Original Article

Comparison of Outcome of Laser and Pneumatic Ureteroscopic Lithotripsy (URS) for Ureteric Stones

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Abstract

Objective: To evaluate and compare the stone-free rate and the extent of stone migration between laser and pneumatic ureteroscopic lithotripsy (URS) in patients presenting with ureteric calculi.

Methodology: A quasi-experimental study was carried out in the Department of Urology over a six-month period, from June to December 2022. A total of 158 patients, aged between 18 and 60 years, with ureteric stones measuring 7–20 mm in diameter, were included. The participants were allocated into two equal groups: Group A, treated with pneumatic URS (n = 79), and Group B, treated with laser URS (n = 79). All underwent standard preoperative evaluation followed by ureteroscopy using either pneumatic or laser lithotripsy. Stone-free rate and stone-migration were assessed outcomes. Data were analyzed using SPSS version 20.0. The Chi-square test was applied for categorical variables and Student's t-test for continuous variables, with $p < 0.05$ considered statistically significant.

Results: In Group A (pneumatic URS), the mean age was 41 ± 12.77 years; 50 (63%) were male and 29 (37%) were female. In Group B (laser URS), the mean age was 41 ± 10.12 years; 51 (65%) were male and 28 (35%) were female. No significant difference between groups regarding age or gender ($p > 0.05$). Stone-free rate was significantly higher in Group B (laser URS) 70 (89%) versus 55 (70%) in Group A ($p = 0.0033$, Chi-square test). stone-migration occurred in 61 (77%) of Group B and 67 (85%) of Group A, with no significant difference ($p = 0.2235$). Perforation observed more in Group A (16%) than Group B (5%) ($p = 0.0208$, Chi-square test), while other complications showed no statistically significant difference ($p > 0.05$).

Conclusion: Laser lithotripsy demonstrated significantly higher stone-free rates and fewer complications, particularly a lower rate of ureteric perforation, compared to pneumatic URS. Although stone-migration was lower in the laser group, the difference was not statistically significant. Overall, laser URS proved to be a more effective and safer option for the management of ureteric stones.

Keywords: Laser therapy, Lithotripsy, Pneumatic Devices, Treatment Outcome, Ureter, Ureteral Calculi

Introduction

Urolithiasis or stone disease of the urinary system is a frequent urological disorder in patients all over the world, with an increasing incidence both in developing and developed nations.[1] Untreated ureteric stones can lead to complications such as recurrent urinary tract infections, hydronephrosis, and progressive renal impairment.[2] Over the past few decades, the management of ureteric stones has evolved remarkably—from traditional open surgery to minimally invasive endourological procedures that reduce morbidity, shorten hospital stay, and promote faster recovery.[3] Ureteroscopy (URS) is now considered a standard approach for stones that fail to pass spontaneously or are associated with complications.[4] The procedure involves direct visualization of the stone using a rigid or flexible ureteroscope, followed by fragmentation with an intracorporeal lithotripsy device.[5] Among the various lithotripsy techniques, pneumatic and laser lithotripsy are the most widely utilized modalities.[6]

Pneumatic lithotripsy works through a ballistic mechanism that delivers mechanical force to fragment the stone. It is economical, simple to operate, and easily available in most centers.[7] However, it is associated with certain drawbacks, such as a higher likelihood of stone retropulsion toward the kidney and a possible need for secondary procedures.[8] On the other hand, laser lithotripsy—particularly using the Holmium:YAG laser—has become the preferred choice in many institutions due to its versatility and efficiency in fragmenting stones of varying compositions and hardness.[9] The technique uses high-energy laser pulses transmitted through a fiber, leading to precise fragmentation with minimal retropulsion.[10] It also allows "stone dusting," which may improve stone-free rates and reduce the need for additional interventions.[11]

Several studies have reported superior outcomes with laser lithotripsy compared to pneumatic lithotripsy, especially regarding stone-free rates and reduced stone migration.[12] Nevertheless, factors such as cost, equipment availability, and surgeon expertise continue to influence the choice of technique in clinical settings.[13] In resource-limited environments, pneumatic lithotripsy remains widely practiced. Therefore, assessing the relative efficacy of these two approaches within different healthcare contexts remains highly relevant.[14]

Although many studies from high-income countries have favored laser lithotripsy, there is a scarcity of data from local or resource-constrained settings. Given the variations in patient characteristics, operator skills, and availability of technology, evaluating the comparative outcomes of laser and pneumatic lithotripsy in our population is crucial to determine their true clinical advantage.This study was therefore designed to compare the stone-free rate and stone-migration between laser and pneumatic URS in patients with ureteric stones.

Methodology

Study Design and Setting

This quasi-experimental study was conducted in the Department of Urology, Lady Reading Hospital, Peshawar.

Duration

The research was carried out over a period of six months, from 14th June 2022 to 14th December 2022.

Ethical Approval

The study was approved by the Institutional Review Board (IRB) of Lady Reading Hospital, Peshawar (Reference No. 395/LRH/MTI). All participants provided written informed consent prior to inclusion in the study.

Sample Size

The sample size was calculated using the WHO sample size calculator, with efficacy for Group A = 86%, efficacy for Group B = 97%, a power of 80%, and a significance level of 5%. The calculated sample size was 158 patients, with 79 patients in each group.

Sampling Technique and Group Allocation

Non-probability consecutive sampling was used. Eligible patients were enrolled consecutively as they presented to the urology department. After confirmation of diagnosis and fulfillment of inclusion criteria, patients were assigned alternately to one of two groups based on the type of lithotripsy procedure to be performed:

Group A: Pneumatic URS

Group B: Laser URS

Both procedures were performed by consultant urologists with comparable levels of surgical experience to minimize operator bias.

Inclusion Criteria

- Patients undergoing laser or pneumatic URS for treatment of ureteric stones
- Age between 18 and 60 years
- Single ureteric stone measuring 7–20 mm in its largest diameter

Exclusion Criteria

- Patients with renal failure
- Previous ureteral surgery
- Signs of urinary tract infection
- Pregnant women

Parameters Measured

The following parameters were recorded for all pa-

tients:

- **Demographic variables:** age and gender
- **Clinical parameters:** stone size (mm) and location (upper, middle, or lower ureter) assessed via non-contrast CT KUB or ultrasonography
- **Operative outcomes:**

  Stone-free rate (SFR): Defined as the absence of any residual stone fragment ≥4 mm on ultrasonography or X-ray KUB at 2 weeks post-procedure.[15]

  Stone-migration: Defined as the upward displacement of the ureteric stone into the renal pelvis or calyces during the procedure, confirmed intraoperatively or radiologically.[16]

  Intraoperative complications: mucosal injury, bleeding, perforation, and postoperative infection or stricture formation.[15]

Bias Control and Minimization of Confounders

To reduce selection bias, consecutive sampling and alternate group assignment were used. Performance bias was minimized by ensuring all procedures were performed by surgeons with similar training and experience using standardized operative protocols. Detection bias was controlled by having postoperative imaging interpreted by radiologists blinded to the intervention type. Information bias was reduced through the use of a predesigned data collection proforma. Strict adherence to inclusion and exclusion criteria further reduced potential confounding effects.

Data Analysis

Data were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 20.0. Quantitative variables (e.g., age, stone size) were expressed as mean ± standard deviation (SD), and qualitative variables (e.g., gender, stone-free rate, complications) as frequencies and percentages. Comparisons between groups were made using the Chi-square test for categorical variables and Student's t-test for continuous variables. A p-value of <0.05 was considered statistically significant.

Results

A total of 158 patients were included in this study, with 79 patients each in Group A (Pneumatic URS) and Group B (Laser URS). In Group A, 47 (59%) patients were aged 18–40 years, while 32 (41%) were aged 41–60 years, with a mean age of 41 ± 12.77 years. In Group B, 48 (61%) patients were aged 18–40 years, and 31 (39%) were aged 41–60 years, with a mean age of 41 ± 10.12 years. No statistically significant difference was observed between the two groups (p = 1.000).In Group A, 50 (63%) patients were male and 29 (37%) were female, whereas in Group B, 51 (65%) were male and 28 (35%) were female. The difference was not statistically significant (p = 0.8684).The stone-free rate in Group A was achieved in 55 (70%) patients, compared to 70 (89%) patients in Group B, which was statistically significant (p = 0.0033). Stone-migration was observed in 67 (85%) patients in Group A and 61 (77%) in Group B (p = 0.2235).In Group A, mucosal injury occurred in 16 (20%) patients, bleeding in 15 (19%), perforation in 13 (16%), stricture formation in 9 (11%), and infection in 17 (22%). In Group B, the corresponding frequencies were 10 (13%), 8 (10%), 4 (5%), 14 (18%), and 14 (18%), respectively. Among these, perforation was significantly higher in Group A (p = 0.0208). Other complications were not statistically significant (Table 1).

Stratified Analysis

For complications stratified by age and gender, no statistically significant differences were noted between groups, except perforation, which was significantly higher in younger patients (18–40 years) undergoing pneumatic URS (17% vs. 4%, p = 0.0412).When out-

Table 1. Gender, Outcomes, and Complications of Patients (n = 158)

Variable	Categories	Group A (Pneumatic URS)	Group B (Laser URS)	p-value
Gender	Male	50 (63%)	51 (65%)	0.8684
	Female	29 (37%)	28 (35%)	
Outcomes	Stone-free rate	55 (70%)	70 (89%)	0.0033*
	Stone-migration	67 (85%)	61 (77%)	0.2235
Complications	Mucosal injury	16 (20%)	10 (13%)	0.1979
	Bleeding	15 (19%)	8 (10%)	0.1143
	Perforation	13 (16%)	4 (5%)	0.0208*
	Stricture formation	9 (11%)	14 (18%)	0.2593
	Infection	17 (22%)	14 (18%)	0.5478

*Significant at p < 0.05

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Table 2. Stratified Analysis of Outcomes and Key Complication

Variable	Comparison	Group A (Pneumatic)	Group B (Laser)	p-value
Age 18–40 years	Stone-free rate	33/47 (70%)	43/48 (90%)	0.0182*
	Stone-migration	40/47 (85%)	37/48 (77%)	0.3184
	Perforation	8/47 (17%)	2/48 (4%)	0.0412*
Age 41–60 years	Stone-free rate	22/32 (69%)	27/31 (87%)	0.0799
	Stone-migration	27/32 (84%)	24/31 (77%)	0.0482*
Gender – Male	Stone-free rate	35/50 (70%)	45/51 (88%)	0.0239*
	Stone-migration	42/50 (84%)	39/51 (76%)	0.3424
Gender – Female	Stone-free rate	20/29 (69%)	25/28 (89%)	0.0599
	Stone-migration	25/29 (86%)	22/28 (79%)	0.4486

*Significant at $p < 0.05$

comes were stratified by age, patients aged 18–40 years in Group B had a significantly higher stone-free rate (90% vs. 70%, p = 0.0182) compared to Group A, while stone-migration showed no significant difference. In the 41–60 years group, the stone-free rate was higher with laser URS (87% vs. 69%, p = 0.0799), while stone-migration was significantly lower in Group B (77% vs. 84%, p = 0.0482).On gender stratification, male patients in Group B had a significantly higher stone-free rate (88% vs. 70%, p = 0.0239), while in females, the difference was not statistically significant (89% vs. 69%, p = 0.0599) (Table 2).

Discussion

The present study demonstrated a significantly higher stone-free rate (SFR) with laser ureteroscopy compared to pneumatic ureteroscopy (89% vs. 70%, p=0.0033), along with a significantly lower perforation rate and a trend toward reduced stone-migration. These findings are in line with a substantial body of literature indicating superior clinical outcomes for Holmium:YAG laser lithotripsy over pneumatic lithotripsy in terms of SFR and complication profiles, though variations exist depending on stone location, patient population, and outcome measures.[17] Table 3 provides a detailed comparative analysis between our results and recent published studies.

In summary, the majority of recent evidence supports the superiority of laser lithotripsy over pneumatic lithotripsy in terms of stone clearance, with several studies also reporting reduced stone-migration, fewer com-

Table 3. Comparative Summary of Present Study and Recent Literature on Laser vs. Pneumatic URS for Ureteric Stones

Study / Year	Population & Stone Location	Key Findings – Stone-Free Rate (SFR)	Stone-Migration / Retropulsion	Operative Time	Complications & Other Findings	Comparison with Present Study
Present Study (n=158)	Adults, all ureteric levels	Laser: 89% vs Pneumatic: 70% (p=0.0033)	Laser: 77% vs Pneumatic: 85% (NS)	–	Perforation: significantly less in laser (5% vs 16%, p=0.0208); other complications comparable	Confirms higher SFR with laser; perforation significantly lower; migration trend favors laser but NS
Ahmed et al., 2022 [18]	Upper ureteric stones (n=60)	Laser: 93.3% vs Pneumatic: 70% (p=0.059)	Laser: 6.7% vs Pneumatic: 26.6% (p<0.038)	Laser shorter (24.47 min vs 27.83 min, p=0.024)	No significant difference in complications	SFR pattern similar; migration significantly lower with laser in Ahmed et al., while our migration difference not statistically significant

ul Mulk et al., 2025 [19]	Proximal ureteric stones (URS laser vs ESWL)	URS Laser: 92.8% vs ESWL: 47% (p=0.001)	–	–	URS laser lower re-treatment (7.2% vs 48.2%)	Although different comparator (ESWL), reinforces high SFR for laser in proximal stones, consistent with our laser results
Irsayanto et al., 2024 (Meta-analysis, pediatrics)[20]	Pediatric ureteral stones	Laser SFR significantly higher (OR 2.06)	Laser retropulsion lower (OR 0.37)	No significant OT difference	Complication rates similar	Consistent with our finding of higher SFR and trend toward lower migration in laser group
Alam et al., 2025[21]	Mid & lower ureteric stones (n=64)	Laser: 83.3% vs Pneumatic: 60% (p=0.04 at 1 month)	No significant difference	No significant OT difference	PL had more hematuria; hospital stay shorter in laser	Both studies show higher early SFR for laser; our overall SFR difference even greater (89% vs 70%)
Islam et al., 2025[22]	All ureteric levels (n=70	Laser clearance higher (p=0.035)	Migration less with laser (p=0.024)	OT shorter in PL (p=0.034)	PL had more hematuria (p=0.044)	Matches our higher SFR and lower migration trend for laser; unlike their finding, our OT not recorded for comparison
Bahçeci et al., 2022[23]	All ureteric levels (n=510)	Laser overall: 98.5% vs Pneumatic: 93.9% (p=0.006); Proximal stones: 94.4% vs 68.9%	–	No difference	Fewer stents in laser group	Consistent with our SFR advantage for laser, particularly notable for proximal stones
Wicaksono et al., 2023 (Meta-analysis) [24]	11 RCTs (n=235)	Laser SFR significantly higher (OR 2.39)	DJ stent use lower with laser	Fragmentation time longer in laser	–	Strongly supports our SFR findings; complication trends align

plications, and shorter hospital stays for laser-treated patients. Our results align with these trends, demonstrating a significantly higher SFR and lower perforation rate with laser URS.

A key strength of this study is the relatively large sample size compared to several earlier single-centre trials, allowing for more robust statistical comparisons. Additionally, outcomes were stratified by age and gender, providing insights into subgroup variations that have not been extensively explored in prior research.

However, the study has limitations. Operative time and irrigation volume were not recorded, which limits comparison with studies that found time differences between modalities. Stone composition analysis was not performed, which may influence fragmentation efficiency. The follow-up period was relatively short, focusing on early stone-free rates without long-term recurrence or stricture assessment. Being a single-centre study may also limit the generalizability of the findings to other settings with different equipment, surgeon experience, or patient demographics.

Future research should aim for multicentre randomized controlled trials with standardized operative protocols, inclusion of stone composition analysis, and extended follow-up to assess long-term outcomes such as recurrence and late complications. Studies could also investigate cost-effectiveness, patient-reported

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outcomes, and technological refinements (e.g., pulse modulation in laser systems) to further optimize ureteroscopic stone management.

Conclusion

Laser lithotripsy demonstrated a significantly higher stone-free rate and fewer intraoperative complications, particularly a lower rate of ureteric perforation, compared to pneumatic URS in the management of ureteric stones. Although stone-migration was less frequent in the laser group, the difference was not statistically significant. Overall, laser URS proved to be a more effective and safer modality for achieving optimal clinical outcomes in patients with ureteric stones.

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Authors' Contribution Statement

MA contributed to the conception, design, acquisition, analysis, interpretation of data, drafting of the manuscript, critical review of the manuscript, and final approval of the version to be published. SA contributed to the design, acquisition, analysis, drafting of the manuscript, and critical review of the manuscript. SUR contributed to the design, acquisition, analysis, drafting of the manuscript, and critical review of the manuscript. SU contributed to the acquisition, analysis, interpretation of data, and drafting of the manuscript. SH contributed to the acquisition, analysis, interpretation of data, and drafting of the manuscript. SZN contributed to the acquisition, analysis, interpretation of data, and drafting of the manuscript. All authors are accountable for their work and ensure the accuracy and integrity of the study.

Conflict of Interest

Authors declared no conflict on interest

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None

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.