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Stone Clearance and Duration of Surgery in Percutaneous Nephrolithotomy Using Laser versus Pneumatic Lithotripsy

Usama Muhammad Kathia[1], Azfar Ali[1*], Mohammad Ahmad[1], Umair Hayat Khan[1], Qaisar Abbas Khan[1], Ammar Tariq Alvi[1], Muhammad Faizan Akbar[1] and Khizar Hayat Gondal[1]

[1]Department of Urology, Lahore General Hospital, Lahore, Pakistan

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***Corresponding Author:**
Azfar Ali
Department of Urology, Lahore General Hospital, Lahore, Pakistan
drazfarali@hotmail.com

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ABSTRACT

Nephrolithiasis is common ailment causing pain and renal impairment. Management strategies depend on stone size and location, with stones larger than 2 cm treated with Percutaneous Nephrolithotomy (PCNL). This study compares two energy sources pneumatic lithoclast and Holmium: YAG laser used in PCNL, focusing on stone-free rate and surgery duration. **Objective:** To know of any difference in Ho:YAG laser and pneumatic probe in terms of stone free rate and surgery duration during PCNL. **Methods:** This study was conducted retrospectively at the Department of Urology, Lahore General Hospital. The data of patients admitted from June 13, 2021, to June 12th, 2022, was taken. 120 patients were enrolled in this study (60 each for pneumatic lithoclast and Ho: YAG laser), using a non-purposive consecutive sampling technique. Data collection included demography, stone size, site, side, clearance status, and surgery duration. Analysis was conducted using SPSS version 21.0, with quantitative variables assessed via t-tests and qualitative variables via chi-square tests. A p-value ≤ 0.05 was considered statistically significant. **Results:** Mean age was 36.6±12.68 years in the pneumatic group and 40.40±8.29 years in the laser group. Stone clearance rates were 60% (n=36) for the pneumatic group and 70% (n=42) for the laser group. Mean surgery duration was shorter in pneumatic group (44.87±22.85 minutes) compared to laser group (142±29.41 minutes). **Conclusion:** Pneumatic lithoclast and Holmium: YAG laser provides comparable stone clearance rates for PCNL. However, the pneumatic probe reduces surgery duration.

INTRODUCTION

Urolithiasis, or nephrolithiasis, refers to the formation of stones within the urinary tract including the kidneys, ureters, bladder, or urethra and encompasses various management approaches, particularly for complex cases like staghorn stones [1]. Globally, nephrolithiasis affects approximately 12% of the population, with a higher incidence in men. Its development is influenced by hydration status, dietary patterns, and underlying metabolic abnormalities [2]. In Pakistan, the estimated prevalence is around 16%, particularly among middle-aged adults due to environmental and dietary factors [3]. The introduction of Percutaneous Nephrolithotomy (PCNL) in 1976 marked a turning point in renal stone management, becoming the gold standard for stones larger than 2 cm or those located in the lower pole exceeding 1 cm [4]. Vitamin D metabolism and hypercalciuria have been linked to stone formation, and hypercalciuria is also considered a specific biomarker in systemic conditions like sarcoidosis [2, 3, 5]. It has largely supplanted open surgery, while smaller stones are typically treated with Extracorporeal Shockwave Lithotripsy (ESWL). PCNL involves percutaneous access to the collecting system, followed by

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stone fragmentation using energy sources. Among these, the Holmium:YAG laser has gained widespread use, offering an alternative to traditional pneumatic lithoclast systems [6, 7]. Studies comparing these modalities report mixed outcomes. For instance, one study from Karachi noted higher stone clearance rates with pneumatic lithoclast (87%) than with the Holmium:YAG laser (83%), while another reported better results with the laser (81%) versus the pneumatic device (67%) [8, 9]. Further complexity arises from studies on high-grade cases, such as Guy's Stone Score Grade 4, where outcomes between methods showed no significant differences. These inconsistencies point to a knowledge gap and underscore the need for further comparative research [10, 11]. While Holmium:YAG lasers are increasingly used in Pakistan, local literature comparing their efficacy to pneumatic lithoclast in PCNL remains limited. As laser technology becomes more prevalent, a clearer understanding of its impact on stone-free rates and surgical efficiency is essential. Recent studies have examined the safety profile of laser modalities and compared the clinical outcomes of various lithotripsy techniques in PCNL, reinforcing the need for localized data to support evidence-based decision-making [12, 13].

Although percutaneous nephrolithotomy (PCNL) is the gold standard for managing large renal stones, there is inconsistent evidence regarding the comparative effectiveness of Holmium:YAG laser and pneumatic lithoclast systems, with studies reporting variable stone-free rates and outcomes. In Pakistan, where laser use is increasing, local comparative data remain limited, creating uncertainty in selecting the most effective lithotripsy modality. Therefore, this study aims to compare the efficacy of Holmium:YAG laser versus pneumatic lithoclast in terms of stone-free rates and surgical outcomes in patients undergoing PCNL.

METHODS

This was a retrospective descriptive study conducted at the Department of Urology, Lahore General Hospital (LGH) and Lahore, Pakistan. The study was approved by the Ethical Committee of this hospital via reference number 2025/ERC/24. The study included patients with renal calculi more than 2 cm in size located anywhere in the kidney, or above 1 cm in size in the lower pole. These patients were assessed using X-ray KUB. A total sample of 120 patients (60 in each group) was calculated using a 95% confidence level, 80% power of the test, and the expected frequency of stone clearance: 88.4% in the laser group versus 47.3% in the pneumatic group. Sampling was done by Non-probability consecutive method [14]. All the patients were included who had a stone of above 1cm in lower pole and 2cm anywhere else in kidney as seen by Xray KUB. All patients with positive urine culture, bleeding disorders and active pregnancy were excluded from the study. A total data of 120 patients who fulfilled the inclusion criteria was included in the study, with 60 patients who underwent pneumatic (Group B) and 60 who underwent Ho:YAG laser (group A) PCNL. Medical charts were reviewed and data was recorded for patients who underwent treatment between 13th June 2021 and 12th June 2022. Patients were counseled about the use of their data in the study and consent was obtained for this telephonically. Stones were broken using Holmium: YAG laser for Group A and pneumatic lithoclast for Group B. Postoperatively, all patients underwent KUB radiograph (Villa Xray machine, model: MoviPlan with 500MA power) on the post-op day 1 to confirm stone clearance. Stone clearance rate was calculated as a percentage of people with stone clearance among the total number of patients in that group. The duration of surgery was recorded starting from the time of successful access to the time of taking out the nephroscope at the end, as it was mentioned in the patient notes. Data were collected through patient records. Patient demographic details, stone size, stone location, and other relevant clinical information were recorded. Stone clearance and duration of surgery were documented for analysis. Data analysis was done using SPSS version 21.0. Descriptive statistics were applied to present quantitative variables such as age and surgery duration as mean and standard deviation. The T-test was employed to compare these variables between the two groups. Qualitative variables, including gender and stone clearance, were expressed as frequency and percentage. The Chi-square test was employed to compare these variables between groups. Post-stratification, Chi-square was applied for stone clearance comparison, and T-test was used to compare surgery duration in stratified groups. A p-value of ≤0.050 was considered statistically significant.

RESULTS

The sample was divided into two groups with 60 patients each in the pneumatic lithotripsy group and Ho:YAG laser group. Variables analysed among these groups included stone clearance rate and surgery duration. In the pneumatic group, 30 patients (50%) were of age 35 years or younger, and 30 patients (50%) were older than 35 years. In the Holmium: YAG group, 16 patients (26.6%) were aged 35 years or younger, while 44 patients (73.2%) were older than 35 years. The mean age in the pneumatic group was 36.6 ± 12.68 years, and for the Holmium: YAG group was 40.40 ± 8.29 years. (A table is not made for this line for the purpose of brevity). The mean stone size in pneumatic group was 2.93 ± 1.25 cm, and in the Holmium: YAG group was 3.167±0.59 cm. (table not made for the purpose of

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brevity).Both groups demonstrated comparable stone sizes. In pneumatic group, 44 patients (73.4%) were male, and 16 patients (26.6%) were female. In Holmium: YAG group, 40 patients (66.6%) were male, and 20 patients (33.3%) were female. Both groups showed similar gender distributions (Table 1).

Table 1: Distribution According to Age and Gender

Group	Age		Total Frequency (%)
	Less than or Equal to 35 Years Frequency (%)	Greater than 35 Years Frequency (%)	
Pneumatic	30 (25.0)	30 (25.0)	60 (50.0)
Holmium Yag Laser	16 (13.3)	44 (36.7)	30 (50.0)
Total	46 (38.3)	74 (61.7)	120 (100.0)
Group	**Gender**		**Total Frequency (%)**
	Male Frequency (%)	**Female Frequency (%)**	
Pneumatic	44 (36.7)	16 (13.3)	60 (50.0)
Holmium Yag Laser	40 (33.3)	20 (16.7)	60 (50.0)
Total	84 (70.0)	36 (30.0)	120 (100.0)

In pneumatic group, 26 patients (43.3%) were operated on the right side and 34 patients (56.7%) on the left side. In Holmium: YAG group, 32 patients (53.3%) were operated on the right side, and 28 patients (46.7%) on the left side. The mean surgery duration in pneumatic lithotripsy group was 44.87±22.85 minutes. Mean surgery duration in Holmium: YAG group was significantly longer at 142 ± 29.41 minutes. In pneumatic group, 60% of the patients had full stone clearance. In Holmium: YAG group, 70% of patients achieved complete stone clearance (Table 2).

Table 2: Comparison of Side Distribution and Stone Clearance in PCNL Using Pneumatic vs. Holmium: YAG Laser

Group	Anatomical Side		Total Frequency (%)
	Right Frequency (%)	Left Frequency (%)	
Pneumatic	26 (21.7)	34 (28.3)	60 (50.0)
Holmium Yag Laser	32 (26.3)	28 (23.3)	60 (50.0)
Total	58 (48.3)	62 (51.7)	120 (100.0)
Group	**Stone Clearance**		**Total Frequency (%)**
	Yes Frequency (%)	**No Frequency (%)**	
Pneumatic	36 (30.0)	24 (20.0)	60 (50.0)
Holmium Yag Laser	42 (35.0)	18 (15.0)	60 (50.0)
Total	78 (65.0)	42 (35.0)	120 (100.0)

The table compares stone clearance outcomes by anatomical side (right vs. left) in patients undergoing percutaneous nephrolithotomy (PCNL) using either pneumatic lithotripsy or Holmium: YAG laser (Table 3).

Table 3: Distribution of Anatomical Side Concerning Stone Clearance According to the Chi-Square Test

Anatomical Side	Group	Stone Clearance		Total Frequency (%)	p-Value (chi-Square Test)
		Yes Frequency (%)	No Frequency (%)		
Right	Pneumatic	20 (34.5)	6 (10.3)	26 (44.8)	0.400
	Holmium Yag Laser	20 (34.5)	12 (20.7)	32 (55.2)	
	Total	40 (69.0)	18 (31.0)	58 (100.0)	
Left	Pneumatic	16 (25.8)	18 (29.0)	34 (54.8)	0.073
	Holmium Yag Laser	22 (35.5)	6 (9.7)	28 (45.2)	
	Total	38 (61.3)	24 (38.7)	62 (100.0)	

Comparison of mean operative time (in minutes) between pneumatic and Holmium: YAG laser lithotripsy by anatomical side, showing significantly shorter durations with the pneumatic group across all categories ($p < 0.050$, t-test) (Table 4).

Table 4: Duration of Surgery According to T-Test

Operative Time (minutes)	Anatomical Side	Group	N	Mean ± SD	p-Value (t-test)
Overall	-	Pneumatic	60	44.87 ± 22.85	<0.001
		Holmium: YAG Laser	60	142.00 ± 29.41	
By Side	Right	Pneumatic	52	47.69 ± 15.97	<0.001
		Holmium: YAG Laser	64	146.25 ± 30.74	
	Left	Pneumatic	68	42.71 ± 27.27	<0.001
		Holmium: YAG Laser	56	137.14 ± 28.13	

Operative time was significantly lower with pneumatic lithotripsy compared to Holmium: YAG laser for both right and left kidney stones ($p < 0.050$, t-test) (Table 5).

Table 5: Comparison of Mean Operative Time Between Pneumatic and Holmium: YAG Laser Lithotripsy by Anatomical Side

Anatomical Side	Group	N	Mean ± SD (min)	p-Value (t-test)
Overall	Pneumatic	60	44.87 ± 22.85	<0.001
	Holmium: YAG Laser	60	142.00 ± 29.41	
Right Side	Pneumatic	52	47.69 ± 15.97	<0.001
	Holmium: YAG Laser	64	146.25 ± 30.74	
Left Side	Pneumatic	68	42.71 ± 27.27	<0.001
	Holmium: YAG Laser	56	137.14 ± 28.13	

Patients treated with Holmium: YAG laser had significantly longer mean operative times than those treated with pneumatic lithotripsy in both age groups ($p < 0.001$) (Table 6).

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Table 6: Comparison of Mean Operative Time (in Minutes) Between Pneumatic and Holmium:YAG Laser Lithotripsy Across Age Groups

Variables	Group	N	Operative Time (Mean ± SD)	p-Value (t-test)
Age				
≤35 Years	Pneumatic	30	45.73 ± 26.52	<0.001
	Holmium: YAG Laser	16	142.50 ± 31.05	
>35 Years	Pneumatic	30	44.00 ± 19.40	<0.001
	Holmium: YAG Laser	44	141.82 ± 6.30	
Gender				
Male	Pneumatic	44	40.18 ± 18.85	<0.001
	Holmium: YAG Laser	40	138.00 ± 28.21	
Female	Pneumatic	16	57.75 ± 28.94	<0.001
	Holmium: YAG Laser	20	150.00 ± 31.62	

DISCUSSION

Renal stones are one of the most prevalent conditions encountered in urology, often requiring surgical intervention. Percutaneous Nephrolithotomy (PCNL) is the gold standard procedure for the renal stones, using many energy sources for stone fragmentation among these, pneumatic lithotripsy, and Ho: YAG laser are commonly used, though understanding the differences in their results particularly for stone clearance rates and surgery duration is crucial. This study compares these two energy sources to assess their efficacy [13-15]. In this study, and compared two key variables: stone clearance and duration of surgery. Stone clearance is a critical objective in PCNL, as the primary aim is to achieve complete removal of renal stones. The duration of surgery is another important factor, influencing both the feasibility of the procedure and its cost. Additionally, prolonged surgical duration can raise concerns regarding patient safety, especially concerning anesthesia. These findings indicate that the pneumatic and Ho: YAG laser groups demonstrated comparable stone clearance rates, with no statistically significant difference. This suggests that both energy sources are similarly effective in achieving stone clearance. These results align with studies by Malik *et al.*, at the Sindh Institute of Urology and Transplant (SIUT), which reported stone clearance rates of 87% with pneumatic lithotripsy and 83% with Ho: YAG laser [16]. Similarly, Liu *et al.*, and Hong et al., found insignificant differences in stone clearance between the two energy modalities in their studies [17, 18]. However, contrasting findings have emerged in some studies. For example, Zyczkowsky *et al.*, from Poland observed a stone-free rate of 88.4% with the laser compared to 47.3% with pneumatic lithotripsy, highlighting the variability in stone clearance rates [19]. This discrepancy in the literature underscores the need for further studies to comprehensively evaluate the efficacy of different energy sources in PCNL. The duration of surgery is a crucial parameter when evaluating energy sources. It impacts the feasibility, cost, and patient safety during the procedure. In this study, the mean duration of surgery for the Ho: YAG laser group was significantly longer (142±29.41 minutes) compared to the pneumatic group (44.87±22.85 minutes). This substantial time difference reflects the well-known limitation of the Ho: YAG laser regarding the time consumption during PCNL. However, variations in the literature regarding surgery duration are evident. Malik *et al.*, found minimal difference between the two modalities at SIUT, with pneumatic PCNL taking 37.2±13 minutes and laser PCNL taking 39.6±11.9 minutes [16]. Similarly, Liu *et al.*, observed a minor difference, with pneumatic lithotripsy taking 55.9±16.5 minutes and laser lithotripsy taking 62.4±17.6 minutes [17]. Conversely, Zyczkowsky *et al.*, reported a shorter mean duration of 34 minutes for laser lithotripsy and 56 minutes for pneumatic lithotripsy, which contradicts these findings [20]. These discrepancies in surgery duration across different studies highlight the complexity of comparing energy sources and indicate that further research is required to establish the true impact of each energy source on surgery time. This study primarily found a significant difference in the duration of surgery between pneumatic lithotripsy and Ho: YAG laser, with the latter taking substantially longer. However, both energy sources showed similar efficacy in achieving stone clearance, with no statistically significant difference. Given the variability in the literature regarding both stone clearance rates and surgery duration, there is a compelling need for further trials and research to better understand the practical differences between these energy sources and to guide clinical decisions. Studies that focus on the economic implications of prolonged surgery duration and the long-term outcomes of different energy sources in PCNL are essential. Additionally, randomized controlled trials with robust methodologies are necessary to establish concrete guidelines for the selection of energy sources in PCNL.

This study was limited by its single-center design and relatively small sample size, which may affect the generalizability of the findings. Additionally, important procedural factors such as stone size, location, density, and surgeon experience were not fully standardized, which may have influenced operative time and outcomes. Future studies should include multi-center randomized controlled trials with stratification of stone characteristics and standardized surgical protocols to better compare the efficacy and operative efficiency of different energy sources in PCNL.

CONCLUSIONS

This study compared the pneumatic probe and Ho: YAG laser probe in percutaneous nephrolithotomy (PCNL),

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evaluating stone-free rate and duration of surgery for each method. Both sources demonstrated comparable effectiveness in stone clearance. However, the mean duration of surgery was significantly longer with the Ho: YAG laser as compared to pneumatic probe.

Authors' Contribution

Conceptualization: AA
Methodology: MA, UHK, ATA
Formal analysis: QAK
Writing and Drafting: UMK, AA, MFA, KHG
Review and Editing: UMK, AA, MA, UHK, QAK, ATA, MFA, KHG

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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