International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Website: https://ijmpr.in/

Original Article

Precision and Performance: A Prospective Study on the Safety and Efficacy of Holmium: YAG Laser Lithotripsy in Ureteric Calculi

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OPEN ACCESS

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Received: 09-04-2026
Accepted: 01-05-2026
Published: 08-05-2026

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ABSTRACT

Background: Ureteric stones are a common urological condition with significant morbidity due to obstruction and intense renal colic. Holmium: YAG (Ho: YAG) laser lithotripsy has emerged as a preferred treatment modality due to its precision, safety, and efficacy. This study was conducted to evaluate the safety, efficacy, and clinical outcomes of Ho: YAG laser lithotripsy in patients with ureteric calculi.
Material and Methods: This prospective observational study was conducted over 18 months in the Department of General Surgery at a tertiary care centre in northern India. Fifty patients aged >16 years with radiologically confirmed ureteric stones underwent Ureteroscopic laser lithotripsy using Ho: YAG. Patient demographics, stone characteristics, operative parameters, intraoperative complications, and postoperative outcomes were analysed. Follow-up was conducted at 1 week, 6 weeks, and 3 months.
Results: The mean age of patients was 48.10 ± 15.42 years, with 68% being male. The most common presenting symptom was flank pain (76%). Most stones were medium-sized (8–12 mm, 44%) and located in the proximal ureter (68%). Hydronephrosis was observed in 44%, and bilateral stones were noted in 32% of patients. The average operative time was under 70 minutes in the majority (72%). Intraoperative complications were minimal, with 84% experiencing none; minor bleeding (8%) and stone migration (6%) were the most common events. At 6-week follow-up, the stone-free rate was 92%. A secondary procedure was required in 12% of patients. Most were discharged within one day (84%), with minimal need for prolonged hospitalisation.
Conclusion: Ho: YAG laser lithotripsy is a safe, effective, and minimally invasive treatment for ureteric stones, offering high clearance rates and low complication risk. Its application should be encouraged in routine urological practice, especially in centres transitioning from pneumatic to laser technologies.

Keywords: *Ureteric stones, Holmium:YAG laser lithotripsy, minimally invasive surgery, Stone-free rate.*

INTRODUCTION

Nephrolithiasis, or kidney stone disease, is a common urological condition, most frequently affecting individuals in their third to fourth decade of life. The lifetime risk is approximately 13% in men and 7% in women, with increasing global prevalence. [1-3] Multiple factors contribute to stone formation, including environmental exposure, metabolic abnormalities, genetic predisposition, and socioeconomic status. Among urinary calculi, ureteric stones are particularly concerning due to their tendency to obstruct urinary flow and cause severe pain. [3,4-7] A previous history of ureteric stones significantly increases recurrence risk, with up to 50% of patients developing a new stone within five to seven years. The most typical symptom is renal colic—intense, episodic pain due to ureteral spasm and obstruction from stone movement. Stones often lodge at three points of physiological narrowing: the pelviureteric junction, crossing over iliac vessels, and the ureteric meatus. [8,9]

Management of ureteric stones is determined by stone size, location, and symptom severity. Current treatment options include extracorporeal shock wave lithotripsy (SWL), ureteroscopic lithotripsy (URS), percutaneous nephrolithotomy

(PCNL), retrograde intrarenal surgery (RIRS), and laparoscopic or robotic surgery. [10-12] Open surgery is now rare, reserved for complex or failed cases. SWL, though non-invasive, is limited by lower success rates, higher recurrence, and need for multiple sessions. [13-15] Intracorporeal lithotripsy techniques such as electrohydraulic, ultrasonic, and laser-based approaches offer better stone clearance. Among these, Holmium: YAG (Ho:YAG) laser lithotripsy has become the preferred method due to its safety, high efficacy, and minimal complications. It operates at a wavelength of 2.1 mm, efficiently absorbed by water, allowing precise targeting with limited tissue injury. Its dusting capability reduces the need for stone retrieval, lowering operative time and trauma. [16,17]

Although Ho:YAG laser lithotripsy is now widely used, data on its effectiveness in certain settings remains limited. At a tertiary care hospital in northern India, most ureteric stones have been managed with pneumatic lithotripsy, with no prior evaluation of Ho:YAG laser outcomes. This prospective observational study aims to assess its safety, efficacy, operative parameters, complication rates, hospital stay, stone-free rate, and need for secondary procedures, thereby contributing valuable clinical insight for optimizing stone management.

MATERIAL AND METHODS

Study Design and Setting

This prospective observational study was designed to evaluate the clinical outcomes of ureteric stone lithotripsy using Holmium: YAG (Ho: YAG) laser technology. The study focused on various parameters including patient demographics, preoperative assessment, intraoperative surgical techniques, postoperative management, and follow-up outcomes. The study was conducted over a duration of 18 months in the Department of General Surgery at a tertiary care hospital in northern India. Patients admitted with a diagnosis of ureteric stones and scheduled laser lithotripsy were enrolled and observed throughout their clinical course.

Study Population

The study population comprised patients with confirmed ureteric stones who fulfilled the inclusion criteria and underwent definitive surgical intervention using the Ho: YAG laser. Inclusion criteria were patients of either sex aged above 16 years, with functional kidneys as confirmed by preoperative investigations, and a radiologically or clinically confirmed diagnosis of ureteric calculi. Exclusion criteria included patients with active urinary tract infections, those deemed unfit for anaesthesia, individuals with coexisting renal or ureteric calculi managed with urinary diversion (e.g., ileal conduit or neobladder), patients with coagulopathy, and pregnant women.

Sample size: Total 50 patients were enrolled in the study

Data Collection

Preoperative assessment involved detailed history taking, thorough clinical examination, and routine investigations including ultrasonography, X-ray KUB, and non-contrast computed tomography (NCCT) KUB. Patients were counselled regarding the procedure, and informed consent was obtained. Ureteric stone lithotripsy was performed under general or spinal anaesthesia with the patient in the dorsal lithotomy position. After ensuring proper sterilisation and sterile draping, a diagnostic 22F/17F cystoscopy was carried out to visualise the ureteric orifice. Cannulation was achieved using a 0.035-inch hydrophilic guidewire under fluoroscopic guidance, and an 8Fr feeding tube was inserted to prevent bladder distension during continuous irrigation. Ureteroscopic procedures utilized either semirigid ureteroscopes (8–9.5F) or flexible ureteroscopes (7.5F), with the latter introduced via a 12F ureteral access sheath over the guidewire. Holmium:YAG (Ho:YAG) laser energy was applied for stone fragmentation at variable settings. Stone fragments larger than 2 mm were retrieved using a stone basket for composition analysis. A ureteric stent was placed in all patients, and postoperative catheterisation was performed. Postoperatively, patients were mobilised on the same day, and oral intake was resumed six hours after the procedure. An X-ray KUB was conducted on the first postoperative day, and Foley's catheter was removed the same day. Pain was managed using NSAIDs. Follow-up was scheduled at 1 week, 6 weeks, and 3 months. At the 6-week visit, NCCT KUB was performed to evaluate stone clearance, and if confirmed, the DJ stent was removed. At the 3-month follow-up, a USG of the abdomen and pelvis was done to assess long-term outcomes.

Statistical analysis: Data was entered in Microsoft excel sheet. Confidentiality of each study participant was maintained throughout the study. The data was analysed using SPSS version 24.0. Descriptive summary using frequencies, percentages, graphs, mean, median (IQR) and standard deviation was used to present study results. Probability (p) was calculated to test statistical significance at the 5% level of significance.

RESULTS

Table 1 shows the age distribution of the 50 study participants. The majority (52%) were aged above 50 years, followed by 20% in the 30–40 age group, 18% in the 20– 30 group, and only 10% in the 40–50 age range. The mean age of the participants was 48.10 years with a standard deviation of ±15.42, indicating that most participants were middle-aged to older adults and sex shows the distribution of the study participants. Out of 50 participants, 34 (68%) were males and 16 (32%) were females, indicating a male predominance in the study population. Fig 1 highlights the chief complaints reported by the study participants. The most common complaint was flank pain, observed in 76% of participants, followed by hematuria and pain during micturition which was 10%. Recurrent urinary tract infection (UTI) was reported by 4% of participants. This suggests that flank pain was the predominant presenting symptom in the study group.

Table 2 summarises the characteristics of ureteric stones among 50 patients. The most common stone size was 8–12 mm, observed in 44% of patients, followed by 12–14 mm and >14 mm sizes, each accounting for 24%, while only 8% had stones measuring 6–8 mm. Regarding stone location, a majority (68%) had stones in the proximal ureter, while 32% had distal ureteric stones. In terms of stone number, 44% of patients had 1–2 stones, 36% had 2–3 stones, and 20% had more than 3 stones. Stone laterality showed that 42% had stones in the left ureter, 26% in the right ureter, and 32% had bilateral ureteric involvement. These findings indicate that most patients presented with medium-sized (8–12 mm), proximally located, and unilateral (predominantly left-sided) stones, though a significant proportion also had bilateral involvement. Fig 2 displays the ultrasound findings of hydronephrosis among the study participants. Hydronephrosis was present in 44% of the participants, while it was absent in 56%, indicating that nearly half of the patients with stones showed signs of urinary tract obstruction on ultrasonography.

Among the 50 patients who underwent NCCT-KUB, the most common finding was the presence of ureteric stones only, seen in 54% of cases, followed by hydronephrosis in 30% and obstruction-related findings in 16%. Analysis of stone hardness revealed that the majority of patients (56%) had stones with a Hounsfield Unit (HU) value between 900–1200, indicating moderately dense stones, while 18% had softer stones (600–900 HU) and 26% had harder stones (>1200 HU). These findings suggest that most patients had moderately dense ureteric stones, which may influence treatment strategies such as the choice of lithotripsy or likelihood of spontaneous passage (Table 3). Table 4 presents the intraoperative time among the study participants. The majority (38%) had procedures lasting between 50–70 minutes, followed by 34% with durations of 30–50 minutes. In 28% of cases, the operative time exceeded 70 minutes, indicating that most surgeries were completed within 70 minutes, with a notable portion requiring longer durations and also outlines the intra-operative complications among the study participants. The majority (84%) experienced no complications during the procedure. Minor bleeding occurred in 8% of cases, stone slip in 6%, and ureteral injury in 2%. This indicates that the procedure was generally safe, with a low rate of complications observed. Table 5 presents the postoperative outcomes of 50 patients treated for ureteric stones. At 6 weeks follow-up, the stone clearance rate was high, with 92% (46 patients) achieving complete clearance, while 8% (4 patients) had residual stones due to stone migration or "slip." A secondary procedure was required in 12% (6 patients), whereas the majority (88%) did not need any further intervention. Postoperative hospital stay was limited to 1 day in most cases (84%), while 10% stayed for 2 days, and only 6% required hospitalisation for more than 2 days. These results indicate that the treatment was largely effective and associated with minimal need for secondary intervention and short hospital stay in most patients.

DISCUSSION

This prospective observational study assessed the clinical characteristics, intraoperative parameters, and treatment outcomes of Ho:YAG laser lithotripsy in 50 patients with ureteric stones. Our findings contribute real-world data to the growing evidence supporting the effectiveness and safety of this minimally invasive modality. The majority of participants were middle-aged to elderly, with a mean age of 48.1 ± 15.42 years, and 52% were over 50 years. A clear male predominance (68%) was observed, in line with earlier studies by Kumar et al. [18], Jindal et al. [19], and Seitz et al. [20], which reported a higher incidence of stone disease in males, likely attributable to sex-based differences in dietary patterns, occupation-related dehydration, and metabolic factors.

Flank pain was the predominant presenting complaint (76%), followed by hematuria and dysuria (10%) and recurrent UTI (4%), consistent with reports by Ullah et al. [21] and Rauf et al. [22], who also noted flank pain as the most common symptom of ureteric colic. These symptoms often correlated with stone-induced obstruction and associated hydronephrosis, which was seen in 44% of patients in our study, similar to the findings of Rauf et al. [22] and Seitz et al., [20] where proximal stones were more likely to result in hydronephrosis.

Most stones were medium-sized (8–12 mm in 44%), located in the proximal ureter (68%), and moderately dense (600–900 HU in 56%). Laterality analysis revealed 42% left-sided, 26% right-sided, and 32% bilateral ureteric involvement, with multiple stones (>2) in 56% of cases, adding to operative complexity. Stone location and density are known to influence clearance rates, as demonstrated by Seitz et al. [20] and Khoder et al. [23], who reported superior stone-free rates (SFR) in distal stones compared to proximal ones and in softer versus harder stones.

Operative duration varied significantly, with 38% of procedures lasting 50–70 minutes, and 28% exceeding 70 minutes. These times are longer than those reported by Ullah et al. [21] and Ulvik et al. [24], likely due to higher stone burden, bilateral disease (32%), and varied laser power settings. Sierra et al. [25] and Ulvik et al. [24] also demonstrated that Thulium Fibre Laser (TFL) may offer shorter operative times and faster ablation, although Ho:YAG remains widely preferred due to its precision and safety.

Ho:YAG lithotripsy showed excellent efficacy, achieving a 92% SFR at 6 weeks, which aligns with findings from Ullah et al. [21] (92.16%), Maghsoudi et al. [26] (95%), and Khoder et al. [23] (95.8%). In contrast, Ulvik et al. [24] reported lower SFRs (67%) for Ho:YAG compared to TFL (92%), particularly in renal stones. Our slightly lower SFR may be explained by the inclusion of patients with larger stones (>14 mm in 24%), multiple calculi, or bilateral involvement.

Intraoperative complications were low: 84% had no complications, while minor bleeding occurred in 8%, stone migration in 6%, and ureteric injury in 2%, similar to the low complication rates reported by Rauf et al. [22] and Khoder et al. [23].

Turna et al. [27] also supported the safe use of Ho:YAG in high-risk populations, including those on anticoagulants. Although Ulvik et al. noted higher bleeding with Ho:YAG (22%) than TFL (5%), our data support its favourable safety profile.

A secondary procedure was required in 12% of patients due to residual stones, though most (88%) achieved clearance in a single sitting. Hospital stay was short for the majority: 84% were discharged within 24 hours, with only 6% requiring >2 days of hospitalisation, indicating fast recovery and minimal morbidity—hallmarks of successful endourological intervention.

Overall, our findings reaffirm Ho:YAG laser lithotripsy as a safe and effective treatment for ureteric stones, even in cases with complex stone burden. However, the study also highlights that variability in surgeon experience, laser settings, and limited access to flexible endoscopic tools can affect operative efficiency and SFR. As Pang et al. [28] and Rauf et al. [22] emphasised, the role of skilled endourologists and standardised protocols is critical to optimising outcomes.

Future directions should include multicentric trials with standardised laser parameters, advanced instrumentation (e.g., flexible ureteroscopes), and tailored energy settings for stone size and density. Such measures may further enhance safety, minimise complications, and improve clearance rates in diverse clinical settings.

CONCLUSION AND RECOMMENDATIONS:

This prospective study affirms that Holmium:YAG (Ho:YAG) laser lithotripsy is a safe and effective treatment for ureteric stones, demonstrating a high stone-free rate (92%) with minimal complications (16%) and short hospital stays. Most stones were medium-sized and proximally located, with operative times generally under 70 minutes. The procedure was well-tolerated, even in patients with bilateral or multiple stones, supporting its role as a reliable minimally invasive modality in diverse clinical scenarios.

To further improve outcomes, we recommend standardising laser energy settings based on stone characteristics, enhancing surgeon training in laser lithotripsy techniques, and incorporating advanced endoscopic tools like flexible ureteroscopes. Preoperative NCCT-based assessment of stone density and location should guide individualised treatment planning. Future multicenter trials with larger sample sizes and protocol uniformity are warranted to validate these findings and explore comparisons with newer technologies such as Thulium Fibre Laser.

RESULTS

Table 1: Age and sex Distribution among the study participants

Age (years) and Sex		N=50	%
Age (years)	20-30	9	18%
	30-40	10	20%
	40-50	5	10%
	>50	26	52%
	Mean Age (years)	48.10±15.42	
Sex	Male	34	68%
	Female	16	32%

Table 2: Distribution of Stone Characteristics in Ureteric Stone Patients

Stone Characteristics		N=50	%
Size of Stones	6-8	4	8.0%
	8-12	22	44.0%
	12-14	12	24.0%
	>14	12	24.0%
Location of stones	Proximal ureter	34	68.0%
	Distal ureter	16	32.0%
	1-2	22	44.0%

Number of stones	2-3	18	36.0%
	>3	10	20.0%
Site of stone	Right Ureter	13	26.0%
	Left Ureter	21	42.0%
	Both the ureter	15	32.0%

Table 3: NCCT-KUB Findings among the study participants

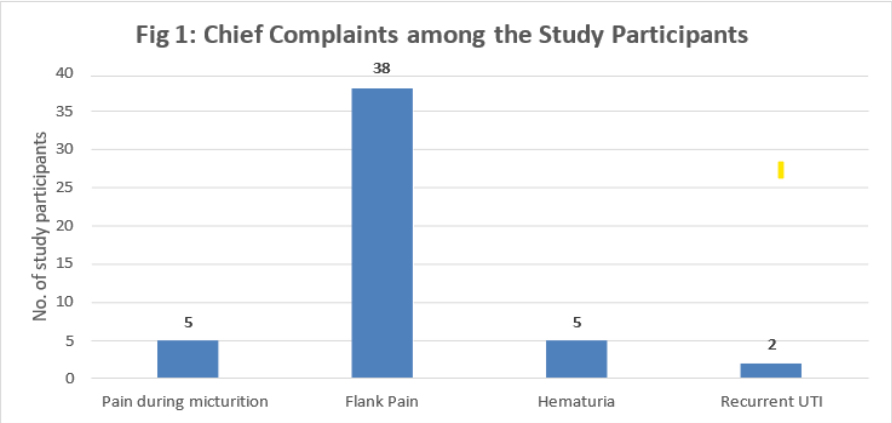
NCCT-KUB		N=50	%
Hydronephrosis		15	30.0%
Obstruction		8	16.0%
Ureteric stone Only		27	54.0%
Stone Hardness (in HU units)	600-900	9	18.0%
	900-1200	28	56.0%
	>1200	13	26.0%

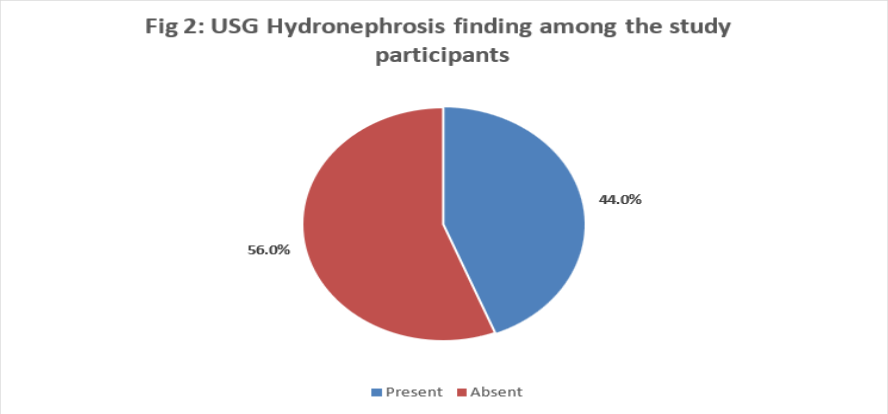
Table 4: Intra operative Time and Complications among the study participants

Parameters		N=50	%
Intra operative time	30-50 min	17	34.0%
	50-70 min	19	38.0%
	>70 min	14	28.0%
Complications	None	42	84.0%
	Minor Bleeding	3	8.0%
	Stone Slip rate	4	6.0%
	Ureteral Injury	1	2.0%

Table 5: Postoperative Outcomes in Patients Undergoing Ureteric Stone Management

Postoperative Outcomes		N=50	%
Stone clearance rate	At 6 weeks follow up	46	92%
	Residual stone due to slip	4	8%
Secondary Procedure	Yes	6	12%
	No	44	88%
Post operative Hospital Stay	1 day	42	84.0%
	2 days	5	10.0%
	>2 days	3	6.0%





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