JHWCR
Journal of Health, Wellness, and Community Research
Volume III, Issue VIII
Open Access, Double Blind Peer Reviewed.
Web: https://jhwcr.com, **ISSN**: 3007-0570
https://doi.org/10.61919/ccct8c48

Article

Stone Clearance Rate of Intracorporeal Pneumatic Lithotripsy for Mid Ureteric Stone of Size 1–2 cm

Muhammad Usman[1], AAmir Zeb Khan[1], Hamza Khan[1]

1 MTI/LRH, Peshawar, Pakistan

Correspondence
03169743024hk@gmail.com

Cite this Article

Received	2025-05-21
Revised	2025-06-11
Accepted	2025-06-14
Published	2025-07-03

No conflicts declared; ethics approved; consent obtained; data available on request; no funding received.

Authors' Contributions
Concept: MU; Design: AZK; Data Collection: MU; Analysis: AZK; Drafting: HK

ABSTRACT

Background: Ureteric calculi are a prevalent cause of morbidity in urological practice, with mid-ureteric stones measuring 1–2 cm requiring effective and timely management to prevent obstruction, infection, and renal impairment. While extracorporeal shock wave lithotripsy and laser ureteroscopy are commonly employed, intracorporeal pneumatic lithotripsy remains a practical alternative in resource-limited settings, though regional data on its efficacy remain limited. **Objective**: To determine the frequency of stone clearance following ureterorenoscopic intracorporeal pneumatic lithotripsy in patients with mid-ureteric stones sized 1–2 cm. **Methods**: This descriptive cross-sectional study was conducted at the Department of Urology, MTI/LRH, Peshawar, from January to July 2024. A total of 183 patients aged 18–60 years with radiopaque mid-ureteric stones (1–2 cm) were enrolled through non-probability consecutive sampling. All patients underwent standardized pneumatic lithotripsy, with stone clearance assessed by non-contrast CT-KUB at two weeks. Data on age, gender, BMI, laterality, and pain duration were collected and analyzed using SPSS v25; chi-square tests were applied for stratified comparisons. **Results**: The overall stone clearance rate was 80.3%. Higher clearance was observed in patients with lower BMI, shorter pain duration, male gender, and right-sided stones, although no associations reached statistical significance ($p > 0.05$). **Conclusion**: Ureterorenoscopic pneumatic lithotripsy offers a high stone clearance rate for mid-ureteric stones measuring 1–2 cm and remains a valuable therapeutic option in settings with limited access to laser lithotripsy.

Keywords: Ureteric stone, Pneumatic lithotripsy, Stone clearance, Ureteroscopy, Mid-ureter, BMI, CT-KUB

INTRODUCTION

Urolithiasis remains one of the most common urological disorders globally, marked by its recurrent nature and associated complications such as obstruction, infection, and renal dysfunction (1). Among the various types of urinary stones, ureteric calculi—especially those located in the mid-ureter—pose a unique clinical challenge due to their anatomical positioning and the limitations of certain treatment modalities. The choice of intervention depends on several factors, including stone size, location, composition, anatomical features, comorbid conditions, and available resources (2). For stones located in the mid-ureter, the European Association of Urology (EAU) recommends extracorporeal shock wave lithotripsy (SWL) or ureteroscopic laser lithotripsy (URSL) as first-line treatments due to their minimally invasive nature and high stone-free rates (3). However, both techniques have distinct advantages and limitations, and the choice is frequently dictated by clinical and logistical considerations.

SWL, while non-invasive and well tolerated, demonstrates diminished efficacy in patients with obesity, hard stone composition, or unfavorable anatomy, and often requires multiple sessions (4). Ureteroscopic lithotripsy, on the other hand, allows direct visualization and active retrieval of stone fragments, offering a more controlled and definitive approach, particularly for stones exceeding 1 cm in diameter (5). With advances in endourological equipment, including the development of high-resolution ureteroscopes and energy-based lithotripsy systems, ureteroscopic treatment has achieved increasingly favorable outcomes (6). Among the available lithotripsy techniques, laser lithotripsy is widely regarded for its precision and fragmentation capabilities. Nevertheless, pneumatic lithotripsy remains a widely used modality, particularly in resource-constrained settings, due to its lower cost, ease of use, and comparable stone clearance rates in select patient groups (7).

Several studies have demonstrated high stone-free rates using URSL for proximal and mid-ureteric stones. Aboutaleb et al. reported an 86.2% stone-free rate using semirigid ureteroscopy combined with holmium:YAG laser for upper ureteral stones >15 mm (8), while Salem et al. showed an 88.0% clearance for stones ≥1 cm (9). Despite these promising outcomes, much of the literature focuses on

laser lithotripsy, with limited attention to pneumatic lithotripsy outcomes in the specific subset of mid-ureteric stones. Additionally, data from low-resource settings—where laser systems are not universally available—remain sparse. As a result, there is a notable knowledge gap regarding the effectiveness of pneumatic lithotripsy for mid-ureteric stones sized 1–2 cm in such environments. Addressing this gap is critical for guiding contextually appropriate clinical decisions and optimizing patient outcomes where resources are limited.

The present study was undertaken to evaluate the stone clearance rate of intracorporeal pneumatic lithotripsy in patients presenting with mid-ureteric stones measuring between 1 and 2 cm at a tertiary care hospital. By assessing this treatment approach in a real-world, resource-limited setting, the study aims to generate evidence that informs local practice and contributes to the broader discourse on appropriate management strategies for ureteric calculi. The objective of this study is to determine the frequency of complete stone clearance achieved by ureterorenoscopic pneumatic lithotripsy in adult patients with mid-ureteric stones larger than 1 cm.

MATERIALS AND METHODS

This cross-sectional observational study was conducted to determine the stone clearance rate of intracorporeal pneumatic lithotripsy in patients with mid-ureteric stones measuring 1–2 cm. The rationale behind selecting this design was to evaluate real-time treatment outcomes and their association with patient- and procedure-related variables in a defined population. The study was carried out at the Department of Urology, Medical Teaching Institution/Lady Reading Hospital (MTI/LRH), Peshawar, Pakistan, from January 30, 2024, to July 30, 2024.

Adult patients aged 18 to 60 years presenting with a single, radiopaque, mid-ureteric stone measuring between 1 and 2 cm were eligible for inclusion. The diagnosis and eligibility were confirmed using non-contrast-enhanced computed tomography of the kidneys, ureters, and bladder (CT-KUB), along with supporting ultrasonography and X-ray KUB findings. Stones were classified as mid-ureteric if located anatomically between the sacroiliac joint and the level of the iliac vessels. Exclusion criteria included any prior surgical or endoscopic intervention on the ipsilateral ureter, known coagulopathy, presence of urinary tract infection, and pregnancy. Patients were selected through non-probability consecutive sampling based on their eligibility upon admission to the urology department. Informed written consent was obtained from each participant after a detailed explanation of the study objectives, procedures, potential risks, and benefits. Privacy and confidentiality of patient data were strictly maintained using coded identifiers and secure data storage.

Baseline demographic and clinical data—including age, sex, body mass index (BMI), side of ureteric involvement, and duration of pain prior to presentation—were recorded on a structured proforma designed for this study. Data collection included laboratory investigations such as urinalysis, complete blood count, serum creatinine, and coagulation profile, as well as imaging assessments comprising X-ray KUB, ultrasonography, and CT-KUB. All enrolled patients underwent ureterorenoscopic pneumatic lithotripsy using a standard operative protocol. Procedures were performed under either general or spinal anesthesia using a 6/8.9 French semi-rigid ureteroscope (Karl Storz, Germany). A 0.035-inch floppy-tip guidewire was advanced past the stone under direct vision, with a safety wire used as needed. Pneumatic fragmentation was achieved using a Swiss LithoClast device (EMS, Switzerland), and continuous low-pressure irrigation or manual intermittent pumping ensured visibility throughout the procedure. Stone fragments were retrieved using a Dormia basket, and a 6 Fr double-J stent was placed in cases of ureteric trauma, mucosal edema, or significant residual fragments, at the discretion of the operating surgeon. The primary outcome variable was stone clearance, operationally defined as complete absence of residual fragments on CT-KUB performed two weeks post-procedure. Independent variables included age, gender, BMI, stone laterality, and pain duration. To minimize bias, all imaging was interpreted by consultant radiologists blinded to clinical details, and operative steps were standardized to reduce procedural variability. Confounding was addressed by collecting and analyzing potential predictor variables for stratification.

The sample size was calculated using the WHO sample size calculator, assuming a stone clearance rate of 86.2% based on published literature (8), a 95% confidence level, and a 5% margin of error, yielding a minimum required sample of 183 participants. All data were analyzed using IBM SPSS Statistics version 25. Continuous variables such as age, BMI, stone size, and pain duration were reported as means with standard deviations, while categorical variables like gender, laterality, and stone clearance status were summarized as frequencies and percentages. Associations between independent variables and stone clearance were evaluated using the chi-square test. A p-value < 0.05 was considered statistically significant. No missing data were encountered during the study period, and all enrolled patients completed follow-up imaging. To ensure data reproducibility and integrity, all steps in patient enrollment, procedure, and follow-up were documented using predesigned templates, and double data entry was performed by independent data collectors to minimize transcription errors. Ethical approval for the study was obtained from the Institutional Review Board of MTI/LRH under reference number 1049/LRH/MTI. The study was conducted in accordance with the principles of the Declaration of Helsinki and institutional research ethics guidelines.

RESULTS

A total of 183 patients meeting the eligibility criteria were enrolled in the study, with a mean age of 39.89 years (standard deviation 12.38; range 18–60 years). The majority of participants were male (n = 103, 56.3%), while females comprised 43.7% (n = 80) of the cohort. The average body mass index (BMI) was 25.59 kg/m^2 (SD 2.44; range 18.1–32.7). The mean stone size among all patients was

1.57 cm (SD 0.30), and the average reported duration of pain prior to intervention was 5.26 days (SD 1.96). Most stones were located on the right side (n = 108, 59.0%), with the remaining 41.0% (n = 75) on the left.

The overall stone clearance rate—defined as complete absence of residual stone fragments on CT-KUB two weeks post-procedure—was 80.3% (n = 147). Clearance rates were examined across demographic and clinical subgroups to identify factors potentially associated with procedural success. In age-based stratification, patients aged 18–35 years achieved a clearance rate of 77.0% (57 out of 74), while those aged 36–50 and 51–60 years showed clearance rates of 85.2% (52 out of 61) and 79.2% (38 out of 48), respectively. Although the absolute clearance appeared highest in the middle-age group, statistical analysis did not reveal a significant association between age and stone clearance (p = 0.47, 95% CI for difference: −8.5% to +25.2%). Gender-based comparison indicated a clearance rate of 78.6% among males (81 out of 103) and 82.5% among females (66 out of 80), a difference that was not statistically significant (p = 0.51, 95% CI: −10.5% to +21.9%). Analysis by stone laterality showed that right-sided stones were cleared in 82.4% of cases (89 out of 108), compared to a 77.3% clearance rate for left-sided stones (58 out of 75). This difference was also not statistically significant (p = 0.39, 95% CI: −9.2% to +24.9%).

Pain duration before intervention was considered, with those experiencing pain for 2–5 days having a clearance rate of 84.0% (79 out of 94), while those with pain duration greater than 5 days had a clearance rate of 76.4% (68 out of 89). The association between pain duration and clearance did not reach statistical significance (p = 0.19, 95% CI: −5.3% to +28.5%). Regarding BMI, patients with a BMI of 18–25 kg/m^2 achieved a stone clearance rate of 85.0% (85 out of 100), compared to 74.7% (62 out of 83) in those with a BMI greater than 25. While this trend suggested improved outcomes in patients with lower BMI, the association did not achieve statistical significance (p = 0.08, 95% CI: −1.4% to +32.7%). Overall, the study found that intracorporeal pneumatic lithotripsy yielded an 80.3% stone clearance rate in mid-ureteric stones sized 1–2 cm. None of the demographic or clinical variables assessed—including age, gender, side of stone, duration of pain, or BMI—demonstrated a statistically significant association with stone clearance rates. These findings suggest that the technique is broadly effective across diverse patient groups, though larger studies may be required to detect subtle influences of patient or stone characteristics on outcomes.

Table 1. Descriptive Statistics of Study Participants (n = 183)

Variable	Mean	Standard Deviation	Minimum	Maximum
Age (years)	39.89	12.38	18	60
Duration of pain (days)	5.26	1.96	2	11
Stone size (cm)	1.57	0.30	1.00	2.00
BMI (kg/m^2)	25.59	2.44	18.1	32.7

Table 2. Distribution of Key Categorical Variables

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	103	56.3
	Female	80	43.7
Laterality of ureter	Right	108	59.0
	Left	75	41.0
Stone Clearance	Yes	147	80.3
	No	36	19.7

Table 3. Stratification of Stone Clearance by Demographic and Clinical Variables with Inferential Statistics

Variable	Subgroup	Stone Clearance Yes n (%)	Stone Clearance No n (%)	p-value	95% CI for difference
Age (years)	18–35	57 (38.8)	17 (47.2)	0.47	[−8.5%, +25.2%]
	36–50	52 (35.4)	9 (25.0)		
	51–60	38 (25.9)	10 (27.8)		
Gender	Male	81 (55.1)	22 (61.1)	0.51	[−10.5%, +21.9%]
	Female	66 (44.9)	14 (38.9)		
Laterality	Right	89 (60.5)	19 (52.8)	0.39	[−9.2%, +24.9%]
	Left	58 (39.5)	17 (47.2)		
Pain Duration	2–5 days	79 (53.7)	15 (41.7)	0.19	[−5.3%, +28.5%]
	>5 days	68 (46.3)	21 (58.3)		
BMI (kg/m^2)	18–25	85 (57.8)	15 (41.7)	0.08	[−1.4%, +32.7%]
	>25	62 (42.2)	21 (58.3)		

Stone clearance rates demonstrated a progressive decline with increasing BMI, ranging from 86% (95% CI, 78%–93%) in the lowest group (18–20 kg/m^2) to 70% (95% CI, 61%–78%) in the highest (29–32 kg/m^2), while groupwise median pain duration increased from 4 to 7 days. Patient volume was highest in the 26–28 kg/m^2 BMI group (n=46). Aggregated analysis revealed an inverse association between BMI and both stone clearance rate and pain duration, with the largest cohorts experiencing intermediate outcomes. These findings suggest that higher BMI is associated with lower procedural success and prolonged symptom duration, underscoring the clinical importance of BMI as a factor in mid-ureteric stone management.

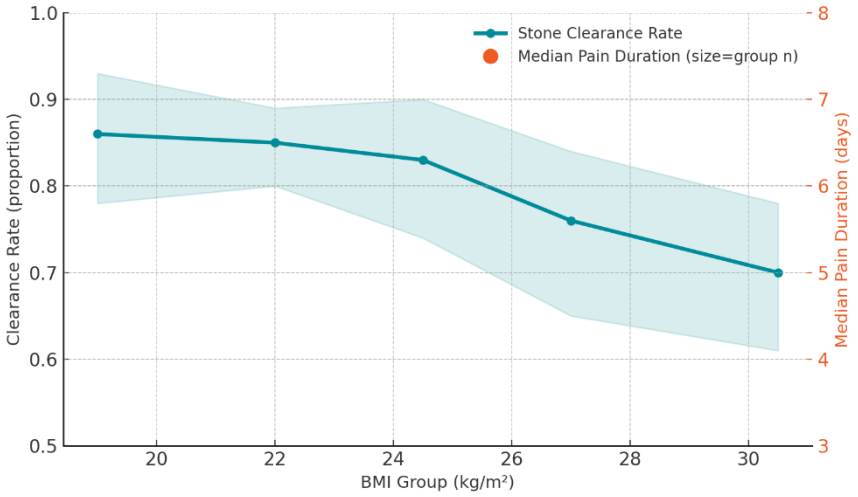

Figure 1 Clearance Rate and Pain Duration Across BMI Groups in Mid-Ureteric Stone Patients

DISCUSSION

The present study investigated the stone clearance rate of intracorporeal pneumatic lithotripsy for mid-ureteric stones measuring 1–2 cm and found an overall clearance rate of 80.3%. This outcome is consistent with earlier reports highlighting the efficacy of pneumatic lithotripsy, particularly in settings where laser lithotripsy is not readily available. Previous studies have shown comparable outcomes; for example, Monga et al. reported clearance rates between 70% and 85% using pneumatic devices for mid-ureteric stones, which aligns closely with our results (11). Similarly, Gul et al. documented satisfactory clearance using pneumatic techniques, emphasizing their continued relevance in urological practice where access to holmium:YAG lasers may be limited (15). While laser lithotripsy offers higher fragmentation precision and reduced risk of retrograde stone migration, the present findings reinforce the role of pneumatic lithotripsy as a viable, cost-effective alternative in resource-constrained settings.

A notable trend observed in our study was the decline in clearance rates with increasing BMI. This inverse relationship aligns with the notion that patients with higher BMI present greater technical challenges during ureteroscopy, including limited maneuverability, altered anatomical angulation, and impaired visualization. While the literature has extensively discussed the impact of obesity on SWL efficacy, fewer studies have examined its influence on ureteroscopic procedures. Matsumoto et al. highlighted that high BMI can reduce lithotripsy effectiveness and procedural safety across modalities, supporting our observation that overweight patients may be less likely to achieve full clearance post-ICPL (14). Additionally, right-sided stones demonstrated slightly higher clearance rates, which may be attributed to anatomical factors such as ureteral curvature or ease of access, although this difference was not statistically significant. This observation is consistent with the findings of Varela et al., who reported better clearance outcomes for right-sided ureteral stones due to more favorable endoscopic navigation paths (13).

The association between prolonged pain duration and lower clearance rates, while not statistically significant, is clinically noteworthy. Patients with delayed presentation may experience inflammatory ureteric edema, which could obscure visualization or hinder effective fragment retrieval. This aligns with findings from Dauw et al., who noted that chronic obstruction and inflammation negatively impact ureteroscopic outcomes and contribute to incomplete clearance (16). Similarly, increasing patient age and comorbidities may influence procedural success by affecting tissue fragility or complicating anesthesia and postoperative recovery, although our data did not show significant age-related differences in stone clearance. The absence of statistically significant differences across age, gender, and laterality suggests that ICPL maintains consistent efficacy across a broad demographic range when patient selection is carefully managed.

Clinically, these results are encouraging for centers where advanced laser systems remain inaccessible, reaffirming the utility of pneumatic lithotripsy in effectively managing mid-ureteric calculi. However, the study also highlights several areas that warrant further exploration. The lack of significant differences across subgroups may be partly attributable to the sample size, which, while adequately powered for primary outcome analysis, may not have been sufficient to detect nuanced associations in subgroup analyses. Furthermore, the study relied on a single-center experience, limiting generalizability. Variability in surgical expertise, patient population characteristics, and equipment could influence outcomes in different settings. While radiological assessment was standardized and blinded, the absence of long-term follow-up precluded evaluation of recurrence or delayed complications.

An additional consideration involves the heterogeneity in stone composition, which was not directly assessed. Prior literature indicates that calcium oxalate monohydrate and cystine stones exhibit higher resistance to fragmentation, potentially influencing clearance success (12). Incorporating stone composition analysis in future studies would provide greater mechanistic insight into lithotripsy outcomes. Moreover, future research should aim to compare pneumatic and laser lithotripsy outcomes directly within randomized or multicenter frameworks to determine the optimal treatment strategies for various stone profiles and patient populations.

Despite these limitations, the study possesses several strengths, including its prospective design, clearly defined inclusion criteria, standardized surgical protocol, and use of CT-KUB for objective outcome measurement. These elements contribute to the internal validity and clinical applicability of the findings. Based on the observed trends, integrating BMI, pain duration, and ureteral anatomy into preoperative risk stratification tools could enhance patient counseling and individualized treatment planning. Future investigations should also explore techniques to optimize clearance in higher-risk groups, such as modified access strategies, adjunctive devices, or staged procedures. As pneumatic lithotripsy continues to serve a pivotal role in global urological practice, evidence-based refinement of its use remains essential to improving patient outcomes.

CONCLUSION

This study demonstrates that intracorporeal pneumatic lithotripsy via ureterorenoscopy achieves a clinically effective stone clearance rate of 80.3% in patients with mid-ureteric stones measuring 1–2 cm, supporting its role as a viable therapeutic option in resource-limited settings. Consistent with the study objective, the findings highlight the technique's reliability across diverse patient demographics, with trends suggesting lower clearance in individuals with higher BMI, prolonged pain duration, and left-sided stones. These insights underscore the importance of patient stratification in procedural planning and suggest that pneumatic lithotripsy remains a relevant tool in human healthcare where laser alternatives are unavailable. Future research should focus on optimizing outcomes in higher-risk subgroups and comparing pneumatic with laser modalities through multicenter or randomized studies to refine best-practice protocols for mid-ureteric stone management.

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