Journal of Comprehensive Surgery

Original Article

DOI: 10.51271/JOCS-0048

Comparison of the efficacy of extracorporeal shock wave lithotripsy, pneumatic lithotripsy, and laser lithotripsy in the treatment of proximal ureteral calculi

Cem Özlük, Fazlı Polat

Department of Urology, Faculty of Medicine, Gazi University, Ankara, Turkiye

Cite this article as: Özlük C, Polat F. Comparison of the efficacy of extracorporeal shock wave lithotripsy, pneumatic lithotripsy, and laser lithotripsy in the treatment of proximal ureteral calculi. *J Compr Surg.* 2025;3(1):9-14.

Received: 15.01.2025 ◆ **Accepted**: 11.02.2025 ◆ **Published**: 23.02.2025

ABSTRACT

Aims: This study aimed to compare the efficacy of extracorporeal shock wave lithotripsy (ESWL), pneumatic lithotripsy, and laser lithotripsy in the treatment of proximal ureteral calculi, focusing on stone-free rates, complication profiles, and the need for additional interventions.

Methods: A retrospective analysis was conducted on 150 patients with proximal ureteral calculi treated with ESWL, pneumatic lithotripsy, or laser lithotripsy. Patients were divided into three equal groups (50 per treatment arm). Demographic and clinical characteristics, procedural outcomes, and complication rates were evaluated. Stone-free status was assessed on postoperative day 1 via direct urinary system radiography and at 1 month using intravenous urography.

Results: For stones smaller than 10 mm, the stone-free rates were 93% in the ESWL group, 80% for pneumatic lithotripsy, and 84% for laser lithotripsy. In stones ≥10 mm, the rates dropped to 55.0%, 52.6%, and 75%, respectively. There were no statistically significant differences in the distributions of stone-free status, minimal residue, or the requirement for post-procedure URS across procedure types. A higher frequency of pusback was observed in the pneumatic lithotripsy group compared to the other groups (pneumatic lithotripsy: 31.6% vs. laser lithotripsy: 12.5% vs. ESWL: 0%, p=0.012). However, for stones smaller than 10 mm, this difference was not statistically significant. The mean operative duration was longest for laser lithotripsy compared to pneumatic lithotripsy and ESWL (pneumatic lithotripsy: 36.6±5.2 vs. laser lithotripsy: 62.8±11.1 vs. ESWL: 28.2±6.4 minutes, p=0.001). Complication rates were comparable across groups.

Conclusion: In smaller ureteral calculi, the three modalities exhibit comparable efficacy. For large ureteral stones, laser lithotripsy achieves better stone-free rates and requires fewer repeat interventions but has a longer operative time. Treatment decisions should be individualized according to stone size, patient factors, and available resources.

Keywords: Ureteral calculi, extracorporeal shock wave lithotripsy, lithotripsy, treatment outcome, ureteroscopy, complications

INTRODUCTION

Proximal ureteral stones constitute a significant portion of urolithiasis cases, and their treatment is crucial to prevent possible urinary system obstruction, pain, hydronephrosis, and potential renal dysfunction.[1] In managing ureteral stones, the main factors considered include stone size, location, structural characteristics, and the clinical condition of the patient.[2] Especially in proximal ureteral stones, the likelihood of spontaneous passage decreases as stone size increases, bringing invasive or semi-invasive treatment approaches to the forefront.[3]

Traditionally, for symptomatic proximal ureteral stones larger than 10 mm, treatment options such as extracorporeal shock wave lithotripsy (ESWL), ureteroscopic pneumatic lithotripsy, or laser lithotripsy have been recommended.[4,5] ESWL is widely accepted as a first-line method due to its favorable tolerability and non-invasive nature, while pneumatic and laser lithotripsy represent two commonly employed energy sources in ureteroscopic procedures.[6,7] Pneumatic lithotripsy effectively fragments hard and large stones, it carries a risk of fragment migration. On the other hand, laser lithotripsy is noted for providing more controlled fragmentation and achieving high success rates with both hard and soft stones.[8,9] Recent research indicates that, particularly for larger stones in the upper ureter, laser lithotripsy may offer higher stone-free rates compared to pneumatic lithotripsy.[10,11] However, studies comparing ESWL with pneumatic or laser lithotripsy have emphasized that while ESWL's non-invasive nature is an advantage, its success rates in larger or harder stones may be lower-sometimes requiring repeat procedures.[12] Although both pneumatic and laser lithotripsy can reduce the need for repeated sessions, thereby helping patients achieve stone-

Corresponding Author: Cem Özlük, dr.cemozluk@yahoo.com

free status more quickly, one must also consider potential complications such as ureteral trauma.[9]

The existing literature on the management of proximal ureteral stones predominantly focuses on comparative analyses involving two treatment modalities, such as ESWL, pneumatic lithotripsy, or laser lithotripsy. However, studies that evaluate and compare the efficacy and safety profiles of all three methods simultaneously are scarce. Therefore, this study aimed to compare the efficacy of ESWL, pneumatic lithotripsy, and laser lithotripsy in the treatment of proximal ureteral calculi.

METHODS

This retrospective study was conducted at the at the Department of Urology, Gazi University Faculty of Medicine, between June 2009 and June 2012, in accordance with the Declaration of Helsinki and Good Clinical Practice Guidelines. The study was derived from a thesis completed prior to 2020 and received institutional approval. The need for informed consent was waived under the approval of the local ethics committee due to the retrospective design.

Patients diagnosed with proximal ureteral calculi and treated with either ESWL, pneumatic ureterorenoscopy (URS), or laser URS during the study period were retrospectively screened for eligibility. Patients were excluded if they were on continuous anticoagulant therapy, had ureteral strictures, multiple stones, anatomical anomalies, or chronic kidney disease. After applying these exclusion criteria, 150 patients were included in the study, with 50 patients in each treatment group.

All patients included in the study had radiopaque stones confirmed by preoperative non-contrast computed tomography evaluation. The localization of upper ureteral stones was defined as the region between the ureteropelvic junction and the bony pelvis. Stone size was calculated as described in the European Association of Urology (EAU) guidelines.[13]

Surgical Methods

The ESWL procedure was performed without anesthesia. The Siemens Lithostar Modularis 140 (SN:792SPV0001) lithotripter was used for stone fragmentation, with C-arm fluoroscopy employed for targeting. Following fragmentation, stone fragments were removed in some cases using a basket or forceps. URS procedures were performed under general or spinal anesthesia using a 10F rigid ureterorenoscope (Karl Storz, Germany). For laser lithotripsy, a Dornier Medilas H20 laser lithotripter (SN: H20-1205, Germany) was used, operating at a pulse energy of 120 mJ and a frequency of 8 Hz at a wavelength of 595 nm. For pneumatic lithotripsy, an Elmed Vibrolith pneumatic lithotripter (SN: 1038VB672, Germany) was used, set at a pressure of 2 bar and a frequency of 10 Hz. During URS, stones were fragmented into pieces ≤2 mm in size. Normal saline was used as the irrigation fluid during the procedure.

To prevent renal colic caused by any remaining fragments or ureteral edema, a 4.8 Fr ureteral catheter was placed in all patients at the end of the procedure. In uncomplicated cases, this catheter was removed on postoperative day 1, whereas in complicated cases it remained in place for 48-72 hours.

Endpoints

Successful treatment was defined as having no fragments larger than 2 mm. If the residual fragment size exceeded 2 mm, the patient was deemed not stone-free, necessitating additional forceps or basket retrieval. In this study, achieving fragmentation to 2 mm or less was considered equivalent to being stone-free.

Complications potentially associated with each treatment method included ureteral perforation, ureteral mucosal laceration, stone migration, hematuria, urinary tract infection, postoperative fever, steinstrasse, and pain. Stone-free status was evaluated on the first postoperative day using a direct urinary system radiography and again at one month via intravenous urography (IVU).

In all groups, post-procedure URS was performed in patients who were found to have residual stone fragments larger than 2 mm on follow-up imaging (direct radiography on postoperative day 1 or IVU at one month) or who had persistent (e.g., ongoing pain, obstruction, or infection) suggesting inadequate fragmentation or incomplete stone clearance.

Statistical Analysis

All data were analyzed using SPSS Statistics Software, version 15 (SPSS, Inc., Chicago, IL, USA). Numerical data determined to be normally distributed based on the results of Kolmogorov-Smirnov tests are given as mean±standard deviation values, while non-normally distributed variables are given as median (min-max) values. Accordingly, student T test and Mann-Whitney U test were used for comparisons between two groups. ANOVA test (post-hoc: Bonferroni test) or Kruskal-Wallis H test (post-hoc: Dunn's test) were used for comparisons between more than two groups. Categorical variables were presented as numbers and percentages, and comparisons between groups were performed using chi-square and Fisher exact tests. Significance was accepted at $p<0.05$ (*) for all statistical analyses.

RESULTS

Table 1 summarizes the demographic and clinical characteristics of the treatment groups. The median age was comparable across all groups (pneumatic lithotripsy: 44 vs. laser lithotripsy: 41 vs. ESWL: 42 years; $p=0.960$). While the proportion of males was higher in all groups, there was no statistically significant difference among the groups (pneumatic lithotripsy: 72% vs. laser lithotripsy: 58% vs. ESWL: 68%, $p=0.355$). Stone location was more frequently observed on the right side, and its distribution was similar across all groups.

Double-J ureteral catheter usage was significantly lower in the ESWL group compared to the other groups (pneumatic lithotripsy: 64% vs. laser lithotripsy: 72% vs. ESWL: 18%, $p<0.001$). The median stone size did not differ significantly among the groups. The mean operation duration was longer in the laser lithotripsy group compared to the other groups (pneumatic lithotripsy: 36.6±5.2 vs. laser lithotripsy: 62.8±11.1 vs. ESWL: 28.2±6.4 minutes, $p=0.001$). Additionally, the ESWL group exhibited a shorter duration of hospital stay compared to the other groups (pneumatic lithotripsy: 24 hours vs. laser lithotripsy: 12 hours vs. ESWL: 1 hour, $p=0.001$) (Table 1).

While the complication rates were comparable among the groups, there were no significant differences in the types of complications observed. The frequency of pusback was higher in the pneumatic lithotripsy group compared to the other groups, while it was not observed in the ESWL group (pneumatic lithotripsy: 22% vs. laser lithotripsy: 12% vs. ESWL: 0%, p=0.001). In the overall population, no significant differences were observed in other outcome findings (Table 2).

Among patients with stones less than 10 mm, there were no statistically significant differences in the distributions of stone-free status, pushback, minimal residue, or the requirement for post-procedure URS across procedure types (Table 3).

Table 1. Demographic and clinical findings of the patients

Variables	Pneumatic lithotripsy n=50	Laser lithotripsy n=50	ESWL n=50	p-value
Age, years	44 (3-77)	41 (10-91)	42 (18-72)	0.960
Gender, n (%)				
Female	14 (28.0)	21 (42.0)	16 (32.0)	0.355
Male	36 (72.0)	29 (58.0)	34 (68.0)	
Stone location, n (%)				
Right	26 (52.0)	29 (58.0)	25 (50.0)	0.778
Left	24 (48.0)	21 (42.0)	25 (50.0)	
Double-J ureteral catheter, n (%)	32 (64.0)	36 (72.0)	9 (18.0)	<0.001*
Stone size, mm	8 (5-15)	9 (5-30)	7 (5-16)	0.060
Operation duration, minutes	36.6±5.2	62.8±11.1	28.2±6.4	0.001*
Hospital stay, hours	24 (1-48)	12 (1-48)	1 (1-24)	0.001*

Data are shown as mean±standard deviation or median (minimum-maximum) or number and percentage (%). *p<0.05 shows statistical significance. Bold characters indicate differences between groups. Abbreviations: ESWL: Extracorporeal shock wave lithotripsy

Table 2. Distribution of postoperative complications and outcomes according to procedure types

Variables	Pneumatic lithotripsy n=50	Laser lithotripsy n=50	ESWL n=50	p-value
Complications, n (%)				
No	31 (62.0)	33 (66.0)	27 (54.0)	0.501
Yes	19 (38.0)	17 (34.0)	23 (46.0)	
Fever	5 (10.0)	4 (8.0)	4 (8.0)	0.999
Migration	6 (12.0)	3 (6.0)	6 (12.0)	0.556
Infection	2 (4.0)	2 (4.0)	3 (6.0)	0.999
Leak	-	-	1 (2.0)	0.999
Hematuria	9 (18.0)	11 (22.0)	18 (36.0)	0.107
Pain	18 (36.0)	15 (30.0)	18 (36.0)	0.791
Steinstrasse	-	-	2 (4.0)	0.326
Outcomes, n (%)				
Stonefree	35 (70.0)	40 (80.0)	39 (78.0)	0.563
Pushback	11 (22.0)	6 (12.0)	-	0.001*
Minimalresidue	1 (2.0)	2 (4.0)	6 (12.0)	0.147
Post-procedure URS	3 (6.0)	2 (4.0)	5 (10.0)	0.600

Data are shown as number and percentage (%). *p<0.05 shows statistical significance. Abbreviations: ESWL: Extracorporeal shock wave lithotripsy, URS: Ureterorenoscopy

Table 3. Comparison of postoperative outcomes among procedure types based on stone size

Outcomes	Pneumatic lithotripsy	Laser lithotripsy	ESWL	p-value
Stones <10 mm, n (%)	**n=31**	**n=26**	**n=30**	
Stonefree	25 (80.6)	22 (84.6)	28 (93.3)	0.364
Pushback	5 (16.1)	3 (11.5)	-	0.063
Minimal residue	-	1 (3.8)	2 (6.7)	0.406
Post-procedure URS	1 (3.2)	-	-	0.999
Stones ≥10 mm, n (%)	**n=19**	**n=24**	**n=20**	
Stonefree	10 (52.6)	18 (75.0)	11 (55.0)	0.238
Pushback	6 (31.6)	3 (12.5)	-	0.012*
Minimal residue	1 (5.3)	1 (4.2)	4 (20.0)	0.272
Post-procedure URS	2 (10.5)	2 (8.3)	5 (25.0)	0.286

Data are shown as number and percentage (%). *p<0.05 shows statistical significance. Abbreviations: ESWL: Extracorporeal shock wave lithotripsy, URS: Ureterorenoscopy

Among patients with stones ≥10 mm, there were no statistically significant differences in the distributions of stone-free status (pneumatic lithotripsy: 52.6% vs. laser lithotripsy: 75.0% vs. ESWL: 55.0%, p=0.238) across procedure types. The frequency of pusback was higher in the pneumatic lithotripsy group compared to the other groups, while it was not observed in the ESWL group (pneumatic lithotripsy: 31.6% vs. laser lithotripsy: 12.5% vs. ESWL: 0%, p=0.012). There were no statistically significant differences in the distributions of minimal residue (pneumatic lithotripsy: 5.3% vs. laser lithotripsy: 4.2% vs. ESWL: 20.0%, p=0.273), and the requirement for post-procedure URS (pneumatic lithotripsy: 10.5% vs. laser lithotripsy: 8.3% vs. ESWL: 25.0%, p=0.286) across procedure types (**Table 3**).

DISCUSSION

Guidelines by both the American Urological Association (AUA) and the European Association of Urology (EAU) indicate that for stones <10 mm, ESWL and URS yield stone-free rates of approximately 90% and 80%, respectively; for stones ≥10 mm, these rates decrease to 68% and 79%.[14] Their meta-analyses further confirm that ureteroscopy outperforms ESWL for stones ≥10 mm in the upper ureter.[14] Similarly, in a large series of patients undergoing URS for upper ureteral stones, a stone-free rate of 91.7% and a low complication rate of 1.8% have been reported.[15] A previous study comparing ultrasonic, electrohydraulic, pulsed-dye laser, and pneumatic lithotripsy in URS have documented an overall success rate of 87.8%; success rates for each modality have been reported as 79.6%, 72%, 86.7%, and 92.7%, respectively.[16] A meta-analysis comparing URS and ESWL for the management of large (>10 mm) proximal ureteral stones revealed that URS achieved a higher stone-free rate, whereas ESWL was associated with a higher retreatment rate. Nonetheless, no significant differences were observed between the two techniques regarding mean operative time, auxiliary procedure rates, or complication rates.[5] In our study, treatment success was defined as achieving stone-free status; any residual fragments and need for repeated interventions were considered a failure. For stones <10 mm, the stone-free rates in the ESWL, pneumatic, and laser lithotripsy groups were 93.3%, 80.6%, and 84.6%, respectively, without statistically significant differences among them. However, for stones ≥10 mm, the rates decreased to 55%, 52.6%, and 75%, respectively. Laser lithotripsy tended to show high success rate than other treatment groups. These findings highlight the impact of stone size on the effectiveness of different treatment modalities.

We observed that the re-intervention rate among patients with stones ≥10 mm treated with ESWL was 25%, compared to 10.5% for pneumatic lithotripsy and 8.3% for laser lithotripsy. Conversely, second procedure rates were markedly lower in cases involving stones <10 mm. Our findings align with previous reports that ESWL might be more suitable for smaller stones, given that larger or impacted stones can yield higher rates of residual fragments and possible steinstrasse.[5,17-19] In response to the drawbacks associated with ESWL-particularly the need for repeated sessions and the associated increased morbidity-endoscopic approaches have gained prominence and, in many centers, have become the first-line treatment for ureteral stones.[20] Historically, ESWL was recommended for upper ureter stones, whereas URS was primarily indicated for mid and distal ureteral stones.[21] However, the development of small-caliber semirigid and flexible ureteroscopes, alongside advances in holmium laser technology, has enabled safer and more effective ureteroscopic intervention at all ureteral levels.[22] Indeed, single-session stone-free rates with flexible ureteroscopy have been reported to reach 81-94% in various series, bringing outcomes closer to those of ESWL, particularly for upper ureteral stones.[14,23-25]

Although ESWL is less invasive, patients must sometimes endure extended periods awaiting spontaneous fragment passage, which can be accompanied by colic, possible additional sessions, or even salvage URS.[26] Meanwhile, URS-whether pneumatic or laser-often can provide a definitive solution in a single session. Consequently, many patients prefer ureteroscopic approaches to avoid the uncertainty and repeated visits associated with ESWL, particularly when stones are large or symptomatic.[27] Nonetheless, institutional factors such as the availability of endoscopic equipment, laser fibers, and the surgeon's experience also play roles in treatment selection.[28,29]

Pneumatic lithotripsy effectively fragments even hard calculi. However, its high-impact mechanical force can drive stone fragments proximally (pushback), leading to longer procedure times, additional interventions, and potentially higher morbidity.[30] In our series, the laser lithotripsy group had the longest mean operative time, which we attribute partly to a steeper learning curve, the delicate nature of laser fragmentation, and the slightly larger stone sizes in that group compared to the other arms. Also, we noted a 12% rate of significant upward stone migration with pneumatic lithotripsy, consistent with other publications.[30-33] Because most pneumatic systems are used with rigid ureteroscopes, retrieving migrated fragments can be technically challenging-especially for upper ureter stones. Laser lithotripsy, often employing holmium: YAG technology, emits energy localized primarily on the stone surface rather than surrounding tissues or irrigation fluid. It is compatible with small-caliber and flexible ureteroscopes, thus broadening its utility for upper ureter or intrarenal stones.[34,35] Beyond stone fragmentation, holmium lasers can assist with coagulation and even the excision of ureteral strictures or other obstructive lesions, offering a "multipurpose" advantage during endoscopic procedures.[36]

Complication rates for ESWL range from 1.5% to 35% in various series.[37] Post-ESWL complications, such as sepsis, steinstrasse, hematuria, and flank pain, do occur but are generally lower than the potential injuries seen in URS (e.g., perforation, mucosal tears).[38] According to the 2007 AUA guidelines, URS complications include a 1-2% risk of stricture, 3-6% ureteral injury, 2-4% urinary tract infection/sepsis, and 0% steinstrasse.[14] Consistent with the literature, our study documented the most frequent postoperative complaints as fever, mucosal lesions, and stone migration-especially in the pneumatic group. In the ESWL group, minimal extravasation was observed in one patient, managed successfully with temporary stenting and no further intervention required. Interestingly, the overall complication distribution also seems tied to surgeon expertise. In our series, laser lithotripsy tended to show fewer complications than pneumatic lithotripsy, potentially reflecting the surgeon's familiarity with the laser device and the localized mechanism of holmium laser energy. This notion is supported by other studies demonstrating that surgeon experience can play a pivotal role in minimizing complications and optimizing outcomes.[38-40]

Limitations

This study has several limitations. The retrospective nature of the study may introduce inherent biases, such as selection bias and the inability to control for all confounding variables. The study was conducted at a single center, which may limit the generalizability of the findings to other institutions or patient populations with different clinical practices, technological access, or surgeon expertise. The study primarily focused on short-term outcomes, such as stone-free rates and complications within the immediate postoperative period. We evaluated stone-free status in the short term using direct urinary system radiography and intravenous urography, which may underestimate final stone-free rates, as the EAU guidelines recommend a longer follow-up-up to three months-for possible delayed fragment passage. Longer-term follow-up is necessary to assess late complications, such as ureteral stricture formation, and to determine the recurrence rates of stones after treatment. Additionally, a longer follow-up period with additional imaging modalities, such as ultrasonography or non-contrast computed tomography, could have provided a more precise assessment of stone-free rates.

CONCLUSION

ESWL remains a valuable non-invasive option, offering shorter hospital stays and minimal procedural risk. However, its efficacy decreases with increasing stone size, often necessitating multiple sessions and additional interventions, which may offset its initial advantages. Pneumatic lithotripsy is effective for stone fragmentation but carries a higher risk of stone migration due to its mechanical impact, particularly in proximal ureteral stones. This migration often leads to extended operative times and additional procedures. Laser lithotripsy demonstrated better stone-free rates, especially for stones ≥10 mm, with lower complication rates compared to other modalities. Despite requiring longer operative times, its precision and ability to manage complex stone scenarios make it a highly effective treatment option.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was produced from a thesis before 2020, and institutional approval was received.

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Lai S, Jiao B, Diao T, et al. Optimal management of large proximal ureteral stones (>10 mm): a systematic review and meta-analysis of 12 randomized controlled trials. *Int J Surg.* 2020;80:205-217. doi:10.1016/j.ijsu.2020.06.025
2. Ordon M, Andonian S, Blew B, Schuler T, Chew B, Pace KT. CUA guideline: management of ureteral calculi. *Can Urol Assoc J.* 2015;9(11-12):E837-E851. doi:10.5489/cuaj.3483
3. Bhanot R, Jones P, Somani B. Minimally invasive surgery for the treatment of ureteric stones-state-of-the-art review. *Res Rep Urol.* 2021;13:227-236. doi:10.2147/RRU.S311010
4. Bader MJ, Eisner B, Porpiglia F, Preminger GM, Tiselius HG. Contemporary management of ureteral stones. *Eur Urol.* 2012;61(4):764-772. doi:10.1016/j.eururo.2012.01.009
5. Cui X, Ji F, Yan H, et al. Comparison between extracorporeal shock wave lithotripsy and ureteroscopic lithotripsy for treating large proximal ureteral stones: a meta-analysis. *Urology.* 2015;85(4):748-756. doi:10.1016/j.urology.2014.11.041
6. Abedi AR, Razzaghi MR, Allameh F, Aliakbari F, FallahKarkan M, Ranjbar A. Pneumatic lithotripsy versus laser lithotripsy for ureteral stones. *J Lasers Med Sci.* 2018;9(4):233-236. doi:10.15171/jlms.2018.42
7. Young MJ, Pang KH, Elmussarah M, Hughes PF, Browning AJ, Symons SJ. Acute extracorporeal shockwave lithotripsy for ureteric stones-7-years' experience from a busy district general hospital. *BJU Int.* 2022;130(5):655-661. doi:10.1111/bju.15820
8. Cho CO, Yu JH, Sung LH, Chung JY, Noh CH. Comparison of percutaneous nephrolithotomy using pneumatic lithotripsy [lithoclast (R)] alone or in combination with ultrasonic lithotripsy. *Korean J Urol.* 2010;51(11):783-787. doi:10.4111/kju.2010.51.11.783
9. Nour HH, Kamel AI, Elmansy H, et al. Pneumatic vs laser lithotripsy for mid-ureteric stones: clinical and cost effectiveness results of a prospective trial in a developing country. *Arab J Urol.* 2020;18(3):181-186. doi:10.1080/2090598X.2020.1749800
10. Bahçeci T, Başer A. Comparison the efficacy of pneumatic and holmium laser ureteroscopic lithotripsy for the treatment of ureteral stones: a retrospective observational study. *Pamukkale Med J.* 2022;15(4):648-655. doi:10.31362/patd.1055563
11. İrer B, Şen V, Erbatu O, et al. Comparison of efficacy and complications of holmium laser and pneumatic lithotripters used in the ureterorenoscopic treatment of proximal ureter stones, a multi-center study of society of urological surgery aegean study group. *J Urol Surg.* 2018;5(3):158-163. doi:10.4274/jus.2143
12. Breda A, Ogunyemi O, Leppert JT, Schulam PG. Flexible ureteroscopy and laser lithotripsy for multiple unilateral intrarenal stones. *Eur Urol.* 2009;55(5):1190-1196. doi:10.1016/j.eururo.2008.06.019
13. Tiselius HG, Ackermann D, Alken P, et al. Guidelines on urolithiasis. *Eur Urol.* 2001;40(4):362-371. doi:10.1159/000049803
14. Preminger GM, Tiselius HG, Assimos DG, et al. 2007 guideline for the management of ureteral calculi. *J Urol.* 2007;178(6):2418-2434. doi:10.1016/j.juro.2007.09.107
15. Krambeck AE, Murat FJ, Gettman MT, Chow GK, Patterson DE, Segura JW. The evolution of ureteroscopy: a modern single-institution series. *Mayo Clin Proc.* 2006;81(4):468-473. doi:10.4065/81.4.468
16. Günlüsoy B, Arslan M, Değirmenci T, Nergiz N, Minareci S, Ayder AR. Değişik yerleşimli üreter taşlarının üreteroskopik tedavisinde farklı litotripsi yöntemlerinin karşılaştırılması. *Türk Ürol Derg.* 2006;32(2):234-239.
17. Wu CF, Shee JJ, Lin WY, Lin CL, Chen CS. Comparison between extracorporeal shock wave lithotripsy and semirigid ureterorenoscope with holmium: YAG laser lithotripsy for treating large proximal ureteral stones. *J Urol.* 2004;172(5 Pt 1):1899-1902. doi:10.1097/01.ju.0000142848.43880.b3
18. Bahçeci T, Kızılay F, Çal AÇ, Şimşir A. Comparison of shockwave lithotripsy and laser ureterolithotripsy for ureteral stones. *J Urol Surg.* 2021;8(3):167-172. doi:10.4274/jus.galenos.2021.2021.0006
19. Mustafa G, Mahar NA, Qureshi HH, Mustafa M, Fayaz M, Hassan AS. Comparison of outcomes of extracorporeal shockwave lithotripsy with ureteroscopic lasertripsy for management of proximal ureteral stones. *J Coll Physicians Surg Pak.* 2024;34(1):101-104. doi:10.29271/jcpsp.2024.01.101
20. Eisner BH, Kurtz MP, Dretler SP. Ureteroscopy for the management of stone disease. *Nat Rev Urol.* 2010;7(1):40-45. doi:10.1038/nrurol.2009.233
21. Leone NT, Garcia-Roig M, Bagley DH. Changing trends in the use of ureteroscopic instruments from 1996 to 2008. *J Endourol.* 2010;24(3):361-365. doi:10.1089/end.2009.0222

22. Alenezi H, Denstedt JD. Flexible ureteroscopy: technological advancements, current indications and outcomes in the treatment of urolithiasis. *Asian J Urol.* 2015;2(3):133-141. doi:10.1016/j.ajur.2015.06.002
23. Kartal I, Cakici MC, Selmi V, Sari S, Ozdemir H, Ersoy H. Retrograde intrarenal surgery and percutaneous nephrolithotomy for the treatment of stones in horseshoe kidney; what are the advantages and disadvantages compared to each other? *Cent European J Urol.* 2019;72(2):156-162. doi:10.5173/ceju.2019.1906
24. Teichman JM. Laser lithotripsy. *Curr Opin Urol.* 2002;12(4):305-309. doi:10.1097/00042307-200207000-00008
25. Tran T, Pareek G. Selecting the appropriate treatment modality for ureteral calculi. ureteral stone management: a practical approach. Springer; 2014:41-62. doi:10.1007/s00240-017-1020-z
26. Wolf JS, Jr., Carroll PR, Stoller ML. Cost-effectiveness v patient preference in the choice of treatment for distal ureteral calculi: a literature-based decision analysis. *J Endourol.* 1995;9(3):243-248. doi:10.1089/end.1995.9.243
27. Gerhard RS, Shrewsberry A, Solomon T, et al. Ureteroscopy versus shock wave lithotripsy: factors influencing patient treatment preferences. *Urol Pract.* 2016;3(6):423-429. doi:10.1016/j.urpr.2015.11.001
28. Giulioni C, Castellani D, Somani BK, et al. The efficacy of retrograde intra-renal surgery (RIRS) for lower pole stones: results from 2946 patients. *World J Urol.* 2023;41(5):1407-1413. doi:10.1007/s00345-023-04363-6
29. Mazzucchi E, Berto FCG, Denstedt J, et al. Treatment of renal lower pole stones: an update. *Int Braz J Urol.* 2022;48(1):165-174. doi:10.1590/S1677-5538.IBJU.2020.1023
30. Eisner BH, Reese A, Sheth S, Stoller ML. Ureteral stone location at emergency room presentation with colic. *J Urol.* 2009;182(1):165-168. doi:10.1016/j.juro.2009.02.131
31. Mustafa M, Al Zabadi H, Mansour S, Nabulsi A. Endoscopic management of upper and lower ureteric stones using pneumatic lithotripter: a retrospective medical records review. *Res Rep Urol.* 2023;15:77-83. doi:10.2147/RRU.S392881
32. Binbay M, Tepeler A, Singh A, et al. Evaluation of pneumatic versus holmium:YAG laser lithotripsy for impacted ureteral stones. *Int Urol Nephrol.* 2011;43(4):989-995. doi:10.1007/s11255-011-9951-8
33. Naqvi SA, Khaliq M, Zafar MN, Rizvi SA. Treatment of ureteric stones. Comparison of laser and pneumatic lithotripsy. *Br J Urol.* 1994;74(6):694-698. doi:10.1111/j.1464-410x.1994.tb07108.x
34. Scarpa RM, De Lisa A, Porru D, Usai E. Holmium: YAG laser ureterolithotripsy. *Eur Urol.* 1999;35(3):233-238. doi:10.1159/000019852
35. Lam JS, Greene TD, Gupta M. Treatment of proximal ureteral calculi: holmium:YAG laser ureterolithotripsy versus extracorporeal shock wave lithotripsy. *J Urol.* 2002;167(5):1972-1976.
36. Bader MJ, Sroka R, Gratzke C, et al. Laser therapy for upper urinary tract transitional cell carcinoma: indications and management. *Eur Urol.* 2009;56(1):65-71. doi:10.1016/j.eururo.2008.12.012
37. Xiao K, Zhou L, Zhu S, Lin L, Di X, Li H. Which frequency is better for pediatric shock wave lithotripsy? Low intermediate or high: a systematic review and meta-analysis. *Front Surg.* 2023;10:1063159. doi:10.3389/fsurg.2023.1063159
38. Ghalayini IF, Al-Ghazo MA, Khader YS. Extracorporeal shockwave lithotripsy versus ureteroscopy for distal ureteric calculi: efficacy and patient satisfaction. *Int Braz J Urol.* 2006;32(6):656-664. doi:10.1590/s1677-55382006000600006
39. Leveillee RJ, Lobik L. Intracorporeal lithotripsy: which modality is best? *Curr Opin Urol.* 2003;13(3):249-253. doi:10.1097/00042307-200305000-00014
40. Zheng W, Denstedt JD. Intracorporeal lithotripsy. Update on technology. *Urol Clin North Am.* 2000;27(2):301-313. doi:10.1016/s0094-0143(05)70259-7