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Original Article

Pneumatic Lithotripsy Versus Laser Lithotripsy in the Endoscopic Treatment of Ureteral Calculi

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Abstract

Ureteroscopy (URS) is a precise, minimally invasive surgical procedure that have emerged as the standard approach for treating large ureteral stones in many medical facilities, owing to their comparatively low complication rates and high success in achieving stone-free outcomes. In the context of ureteroscopic lithotripsy, various types of lithotripters are available, including electrohydraulic, ultrasonic, pneumatic, and laser options. Among these, laser lithotripsy (LL) and pneumatic lithotripsy (PL) are the most commonly utilized methods. The aim of this cross-sectional analytical study was carried out to compare the outcome of LL and PL in the management of ureteric calculi. Over the course of a year (from November 2022 to October 2023), this study was conducted among 96 patients with ureteral calculi in the Department of Urology at Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. Following the acquisition of both verbal and written consent from every patient, participants were enrolled in this study. The patients were categorized into two groups: Group A and Group B. Those who underwent procedure LL were placed in Group A, whereas those who received PL were assigned to Group B. A questionnaire was developed to gather data. Each patient was interviewed regarding their medical history and clinical characteristics, which included outcome variables such as the size of the stone, its location, the stone clearance rate, the duration of the procedure, the necessity for the Double J (DJ) method, the length of hospital stay, complications, the frequency of stone retrieval instrument usage, the rate of proximal fragment migration, and the requirement for Extracorporeal Shock Wave Lithotripsy (ESWL). The outcomes of the two procedures were compared in terms of stone clearance rate, duration of the procedure, requirement for DJ, length of hospital stay, complications, frequency of stone retrieval instrument usage, rate of proximal fragment migration, and necessity for ESWL. The data were analyzed using the statistical package for social sciences (SPSS) version 23.0. The mean age of participants in the LL group was 38.94 ± 9.47 years (range: 21-55), while in the PL group it was 36.46 ± 8.72 years (range: 23-50), with no significant difference (p>0.05). There was a predominance of males in both groups (p>0.05). The LL group had more right-sided stones while the PL group had more bilateral instances (p>0.05). Laser lithotripsy demonstrated less stone migration and DJ stenting, a higher stone-free rate, and shorter operative times compared to pneumatic lithotripsy. Both modalities were effective and safe for proximal ureteric calculus management. The mean size of stones was almost similar in both the LL and PL groups, with no significant difference observed. The stone size measured 10.37 ± 2.45 (ranging from 7.25 to 19.0) mm in the LL group, while it was 9.98 ± 2.26 (ranging from 7 to 17) mm in the PL group. The operative time was significantly short in the LL group compared to the PL group, recorded at 43.35 ± 3.86 minutes versus 55.08 ± 3.79 minutes; p<0.05. The immediate stone-free rate was significantly greater in the LL group (95.8%) compared to the PL group (79.2%). Additionally, stone migration was significantly less in the LL group than in the PL group. The rate of DJ stenting was also significantly lower in the LL group (33.3%) compared to the pneumatic group (54.2%). Although the complication rate was lower in the LL group (2.1%) than in the PL group (12.5%), this difference was not statistically significant. LL exhibited reduced stone migration and DJ stenting, a higher stone-free rate, and shorter operative times when compared to PL. Both procedures proved to be effective and safe for the management of proximal ureteric calculi.

Keywords: *Ureteral calculi, laser lithotripsy, pneumatic lithotripsy, DJ stenting.*

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INTRODUCTION

Urinary tract stones impact a considerable segment of the population. Although men are typically more prone to developing these stones, recent years have shown that the

occurrence of urinary tract stones in women is approaching that of men. Individuals suffering from urolithiasis often present with comorbid conditions or systemic disorders that facilitate the formation of stones.1 For example, obesity and chronic diseases such as diabetes are linked to a heightened risk of developing urinary tract stones.2 The most prevalent symptom reported by patients is renal colic, commonly referred to as flank pain. This intense pain is often accompanied by nausea and vomiting.[3]

Renal obstruction may result from ureteral calculi; thus, it is essential to prevent irreversible kidney damage. Conservative management might be considered if the stone measures less than 5 mm in diameter. Conversely, the likelihood of spontaneous passage is considerably reduced for larger and more proximal stones, necessitating intervention. The decisions regarding treatment for ureteral calculi are based on the size of the stone and the associated symptoms. In recent decades, the approach to treating ureteral calculi has evolved significantly, shifting from open ureterolithotomy to less invasive methods such as extracorporeal shock wave lithotripsy, ureteroscopic lithotripsy, and laparoscopic lithotripsy.[4]

Ureteroscopic lithotripsy presents the least number of contraindications, except for severe ureteral strictures that obstruct the effective passage of the scope.[5] Ureteroscopic procedures have emerged as the standard treatment for large ureteral stones in various centers, attributed to their relatively low complication rates and high stone-free rates. For ureteroscopic lithotripsy, various lithotripters such as electrohydraulic, ultrasonic, pneumatic, and laser are available. Among these, laser lithotripsy (LL) and pneumatic lithotripsy (PL) are the most commonly utilized methods.[6] There is a growing preference for LL due to its advantages in flexibility and fragmentation.[7] Conversely, some authors have argued that PL is comparable to LL regarding fragmentation efficiency, with the added benefits of lower costs and ease of installation.[8] The data comparing the efficacy and safety of LL and PL over the last decade has yielded inconclusive results.[8-10] In their meta-analysis, Yin et al.[11] found that LL exhibited a higher rate of maintaining JJ catheters, a lower migration rate, and a superior stone-free rate compared to PL. LL has been endorsed as a safe, effective, and powerful treatment option for distal ureteral stones. Since 2012, three randomized controlled trials (RCTs) have been published, each featuring a larger sample size and additional insights into complications. Additionally, another RCT on the same subject, published in 2008 by Manohar et al.[10], was identified through a comprehensive search. The reliability of the findings in the 2013 assessment by Yin et al. when comparing the efficacy and safety of LL and PL was affected by a relatively small patient cohort and the loss of usable data in many of the included studies.

The purpose of this research is to compare the effectiveness of laser lithotripsy (LL) with pneumatic lithotripsy (PL) in the treatment of ureteric calculi.

MATERIALS AND METHODS

Ethical approval was obtained from the institutional review board, adhering to the principles outlined in the Declaration of Helsinki. This study included patients of both genders who had a single ureteral stone measuring between 7-20mm and were aged 18 years or older. Patients who lacked a stone analysis report, had renal failure, presented with multiple stones, experienced difficulties during ureteroscopy, or did not provide consent to participate were excluded from the study.

This study was a cross-sectional analytical study carried out in the Department of Urology at BSMMU, Dhaka, over the course of one year from November 2022 to October 2023. A total of 96 patients with ureteral calculi participated in this research work after providing written consent. Subsequently, the patients were categorized into two groups. Patients in Group A underwent the LL procedure, while those in Group B underwent the LL procedure. Each patient was interviewed to gather their medical history and clinical characteristics. Detailed information was collected from each patient regarding the size and location of the stone, stone clearance rate, duration of the procedure, necessity for DJ stenting, length of hospital stay, complications, rate of use of stone retrieval instruments, rate of proximal migration of fragments, and the requirement for ESWL.

Method of laser lithotripsy:

The preoperative workup included urinalysis, a plain radiograph of kidneys, ureters and bladder (KUB) and ultrasonography (US) of KUB were done. An intravenous urogram (IVU) and non-contrast CT (NCCT) of abdomen was obtained in every patient. Renal parameters were reviewed in all patients. Prophylactic antibiotic (Tab ciprofloxacin/levofloxacin) was given in all patients. All procedures were performed with fluoroscopic guidance. The ureteroscope (8 Fr Karl Stroz), fluoroscopy, video monitors and irrigation devices were the same.

After proper position and thorough preparation and under spinal /epidural anesthesia, initial cystoscopy was done use a 20F sheath with passage of a 0.035 guide wire. A 8 Fr Storz rigid ureteroscope was placed through the urethra. When the stone was clearly visible, the laser fiber was advanced through the working channel, directly to the surface of the stone which was facilitated by the red helium- neon tracer light. Holmium: YAG lithotripsy was performed using a LISA Sphinx (LISA laser OHG, Kaltenburg, Germany) Holmium laser unit having a power output range of 1 – 80 watt. A 365 micro meter percu end firing fiber was used with laser settings of a maximum of 1.2 joule and a frequency of not more than 15 Hz. Low frequency setup was helpful for preventing the migration of stone/fragments. Initially a cavity was created on the surface of the stone which was be enlarged using an up-and-down motion. Stone cones or baskets will not be used to prevent stone migration. Sometimes forceps will be used for removal of remaining fragments. A 6Fr (25 cm) D-J stent was kept in situ. After completion of the procedure stone clearance was confirmed by fluoroscopy. Patients with migrated stones or incomplete clearance was undergone ESWL later on. Urethral catheter was removed on 1st POD routinely except few cases who had gross haematuria. In those cases catheter was removed when urine became clear. Injectable antibiotics was given to all the patients then oral antibiotics was continued up to 7th POD. X-ray was done on the 1st POD and after one month of the procedure during the removal of the stent.

Method of Pneumatic lithotripsy (Swiss lithoclast, SLC):

The preoperative workup included urinalysis, a plain radiograph of kidneys, ureters and bladder (KUB) and ultrasonography (US) was done. An intravenous urogram (IVU) and non-contrast CT (NCCT) was done. Renal parameters were reviewed in all patients. Prophylactic antibiotic (Tab ciprofloxacin/levofloxacin) was given to all patients. All procedures were performed with fluoroscopic guidance. After proper position and through preparation and under spinal /epidural anesthesia, initial cystoscopy was done using a 20F sheath with passage of a 0.035 guide wire. A 8F Storz rigid ureteroscope was placed through the urethra. The 0.8mm EMS Swiss lithoclast 2 probe was advanced through the working channel of the ureteroscope and then was fastened with the handle and connected to the air compressor. Air pressure (0-3 bar) will be used and frequency (2-12 Hz) to propel the metal projectile within the hand piece. Forceps/dormia baskets was used for the retrieval of stone fragments. A 6Fr (25 cm) D-J stent was kept in situ. After completion of the procedure fluoroscopy was done to confirm stone clearance. Patients with migrated stones or incomplete clearance was undergone ESWL later on. Urethral catheter was removed on 1st POD routinely or when urine was become clear. Injectable antibiotics was given to all the patients then oral antibiotics up to 7th POD. X-ray was done on the 1st POD and after 1 month of the procedure during the removal of the stent.

Statistical analyses were performed using SPSS 20.0 software (SPSS, Chicago, IL, USA). Numerical data was presented as mean & SD and categorical data was presented as frequency with percentage. Numerical data was analyzed using unpaired t test or Mann Whitney U test and categorical data was analyzed using Chi-Square test or Fisher's exact test. Statistical significance will be considered as $P \leq 0.05$

RESULTS

Table I states the demographic profile of the study subjects; the mean age of the participants was 38.94 ± 9.47 years (ranging 21 to 55 years) in the LL group, while in the PL group it was 36.46 ± 8.72 years (ranging 23 to 50 years). The age difference between the two procedures was not statistically significant. There were 67 males (69.79%) and 29 females (30.21%), resulting in a male-to-female ratio of 2.31:1. In the LL group, there were 32 males (66.7%) and 16 females (33.3%), whereas in the PL group, there were 35 males (72.9%) and 13 females (27.1%). However, the sex differences between the two procedures were not statistically significant.

Table- I: Demographic profile of the study subjects (N=96)

		Total	Laser lithotripsy (n=48)	Pneumatic lithotripsy (n=48)	p-value
Age (years)	Mean ± SD		38.94 ± 9.47	36.46 ± 8.72	0.185
	Min - max		21 - 55	23 - 52	
Gender	Male	67 (69.79%)	32 (66.7%)	35 (72.9%)	0.505
	Female	29 (30.21%)	16 (33.3%)	13 (27.1%)	

* Unpaired t test and Chi-Square test was done

The patients' stone laterality is shown in Table II; in this case, the PL group had 4 bilateral stones (8.3%) while the LL group had 2 (4.2%). The LL group had 22 (45.8%) and 24 (50.0%) left-sided stones, while the PL group had 23 (47.9%) and 21 (43.8%). Nevertheless, it was not statistically significant.

Table- II: CStone laterality of the study subjects (N=96)

Stone laterality	Laser lithotripsy (n=48)	Pneumatic lithotripsy (n=48)	p-value
Bilateral	2 (4.2%)	4 (8.3%)	0.641
Left	22 (45.8%)	23 (47.9%)	
Right	24 (50.0%)	21 (43.8%)	

* Chi-Square test was done

According to Table III, the mean stone size in the two procedures was 10.37 ± 2.45 (range 7.25-19.0) mm in the LL group and 9.98 ± 2.26 (range 7-17) mm in the PL group; however, there was no discernible difference.

Table- III: Stone size in the two procedure (N=96)

Stone size (mm)	Laser lithotripsy (n=48)	Pneumatic lithotripsy (n=48)	p-value
Mean ± SD	10.37 ± 2.45	9.98 ± 2.26	0.414
Min - max	7.25 – 19.0	7 - 17	

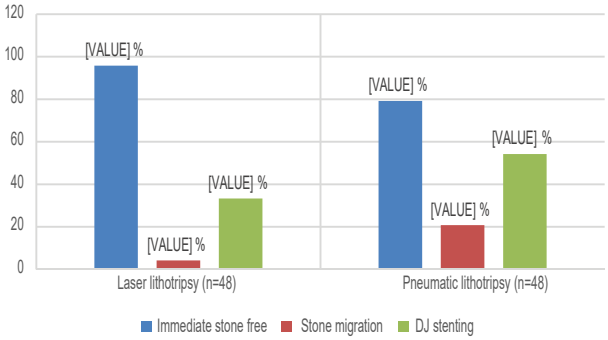
* Unpaired t test was done

The operating time required for the two procedures is shown in Table IV. The mean operative time for the LL procedure was 43.35 ± 3.86 (range 30 to 50) minutes, and for the PL, it was 55.08 ± 3.79 (range 50 to 60) minutes. Operative time was significantly shorter in LL than PL group.

Table- IV: Operating time required in the two procedure (N=96)

Operative time (min)	Laser lithotripsy (n=48)	Pneumatic lithotripsy (n=48)	p-value
Mean ± SD	43.35 ± 3.86	55.08±3.79	<0.001
Minimum - maximum	30 - 50	50 - 60	

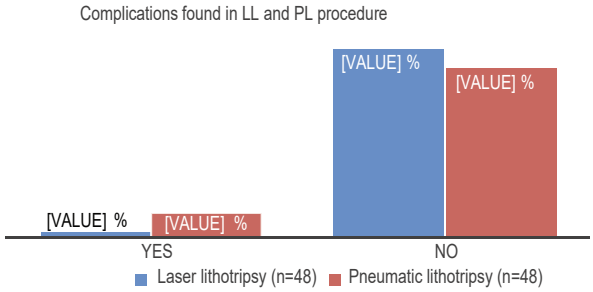
* Unpaired t test was done



* Chi-Square test was done

Figure- 1: Stone free rate in the two procedure (N=96)

Figure 1 depicts the stone-free rate for the two procedures, showing immediate stone-free rates, stone migration, and DJ stenting observed in 95.8%, 4.2%, and 33.3% of patients in the LL group, compared to 79.2%, 20.8%, and 54.2% in the PL group respectively. The stone migration rate was considerably lower in the LL group compared to the PL group. The DJ stenting rate in the LL group was significantly lower compared to the PL group (54.2%).



* Chi-Square test was done

Figure- 2: Complications in the two procedure (N=96)

Figure 2 shows the complications in the two procedure; 2.1% of the patients were experienced complication in LL and 12.5% in PL group, but the difference was not statistically significant.

DISCUSSION

Urinary calculus is a common occurrence in the surgical outpatient department. The treatment of ureteric calculus is contingent upon the location, size, density, and obstructive features. A variety of treatment modalities are available. Medical expulsion therapy with alpha-1 antagonists is effective for stones that are less than five millimeters in size. Soft proximal ureteric stones that are less than one

centimeter in size can be treated non-invasively using extracorporeal shockwave therapy.[12] As medical science has advanced, the treatment of urolithiasis has witnessed substantial changes.[13] Endoluminal surgery is employed to address urolithiasis. In endoluminal surgery, a diverse array of energy sources is employed to crush stones. Pneumatic lithotripsy does have certain limitations, including the migration of stones, notably in the presence of proximal ureteric calculus, despite its affordability and safety.[14] Holmium lasers are the optimal treatment for proximal calculus, as they produce a mild shock wave that impedes calculus migration. It is a consistent source of lithotripter, regardless of the calculus's density and composition.[15] LL is a preferable alternative to PL in terms of SFR, stone migration, DJ stenting, and complication, as our study has shown.

This study demonstrated that the immediate stone-free rate was significantly greater in the laser group (95.8%) compared to the pneumatic group (79.2%). Additionally, stone migration was significantly lower in the laser group (4.2%) relative to the pneumatic group (20.8%). The rate of DJ stenting was also significantly lower in the laser group (33.3%) than in the pneumatic group (54.2%). Furthermore, complications were less frequent in the laser group (2.1%) compared to the pneumatic group (12.5%). Koju et al.[16] demonstrated that laser lithotripsy outperformed pneumatic lithotripsy for immediate stone-free rate (99.05% vs 76.19%; p<0.001), stone migration rate (0.95% vs 14.29%; p<0.001), DJ stenting (69.52% vs 87.62%; p<0.001), and complications (1.90% vs 9.52%; p<0.017). Islam et al.[17] (2021) disclosed nearly identical findings. Razaghi and Razi[14] documented a 100% instantaneous stone-free rate in the LL arm (N=12) and a 42.9% rate in the PL arm (N=14), p=0.001; there was no migration in the LL arm, while migration occurred in 57.1% of cases in the PL arm for upper ureteric calculus.

Bapat et al.[18] documented a superior stone-free rate in the LL arm (97.01% versus 86.01%) and a reduced incidence of auxiliary procedures in the LL arm (1.99% versus 13.98%) for proximal ureteric calculi. Garg et al.[19] observed a significantly greater immediate stone-free rate in the LL arm (p=0.001) alongside a notable stone migration rate in the PL arm (16%). The findings of these investigations aligned with this study. Akdeniz et al.[8] documented an 89.9% success rate in the PL group and an 87.9% success rate in the LL group, p=0.791. Irer et al.[20] showed comparable complication rates in the PL and LL groups; however, there was a higher incidence of proximal migration in the PL group. Rabani et al.[21] documented a stone-free rate of 79.31% in the LL arm and 77.96% in the PL arm, p=0.52.

In this study operative time also shorter in laser group than pneumatic group (43.35 ± 3.86 vs 55.08 ± 3.79; p<0.001). Similar finding also observed in the study of Islam et al.[17] (2021), Guzel et al.[22] (2015) and Sun et al.[23] (2001).

CONCLUSION:

The Laser Lithotripsy group had less stone migration, decreased need for DJ stenting, and a higher stone-free rate compared to the Pneumatic Lithotripsy group. The operative duration was shorter in the laser group compared to the pneumatic group. Both techniques were successful and safe for the therapy of proximal ureteric calculi.

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