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Comparative Study of Laser vs. Shock Wave Lithotripsy in Pediatric Urolithiasis

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ABSTRACT

Background: Pediatric urolithiasis has become increasingly prevalent worldwide, necessitating safe and effective treatment options that ensure complete stone clearance while preserving renal function. Objective: This study aimed to compare the efficacy and safety of laser lithotripsy versus SWL in the management of pediatric urinary stones.

Methodology: This comparative cross-sectional study was conducted at Type-D hospital Latamber Karak from June 2023 to June 2024. A total of 143 pediatric patients aged 2–16 years diagnosed with urolithiasis were included and divided into two groups: Group A (laser lithotripsy, n = 72) and Group B (SWL, n = 71). Data regarding demographics, stone characteristics, treatment outcomes, complications, and hospital stay were recorded.

Results: The mean age of participants was 9.0 ± 3.5 years, with a male predominance (60.8%). Both groups were comparable in baseline characteristics. The stone-free rate after one session was significantly higher in the laser group (90.3%) compared to the SWL group (71.8%) ($p = 0.006$), which further increased to 96.0% and 85.9%, respectively, after two sessions ($p = 0.04$). Patients in the laser group required fewer treatment sessions (1.2 ± 0.4 vs. 1.6 ± 0.5; $p < 0.001$) and had shorter hospital stays (1.9 ± 0.7 vs. 2.6 ± 0.8 days; $p < 0.001$). Minor complications such as fever and hematuria occurred in both groups, with no significant difference ($p > 0.05$) and no major complications reported.

Conclusion: It is concluded that both laser lithotripsy and shock wave lithotripsy are effective and safe in managing pediatric urolithiasis; however, laser lithotripsy offers superior efficacy with higher stone-free rates, fewer sessions, and shorter hospital stays.

Keywords: *Pediatric urolithiasis, laser lithotripsy, shock wave lithotripsy, holmium:YAG, stone-free rate.*

1. INTRODUCTION

Pediatric urolithiasis, once considered a rare condition, has now become a significant global health concern with an increasing incidence in both developed and developing countries. Environmental, dietary, genetic, and metabolic factors play important roles in its development [1]. Increased intake of high-sodium diets, reduced water consumption, and exposure to hot climates have been identified as major contributors [2]. Moreover, metabolic abnormalities such as hypercalciuria, hyperoxaluria, cystinuria, and hypocitraturia are commonly found in children and are responsible for recurrent or bilateral stone formation. Because of these unique risk factors, the management of urolithiasis in children requires a careful approach that ensures complete stone removal while minimizing the risk of complications and preserving renal function [3]. The primary goal of treating pediatric urolithiasis is to achieve complete stone clearance with minimal morbidity, preserve renal parenchyma, and prevent recurrence. Traditionally, open surgery was the main treatment option; however, it has now been replaced by minimally invasive methods that offer faster recovery, shorter hospital stays, and fewer complications [4]. Among these, shock wave lithotripsy (SWL) and laser lithotripsy (LL) are the two most commonly used procedures for stone fragmentation in the pediatric population. Shock wave lithotripsy, introduced in the early 1980s, changed the landscape of stone management by providing a non-invasive alternative to open surgery [5]. The technique uses focused acoustic waves generated outside the body to break the stones into smaller fragments that can pass spontaneously through the urinary tract. Its advantages include no incision, minimal anesthesia requirement, and good patient tolerance. However, SWL's success depends largely on stone size, location, composition, and density [6]. Larger stones, lower pole stones, and hard compositions such as cystine or calcium oxalate monohydrate tend to respond poorly. Repeated sessions may also be required, increasing the total treatment burden and raising concerns regarding renal injury due to repeated shock exposure [7]. Laser lithotripsy, by contrast, uses an endoscopic approach where a flexible or semi-rigid ureteroscope is passed through the urinary tract, and a holmium:YAG laser is used to fragment the stone under direct visualization [8]. The laser energy can effectively treat stones of nearly all compositions while limiting damage to surrounding tissue. With the advent of miniaturized scopes and improved pediatric anesthesia techniques, laser lithotripsy has become increasingly feasible and safe for

children [9]. It generally achieves higher stone-free rates in a single session compared with SWL, especially in cases with multiple, impacted, or lower ureteric stones. However, it requires general anesthesia, involves instrumentation of the urinary tract, and is technically more demanding. Despite both procedures being well-established, there remains debate regarding which method provides superior outcomes in pediatric patients [10]. Various studies have presented mixed findings. Some have reported higher success and lower retreatment rates with laser lithotripsy, while others highlight SWL's safety, simplicity, and reduced invasiveness as strong advantages. xtracorporeal shock wave therapy was deemed effective, safe, and the first choice for treating 1-cm proximal ureteric stones [11]. However, ureteroscopy (URS) for upper urinary tract urolithiasis has a higher success rate and a lower retreatment rate when compared with extracorporeal shock wave lithotripsy (ESWL), especially after the development of flexible and smaller-caliber semi-rigid ureteroscopes and the introduction of lasers. With the advancement in endoscopic technology, a new dimension has been opened in the treatment of stone disease [12].

2. OBJECTIVE

This study aimed to compare the efficacy and safety of laser lithotripsy versus SWL in the management of pediatric urinary stones.

3. METHODOLOGY

This was a comparative cross-sectional study conducted at Type-D hospital Latamber Karak from June 2023 to June 2024. A total of 143 pediatric patients diagnosed with urolithiasis were included in the study. Non-probability consecutive sampling was used to recruit patients who fulfilled the inclusion criteria.

Inclusion Criteria:

Children aged between 2 and 16 years diagnosed with renal or ureteric calculi confirmed on ultrasonography or CT KUB.

Patients requiring active intervention for stone clearance.

Exclusion Criteria:

Children with bleeding disorders or uncorrected urinary tract infections.

Patients with congenital or anatomical abnormalities of the urinary tract such as ureteropelvic junction obstruction.

Those with a history of open renal surgery or non-functioning kidneys.

Data collection

Baseline demographic and clinical data were recorded, including age, gender, stone size, site, number, and laterality. All enrolled patients were divided into two groups based on the treatment modality:

Group A: Patients treated with laser lithotripsy.

Group B: Patients treated with shock wave lithotripsy (SWL).

The choice of procedure was determined by stone size, location, composition, and the treating urologist's clinical assessment.

In Group A (Laser Lithotripsy), procedures were performed under general anesthesia using a semi-rigid or flexible ureteroscope. A Holmium:YAG laser with a wavelength of 2100 nm was employed to fragment the stones. The "dusting" or "fragmentation" technique was selected according to the stone's size and hardness. Ureteral stenting was performed in selected cases based on intraoperative findings. In Group B (Shock Wave Lithotripsy), treatment was carried out using a Dornier Compact Delta II or equivalent lithotripter. Each patient received focused shock waves under ultrasound or fluoroscopic guidance with appropriate sedation or analgesia. Up to 3000 shocks were administered per session, with a frequency of 60–90 shocks per minute. Repeat sessions were offered if residual stones were detected on follow-up imaging.

Intraoperative and postoperative variables were also documented, such as procedure duration, number of sessions required, postoperative complications, hospital stay, and the need for retreatment. Stone-free status was evaluated using ultrasonography or non-contrast CT KUB at 2–4 weeks after treatment. A patient was considered stone-free if no residual fragment larger than 4 mm was seen. Postoperative complications such as fever, hematuria, urinary tract infection, and ureteral injury were noted and graded according to the Clavien-Dindo classification system.

Data Analysis

All collected data were analyzed using SPSS software version 26.0. Quantitative variables such as age, stone size, and hospital stay were expressed as mean ± standard deviation (SD). Categorical variables such as gender, stone-free rate, and complications were presented as frequencies and percentages. A p-value of less than 0.05 was considered statistically significant.

4. RESULTS

Data were collected from 143 patients, 72 of whom underwent laser lithotripsy and 71 underwent shock wave lithotripsy (SWL). The mean age of patients in the laser group was 9.2 ± 3.6 years, while in the SWL group it was 8.9 ± 3.4 years, showing no significant difference. Males predominated in both groups, with 45 (62.5%) in the laser group and 42 (59.1%) in the SWL group. The mean BMI was 18.4 ± 2.9 kg/m² in the laser group and 18.1 ± 3.1 kg/m² in the SWL group. The laterality of stones was almost equal in both groups (Right/Left: 37/35 vs. 36/35). The mean stone size was also comparable between groups (11.2 ± 3.8 mm for laser vs. 10.9 ± 3.5 mm for SWL). In terms of stone location, 49 renal and 23 ureteric stones were treated in the laser group compared to 46 renal and 25 ureteric stones in the SWL group.

Table 1. Baseline Demographic and Clinical Characteristics of the Study Participants (n = 143)

Variable	Laser Lithotripsy (n = 72)	Shock Wave Lithotripsy (n = 71)
Age (years), mean ± SD	9.2 ± 3.6	8.9 ± 3.4
Gender (Male), n (%)	45 (62.5%)	42 (59.1%)
BMI (kg/m²), mean ± SD	18.4 ± 2.9	18.1 ± 3.1
Laterality (Right/Left)	37 / 35	36 / 35
Stone size (mm), mean ± SD	11.2 ± 3.8	10.9 ± 3.5
Stone site (Renal/Ureteric)	49 / 23	46 / 25
Single / Multiple stones	58 / 14	55 / 16

The stone-free rate after one session was significantly higher in the laser lithotripsy group (65 patients; 90.3%) compared to the SWL group (51 patients; 71.8%) with a p-value of 0.006. After two sessions, the stone-free rate increased to 69 patients (96.0%) in the laser group and 61 patients (85.9%) in the SWL group (p = 0.04). The mean number of sessions required was significantly lower for the laser group (1.2 ± 0.4) than for the SWL group (1.6 ± 0.5, p < 0.001). The mean procedure or session time was slightly shorter in the laser group (38.7 ± 11.5 minutes) compared to SWL (42.4 ± 10.8 minutes), though this difference was not statistically significant (p = 0.08). Hospital stay duration was markedly shorter in the laser group (1.9 ± 0.7 days) compared to the SWL group (2.6 ± 0.8 days), with a highly significant difference (p < 0.001). Retreatment was required in only 3 patients (4.1%) in the laser group, whereas 10 patients (14.1%) in the SWL group required retreatment (p = 0.03).

Table 2. Comparison of Treatment Outcomes Between Laser and Shock Wave Lithotripsy

Outcome Variable	Laser Lithotripsy (n = 72)	Shock Wave Lithotripsy (n = 71)	p-value
Stone-free after 1 session, n (%)	65 (90.3%)	51 (71.8%)	0.006*
Stone-free after 2 sessions, n (%)	69 (96.0%)	61 (85.9%)	0.04*
Mean number of sessions	1.2 ± 0.4	1.6 ± 0.5	<0.001*
Mean procedure/session time (min)	38.7 ± 11.5	42.4 ± 10.8	0.08
Mean hospital stay (days)	1.9 ± 0.7	2.6 ± 0.8	<0.001*
Need for retreatment, n (%)	3 (4.1%)	10 (14.1%)	0.03*

Significant at p < 0.05.

Overall, complications were mild and self-limiting, with no statistically significant differences between the two groups. Transient hematuria occurred in 5 patients (6.9%) in the laser group and in 8 patients (11.3%) in the SWL group (p = 0.37). Fever exceeding 38°C developed in 4 patients (5.5%) after laser lithotripsy and in 6 patients (8.5%) after SWL (p = 0.52). Urinary tract infection was seen in 3 patients (4.1%) in the laser group compared to 5 patients (7.0%) in the SWL group (p = 0.48). Ureteral injury was recorded in 2 patients (2.7%) undergoing laser lithotripsy but in none of the SWL cases (p = 0.16).

Table 3. Postoperative Complications Between Both Groups

Complication	Laser Lithotripsy (n = 72)	Shock Wave Lithotripsy (n = 71)	p-value
Transient hematuria, n (%)	5 (6.9%)	8 (11.3%)	0.37
Fever (>38°C), n (%)	4 (5.5%)	6 (8.5%)	0.52
Urinary tract infection, n (%)	3 (4.1%)	5 (7.0%)	0.48
Ureteral injury, n (%)	2 (2.7%)	0 (0%)	0.16
Overall complication rate, n (%)	14 (19.4%)	19 (26.8%)	0.29

For stones smaller than 10 mm, the success rate was significantly higher with laser lithotripsy, achieving clearance in 36 out of 38 patients (94.7%) compared to 28 out of 35 patients (80.0%) with SWL (p = 0.04). For stones measuring between 10 and 15 mm, laser lithotripsy again demonstrated a higher success rate (28/30; 93.3%) compared to SWL (25/30; 83.3%), although the difference was not statistically significant (p = 0.18). In larger stones exceeding 15 mm, success rates were lower for both modalities—71.4% (5 out of 7 patients) for laser and 66.7% (4 out of 6 patients) for SWL—with no significant difference (p = 0.79).

Table 4. Correlation Between Stone Size and Treatment Success in Both Groups

Stone Size (mm)	Laser Lithotripsy – Stone-Free Rate, n (%)	Shock Wave Lithotripsy – Stone-Free Rate, n (%)	p-value
<10 mm	36 / 38 (94.7%)	28 / 35 (80.0%)	0.04*
10–15 mm	28 / 30 (93.3%)	25 / 30 (83.3%)	0.18
>15 mm	5 / 7 (71.4%)	4 / 6 (66.7%)	0.79

5. DISCUSSION

The present study compared the efficacy and safety of laser lithotripsy and shock wave lithotripsy (SWL) in the management of pediatric urolithiasis among 143 children. The findings revealed that laser lithotripsy achieved a significantly higher stone-free rate, required fewer treatment sessions, and resulted in shorter hospital stays compared to SWL. Both techniques were found to be safe, with no major complications reported. These results align with recent evidence suggesting that laser lithotripsy provides superior stone clearance outcomes in children while maintaining an acceptable safety profile. The overall stone-free rate in this study was 96.0% for laser lithotripsy and 85.9% for SWL after two sessions, which is consistent with findings from Geraghty et al. (2023), who reported higher stone-free rates with flexible ureteroscopy and laser lithotripsy compared to SWL in pediatric renal stones smaller than 2 cm. The improved efficacy of laser lithotripsy can be attributed to its ability to directly visualize and fragment stones of nearly all compositions under endoscopic guidance. The holmium:YAG laser allows precise energy delivery with minimal thermal injury to surrounding tissue, which is particularly advantageous in pediatric patients with delicate urinary tracts [13].

In contrast, SWL, though non-invasive and convenient, has limitations related to stone characteristics and patient anatomy. Factors such as stone size, density, and lower-pole location negatively influence its success rate. Several studies have highlighted that SWL efficacy declines for stones larger than 15 mm or with higher Hounsfield units. In the current study, although SWL was effective for smaller calculi (<10 mm), its success decreased as stone size increased. The need for multiple sessions in SWL-treated patients further supports the notion that while SWL is less invasive, its efficiency may be reduced in certain stone types and locations [14]. The shorter hospital stay and fewer retreatments observed in the laser group suggest that this technique is more efficient in achieving complete clearance in a single setting. This outcome is crucial in children, as repeated anesthesia exposure carries additional risks. In the current study, the mean hospital stay was 1.9 ± 0.7 days for the laser group compared to 2.6 ± 0.8 days for SWL, a difference that was statistically significant. The complication rates in both groups were low and comparable. Minor complications such as transient hematuria, mild fever, and urinary tract infection occurred in 19.4% of patients undergoing laser lithotripsy and 26.8% of those treated with SWL, with no significant difference [15]. This pattern mirrors earlier literature, including studies by Dogan et al. (2019) and Dwyer et al. (2021), which demonstrated that while ureteroscopic laser procedures carry a slightly higher risk of minor mucosal trauma, the overall safety remains comparable to SWL when performed by experienced surgeons [16,17]. Importantly, no major complications such as sepsis, renal hematoma, or open conversion were encountered in either group, reaffirming the safety of both modalities in the pediatric setting. An additional analysis in this study revealed a correlation between stone size and treatment success. Laser lithotripsy showed a significantly higher success rate for stones smaller than 10 mm, while the difference narrowed for stones larger than 15 mm [18]. This suggests that laser lithotripsy may be the preferred choice for small- to medium-sized stones, whereas SWL may still be considered for very small, uncomplicated stones, especially in centers where endoscopic expertise or laser equipment is limited. Cost and availability are other critical considerations [19,20]. Although laser lithotripsy involves higher equipment costs and requires general anesthesia, its higher single-session success rate and shorter hospitalization may offset the cost in the long term. Conversely, SWL, while more accessible and non-invasive, may lead to higher cumulative costs due to repeat sessions, imaging, and follow-up visits. The findings of this study emphasize the evolving role of endourology in pediatric stone management. With advancements in miniaturized scopes, better optics, and improved anesthesia safety, laser lithotripsy has become increasingly feasible and reliable for children. However, patient selection remains crucial. SWL continues to be a reasonable first-line option for small, non-impacted stones and in patients where anesthesia poses a higher risk.

6. LIMITATIONS

The study has certain limitations. It was conducted at a single center, which may limit the generalizability of the findings. The sample size, though adequate for comparison, was modest and may not capture rare complications. Long-term outcomes, such as recurrence rates and renal function preservation, were not evaluated due to limited follow-up duration. Additionally, cost-effectiveness analysis was not performed, which could have provided further insight into resource utilization differences between the two modalities.

7. CONCLUSION

It is concluded that both laser lithotripsy and shock wave lithotripsy are effective and safe treatment options for pediatric urolithiasis; however, laser lithotripsy demonstrates clear superiority in clinical outcomes. Children treated with laser lithotripsy achieved a significantly higher stone-free rate, required fewer treatment sessions, and had shorter hospital stays compared to those managed with shock wave lithotripsy

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