Safety and Efficacy of Pneumatic Lithotripters Versus Holmium Laser in Management of Ureteral Calculi

A Randomized Clinical Trial

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Purpose: To compare efficacy and safety of holmium:YAG laser and pneumatic lithotripter in the management of ureteral stones.

Materials and Methods: One hundred and twelve patients with 1 to 2 cm ureteral calculi were selected for pneumatic or holmium:YAG laser transurethral ureterolithotripsy (56 patients in each group). Ultrasonography and plain abdominal x-ray were performed for all the patients before the operation. The pneumatic lithoclast was Swiss LithoClast, while in laser lithotripsy, holmium:YAG laser frequency was used, which was usually set between 5 and 10 Hz at a power of 10 to 15 Watt. Intravenous urography was performed for all the patients at 3 months to assess functional status and to delineate the ureteral anatomy.

Results: The mean patients' age and stones' size were the same in both groups, and there were no statistical differences. Mean duration of lithotripsy was 13.7 ± 12.6 minutes in laser group and 7.9 ± 4.2 minutes in pneumatic lithotripsy group. Immediate stone-free rate was 100% and 82.1% in the laser and pneumatic groups, respectively (P = .001). Stone pushing back occurred only in 10 (17.9%) patients in pneumatic group. In terms of complications, such as perforation, mucosal injury, and bleeding, there were no differences between the two groups. No intravenous pyelography related complication was seen at 3-month follow-up.

Conclusion: Laser lithotripsy is a superior approach for the management of upper ureteral stones of 1 to 2 cm in size due to its higher rate of stone clearance.

Keywords: ureteral calculi, lasers, lithotripsy

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INTRODUCTION

Ureteral stones and their subsequent obstructive uropathy can deteriorate renal function.[1] The patient's symptoms and stone size are not good predictors for renal function loss. Furthermore, there is no clear time threshold for irreversible damage. Therefore, intervention should be strongly considered in any patient with ureteral obstruction unless close monitoring of renal function is available.[2]

Several reports have suggested that ureteroscopy should be the primary approach for the ureteral stones, especially flexible ureteroscopic lithotripsy using a variety of lithotripters, including ultrasonic, electrohydraulic, pneumatic, and laser.[3-5] The most widely used method for stone fragmentation is pneumatic lithotripsy; however, it has a high possibility of stone migration.

Recently, there has been an increase in the use of the holmium laser for stone fragmentation due to its fewer complications and lower incidence of stone up-migration.[6] The holmium:YAG laser is transmittable via flexible fibers. Formation of plasma bubble at the tip of the holmium:YAG laser fiber can induce thermal effect on stones and soft tissues.[7]

This randomized clinical study was designed to compare holmium:YAG laser and pneumatic lithotripter in transurethral ureterolithotripsy (TUL) for the management of 1 to 2 cm ureteral calculi.

MATERIALS AND METHODS

A total of 112 patients with 1 to 2 cm ureteral stones, who were candidate for TUL, were assigned to two groups (56 patients in each group) using pseudo-randomization between 2007 and 2009. Patients in groups 1 and 2 underwent TUL using pneumatic or holmium:YAG laser, respectively. One surgical team experienced in endourology performed all surgical procedures in both groups. The ethics committee of the Laser Application in Medical Sciences Research Center approved the study protocol, and informed consents were obtained from all the subjects.

Patients with renal anomalies, pelvic or caliceal stones, pregnancy, severe musculoskeletal deformity, and history of uncontrolled coagulopathy or immunosuppression were excluded from the study. Before the procedure, urine cultures were obtained, and if positive, antibiotics were administered. All of the subjects should have negative urine cultures preoperatively. Patients were assessed by ultrasonography and plain abdominal x-ray (kidney, ureters, and bladder) before performing TUL to evaluate stone's size and situation.

All the patients underwent spinal anesthesia after receiving a single shot of prophylactic antibiotic, and then, were placed in a lithotomy position. After passing a 0.038-inch floppy tip guidewire by the side of stone, ureteroscope negotiation was performed. All the procedures were done by an 8F semi-rigid ureteroscope in both holmium:YAG laser and pneumatic lithotripsy groups. The pneumatic lithoclast was Swiss LithoClast. In laser lithotripsy, holmium:YAG laser frequency was usually set between 5 and 10 Hz at a power of 10 to 15 Watt. In order to maintain a clear ureteroscopic view, irrigant was pumped manually and intermittently during the procedure. Calculi were disintegrated by single or multiple mode of firing in pneumatic lithoclast group.

After stone fragmentation, final ureteroscopy was performed under direct vision to detect any residual stone or injury to the ureteral wall or adjacent organs. Indwelling ureteral double-J stent was placed for all the patients and removed after 4 weeks. The catheter was removed on the 1st postoperative day. All the subjects were evaluated at 1 and 3 months postoperatively. The intravenous urography was used to evaluate the ureteral anatomy and renal function status at 3 months postoperatively.

Demographic characteristics, operation time (from the first fire to the stone to the last fire), hospitalization, and complications, such as hematuria, mucosal damage (evidenced by edema or hemorrhage), ureteral perforation, and postoperative fever (oral temperature >38 °C) were compared between the two groups. Stone-free status (residual stone fragments <2 mm) and stone pushing back were determined intra-operatively. Intravenous urography study was carried out three months after the treatment routinely.

Data analysis was performed using SPSS software (the Statistical Package for the Social Sciences, Version 15.0, SPSS Inc, Chicago, Illinois, USA) through Student's *t* test and Chi-Square test for continuous and categorical variables, respectively. A *P* value less than .05 was considered statically significant.

Table 1. Demographic and clinical characteristics of patients.*

Variable	Laser (n = 56)	Pneumatic (n = 56)	*P*
Mean age ± SD, y	35.9 ± 13.4	36.4 ± 12.5	.90
Male, n (%)	44 (78.5)	40 (71.5)	.383
Previous history of TUL, n (%)	4 (7.1)	8 (14.3)	.222
Stone laterality			
Right side, n (%)	35 (62.5)	30 (53.6)	.338
Left side, n (%)	21 (37.5)	26 (46.4)	
Stone location			
Proximal, n (%)	12 (21.4)	14 (25)	.897
Middle, n (%)	12 (21.4)	12 (21.4)	
Distal, n (%)	32 (57.1)	30 (53.6)	
Stone diameter, mm	11.7 ± 4.5	10.0 ± 5.6	.434

*SD indicates standard deviation; and TUL, transurethral ureterolithotripsy.

RESULTS

Patients' demographics and clinical characteristics are shown in Table 1. Mean patients' age, male-to-female ratio, and stone size were similar between the two groups.

Mean ± standard deviation (SD) duration of lithotripsy was 13.7 ± 12.6 minutes in laser group and 7.9 ± 4.2 minutes in pneumatic group (*P* = .029). The mean ± SD hospital stay was 24.4 ± 3.2 and 25.3 ± 0.3 hours in laser and pneumatic groups, respectively (*P* = .89). Immediate stone-free rate was 100% in laser group and 82.1% in pneumatic group (*P* = .001). Stone pushing back occurred only in 10 (17.9%) patients in pneumatic group. Three of them were managed with conservative measures in 3 months as it was partially fragmented to small pieces, while others required extracorporeal shockwave lithotripsy (ESWL). The 3-month stone-free rate increased to 87.5%. In comparison with the pneumatic group, patients in the laser group had significantly higher stone-free rate for the proximal ureteral stones (42.9% versus 100%; *P* = .002).

Table 2 summarizes the intra-operative and postoperative patients' data in the two groups. In terms of complications, such as perforation, mucosal injury, and bleeding, there were no differences between the two groups. Fever was observed in 1.8% of patients in laser and 3.6% in pneumatic group (*P* = 1). After 12 weeks, no complication was seen in intravenous pyelography.

DISCUSSION

Surgical options for the treatment of proximal ureteral stones include ESWL, ureteroscopy, percutaneous nephrolithotomy, laparoscopy, and rarely open surgery.[2] Park and colleagues compared the results of ESWL and ureteroscopy for ureteral stones (proximal and distal). They concluded that although the efficacy of ESWL decreased significantly for stones larger than 1 cm (83.6% versus 42.1%), the stone-free rate with ureteroscopic manipulation did not change by the stone size (88.9% versus 86.6%).[8] In fact, endourologic procedures expand their role continuously for treatment of urinary calculi. Various power sources can be chosen for the disintegration of ureteral stones. However, since the nature of the power source affects the ureteroscopic method and the type of used instruments, varying results have been reported.[9]

Lithoclast lithotripsy fragments calculi in a mechanism similar to that of a pneumatic jackhammer.[10] Compressed air pushes a small projectile against the probe; hence, the probe oscillates back at a frequency of 12 cycles per second. Breakup occurs as the probe tip repetitively impacts the stone. Retrograde expulsion of very mobile fragments of stones in the ureteral lumen is the most challenging drawback of the lithoclast technique.[11,12]

Holmium:YAG lithotripsy mainly uses photothermal mechanism to fragment stones.[13] Holmium:YAG laser makes stone crater and small fragments by its thermal effect on the stone

Table 2. Patients' intra-operative and postoperative data.

Group	Laser (n = 56)	Pneumatic (n = 56)	*P*
Complications			
Hematuria, n (%)	0 (0)	0 (0)	-
Mucosal damage, n (%)	2 (3.6)	1 (1.8)	1
Ureteral perforation, n (%)	0 (0)	0 (0)	-
Postoperative fever, n (%)	1 (1.8)	2 (3.6)	1
Mean operation time ± SD, min	13.7 ± 12.6	7.9 ± 4.2	.029
Mean hospital stay ± SD, hr	24.4 ± 3.2	25.3 ± 0.3	.89
Immediate stone-free status, n (%)	56 (100)	46 (82.1)	.001
3-month stone-free status, n (%)	56 (100)	49 (87.5)	.013
Stone location stone-free status			
Proximal, n (%)	12/12 (100)	6/14 (42.9)	.002
Middle, n (%)	12/12 (100)	10/12 (83.3)	.478
Distal, n (%)	32/32 (100)	30/30 (100)	-

SD indicates standard deviation.

composition. Therefore, the risk of upward dislocation of ureteral stones fragments in its lumen could be lowered.[14]
During the pneumatic procedure, there is no electricity, and little heat energy is produced; thus, the mucosal injury is mild and transitory.[15] However, there is no difference between the two groups in terms of such a complication. In fact, Holmium:YAG laser energy is delivered in a pulsatile manner with tissue penetration of less than 0.5 mm. Therefore, subsequent injury of the ureter is unlikely to happen as long as the lithotripsy is performed under direct vision.[15]
Literature shows excellent results, including stone-free rate of 95% and low perforation and stricture rates of about 1%, for holmium laser lithotripsy for the management of the proximal ureteral calculi.[4] For this purpose, a better outcome could be achieved by flexible ureteroscopic lithotripsy as the primary approach. Although holmium laser or flexible ureteroscopic lithotripsy is expensive and not available in many centers, the use of holmium laser is appropriate and logical when there is a high risk of stone migration in pneumatic procedure.[5,16]
In this study, the operation time considered for stone fragmentation into small and removable size was less in the pneumatic group in comparison with laser. In a study by Jeon and associates, operation time was longer in pneumatic group. They explained that in pneumatic lithotripsy, the urologist has to change position of the ureteroscope to seek out the mobile stones. Furthermore, lithoclast lithotripsy fragments the calculi into multiple chunks that need to be basketed and removed.[17]
The major drawback of urolithiasis treatment is probably the high cost of the holmium laser equipment. However, holmium:YAG laser can be used for a variety of urological procedures, such as prostate resection and ablation, strictures incision, and urothelial tumors ablation.[18] The small number of the patients and the short-term follow-up period were the limitations of this study. Therefore, we recommend conducting clinical trials with more number of participants and a longer follow-up period in order to compare these two methods.

CONCLUSION

Holmium:YAG laser is a more safe and effective lithotripter compared with the pneumatic lithotripsy for the management of upper ureteral stones. To draw final conclusion, further large scale studies are needed.

CONFLICT OF INTEREST

None declared.

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