

Original Research Article

Comparison of pneumatic lithotripsy versus laser lithotripsy for upper ureteral calculi

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ABSTRACT

Background: Several modalities are available for upper ureteric stone fragmentation. From them pneumatic and holmium: yttrium-aluminum-garnet lithotripsy has favourable outcomes. In this study we studied 50 patients who underwent ureteroscopic pneumatic lithotripsy or laser lithotripsy. This study aims to compare the outcome of PL and LL in the management of upper ureteric calculi.

Methods: This is a prospective, randomized study of 50 cases; 25 cases of TUL with pneumatic lithotripter and 25 cases of TUL with laser lithotripter over two years. The purpose of this study was to analyze the factors predicting the stone-free rate, assess the complications following PL and LL, and assess the need for a second procedure if retropulsion of calculi occurs.

Results: Two groups were similar in age, gender, mean size of stones, retropulsion and complications. There was a statistical difference in terms of stone free rate in favour of LL group ($p \leq 0.05$) and mean operative time in favor of the PL group ($p \leq 0.05$).

Conclusions: In conclusion, we found that both the PL and LL approaches were effective and safe for upper ureteric calculi, but the LL method had advantages, especially in stone free rate, over the PL treatment. Another advantage of the LL method was safe stone fragmentation in upper ureteral calculi due to lower retropulsion rate in contrast with the PL method.

Keywords: Laser lithotripsy, Pneumatic lithotripsy, Ureteroscopy

INTRODUCTION

The incidence of urinary stone disease is the third-highest among all urinary problems.¹ The spontaneous passage of stone is 68% in patients with stone size less than 5mm, and spontaneous passage is very low, 5% when the stone size is more than 6mm. According to the site, size and other factors, there are many treatment options for the removal of stone from the ureter like conservative medical expulsion therapy, extracorporeal shock wave therapy (ESWL), stone fragmentation through antegrade

and retrograde ureteroscopy (URS), laparoscopy and open ureterolithotomy.^{2,3} Ureteroscopy occupies an important place in the treatment of ureteric calculi as increasing technological advancements allow easier access to stones in all parts of the kidney and ureter. In particular, improvements in ureteroscopic equipment emphasize the need for appropriate and effective miniaturized intracorporeal lithotripsy devices. As a result, complication rate, most notably the ureteral perforation rate, have been reduced to less than 5%, and long term complications such as stricture formation occur

with an incidence of 2% or less. Overall, the stone-free rate is remarkably high at 81% to 94% depending on stone location and size, with the vast majority of patients rendered stone-free in a single procedure.⁴

Laser is an acronym for light amplification by stimulated emission of radiation. The holmium: yttrium, aluminum, Garnet laser (holmium: YAG laser) was developed in the early 1990s. The holmium laser is a solid-state laser system that operates at a wavelength of 2140 nm in the pulsed mode with a pulse duration range of 250 to 350 microseconds. Its growing success is a result of its excellent performance as both a lithotripter and a surgical laser. It can vaporize as well as coagulate the tissues. It has a wide range of endoscopic applications and has demonstrated effectiveness in clearing stones of all compositions. The holmium: YAG laser is transmittable via flexible fibres. The thermal effect produced by holmium: YAG laser's pulses are due to the formation of a plasma bubble. The zone of thermal injury associated with laser ablation ranges from 0.5 to 1.0 mm⁵. Holmium laser lithotripsy occurs primarily through a photothermal mechanism, as pulse duration produce an elongated cavitation bubble that generates only a weak shock wave which causes stone vaporization. Ureteroscopy with laser lithotripsy occupies an important place in treating ureteric calculi as the holmium laser is one of the safest, most effective, and most versatile intracorporeal lithotripters.^{6,7}

Pneumatic (Ballistic) lithotripsy relies on energy generated by the movement of a projectile. Once the projectile is in contact with another object, the ballistic energy is transferred to the object. The Swiss Litho Clast, introduced in the early 1990s, was the first ballistic lithotrite. The metal projectile in the hand piece of the Litho-Clast is propelled by measured bursts of compressed air against the head of a metal probe at a frequency of 12 cycles per second. The probe tip is placed against the stone, and the Litho Clast is activated by a foot pedal when it is in contact with inflexible objects, such as stone, fragments on impact (jackhammer effect). The advantages of ballistic lithotrites are their relatively low cost and low maintenance. Disadvantages of ballistic devices include the rigid nature of the technology, which requires ureteroscopes or nephroscope with straight working channels. In addition, ballistic lithotripsy is associated with a relatively high rate of stone retropulsion.⁸

Aims and objectives

This study aims to evaluate the efficacy of holmium: YAG laser and pneumatic (Ballistic) lithotripter in treating upper ureteric calculi with regards to stone-free rate (SFR), safety, morbidity, feasibility and complications and further need of an additional procedure to achieve complete stone clearance. Current study was designed to evaluate pneumatic lithotripter (PL) and laser lithotripter (LL) efficacy in the management of upper ureteric calculi. This study aims to compare the outcome

of PL and LL in the management of upper ureteric calculi, analyze the factors predicting the stone-free rate, assess the complications following PL and LL, and assess the need for a second procedure if retropulsion of calculi occurs.

METHODS

This is a prospective, randomized study of 50 cases (25 cases of TUL with PL and 25 cases of TUL with LL over two years from March 2018 to February 2020. Inclusion criteria are all cases of upper ureteric calculi located above transverse process of L4 vertebral level having a size of 1 to 2 cm. Exclusion criteria are stone size > 20 mm & <10 mm, Presence of urinary sepsis, paediatric age group patients, multiple stones, bleeding disorders, Pregnancy, patients in whom 6/7.5 Fr size URS not negotiated through the lower ureter. All the patients were to undergo preoperative routine blood investigations, urine analysis and radiological evaluation using USG KUB, X-Ray KUB, IVU, or CT KUB. Informed and written consent was obtained from all the patients.

In the laser lithotripsy group, holmium: YAG laser frequency was usually set between 5 and 10 Hz at a power setting of 0.5 to 1.4 J. Using 550-micron fibre and 6/7.5Fr semi-rigid ureteroscope (Richard Wolf, Germany) with the preformed type of basket for stabilization of stone whenever necessary. In the pneumatic lithotripsy group, the swiss lithoclast with 3 fr size lithoclast probe used, which works by propelling measured bursts of compressed air against the head of metal probe at 3 atm pressure and 12HZ frequency (12 cycles per second). All the procedures are done with a 6/7.5Fr semi-rigid ureteroscope. In all the procedures, a double J stent (5Fr) was placed after the procedure in every case, followed by catheterization. Check ultrasonography and plain X-ray KUB was done in all the patients on the second postoperative day to look for any residual stone. Foleys catheter was removed the following day. Double J stent was removed after 15 days. Patients were discharged on the third postoperative day, given uneventful recovery. Only one patient of the PL group who had a ureteric perforation stent was removed after four weeks, and at the same time stone was cleared with TUL using a Pneumatic lithotripsy device with a repeat stent placed for two weeks. To check for the complications during the hospital stay, patients were individually checked by the investigator on a twice-daily basis. While after discharge, the patients were called on the 15th day of discharge and check X-ray KUB and USG KUB was done to see stone clearance in patients with residual stone. Stone size, location, duration of surgery, duration of lithotripsy, clearance of stone and use of any additional instrument like dormia basket, intra-operative complications (mucosal injury, ureteric perforation, avulsion, haematuria) and causes of failure of procedure like retro propulsion, retained stone and need for an alternative procedure like PCNL/ESWL was recorded along with its outcomes.

Statistical analysis

For statistical evaluation Statistical Package of Social Sciences 15 (SPSS 15) program was used. Descriptive statistics (mean±standard deviation) and Student's t test was used to show and analyze the quantitative outcomes. The p values less than 0.05 were considered statistically significant.

RESULTS

The youngest pt in the series was 19 years old, and the oldest was 63 years old. Thus, most patients (78%) belong to the 3rd and 4th decade of life, with an average age of 33.5 years in the PL group and 35.5 years in the LL group. There was 26 male and 24 female pts enrolled in this study, among which 13 male and 12 female patients were included in each study group. Statistically, there was no difference in patient's age and gender among both study groups ($p>0.07$) (Table 1).

Table 1: Age and gender distribution among study groups.

Age (years)	Female		Male	
	PL	LL	PL	LL
12-20	00	01	00	00
21-30	06	01	05	08
31-40	04	06	07	02
41-50	01	03	01	02
51-60	00	01	00	01
61 and above	01	00	00	00
Total	24		26	

Table 2: Comparison of previous studies with our study.

Study	Clearance rate		Complications	
	PL (%)	LL (%)	PL (%)	LL (%)
Sarwar Noori Mohamood, et al (J Endourol 2016). ¹⁸	94	98	32	8
Manohar T, et al (J Endourol 2005). ¹⁴	88	84	16	24
Bapat SS (J Endourol 2007). ¹⁵	86.01	97.01	13.98	1.99
Razagi MR, et al (Urol J 2013). ¹⁶	87	100	8	0
Farhan SD (J Endourol 2012). ¹⁷	72.5	84	22.5	4
Akdeniz et al (Turk j urol2014). ¹⁹	75	74	9.1	5
Our study (2015-2017)	84	92	16	8

In the PL group, the maximum size of calculi is 18 mm, and the minimum size is 11 mm, with an average stone size is 14.6mm in studied patients. In the LL group, the maximum calculi size is 17 mm and minimum 10 mm, with an average size of 14mm in studied patients. There is no statistically significant difference in stone size among the two study groups ($p>0.006$). The average lithotripsy time for fragmentation during ureteroscopic removal of calculi (with or without the use of dormia basket depending upon need) is 8.6 minutes in the PL group and 11.16 minutes in the LL group. Statistically, there was no significant difference between the study groups in mean Lithotripsy time ($p>0.08$).

The average operating time in the PL group is 39.76 minutes, and in the LL group is 48.24 minutes, with the shortest operating time of 25 minutes & 32 minutes and longest operating time of 70 minutes & 82 minutes in the PL and LL group, respectively ($p<0.05$). Among 25 patients with proximal ureteric calculi in the PL group, retropropulsion occurred In 3 cases, thus average stone retropropulsion rate of 12% (3/25). Among 25 patients with proximal ureteric calculi in the LL group, retropropulsion occurred among 2 cases with an average retropropulsion rate of 8% (2/25). There was no statistically significant difference in retropropulsion rate among both the groups ($p>0.06$). Among the PL study group during the procedure, three calculi migrated to the kidney, and in one patient, stenting was done, and procedure abandoned due to partial ureteric perforation occurred during basket use; thus, 84% of patients were stone free in a single sitting and 16% (4/25) patients required second procedure to achieve 100% stone-free rate in the form of PCNL, ESWL and repeat TUL. Among the LL group, 23/25 subjects (92%) achieved 100% stone clearance using transureteric laser lithotripsy in a single sitting, and retropropulsion occurred in 2/25 patients (8%), which cleared with either PCNL or ESWL, depending on stone characteristics and renal anatomy, $p<0.05$, showed a statistically significant difference in stone clearance while managing proximal ureteric calculi, clearly showing that laser lithotripsy is a better and effective lithotripter in managing proximal ureteric calculus.

In the PL study group, one ureteric perforation occurred during placement of dormia basket, and pt stented and procedure abandoned, which later on cleared with TUL using PL after one month. In addition, minor complications like mucosal injury occurred in 2 patients, and haematuria and low-grade fever observed among four patients. In the LL study group, no major complication like ureteric perforation, avulsion & sepsis encountered. However, minor complications like low-grade fever observed in 1 patient and haematuria observed in 1 patient. In both study groups, all the patients were stented for two weeks, a 5 Fr,26 cm size stent placed under fluoroscopy guidance. After the procedure, stent-related complications in frequency, dysurea, urgency and dull aching flank pain were observed in 4 (16%) patients in

each study group. There was no statistically significant difference in stents related symptoms among study groups. At the three-week follow-up period, all patients included in the study underwent plain x-ray KUB and usg KUB, SFR among PL group is 96% (24/25), and in LL study group 100% SFR (25/25) noted.

DISCUSSION

Stones in the ureter are managed with as minimally invasive a procedure as possible. Stone fragmentation through URS and ESWL is the frequently used procedures for ureteric stones.^{2,3} ESWL is no doubt a non-invasive procedure, but there are many factors like the site, size and composition of the stone, degree of impaction in the ureteric walls, presence of bones and bowel loops intervening between the stone and the lithotripter, obesity, other causes of ureteric obstruction like stricture, which reduces the efficacy of ESWL.⁹ Bilateral ESWL in one sitting is not advised, while bilateral URS is feasible.¹⁰ This has further promoted the role of URS in the fragmentation of the ureteric stones.

Ureteroscopy (URS) with pneumatic lithotripsy was developed in 1990 and was reported to be the most effective procedure to treat ureteral stones. URS is a safe method, particularly in calculus obstruction or non-opaque stones.¹⁰ Overall for stones in the proximal ureter (n=8670), there is no difference in stone-free rates between SWL and URS. However, for proximal ureteral stones of >10 mm (n=523), URS has a superior stone-free rate. This difference arises because the stone-free rate for proximal ureteral stones treated with URS did not significantly vary with size, whereas the stone-free rate following SWL was inversely related to stone size. The AUA/EAU ureteral stones guideline panel reported that the stone-free rate for both SWL and ureteroscopy (URS) when treating proximal ureteral stones is around 81%. However, the rate for stones >10 mm decreased to 68% and 79% if they were treated by SWL and URS, respectively.⁴ Holmium: YAG laser lithotripsy: Differs from prior generation lasers such as alexandrite, pulsed dye, and Q-switched lasers. Older lithotripters had short pulse durations that deposited laser energy quickly, causing a high-energy vapour bubble. This bubble subsequently collapsed, thereby fragmenting calculi through a 'photoacoustic effect'. In contrast, the holmium: YAG laser has a long pulse duration with a pear-shaped bubble, and fragmentation occurs through a 'photothermal mechanism'. The net result of this modality is smaller fragmentation and, thereby, slower lithotripsy. However, the overriding significant advantage is its ability to fragment all stone compositions.¹¹

Pneumatic lithotripter: Originally developed at the university teaching hospital in Lausanne, Switzerland, it is based on a jackhammer principle.⁷ A projectile in the handpiece is propelled by compressed air through the probe. The compressed air originates from a small generator that is connected to a dry, clean air supply. The

ballistic energy produced is conveyed to the probe base at 12 Hz.¹² Continued impaction of the probe tip against the stone results in stone breakage once the tensile forces of the calculus are overcome. The metallic probe rods are available in various sizes. Pneumatic lithotripsy has the benefit of better stone targeting and visualization than is possible with the laser. However, rapid flashes of light emanating from the laser may interfere with targeting.

Mahmood et al performed a similar comparative study to compare pneumatic lithotripsy and laser lithotripsy outcomes in the management of upper ureteric calculi 100 patients were included in the study and randomized in two groups of 50 patients each.¹³ There was no difference in patients age, gender, stone size and location of stones in the two groups. They noticed that the stone clearance rate in the PL group was 94% and in the LL group 98% with a mean operative time of 60±40 min and 40±26 min in both the PL and LL study groups, respectively. They noticed complications like a ureteric perforation in two patients in the PL study group (8%) and found no significant difference in minor complications like haematuria, fever among both PL and LL study groups. Our study found a stone clearance rate of 84% in the PL group and 92% in the LL group, with a mean operative time of 39.76 min in the PL group and 48.24 min in the LL group, respectively with statistical significance between both the groups. Ureteric perforation occurred in one pt (4%), mucosal injury in two patients (8%) of the PL group; however, no such events observed in the LL group. Postoperative minor complications like fever, mild haematuria, and stent symptoms were the same among both groups. The final clearance rate of 100% is achieved using second auxiliary procedures like PCNL and ESWL, depending on the need of the situation. The main reason for the failure of the procedure was retro propulsion of stone to the kidney, which occurred in 12% of patients of the PL group and 8% of patients in the LL group and ureteric perforation in 4% of patients of the PL group. However, the stone clearance rate was slightly lower than the previous study but is still comparable.

Manohar et al found a stone clearance rate of 88% with pneumatic lithotripsy and 82% with laser lithotripsy for proximal ureteric calculus with an overall complication rate of 16% in the PL group and 24% in the LL group, in our study we found better clearance rate with less complication in LL group than PL group, but still, it is comparable (Table 2).¹⁴ Bapat et al noticed 86.01% and 97.01% clearance rate in PL and LL group with an average complication rate of 13.98% and 1.99%, respectively, which clearly shows that laser device is far better than pneumatic in management of proximal ureteric calculi with the semi-rigid ureteroscope.¹⁵ In our study we also noticed the same and comparable findings (Table 2). Razagi M et al conducted a comparative study.¹⁶ The aim was to compare two types of a lithotripter, including holmium: YAG laser and pneumatic one in transurethral ureterolithotripsy (TUL)

to manage ureteral calculi ≥ 1 cm. 112 patients with ureteral calculi more than 1 cm were selected in randomized order for pneumatic or holmium: YAG laser transurethral ureterolithotripsy (56 patients in each group). The success rate was 85.7% in the pneumatic group and 100% in the holmium: YAG laser group ($p=0.003$). Stone migration up in the pelvicalyceal system was observed only in 8 cases of the pneumatic group. No statically differences were observed regarding patients' age, hospital stay, and complications between the two groups. The conclusion is that Holmium: YAG Laser lithotripsy is more superior technology than pneumatic lithoclast in terms of rate of stone clearance and complications. Our study also found a significant difference in stone clearance rate, which is far better in the LL group with very minimal complications and less need for additional procedures to achieve a 100% clearance rate than the PL group. Farhan SD conducted a prospective comparative study.¹⁷ The aim was to compare the efficacy and safety of Holmium: YAG laser and pneumatic lithoclast in treating ureteric calculi. The study included a total of 65 patients divided into two groups of laser lithotripsy (LL) (25 patients) and pneumatic lithoclast (PL) (40 patients). The mean patient age, the male to female ratio, stone size and site were similar between the two groups. Mean operative time in the LL group was 35.5 minutes compared to 25.7 minutes in the PL group; the Stone migration up in pelvicalyceal system occurred in one patient (4%) of LL group while in nine patients (22.5%) of PL group. Stone free rate at four weeks was 84% in the LL group compared to 72.5% in the PL group. In our study, we noticed an 84% clearance rate in the PL group with stone migration occurred in three patients who were cleared with the auxiliary procedure at the same time, and we achieve a 96% clearance rate in a single sitting and in the LL group we found 92% clearance rate and stone migration to the pelvicalyceal system occurred in 2 patients who required additional procedures. Finally, we achieved a 100% clearance rate in the same sitting in the LL group.

CONCLUSION

We conclude that Holmium: YAG laser lithotripsy is a superior technology than pneumatic lithoclast in terms of rate of stone clearance, complications and secondary procedure rate especially in upper ureteric stones with the semi-rigid ureteroscope. However the mean operative time was shorter with pneumatic lithoclast.

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