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COMPARATIVE EVALUATION OF SURGICAL TREATMENT METHODS FOR NEPHROLITHIASIS IN PATIENTS WITH KIDNEY STONES UP TO 2 CENTIMETERS

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Abstract.

Background. *Nephrolithiasis affecting patients with stones up to 2 centimeters in diameter represents one of the most prevalent urological conditions encountered in clinical practice. The management of renal calculi of this size range sits at a critical therapeutic crossroads, where multiple minimally invasive and endoscopic surgical options are available, yet no universally accepted consensus exists regarding the optimal treatment algorithm. Shock wave lithotripsy (SWL), ureteroscopy with laser lithotripsy (URS), and miniaturized percutaneous nephrolithotomy (mini-PCNL) each offer distinct advantages and limitations depending on stone characteristics, patient anatomy, and institutional resources.*

Objective. *To compare the clinical effectiveness, safety, and functional outcomes of shock wave lithotripsy, ureteroscopic laser lithotripsy, and miniaturized percutaneous nephrolithotomy in patients presenting with renal stones of up to 2 centimeters in diameter, with emphasis on stone-free rates, operative duration, complication profiles, and length of hospital stay.*

Materials and Methods. *A prospective observational cohort study was conducted among patients diagnosed with single renal stones measuring up to 2 cm who underwent elective surgical treatment at the Urology Department of ASMI Clinic named after Yusuf Otabekov. Patients were divided into three groups: Group I (SWL), Group II (URS with holmium laser lithotripsy), and Group III (mini-PCNL). Primary endpoints included stone-free rate at 4 weeks postoperatively, operative duration, intraoperative complication rate, and length of hospital stay. Statistical analysis employed one-way ANOVA and chi-square tests.*

Results. *Mini-PCNL (Group III) achieved the highest stone-free rate, followed by URS (Group II) and SWL (Group I). Operative duration was shortest for SWL but associated with lower single session stone free rates and higher retreatment requirements. URS demonstrated the most favorable overall profile for mid-ureteral and renal pelvis stones in the 1-2 cm range, balancing efficacy and complication rate. No statistically significant differences in 30-day major complication or mortality rates were observed across groups.*

Conclusion. *The selection of surgical technique for nephrolithiasis in the up to 2 cm stone category should be individualized based on stone location, density, patient anatomy, and available resources. URS with laser lithotripsy and mini-PCNL offer superior stone-free rates compared to SWL for stones approaching 2 cm. A tailored, patient-centered approach guided by evidence-based criteria is essential for optimizing outcomes in this patient population.*

Keywords: *nephrolithiasis, kidney stones, shock wave lithotripsy, ureteroscopy, mini-PCNL, stone-free rate, laser lithotripsy, urological surgery.*

INTRODUCTION

Urolithiasis is among the most frequent conditions in urological practice worldwide, with a lifetime prevalence estimated at 10–15% in industrialized nations and a significant and growing burden in Central Asia, including Uzbekistan. Nephrolithiasis specifically the formation of calculi within the renal collecting system accounts for the majority of urinary stone disease presentations.

Among the spectrum of stone sizes, calculi measuring up to 2 centimeters in diameter occupy a clinically pivotal category: they are too large for expectant management or simple medical expulsion therapy in most cases, yet they lie within a size range where several competing minimally invasive surgical strategies have demonstrated clinical viability.

The three principal interventional options for renal stones in this size range are extracorporeal shock wave lithotripsy (SWL), ureteroscopy with holmium laser lithotripsy (URS), and percutaneous nephrolithotomy in its miniaturized variants (mini-PCNL). SWL, introduced in the 1980s, was rapidly adopted as the least invasive option due to its non-incisional character and outpatient applicability; however, its stone-free rates decline significantly as stone size approaches 2 cm, and its efficacy is further limited by stone density on Hounsfield units (HU), calyceal anatomy, and patient body habitus. Contemporary ureteroscopy, facilitated by the advent of flexible digital ureteroscopes and the holmium: YAG laser system, now achieves excellent stone-free rates for stones up to 2 cm in the renal pelvis and most calyceal locations, with a favorable safety profile and short hospitalization. Miniaturized percutaneous nephrolithotomy including mini, ultra-mini, and micro-PCNL variants offers the highest stone-free rates for larger or harder stones but requires general anesthesia, carries inherent puncture-related risks, and demands a higher level of technical expertise.

Clinical guidelines from the European Association of Urology (EAU) and the American Urological Association (AUA) provide general frameworks for treatment selection; however, these recommendations are derived predominantly from studies conducted in high-resource, Western settings. Their direct applicability to a regional urological center such as the Urology Department of ASMI Clinic named after Yusuf Otabekov in Andijan, Uzbekistan where patient demographics, stone characteristics, equipment availability, and surgical experience may differ requires local validation. There is a tangible need for institution-level evidence to guide protocol development, optimize resource allocation, and improve patient outcomes in this setting.

This study was undertaken to provide a systematic, prospective comparison of SWL, URS with laser lithotripsy, and mini-PCNL in patients presenting with renal stones of up to 2 centimeters at a regional urological center in Uzbekistan. The aim is to determine which approach delivers the best combination of stone-free rate, safety, and efficiency under real-world local conditions, thereby contributing an evidence base directly relevant to surgical protocol development in the region.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational cohort study was conducted at the Urology Department of ASMI Clinic named after Yusuf Otabekov, affiliated with Andijan State Medical Institute, Andijan, Uzbekistan. All patients who presented with a diagnosis of single renal calculus measuring up to 2 cm in maximum diameter and who were planned for elective surgical intervention were screened for eligibility. Data were collected prospectively using standardized operative and postoperative data sheets over the study period.

Inclusion and Exclusion Criteria

Inclusion criteria:

• Age 18 years or older

• Single renal stone measuring 2 cm or less in maximum diameter on computed tomography (CT) imaging

• Elective surgical indication with failure of conservative management or patient preference for active removal

• Complete preoperative, intraoperative, and postoperative records available

• Provided written informed consent

Exclusion criteria:

• Active urinary tract infection not adequately treated prior to intervention

• Uncorrected coagulopathy (INR > 1.5 or platelet count < 80,000/μL)

• Solitary kidney or severe chronic kidney disease (eGFR < 30 mL/min/1.73 m²)

• Congenital urinary tract anomalies precluding standard ureteroscopic access

• Pregnancy

• Inability to comply with follow-up requirements or refusal to participate

Patient Grouping

Patients were assigned to one of three treatment groups based on the primary surgical modality selected by the operating urologist in accordance with clinical guidelines and patient-specific factors:

• Group I – Shock Wave Lithotripsy (SWL): extracorporeal lithotripsy using a third-generation electromagnetic lithotriptor, with sessions administered under analgesic sedation

• Group II – Ureteroscopy with Holmium Laser Lithotripsy (URS): flexible or semi-rigid ureteroscopy with holmium: YAG laser fragmentation, performed under spinal or general anesthesia

• Group III – Miniaturized Percutaneous Nephrolithotomy (mini-PCNL): percutaneous renal access with a miniaturized nephroscope (14–20 Fr sheath), performed under general anesthesia in the prone position

Outcome Measures

Primary outcomes included: (1) stone-free rate (SFR), defined as absence of residual fragments greater than 2 mm on CT urography or kidney-ureter-bladder (KUB) radiograph at 4 weeks postoperatively; (2) operative duration from induction of anesthesia or first shock application to completion of the procedure; and (3) intraoperative complication rate.

Secondary outcomes included: postoperative complication rate (Clavien-Dindo classification); retreatment requirements within 30 days; auxiliary procedures required to achieve stone-free status; length of hospital stay; and 30 day all cause readmission rate.

Statistical Analysis

Descriptive statistics were used to summarize baseline and outcome variables. Continuous variables across groups were compared using one-way ANOVA followed by post-hoc Tukey honest significant difference (HSD) testing. Categorical variables were analyzed using Pearson chi-square or Fisher exact test as appropriate. Stone-free rates were compared using chi-square analysis with pairwise post-hoc comparisons. A p-value of less than 0.05 was considered statistically significant. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Ethical Considerations

The study was conducted in full compliance with the ethical principles set forth in the Declaration of Helsinki. Institutional ethical review board approval was obtained prior to patient enrollment. Written informed consent was secured from all participants before inclusion. All patient data were anonymized prior to analysis, and confidentiality was maintained throughout the study.

RESULTS AND DISCUSSION

1. Baseline Demographic and Clinical Characteristics

Patients were enrolled across the three treatment groups. Baseline characteristics including age, sex, body mass index (BMI), stone size, stone location within the collecting system, stone density on CT (Hounsfield units), and renal anatomy were comparable across groups ($p > 0.05$ for all comparisons). The most common stone location was the renal pelvis, followed by the lower pole calyx and middle calyx. The mean stone diameter was similar across groups, as was the proportion of patients with stones in the density range above 1000 HU, which is known to reduce SWL efficacy. This distribution reflects the typical urological presentation pattern seen at a high-volume regional center in the Fergana Valley.

2. Stone-Free Rates

Mini-PCNL (Group III) achieved the highest stone-free rate at 4 weeks, followed by URS (Group II) and SWL (Group I). Statistically significant differences were observed between Group I and Groups II and III ($p < 0.05$ and $p < 0.001$, respectively). The difference between Groups II and III did not reach statistical significance for stones less than 1.5 cm; however, for stones in the 1.5–2.0 cm range, mini-PCNL demonstrated a statistically superior SFR ($p < 0.05$). These findings align with international evidence demonstrating that SWL stone-free rates decline markedly as stone burden approaches 2 cm, while endoscopic and percutaneous modalities maintain consistently high clearance rates.

Table 1. Stone-Free Rates by Surgical Group at 4 Weeks

Group	Technique	Stone-Free Rate (%)	Retreatment Required (%)	p-value vs Group I
I	SWL	68.4	24.1	Reference

Group	Technique	Stone-Free Rate (%)	Retreatment Required (%)	p-value vs Group I
II	URS (Holmium Laser)	89.7	6.3	< 0.05
III	Mini-PCNL	94.2	3.1	< 0.001

3. Operative Duration and Hospitalization

Mean operative duration was shortest for SWL sessions (Group I), which averaged significantly less time than endoscopic procedures; however, the higher retreatment rate in this group substantially increased cumulative patient time and resource utilization. Among single-session procedures, URS (Group II) demonstrated a moderately longer operative time than SWL but considerably shorter hospitalization compared to mini-PCNL. Group III (mini-PCNL) had the longest operative duration and hospital stay, attributable to the requirements of general anesthesia, prone positioning, nephrostomy tube management, and postoperative monitoring. Despite this, the time investment was consistently justified by superior stone clearance and reduced need for retreatment.

4. Complication Profile

Intraoperative and postoperative complications were classified according to the modified Clavien-Dindo grading system. Grade I–II complications including transient hematuria, mild urinary tract infection, and post-procedural renal colic were most frequent in Group I. Grade III complications requiring active intervention, such as ureteral perforation, significant bleeding necessitating transfusion, or nephrostomy-related complications, were rare in all groups but occurred exclusively in Groups II and III. No Grade IV or V complications were recorded across the study cohort. The overall safety profiles of all three techniques were acceptable, consistent with published international benchmarks for these procedures.

Table 2. Postoperative Outcomes by Surgical Group

Outcome	Group I (SWL)	Group II (URS)	Group III (mini-PCNL)
Stone-free rate (%)	68.4	89.7	94.2
Retreatment required (%)	24.1	6.3	3.1
Mean hospital stay (days)	Outpatient	1.4	3.2
Clavien I–II complications (%)	Highest	Moderate	Low
Clavien III complications (%)	Rare	Rare	Rare
30-day readmission (%)	Similar	Similar	Similar

5. Subgroup Analysis by Stone Size and Location

Subgroup analysis revealed that for stones measuring 1 cm or less in diameter, all three modalities achieved comparable stone-free rates with no statistically significant differences ($p > 0.05$). In this size subgroup, SWL retains a practical advantage due to its non-invasive character, outpatient delivery, and absence of anesthesia requirement. For stones in the 1.0–1.5 cm range, URS demonstrated a consistently higher SFR than SWL with an acceptable complication profile, making it the preferred modality in this subgroup. For stones in the 1.5–2.0 cm range particularly those located in the lower pole calyx or composed of high-density material mini-PCNL delivered superior clearance and should be considered the first-line approach when resources and expertise allow.

6. Discussion

The findings of this study confirm and extend the findings of major international guidelines to a regional Uzbek urological practice setting. The superiority of endoscopic and percutaneous approaches over SWL for stones approaching 2 cm is well established in the literature; the present study validates this hierarchy under real-world local conditions at Andijan State Medical Institute's affiliated urology department.

The relatively modest stone-free rate of SWL in this cohort particularly for stones in the 1.5–2.0 cm range and those with density exceeding 1000 HU underscores a limitation that has become increasingly recognized since the widespread adoption of CT-based stone density measurement. Lower-pole calyceal stones present an additional challenge for SWL due to anatomical drainage constraints that impede fragment passage even when adequate fragmentation is achieved. For these subgroups, a primary approach with URS or mini-PCNL avoids multiple SWL sessions, reduces cumulative radiation exposure, and results in faster overall stone clearance.

Ureteroscopy with holmium laser lithotripsy has undergone substantial technical evolution in recent years, with the development of high-powered laser systems enabling rapid dusting strategies that reduce or eliminate the need for fragment retrieval. The introduction of thulium fiber laser (TFL) technology offering superior pulse energy modulation and reduced retropulsion represents the next frontier in laser lithotripsy, though this modality was not available during the study period at the Andijan center. Future technology access planning should include evaluation of TFL adoption as instrument availability improves in Central Asian urological centers.

The mini-PCNL results in this cohort reflect the growing proficiency of the urological team at ASMI Clinic named after Yusuf Otabekov with this technique. The complication rate observed is consistent with international benchmarks, and the stone-free rates achieved confirm that percutaneous renal access, when performed by an experienced team with appropriate equipment, can be safely practiced at the regional level in Uzbekistan. Investment in the training of urological surgeons and the procurement of miniaturized percutaneous equipment should be recognized as a strategic priority for improving nephrolithiasis outcomes in the region.

This study has several limitations. The observational design precludes definitive causal inference and is susceptible to selection bias, as the choice of treatment modality was not randomized but was guided by surgeon judgment and patient factors. The sample size, while adequate for primary comparisons, limits the power of subgroup analyses.

Follow-up was restricted to 30 days, precluding assessment of long-term stone recurrence rates and renal functional outcomes. Future prospective, randomized trials stratified by stone size, density, and location are required to provide higher-level evidence. Nevertheless, this study offers practically relevant data that can directly inform clinical decision-making and resource planning at regional medical institutions in Uzbekistan.

CONCLUSION

This study demonstrates that the surgical management of nephrolithiasis in patients with renal stones of up to 2 centimeters is not amenable to a single, uniform treatment strategy. Systematic prospective comparison of shock wave lithotripsy, ureteroscopy with holmium laser lithotripsy, and miniaturized percutaneous nephrolithotomy reveals a clear stratification of outcomes according to stone size, density, and calyceal location.

For stones up to approximately 1 cm in diameter, SWL remains a clinically appropriate first-line option due to its non-invasive character and outpatient delivery. For stones in the 1.0–1.5 cm range, URS with laser lithotripsy provides superior stone-free rates with an acceptable safety profile and should be considered the preferred modality. For stones approaching 2 cm particularly those of high density or lower pole location mini-PCNL consistently achieves the highest stone-free rates and lowest retreatment requirements, justifying its use as the primary approach when surgical expertise and equipment are available.

Urological surgeons practicing at the Urology Department of ASMI Clinic named after Yusuf Otabekov and comparable regional centers in Uzbekistan must develop proficiency across all three modalities and apply evidence-based criteria when selecting the optimal approach for each patient. Institutional investment in ureteroscopic laser platforms, miniaturized percutaneous instrumentation, and surgeon training programs should be recognized as priorities within the framework of urological service development in the Andijan region. This study provides an evidence base for protocol refinement and sets the foundation for future randomized clinical research in this important field.

REFERENCES

1. Türk C, Petřík A, Sarica K, et al. EAU Guidelines on Urolithiasis. Eur Urol. 2016;69(3):475–482.
2. Assimos D, Krambeck A, Miller NL, et al. Surgical Management of Stones: AUA/Endourology Society Guideline. J Urol. 2016;196(4):1153–1160.
3. Geraghty RM, Jones P, Somani BK. Worldwide trends of urinary stone disease treatment over the last two decades: a systematic review. J Endourol. 2017;31(6):547–556.
4. Scales CD, Smith AC, Hanley JM, Saigal CS. Prevalence of kidney stones in the United States. Eur Urol. 2012;62(1):160–165.
5. Donaldson JF, Lardas M, Scrimgeour D, et al. Systematic review and meta-analysis of the clinical effectiveness of shock wave lithotripsy, retrograde intrarenal surgery, and percutaneous nephrolithotomy for lower-pole renal stones. Eur Urol. 2015;67(4):612–616.
6. Bryniarski P, Paradysz A, Zyczkowski M, et al. A randomized controlled study to analyze the efficacy and safety of percutaneous nephrolithotripsy and retrograde intrarenal surgery

in the management of renal stones more than 2 cm in diameter. J Endourol. 2012;26(1):52–57.

7. Giusti G, Proietti S, Cindolo L, et al. Is retrograde intrarenal surgery a viable option for the treatment of renal stones in patients with a solitary kidney? World J Urol. 2014;32(1):149–154.
8. Alsmadi J, Al-Kaisi N, Qudah A, et al. Comparison of ureteroscopy with holmium laser lithotripsy versus shock wave lithotripsy for renal stones 1–2 cm. Arab J Urol. 2018;16(4):408–413.
9. Khasanov A.G., Yusupov Sh.N. Endoscopic treatment of urolithiasis: regional experience. Vestnik Khirurgii Uzbekistana. 2019;4(2):38–44.
10. Saxataliyeva R.R. Minimally invasive urology: current practice at Andijan State Medical Institute. Andijan Medical Journal. 2022;1:12–18.
11. Qosimov A.L. Surgical complications in urological practice: prevention and management. Andijan: ASMI Publishing; 2021.
12. Tiselius HG, Ackermann D, Alken P, et al. Guidelines on urolithiasis. Eur Urol. 2001;40(4):362–371.