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COMPARATIVE EVALUATION OF PNEUMATIC AND LASER LITHOTRIPSY FOR THE MANAGEMENT OF PROXIMAL URETERIC STONES

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Abstract
This study aimed to compare the outcomes of pneumatic and laser lithotripsy in patients with proximal ureteric stones. A prospective randomized controlled trial was conducted in the Department of Urology at the Sindh Institute of Urology and Transplantation (SIUT), Karachi. Patients aged 18–70 years of either gender with proximal ureteric stones measuring 8–15 mm were enrolled using non-probability consecutive sampling and randomly assigned to two equal groups: pneumatic lithotripsy and laser lithotripsy. The diagnosis and stone size were confirmed using CT KUB scans. Empirical antibiotics were administered preoperatively and for at least five days postoperatively. Follow-up evaluations were performed at four weeks to assess stone clearance, migration, and the need for secondary interventions. Data were analyzed using SPSS version 26.0 with a 95% confidence interval and a 5% level of significance. The mean age was 40.83 ± 14.09 years in the pneumatic group and 40.40 ± 14.28 years in the laser group. Stone clearance was significantly higher in the laser group (74.3%) compared to the pneumatic group (48.6%). Stone migration occurred more frequently in the pneumatic group (42.9%) than in the laser group (14.3%), and secondary interventions were required more often in the pneumatic group (51.4%) than in the laser group (28.6%). These findings demonstrate that laser lithotripsy is more effective than pneumatic lithotripsy for managing proximal ureteric stones, offering higher stone clearance rates and reduced migration. Although laser lithotripsy requires greater time and cost, its lower rate of secondary intervention supports its preference in clinical practice. Further large-scale studies are recommended to confirm these findings and refine treatment guidelines.

INTRODUCTION

Urinary stones are a global progression and one of the main urological conditions affecting both sexes [1]. Ureteral stones account for about 20% of all urinary stones and the most common locations are in the upper ureter [2]. Untreated proximal ureteric stones can result in morbidity and life-threatening complications. This is why management of these stones is crucial [3].

Besides open surgical procedures for proximal ureteric stones, management of proximal ureteric stones includes medical management, extracorporeal shock wave lithotripsy (ESWL), ureteroscopy + lithoclast [4]. Among them, ESWL and ureteroscopy + lithoclast are conventional treatments. Laser lithotripsy is a well-developed technology that has shown improved efficiency in

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managing proximal ureteric stones and has gained wide popularity [5]. This problem has raised an argument whether pneumatic lithotripsy or laser lithotripsy is a better treatment [6].

Pneumatic lithotripsy or ballistic lithotripsy is another available tool, done using a device which creates high-pressure bursts of air to shatter the stone [7]. This three-part device is composed of a handpiece, air compressor, and foot pedal. A high-pressure pulse of air is produced when the foot pedal is pressed, which is carried through the handpiece and directed onto the stone. This leads to the stone breaking into smaller fragments that can then pass through your body with a urine outflow [8].

Instead, laser lithotripsy uses a laser to dust off the stone. The laser creates short bursts of heat, all concentrated in one place of the stone. To blow off a part of the stone, lasers would deliver energy to shatter the stone into little pieces and which can then be excreted out of body easily [9].

Every coin has two faces, and when it comes to lithotripsy, pneumatic lithotripsy also have pros & cons. Pneumatic lithotripsy is also cheaper than laser lithotripsy, and can be used which a small portable simpler device [10]. Pneumatic blasts cause stones to be fragmented in different sizes and because of the jerks caused by vibrations, there is a risk of stone migration into the renal pelvis and calyces [11].

Laser lithotripsy is an effective method for stone fragmentation and has relatively less probability for recommendation to have adjunctive procedures [12]. It also has a reduced risk of stone migration. Nevertheless, it costs more than pneumatic lithotripsy and must be performed with specific equipment and training. There is decreased risk of injury to the ureter or adjacent tissue [13].

Proximal ureteric stones are being difficult during lithotripsy and intracorporeal techniques like pneumatic and laser lithotripsy have been used. Upper uretheric stones tend to migrate and so carries the risk of remnant stones leading to procedures like DJ stenting or a need for extra corporeal shock wave lithotripsy (ESWL). This study seeks to conduct a thorough comparison of stone-free rates, stone migration tendencies, and the need for auxiliary procedures between pneumatic and laser lithotripsy in patients with proximal ureteric stones. The resultant findings are anticipated to offer valuable insights for clinicians in selecting the optimal treatment modality, thereby enhancing overall outcomes in the management of proximal ureteric stones.

METHODOLOGY

This prospective randomized control trial study was conducted at Department of Urology, Sindh Institute of Urology and Transplantation (SIUT), Karachi. The total sample size of 70 cases were included in this RCT through non-probability sampling technique; in group-A 35 patients were underwent pneumatic lithotripsy and in group-B also 35 patients were treated by laser lithotripsy.

Inclusion criteria were patients 18 -70 years of age, either sex, 8-15 mm proximal ureteric stones ASA status I or II. Exclusion criteria included patients with anomalous renal systems, ureteric strictures, urinary tract infections, bleeding disorders, malignancies, or those patients participating in other clinical trials, pregnant and lactating females.

The study was approved by the ethics committee and all enrolled patients signed informed consent. Upon presentation they were subjected to a CT KUB scan to confirm the presence and size of ureteric stones, and all patients underwent evaluation by an anesthesiologist for surgical fitness. All surgeries were done under general anesthesia and the empirical antibiotics were given both just before procedure (preoperative) and at least 5 days post-procedure or more.

Follow-up assessment was recorded after 4 weeks, in which patient outcomes like stone clearance, migration and need of any secondary interventions (DJ stenting or ESWL). SPSS version 26.0 was used for data analysis. Continuous variables were expressed as Mean±SD and categorical as frequency with percentage, respectively. Using Chi-square test to compare the outcomes of pneumatic vs laser lithotripsy at 5% level of significance.

RESULTS

Table I presents the clinical and demographic features of patients who had pneumatic lithotripsy (n=35) as opposed to laser lithotripsy (n=35) at the preliminary stage of the treatment. In terms of age (p = 0.900), body mass index (p = 0.167), number of stones (p = 0.726), gender (p = 0.229), residential

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status (p = 0.101), American Society of anaesthesiology (ASA) class (p = 0.619), and history of comorbidities, such as diabetes mellitus (p = 0.550), smoking history (p = 0.329), and hypertension (p = 0.607), there was no significant difference between the two groups. In contrast, the stone size in the laser group was significantly larger (14.06 ± 1.28 mm) when compared to the stone size in the pneumatic group (12.31 ± 1.58 mm) (p=0.0001). Furthermore, the duration of the procedure was significantly longer in the laser group (36.89 ± 7.16 minutes) compared to the pneumatic group (12.71 ± 3.45 minutes) (p=0.0001). Laterality was found to be roughly within the range of statistical significance (p = 0.056), with a greater frequency of right stone sided locations (60%) for the pneumatic group in comparison to the laser group (37.1%). Despite the fact that laser lithotripsy is conducted on patients who belong to the same demographic, these statistics suggest that lasers are more frequently utilised for stones that are larger in size and has more proximal location in ureter.

Pneumatic and laser lithotripsy were administered to a total of seventy patients, and Table II illustrates the differences in outcomes between the two methods. The laser group with an O.R. of 0.327 (95% confidence interval: 0.119–0.895, p-value=0.027) has a considerably higher stone clearance than the pneumatic group, which has a clearance rate of 48.6%. The laser group has a clearance rate of 74.3 percent. In addition, stone migration was much more common in the pneumatic group than it was in the laser group (42.9% versus 14.3%, odds ratio = 4.500, 95% confidence interval: 0.044–5.541). This was one of the characteristics that significantly differentiated the two groups (p = 0.008). A higher percentage of patients in the pneumatic group (51.4%) required secondary intervention than those in the laser group (28.6%), however this difference was not statistically significant (p = 0.051). In the end, the laser approach demonstrated a higher stone clearance rate and less stone migration as compared to pneumatic lithotripsy. There was also less stone migration.

Table I: Baseline Characteristics of Study Participants (n=70)

Variables		Groups		P-Value
		Pneumatic (n=35)	Laser (n=35)	
Age in years, Mean ± SD		40.83 ± 14.09	40.40 ± 14.28	0.900
BMI in kg/m^2, Mean ± SD		26.06 ± 3.57	24.90 ± 3.36	0.167
Size of Stone in mm, Mean ± SD		12.31 ± 1.58	14.06 ± 1.28	0.0001
Duration of Procedure in mins, Mean ± SD		12.71 ± 3.45	36.89 ± 7.16	0.0001
Number of Stone, Mean ± SD		1.11 ± 0.32	1.14 ± 0.35	0.726
Gender	Male, *n* (%)	17 (48.6)	22 (62.9)	0.229
	Female, *n* (%)	18 (51.4)	13 (37.1)	
Residential Status	Urban, *n* (%)	23 (65.7)	29 (82.9)	0.101
	Rural, *n* (%)	12 (34.3)	6 (17.1)	
Laterality	Right, *n* (%)	21 (60.0)	13 (37.1)	0.056
	Left, *n* (%)	14 (40.0)	22 (62.9)	
ASA Class	I, *n* (%)	17 (48.6)	14 (40.0)	0.619
	II, *n* (%)	15 (42.9)	19 (54.3)	
	III, *n* (%)	3 (8.6)	2 (5.7)	
Diabetes Mellitus, *n* (%)		8 (22.9)	6 (17.1)	0.550
Smoking History, *n* (%)		12 (34.3)	16 (45.7)	0.329

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Hypertension, *n* (%)	10 (28.6)	12 (34.3)	0.607

Table II: Comparison of Outcomes between Pneumatic and Laser Lithotripsy in Patients (n=70)

Variables	Groups			P-Value
	Pneumatic (n=35)	Laser (n=35)	O.R 95% C. I	
Stone Clearance, *n* (%)	17 (48.6)	26 (74.3)	0.327 (0.119—0.895)	0.027
Stone Migration, *n* (%)	15 (42.9)	5 (14.3)	4.500 (0.044—5.541)	0.008
Need of Secondary Intervention, *n* (%)	18 (51.4)	10 (28.6)	2.647 (0.985—7.113)	0.051

DISCUSSION

The choice between pneumatic and laser lithotripsy for treatment of proximal ureteric stones has been investigated previously since each method offers different benefits as well as disadvantages. According to this study, laser lithotripsy showed a better stone clearance and reduced stone migration in relation to pneumatic lithotripsy.

These findings are in line with previous studies. For instance, Chen et al. [9] implemented a meta-analysis in order to compare holmium.

Only two of these studies directly compared laser and pneumatic lithotripsy with higher stone clearance rates reported for the former [14,15]. Our data confirm this finding as well, with a 74.3% stone clearance rate in the laser group and a significantly lower 48.6% in the pneumatic group (p=0.027). The improved effectiveness of laser lithotripsy is likely predicted on the capacity to generate smaller stone fragments that can be evacuated more readily. Compared to mechanical lithotripsy, pneumatic lithotripsy fragments larger stones that may not pass all spontaneously and frequently need subsequent procedures [16].

Influencing the effectiveness of lithotripsy during lithotripsy, according to previous research, can lead to significant migration of stones, especially in proximal ureteric stones. Stone migration occurred nearly three times more frequently in the pneumatic lithotripsy group than laser group; 42.9 % versus 14.3%, respectively (p=0.008). This is consistent with the findings by Ventimiglia et al., [12]. Laser lithotripsy is also relatively safe in terms of risk of stone migration, given the controlled and accurate nature of energy transmission. The migration of fragments to the renal pelvis or calyces is a known complication of pneumatic lithotripsy, as high-pressure bursts may displace stones more than completely fragment them [17,18]. Not only does this migration decrease the immediate efficacy of the procedure, but it also raises the odds that secondary interventions will be necessary.

More numbers of secondary interventions (DJ stenting or ESWL) were required with the pneumatic group (51.4%) than that in laser group (28.6%), but the difference was not statistically significant (p=0.051). Abedi et al also support this trend [10] reported that the use of pneumatic lithotripsy was associated with a higher rate of residual stones and migration of stone fragments requiring additional procedures. Our study was under powered in detecting group difference for secondary interventions, but the tendency supports a clinical benefit of laser lithotripsy to have less requirement for supplemental treatments.

From a technical perspective, pneumatic lithotripsy has certain advantages in that it is less expensive and does not need complex fixed devices. However, these benefits are counter balanced by higher stone migration and additional procedure rates. Although more expensive, requiring specific training and equipment, laser lithotripsy has the strongest overall evidence for efficacy with fewer complications [19,20].

In summary, we acknowledge the strengths and limitations of this study comparing pneumatic and laser lithotripsy for proximal ureteric stones. This study has several strengths including its randomized controlled design which minimizes selection bias and the head to head comparison of two well established lithotripsy techniques Furthermore, the study used clinically meaningful endpoints in a clear manner ~ including stone clearance, migration and need for secondary intervention, each of which is a valuable and quantifiable proxy for procedural success. Secondly, the focus on procedural efficiency is also a real-world strength, with data as to how long the procedures took (objectively important for clinical decision-making). This set of results has high relevance for the clinical arena - ureteric stones are a common problem, and therefore these modes of therapy are in routine use.

These inferences should be tempered by several potential limitations. This small sample of 70 patients is, whilst exploratory and hypothesis-generating in nature, limited by a single-center design which may introduce institutional bias making it difficult to apply these results to other populations. In addition, the follow-up period is 4 weeks only and it may limit the ability of this study to gauge essential long-term outcomes such as stone recurrence or late complications. In addition, not all patient populations are included and exclusion of patients with specific conditions (such as urinary tract infection or anatomical abnormalities) limit the relevance for more complex patient groups. Lastly, there might be an effect due to operator experience (even though the surgeons were ensured to have a similar level of experience).

Nonetheless, the present study provides useful information about efficacy of pneumatic and laser lithotripsy. Compared with the other procedures, laser lithotripsy had significantly higher stone clearance and lower stone migration rates during the same period that made it more suitable for proximal ureteric stones treatment. The procedure time, cost and need for equipment are obviously important concerns of clinical practice, although the higher costs and longer procedural times with laser lithotripsy. An additional volume of large multicenter studies with longer follow-up is warranted to validate these findings and to guide management in unselected patients.

CONCLUSION

The results of this study indicate that laser lithotripsy was more efficacious in the treatment of proximal ureteral stones compared to pneumatic lithotripsy with higher stone clearance, and lower rates of migration. Although more time and expense are required for laser lithotripsy, its low requirement of secondary interventions makes it the preferable option. For these particularly high-risk cases, laser lithotripsy should be selected to minimize stone migration and promote clearance. Larger studies are warranted to validate these results and to inform treatment algorithms.

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