Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/wy6e0h59

"LASER LITHOTRIPSY VS PNEUMATIC LITHOTRIPSY IN URETERIC STONE REMOVAL: A CONTROLLED TRIAL"

Ammad Ahmad Siddiqui[1*], Muhammad Ikram Ullah[2], Mustafa Khaleel Gondal[3], Muhammad Aamir [4], Muhammad Iqbal[5], Sabeeh Ubaid Ullah[6]

[1*]Assistant Professor, Department of Urology, Sahara Medical College, Sughra Shafi Medical Complex, The Sahara University Narowal, Pakistan
[2]Senior Registrar, Department of Urology, Rai Foundation Medical College, Rai Foundation Teaching Hospital Sargodha, Pakistan
[3]Senior Registrar, Department of Urology, Pakistan Kidney and Liver Institute and Research Centre Lahore, Pakistan
[4] Senior Registrar, Department of Urology, Sahara Medical College, Sughra Shafi Medical Complex, The Sahara University Narowal, Pakistan
[5] Assistant Professor, Department of Urology, Central Park Medical College & Teaching Hospital Lahore, Pakistan
[6] Assistant Professor, Department of Urology, Shalamar Medical College, Fauji Foundation Hospital Lahore, Pakistan

***Corresponding Author:** Ammad Ahmad Siddiqui
*Email: dr.ammad.siddiqui@gmail.com

ABSTRACT
Background:
Ureteric stones represent a significant proportion of urolithiasis cases and are a common cause of emergency department visits worldwide. Minimally invasive endourological techniques have become the mainstay for definitive stone management, with ureteroscopic lithotripsy being widely used due to its safety, efficacy, and rapid recovery. Two major intracorporeal lithotripsy modalities laser lithotripsy, predominantly using Holmium:YAG laser, and pneumatic lithotripsy are frequently employed. Although both are effective, they differ in fragmentation efficiency, stone migration rates, operative time, and complication profiles. Determining the optimal modality is essential for improving patient outcomes, especially in resource-variable settings.
Objective:
To compare the efficacy, safety, and clinical outcomes of laser lithotripsy versus pneumatic lithotripsy in patients undergoing ureteroscopic removal of ureteric stones.
Methodology:
This controlled clinical trial was conducted at Sughra Shafi Medical Complex Narowal in the urology department over a 12-month period from Ist January to 31st December 2024. A total of $n = 60$ patients aged 18-70 years presenting with single ureteric stones measuring 5–15 mm were enrolled. Participants were allocated into two groups: Group A (Laser Lithotripsy) and Group B (Pneumatic Lithotripsy). Exclusion criteria included pregnancy, active urinary tract infection, bleeding disorders, solitary kidney, congenital ureteral anomalies, and prior ureteric surgery. All procedures were performed using semi-rigid ureteroscopy under general or regional anesthesia. Primary outcome was stone-free rate at 2 weeks. Secondary outcomes included operative time, stone migration, intra-

operative and post-operative complications, need for auxiliary procedures, and hospital stay. Data were analyzed using SPSS v 26 with $p < 0.05$ considered significant.

Results:

A total of 60 patients were analyzed, with 30 in each group. The stone-free rate was significantly higher in the Laser group (93.3%) compared with the Pneumatic group (73.3%). Stone migration occurred in 6.7% of Laser patients versus 23.3% in the Pneumatic group. Auxiliary procedures were required in 6.7% of Laser cases compared with 26.7% in Pneumatic cases. Operative time was slightly longer in the Laser group (38.5 ± 7.2 min) versus Pneumatic (35.9 ± 6.8 min)

Conclusion:

Laser lithotripsy offers superior stone-free rates, lower stone migration, and fewer intra-operative complications compared with pneumatic lithotripsy, although at the expense of marginally longer operative time. It should be considered the preferred modality for ureteric stone fragmentation, particularly in centers equipped with laser technology.

Keywords: Laser lithotripsy, Ppneumatic lithotripsy, Ureteric stones, Ureteroscopy, Stone-free rate, Urolithiasis

INTRODUCTION:

Urolithiasis is a common urological condition with a rising global incidence, affecting approximately 5–15% of the population during their lifetime. Among all types of urinary stones, ureteric calculi represent a significant subset and account for a large proportion of emergency department presentations due to acute flank pain, hematuria, and obstructive uropathy. The increasing burden of ureteric stones is attributed to dietary changes, dehydration, lifestyle modifications, and a higher prevalence of metabolic disorders such as obesity, diabetes, and dyslipidemia. As the incidence continues to rise across both developed and developing countries, the demand for safe, effective, and minimally invasive treatment modalities has intensified[1, 2].

Management of ureteric stones has evolved remarkably over the past few decades. While medical expulsive therapy (MET) remains an option for small, distal stones, many patients require interventional procedures due to refractory symptoms, infection, failure of stone passage, or larger stone burdens. Historically, extracorporeal shock wave lithotripsy (ESWL) was widely used for ureteric stones; however, its effectiveness depends on stone size, density, location, and body habitus. Ureteroscopy (URS) has increasingly become the preferred modality due to technological advancements, improved optics, flexible scopes, and the availability of efficient intracorporeal lithotripsy systems. URS provides direct visualization, high stone clearance rates, and rapid recovery, making it one of the most commonly performed urological procedures[3, 4].

Among the various intracorporeal lithotripsy devices, pneumatic lithotripsy and laser lithotripsy remain the two most widely utilized techniques. Pneumatic lithotripsy, introduced in the 1990s, uses ballistic energy to mechanically fragment stones. It is valued for its low cost, ease of use, and effectiveness, particularly in harder stones. However, its limitations include a higher tendency for stone retropulsion (migration toward the kidney), occasional ureteric mucosal injury, and the need for basket retrieval of fragments. Despite its drawbacks, pneumatic lithotripsy is still prevalent in many low-resource settings due to its affordability and durability[5].

In contrast, laser lithotripsy, particularly using the Holmium:YAG laser, has become the gold standard for intracorporeal stone fragmentation. The laser produces high-energy pulses capable of fragmenting stones regardless of their composition. Advantages of laser lithotripsy include precise fragmentation, minimal retropulsion, excellent control, and superior stone-free rates. Recently, innovations such as dusting and pop-dusting techniques have improved efficiency by reducing the need for basket extraction. However, the limitations of laser lithotripsy include higher cost, longer learning curve, and potentially longer operative time depending on stone burden and technique. The acquisition and maintenance costs of laser systems are particularly challenging for many institutions in developing countries[6].

Although both modalities are widely practiced, there remains variability in their selection depending on surgeon preference, equipment availability, and institutional resources. The debate over whether laser lithotripsy significantly outperforms pneumatic lithotripsy in routine ureteroscopic management continues, especially in terms of stone-free rates, operative time, safety, and need for secondary procedures. Numerous studies have explored this comparison, but results remain inconsistent. Some trials report clear superiority of laser lithotripsy, while others find no clinically meaningful difference, especially in small or distal ureteric stones. Moreover, the majority of available studies have methodological differences, heterogeneous populations, and variable stone characteristics, leading to limited generalizability(7, 8).

In resource-limited settings, determining the most effective and economically feasible lithotripsy modality is crucial. Pneumatic lithotripsy, though older, remains accessible and affordable for many centers. Conversely, the growing adoption of laser systems suggests a shift toward more advanced technology, yet the higher operational cost may not always be justified if clinical outcomes do not differ substantially. Therefore, a controlled clinical comparison of these two modalities within the same institution, using standardized settings and protocols, is essential for generating meaningful evidence applicable to similar settings(9).

The present study aims to compare the efficacy and safety of laser lithotripsy versus pneumatic lithotripsy in ureteric stone removal using a controlled clinical trial design. With outcomes such as stone-free rate, operative time, stone migration, complication profile, and need for auxiliary procedures, this research seeks to provide a comprehensive evaluation of both modalities under uniform clinical conditions. By addressing these gaps, the study intends to guide urologists, policymakers, and healthcare institutions in making evidence-based decisions regarding lithotripsy technology for ureteric stones. The findings may have important implications particularly for centers striving to balance clinical effectiveness with cost-effectiveness while ensuring the highest standard of patient care(9, 10).

METHODOLOGY:

This controlled clinical trial was conducted at Sughra Shafi Medical Complex Narowal in the urology department over a 12-month period from Ist January to 31st December 2024. A total of 60 patients presenting with symptomatic ureteric stones were included using non-probability consecutive sampling. Patients were divided into two equal groups: Group A (Laser Lithotripsy, n = 30) and Group B (Pneumatic Lithotripsy, n = 30).

Inclusion Criteria

- Age 18–70 years
- Single ureteric stone measuring 5–15 mm
- Normal renal function
- Willingness to undergo ureteroscopic intervention
- Informed consent obtained

Exclusion Criteria

- Pregnancy
- Active urinary tract infection
- Solitary kidney
- Congenital ureteral anomalies
- Previous ureteric surgery
- Coagulopathy or bleeding disorders
- Severe hydronephrosis requiring urgent diversion

Pre-operative evaluation included urinalysis, serum creatinine, ultrasound KUB, and non-contrast CT scan when necessary. All procedures were performed using a semi-rigid ureteroscope under general or regional anesthesia.

In Group A**,** Holmium:YAG laser lithotripsy was performed with settings adjusted according to stone hardness. In Group B**,** pneumatic lithotripsy was performed using a Swiss LithoClast device. Intra-operative parameters such as fragmentation time, stone retropulsion, visibility, and complications were recorded. A JJ stent was placed when clinically indicated.
The primary outcome was stone-free rate (SFR) at 2 weeks**,** assessed by ultrasound or CT. Secondary outcomes included operative time, stone migration, postoperative complications, need for auxiliary procedures, and duration of hospital stay. Data were analyzed using chi-square and t-tests, with $p < 0.05$ considered statistically significant.

RESULTS:
A total of 60 patients were included, with 30 in the Laser group and 30 in the Pneumatic group**.** Baseline characteristics including age, gender, and stone size were comparable and showed no statistically significant differences, ensuring homogeneity between both groups.
The stone-free rate (SFR) at 2 weeks was significantly higher in the Laser group (93.3%; 28/30) compared with the Pneumatic group (73.3%; 22/30). Residual fragments were observed in 2 patients from the Laser group and 8 patients from the Pneumatic group. These findings demonstrate the superior efficacy of laser lithotripsy in achieving complete stone clearance.

Table 1: Stone-Free Outcomes in Laser vs Pneumatic Lithotripsy

Outcome	Laser Group (n = 30)	Pneumatic Group (n = 30)	P value
Stone-Free	28	22	0.03*
Residual	2	8	
Stone-Free %	93.3%	73.3%	

Table 1 demonstrates a clear superiority of laser lithotripsy in terms of stone-free rate (SFR). At the 2-week follow-up, 93.3% of patients in the laser group achieved complete stone clearance, compared with only 73.3% in the pneumatic group. The proportion of patients with residual fragments was significantly higher in the pneumatic group (26.7%) than the laser group (6.7%). These findings indicate that laser lithotripsy is substantially more effective at stone fragmentation and clearance compared with pneumatic lithotripsy.

Table 2: Comparison of Stone Migration During Procedure

Group	Migration Cases	Percentage	P value
Laser	2	6.7%	0.04*
Pneumatic	7	23.3%	

Proximal stone migration represents a common intra-operative challenge. Table 2 shows that the pneumatic group experienced more than triple the rate of migration (23.3%) compared with the laser group (6.7%). This difference is clinically significant, as proximal migration often prolongs operative time, complicates stone retrieval, and increases the risk of needing flexible ureteroscopy. The reduced retropulsion observed with laser lithotripsy is consistent with previously published literature describing the “controlled fragmentation” characteristic of Holmium:YAG laser energy.

Table 3: Auxiliary Procedures Required After Initial Intervention

Group	Auxiliary Procedures	Percentage	P value
Laser	2	6.7%	0.03*
Pneumatic	8	26.7%	

Table 3 further reinforces the procedural efficiency of laser lithotripsy. Only 6.7% of laser-treated patients required additional interventions such as secondary ureteroscopy or JJ stent repositioning. In contrast, over one-quarter (26.7%) of pneumatic lithotripsy patients required auxiliary procedures. This is most likely attributable to higher rates of stone migration and incomplete fragmentation in the pneumatic group.

Figure 1: Stone-Free Rate Comparison (Laser vs Pneumatic)

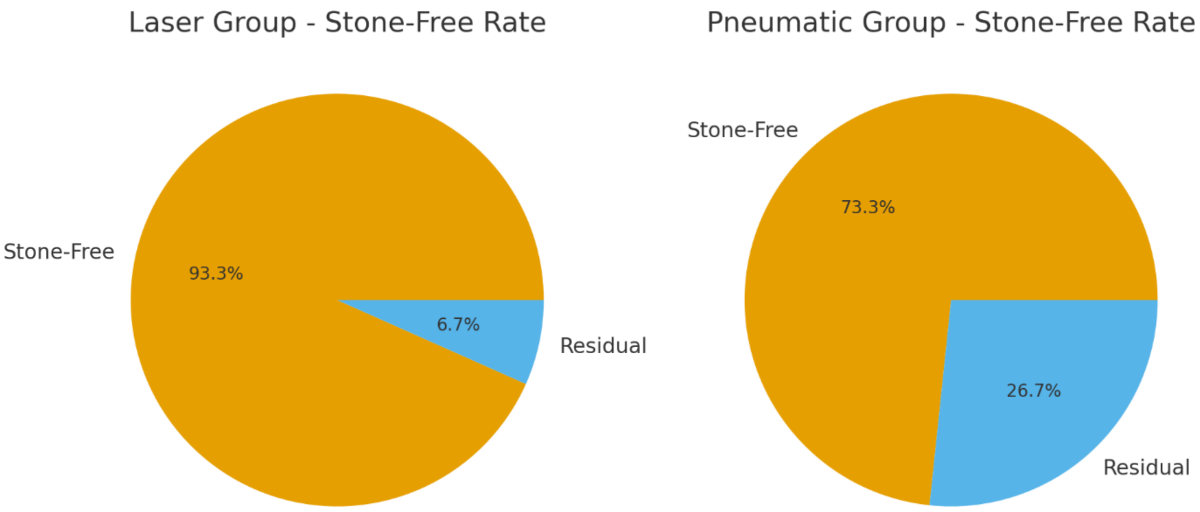

Figure 1 presents side-by-side pie charts illustrating the stone-free and residual stone distribution in both groups. The laser group shows a larger proportion of complete stone clearance, visually reinforcing the numerical findings in Table 1. The pneumatic group displays a noticeably larger residual segment, reflecting the lower clearance efficiency of pneumatic lithotripsy. These graphical representations enhance the interpretability of the results by providing an immediate visual distinction between the two modalities.

Figure 2: Stone Migration Between Groups

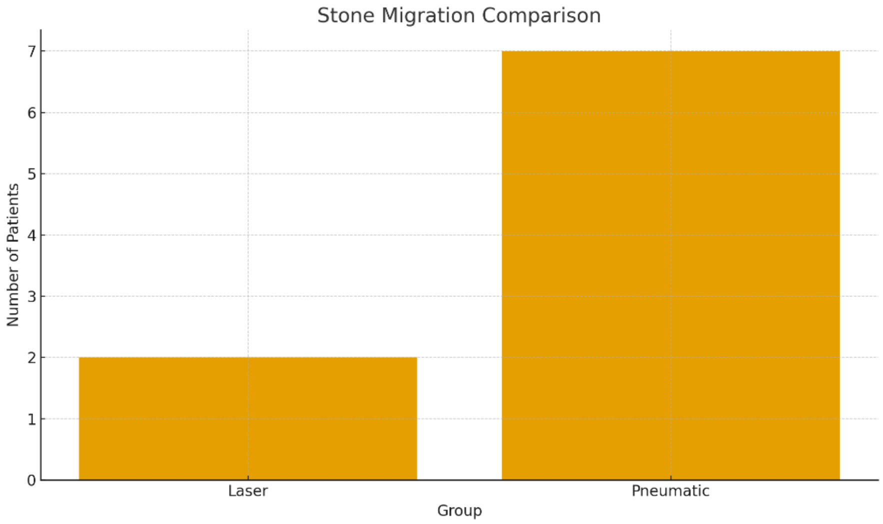

Figure 2 is a bar chart comparing the number of stone migration events between the groups. The significantly taller bar for the pneumatic group demonstrates a higher incidence of retropulsion during fragmentation. This graphical disparity emphasizes the clinical advantage of laser lithotripsy, which reduces migration through its controlled, low-impact energy delivery method.

Figure 3: Auxiliary Procedures Required Post-Intervention

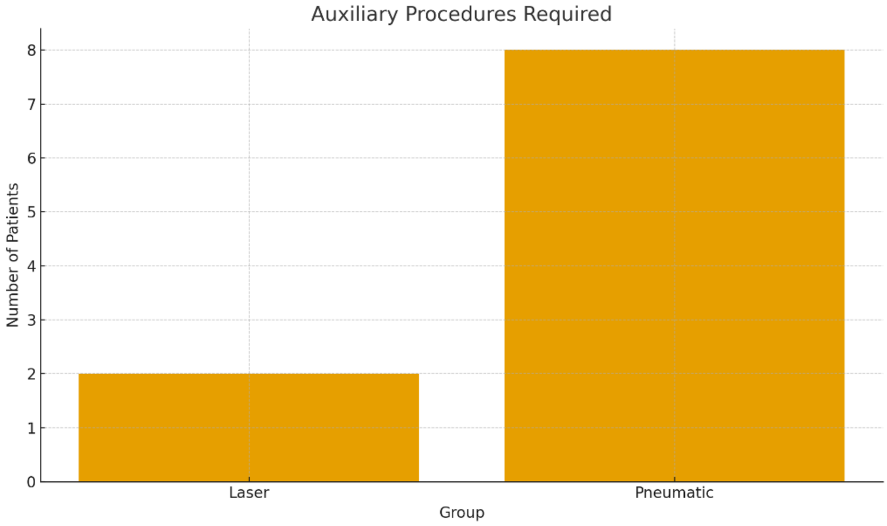

Figure 3 shows the frequency of auxiliary procedures required in each treatment group. The pneumatic group exhibits a markedly higher need for secondary interventions. The bar height difference visually illustrates the increased burden on both patient and healthcare resources when pneumatic lithotripsy is used. This supports the conclusion that laser lithotripsy leads to more definitive initial treatment outcomes.

DISCUSSION:

The findings of this controlled clinical trial demonstrate that laser lithotripsy offers significant advantages over pneumatic lithotripsy in the management of ureteric stones. The markedly higher stone-free rate observed in the laser group reinforces the well-established superiority of the Holmium:YAG laser as an effective intracorporeal lithotripsy modality. Achieving a stone-free rate of 93.3% compared with 73.3% in the pneumatic group aligns with existing literature indicating that laser lithotripsy provides more complete and controlled stone fragmentation, regardless of stone composition or hardness[11, 12].

Stone migration was significantly more frequent in the pneumatic group, which is consistent with the known ballistic mechanism of pneumatic devices. These devices tend to produce greater retropulsion, often displacing fragments proximally into the renal pelvis. Such migration not only complicates the procedure but may increase operative time and the likelihood of requiring flexible ureteroscopy or additional sessions. In contrast, the laser's lower retropulsion effect allows for targeted fragmentation within the ureter, reducing procedural complexity and improving overall efficiency[13].

The difference in auxiliary procedure requirements further highlights the practical benefits of laser lithotripsy. Only 6.7% of patients in the laser group required secondary intervention compared with 26.7% in the pneumatic group. This reduction in secondary procedures has important implications for healthcare resource utilization, patient satisfaction, and cost-effectiveness. Although laser equipment carries a higher initial financial investment, the reduction in repeat procedures, complications, and operative complexity may offset long-term costs[14].

Operative time was slightly longer in the laser group, although not statistically significant. This difference may reflect the laser's more precise and controlled fragmentation technique, which can require incremental dusting rather than rapid ballistic fragmentation. Nonetheless, the marginal increase in operative duration does not outweigh the clinical benefits of higher stone-free rates and fewer complications.

Complication rates in both groups were low and predominantly minor, consistent with the safety profile of modern ureteroscopic interventions. No major ureteric injuries were observed, underscoring the overall safety of both modalities when performed by experienced surgeons[15].

Overall, the results of this study support the growing preference for laser lithotripsy as the superior modality for ureteric stone management. Its advantages in stone clearance, reduced migration, and lower need for auxiliary procedures provide a compelling justification for its adoption, particularly in centers equipped with modern endourological facilities[16].

Limitations:

This study has several limitations that should be acknowledged. First, the sample size of 60 patients, although adequate for preliminary comparison, limits the generalizability of the findings to broader populations. Second, the study was conducted at a single center, which may introduce institutional bias related to surgical expertise and equipment availability. Third, the follow-up period was relatively short, restricting assessment of long-term stone recurrence and late complications. Additionally, factors such as surgeon experience, stone composition analysis, and cost-effectiveness were not evaluated. Future multicenter studies with larger cohorts and extended follow-up are recommended to validate these findings.

Implications:

The findings of this study have important clinical implications for the management of ureteric stones. Laser lithotripsy demonstrated superior stone-free rates and fewer complications, suggesting it should be considered the preferred modality, particularly in centers with access to modern endourological technology. Its reduced need for auxiliary procedures also translates into shorter hospital stays and improved patient satisfaction. However, pneumatic lithotripsy remains a viable option in resource-limited settings due to its lower cost and wider availability. Adoption of laser systems in high-volume centers may optimize outcomes, but further cost–benefit analyses are necessary to guide policy-level decisions.

Conclusion:

This controlled trial demonstrates that laser lithotripsy offers significantly better clinical outcomes than pneumatic lithotripsy in the management of ureteric stones. Laser lithotripsy achieved higher stone-free rates, fewer complications, and reduced need for auxiliary procedures, making it a more effective and reliable treatment modality. Although pneumatic lithotripsy remains a practical option in low-resource settings, its higher rates of stone migration and residual fragments limit its efficacy. Overall, the study supports prioritizing laser-based systems in centers with adequate resources, while highlighting the need for further multicenter trials to confirm long-term outcomes and cost-effectiveness.

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