strategy for fURSL.

Keywords: flexible ureteroscope; Ho: YAG laser; intracorporeal lithotripsy; upper urinary tract calculi

INTRODUCTION

Urolithiasis is a common health disorder in the world and it has already put a heavy burden on the global health system[1]. The goal of treatment is to achieve the highest stone-free rate with the least invasion[2]. Percutaneous nephrolithotomy (PCNL) and flexible ureteroscopic lithotripsy (fURSL) are two main minimal invasive procedures for the treatment of upper urinary tract stones[3]. In the last decade, with the development of ureteroscope and intracorporeal lithotripters, fURSL is rapidly becoming the first-line modality[4]. Advances in Ho:YAG laser play a key role in this process. With an excellent safety profile and the ability of comminuting any type of urinary stones, the Ho:YAG laser is currently the most efficient intracorporeal lithotrite[5]. Though widely used in fURSL, the optimal power settings of Ho:YAG laser, however, is still inconclusive.

Options for fURSL include dusting and basketing (fragmentation). Dusting is to dust stone into small fragments for passive elimination. And basketing is to break stone into discrete fragments for active extraction. Advantages of dusting are shorter operative time, lower cost, decreased ureteral trauma, which make it a good choice for fURSL[6,7]. In contrast to basketing, low energy/high frequency is often suggested for dusting in the literature[8]. However, there is scant evidence to compare different energy settings on the dusting efficiency during fURSL. Whether increasing pulse energy will increase dusting efficacy or shorten lithotripsy time remains unknown. Therefore, we conducted this study by retrospectively analyzing our consecutive fURSL cases using different energy settings in our department in order to provide practical results for urologists.

PATIENTS AND METHODS

Study population

We retrospectively analyzed the data of 88 consecutive patients who underwent fURSL for upper urinary tract calculi from August 2017 and August 2018 by a single surgeon in our department. Patient selection was according to the following inclusion and exclusion criteria. The study was approved by the Research Ethics Board of Affiliated hospital of Zunyi medical college. Inclusion criteria: 1. Age > 18 years. 2. Free of uretero-stenosis. 3. Solitary stone in unilateral proximal ureter or kidney.

Department of Urology, Affiliated Hospital of Zunyi Medical College, Zunyi, Guizhou, China.
# These authors contributed equally to this work.
Correspondence: Department of Urology, Affiliated Hospital of Zunyi Medical College 149 Dalian Road, Zunyi, Guizhou, 563000, China. Tel: 86-189-8496 5855. Fax: 86-0851-28608067. E-mail: lx@zmc.edu.cn.
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Table 1. Patient demographic characteristics of different energy setting groups

	Total n = 88	LE n = 32	ME n = 36	HE n = 20	*p* value
Age; Mean±SD, year	44.5 ± 12.1	44.4 ± 12.1	42.1 ± 12.4	46.8 ± 12.0	0.73
Gender, no. (%)					0.95
male	59(67.0)	21(65.6)	24(66.7)	14(70.0)	
Female	29(33.0)	11(34.4)	12(33.3)	6(30.0)	
Stone diameter (cm); Mean±SD	1.6 ± 0.5	1.5 ± 0.5	1.5 ± 0.5	1.7 ± 0.6	0.57
Mean stone CT value (HU); Mean±SD	829.6 ± 247.87	78.43 ± 229.45	838.2 ± 289.4	862.3 ± 236.9	0.59
Stone location, no. (%)					0.89
proximal ureter	24(27.3)	12(37.5)	8(22.2)	4(20.0)	
Renal pelvis	29(33.0)	7(21.9)	15(41.7)	7(35.0)	
Upper or middle calyx	13(14.7)	4(12.5)	6(16.7)	3(15.0)	
lower calyx	22(25.0)	9(28.1)	7(19.4)	6(30.0)	

LE: 0.3-0.6J/30Hz; ME: 0.7-1.0J/30Hz; HE: 1.1-1.5J/30Hz;

Exclusion criteria: 1. UPJ obstruction. 2. High insertion of the ureter. 3. Horseshoe kidney. 4. Medullar sponge kidney. 5. Polycystic kidney. 6. Stones in a caliceal diverticulum or infundibular stenosis. 7. Renal insufficiency or chronic kidney disease (stage 3A or higher; glomerular filtration rate < 45mL/minute). 8. Transplant kidneys. 9. Pregnancy. 10. Stone diameter > 2.5cm. 11. Severe hydronephrosis.

According to the settings of Ho: YAG laser pulse energy, patients were divided into three groups- low energy group (LE: 0.3-0.6J), middle energy group (ME: 0.7-1.0J), high energy group (HE: 1.1~1.5J).

Surgical technique

Patients with urinary tract infection or positive culture received appropriate antimicrobial drugs prior to fURSL. Two weeks before operation, a 4.7Fr ureteral stent was inserted. Under general anesthesia, patients were placed in the dorsal lithotomy and, simultaneously, intravenous antibiotics were given. Using 8.5Fr rigid ureteroscope, the ureteral stent was removed, then a 0.035-mm and another 0.038-mm guidewire were placed. Under the guidance of guidewire, a ureteral access sheath (12/14F) was inserted. Flexible ureteroscope of 8.5/9.9Fr (Olympus URF-V) and Lumenis Power Suite 100W lithotripter with a 200 μm laser fiber were used for fragmentating stones. The holmium laser was set at an energy level of 0.3-1.5 J and at a frequency of 30 Hz. The stone was comminuted into small fragments for passive elimination. The criteria for terminating laser lithotripsy were complete fragmentation (residual fragments ≤2 mm). After lithotripsy, a 4.7 Fr double-J stent was placed. All patients were treated with tamsulosin hydrochloride (0.2mg) one time per day.

Outcome assessment

Stone clearance was assessed using KUB and ultrasound for patients with radiopaque stones and CT for those with radiolucent stones at 1 day (early stone-free rate, eSFR) and 3 months (overall stone-free rate, oSFR). Stone-free status was defined as the absence of fragments or residual fragments < 2 mm in the upper urinary tract. The operation time was calculated from the insertion of a rigid ureteroscope to the final catheterization at the end of the procedure. The lithotripsy time was calculated from the first launch to the removal of the laser fiber.

The preoperative factors analyzed included the stone dimension (cm), age, sex, lower pole calculi or non-lower pole calculi, stone mean CT value (HU). The dimension was evaluated on a plain KUB film, in inconclusive situations with radiolucent stones, a CT was performed. Meanwhile, we evaluated intraoperative and postoperative complications using the Clavien–Dindo classification system.

Statistical analysis

SPSS 20 software was used for statistical analysis. Normality and homogeneity of variances tests were initially performed. Analysis of variances (ANOVA) were used to compare age, mean lithotripsy and operation time, stone size, and CT value. Chi-square tests were used for the comparison of gender, stone location, eSFR, oSFR, and complication rate. Statistical significance was set at $p < 0.05$.

RESULTS

Table 2. Comparison of operation parameters and complication rates of different energy

Parameter	total (n=88)	groups LE	ME	HE	*P*-value
Lithotripsy time (min)	16.1±11.1	10.9 ± 7.6	16.1±7.0	23.0 ± 15.0	0.002
Operation time(min)	22.1±11.2	16.9 ± 7.7	22.3±7.1	29.2 ± 14.9	0.001
No. stone free					
early	28 (31.8)	9 (28.1)	12(33.3)	7(35.0)	0.847
overall	77 (87.5)	28 (87.5)	32(88.9)	17(85.0)	0.915
Dindo-modified Clavien grade complications					
I	5 (5.7)	2(6.3)	2 (5.6)	1(5.0)	0.969
II	4 (4.5)	1(3.1)	2 (5.6)	1(5.0)	0.967
III	0 (0.0)	0(0.0)	0 (0.0)	0 (0.0)	-
IV/V	0 (0.0)	0(0.0)	0 (0.0)	0 (0.0)	-

LE: 0.3-0.6J/30Hz; ME: 0.7-1.0J/30Hz; HE: 1.1-1.5J/30Hz;

There were 88 consecutive patients: 59 males and 29 females. The mean patient age was 44.5 ± 12.1 years. There was a total of 22 lower calyceal stones and 66 non-lower calyceal stones. The mean stone diameter was 1.6 ± 0.5cm, with mean CT value 829.6 ± 247.8 HU. Differences of age, gender, stone diameter, CT value, stone location among the three groups were not significant. Details are shown in **Table 1**.

The mean lithotripsy time of LE, ME, HE was 10.9±7.6, 16.1 ± 7.0, 23.0 ± 15.0 min respectively. The mean operation time of the three groups was 16.9 ± 7.7, 22.3 ± 7.1, 29.2 ± 14.9 min respectively. There were significant differences on the mean lithotripsy time (P = 0.002) and the mean operation time (P = 0.001) among the three groups. The overall stone-free rate was 31.8% and 87.5% respectively in eSFR and oSFR. And no statistical significance was detected on the eSFR (P = 0.89) and oSFR (P = 0.86) among the three groups. According to the Clavien–Dindo classification system, 5 patients were grade I (5.7%), 4 patients were grade II (4.5%), no patient was grade III/IV/V (0%), and the total complication rate was 10.2%, and there was no significant difference among the different power settings. Data in details are presented in **Table 2**.

DISCUSSION

We report what is to our knowledge the first clinical results of the correlation between energy settings and dusting efficiency. For clinical application of dusting in fURSL, most studies recommended low power/high frequency (LP/HF) laser settings. However, this deduction mainly comes from laboratory results. These studies only looked into the scientific rationale around energy settings under the condition of fixed stone hardness and lithotripsy space, and provided some indications for clinical application[9-11], but they never took the effect of movement of stones with breaths, variable stone density or renal anatomical factors on the lithotripsy efficiency into consideration as clinical scenario [12,13]. To investigate the optimal dusting energy settings of Ho:YAG laser in clinical application, we retrospectively analyzed 88 consecutive upper urinary tract stone cases underwent fURSL. Our data demonstrated that LE group generated the shortest lithotripsy and operation time with comparable eSFR, oSFR and complication rate when compared with ME and HE groups.

During fURSL with dusting technique, our aim is to comminute stone into small fragments so that they can be easily expulsed through urinary tract without causing pain or obstruction. Usually, two modes can be used, dusting (low energy-high frequency) and popcorn effect (high energy-high frequency), which consist of a wide range of pulse energy settings[14,15]. A previous study from Pietropaolo and his colleagues combined dusting and pop-dusting technique to break stone into submillimeter fragments for passive elimination with 100W laser and showed higher SFR compared to our study with longer operative time[16]. Using constant laser settings in our study might account for this disparity. Some significant pieces are remaining at the end of lithotripsy which can be better addressed with popcorn effect[4]. Tracey et al. using dusting technique with ultra-high pulse frequencies (80Hz), showed comparable SFR with retrieval[17].

The efficiency of popcorn effect, another dusting technique, was also be assessed in vitro. Studies from Wollin and Aldoukhi found popcorn effect is more efficient in smaller space with a moderate energy (at least 0.5J per pulse) and higher frequencies[8,18]. However, in clinical, there is rare study to compare the dusting efficiency of different energy settings. In our study, the pulse frequency was fixed at 30Hz, the lithotripsy and operation time was inversely proportional to pulse energy. When pulse energy exceeded 1J, the dusting efficiency decreased dramatically. Our results are in accordance with the rationale concluded from laboratory studies-high pulse energy settings are not suitable for dusting technique in fURSL. Two factors may account for this. First, larger fragments produced by high pulse energy floated in the renal pelvis with irrigation and significantly increased the fragmenting difficulty and lithotripsy time[19]. Second, high pulse energy resulted in more retropulsion which increase the distance between the fiber tip and the stone and reduce lithotripsy efficiency[20].

There are some limitations to this study. This is a retrospective study from a single center, the confounding factors and measurement bias cannot be minimized as much as they could be in prospective, randomized study. Another limitation of this study is that not all possible laser settings were tested because of case constraints. Although several in vitro studies investigated the optimal power settings of Ho:YAG laser, no systematic in vivo study exists to verify previous results[9,21,22]. This study is an initial report and may provide some guidance for clinical practice.

CONCLUSIONS

In fURSL with dusting, low pulse energy (0.3-0.6J) is more efficient than middle (0.7-1.0J) and high pulse energy (1.1-1.5J). As energy exceeded 1.0J, dusting efficiency decreased dramatically. Consequently, we recommend low pulse energy (0.3-0.6J) as the optimal dusting strategy for fURSL.

CONFLICT OF INTEREST

The authors report no conflict of interest.

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