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ORIGINAL ARTICLE

Comparative Outcomes of Extracorporeal Shock Wave Lithotripsy, Pneumatic Lithotripsy, and Laparoscopic Ureterolithotomy in the Management of Large Proximal Ureteral Stones

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ABSTRACT

Background: *Large proximal ureteral stones are difficult to manage because of low spontaneous passage rates and reduced success with non-invasive treatments. ESWL, ureteroscopic pneumatic lithotripsy, and laparoscopic ureterolithotomy are commonly used modalities, but their comparative outcomes remain unclear. The aim of this study was to compare the effectiveness of ESWL, pneumatic ureteroscopic lithotripsy, and laparoscopic ureterolithotomy in patients with large proximal ureteral stones.* ***Methods & Materials:*** *This prospective observational study was conducted at Bangladesh Medical University, Dhaka, from July 2023 to June 2024. A total of 120 adult patients with proximal ureteral stones ≥10 mm was divided into three equal groups: ESWL (n = 40), pneumatic URS (n = 40), and laparoscopic ureterolithotomy (n = 40). Outcomes included stone-free rate, auxiliary procedures, complications, hospital stay, and recovery time.* ***Results:*** *Immediate stone-free rates were highest with laparoscopic ureterolithotomy (95%), followed by pneumatic URS (75%) and ESWL (55%) (p <0.001). At 3 months, stone-free rates were 100%, 85%, and 70%, respectively (p <0.001). ESWL required significantly more auxiliary procedures, while laparoscopic ureterolithotomy was associated with longer hospital stay and delayed recovery.* ***Conclusion:*** *Laparoscopic ureterolithotomy provides the highest definitive stone clearance for large proximal ureteral stones. Pneumatic lithotripsy offers a less invasive alternative with good effectiveness, while ESWL remains the least invasive option but with lower success rates.*

Key words: *Large proximal ureteral stones; ESWL; Pneumatic lithotripsy; Laparoscopic ureterolithotomy; Stone-free rate*

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INTRODUCTION

Ureteral stone disease is a frequent urologic emergency and a major source of acute flank pain, lost workdays, and healthcare utilization. Contemporary guidance before 2012 recognized ureteric calculi as a common component of urolithiasis burden and emphasized that treatment selection should balance stone-free efficacy with invasiveness, complications, and need for repeat procedures[1].Large proximal ureteral stones (commonly defined in practice as >10 mm, and often "impacted" at the upper ureter) are clinically important because they are less likely to pass spontaneously, more likely to cause persistent obstruction and hydronephrosis, and may be associated with infection risk or deterioration of renal function if not relieved in time. These stones also present a technical challenge: the proximal location increases retropulsion during endoscopic fragmentation, while impaction and surrounding edema can reduce working space and decrease fragmentation efficiency for some modalities [2,3]. Extracorporeal shock wave lithotripsy (ESWL/SWL) remained a widely used first-line, non-invasive option for many ureteral stones because it avoids ureteral instrumentation and can often be performed with relatively short recovery [1]. However, outcomes with ESWL are strongly influenced by stone size and other stone- and patient-related factors. As stone diameter increases, fragmentation success declines and the likelihood of requiring multiple sessions rises, thereby prolonging time to stone clearance and increasing cumulative cost and follow-up burden. Observational evidence from this era consistently noted lower success for larger stones and highlighted size as a key predictor of ESWL outcome [4,5]. For large proximal ureteral stones—especially when associated with moderate-to-severe hydronephrosis or impaction—authors before 2012 cautioned that ESWL may yield suboptimal stone-free rates, prompting consideration of endoscopic or surgical alternatives either as primary therapy or after early ESWL failure [6].

Ureteroscopy (URS) with intracorporeal lithotripsy evolved rapidly as ureteroscopes became smaller and optics improved. In many centers, pneumatic lithotripsy (e.g., Lithoclast-type devices) was among the most accessible, robust energy sources for URS, particularly in resource-variable settings. Technique

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descriptions from this period reflect routine semirigid ureteroscopic access, guidewire placement, fragmentation with pneumatic devices, and selective postoperative stenting [7]. URS offers the advantage of immediate stone visualization and active extraction of fragments, which can shorten the time to stone-free status. Nevertheless, large proximal stones—especially impacted stones—remain challenging for semirigid URS due to limited maneuverability in the upper ureter and the risk of stone migration/retropulsion into the kidney, potentially reducing single-session success and increasing the need for auxiliary procedures. Clinical work focused on impacted upper ureteral stones reported that these cases are harder to treat with ESWL and described ureteroscopy with pneumatic lithotripsy as a practical approach, while also documenting procedure-specific complications and the importance of careful technique [2,8].

Laparoscopic ureterolithotomy (LU) has emerged as an effective minimally invasive surgical alternative for selected patients with large proximal ureteral calculi, particularly when stones are impacted, endoscopic approaches fail, or when rapid, definitive clearance is desired. Compared with URS, LU can provide very high immediate stone clearance because the stone is removed intact or with minimal fragmentation, thereby minimizing concerns about retropulsion and residual fragments. A pivotal comparative study evaluated LU as a primary modality for large proximal ureteral stones against ureterorenoscopic management, reinforcing the concept that LU may offer superior single-procedure stone-free rates at the cost of greater invasiveness and operative demands [9]. Given these modality-specific trade-offs, comparative evaluation of ESWL, pneumatic lithotripsy via ureteroscopy, and laparoscopic ureterolithotomy for large proximal ureteral stones is clinically meaningful. The key outcomes of interest include stone-free rate (immediate and at follow-up), need for auxiliary or repeat procedures, complication profiles (e.g., ureteral injury, infection, stricture, postoperative pain), length of hospital stay, and overall patient recovery. Contemporary literature and guideline recommendations emphasized that optimal treatment selection depends on stone size, degree of impaction, obstruction severity, patient factors, and institutional expertise. The present study was undertaken to compare the outcomes of extracorporeal shock wave lithotripsy, pneumatic lithotripsy via ureteroscopy, and laparoscopic ureterolithotomy in the management of large proximal ureteral stones, with particular emphasis on stone-free rates, complication profiles, need for auxiliary procedures, and hospital stay, in order to identify the most effective and safe treatment modality within routine clinical practice.

METHODS & MATERIALS

This prospective observational study was conducted in the Department of Urology, Bangladesh Medical University (BMU), Dhaka, Bangladesh over a one-year period from July 2023 to June 2024.

Inclusion Criteria:

1. Patients aged ≥18 years.
2. Presence of a single proximal ureteral stone ≥10 mm in size.
3. Radiologically confirmed stone location by ultrasonography, plain X-ray KUB, and/or intravenous urography (IVU).
4. Patients fit for anesthesia and surgical intervention.

Exclusion Criteria:

1. Multiple ureteral stones or bilateral ureteral stones.
2. Concomitant renal stones requiring separate intervention.
3. Distal or mid-ureteral stones.
4. Active urinary tract infection at presentation.
5. Pregnancy.
6. Bleeding disorders or uncorrected coagulopathy.
7. Severe cardiopulmonary disease contraindicating anesthesia.
8. Previous ureteral surgery or ureteral stricture.

A total of 120 adult patients (≥18 years) diagnosed with large proximal ureteral stones were enrolled after obtaining informed written consent. Large proximal ureteral stones were defined as stones measuring ≥10 mm in maximum diameter located in the proximal ureter, as confirmed by ultrasonography, plain X-ray KUB, and/or intravenous urography. Patients with multiple or bilateral ureteral stones, concomitant renal stones requiring separate intervention, distal or mid-ureteral stones, active urinary tract infection, pregnancy, bleeding disorders, severe cardiopulmonary disease contraindicating anesthesia, previous ureteral surgery, or ureteral stricture were excluded. Eligible patients were assigned to three groups based on the treatment modality received: Group A (n = 40) underwent extracorporeal shock wave lithotripsy (ESWL); Group B (n = 40) underwent semirigid ureteroscopy with pneumatic lithotripsy; and Group C (n = 40) underwent laparoscopic ureterolithotomy. The choice of treatment modality was based on stone characteristics, patient preference, and availability of equipment and surgical expertise. ESWL was performed using a standard lithotripter under fluoroscopic and/or ultrasonographic guidance with appropriate analgesia or sedation, and repeat sessions were offered if residual fragments >4 mm persisted. Ureteroscopy was performed under regional or general anesthesia using a semirigid ureteroscope, with stone fragmentation achieved using a pneumatic lithotripter and selective placement of a double-J ureteral stent. Laparoscopic ureterolithotomy was performed under general anesthesia using a transperitoneal or retroperitoneal approach, with intact stone removal through a ureterotomy that was closed over a double-J stent. Patients were followed at 2–4 weeks and at 3 months with clinical assessment and imaging to determine stone clearance and complications. Outcome measures included stone-free rate (immediate and at follow-up), need for auxiliary or repeat procedures, perioperative and postoperative complications, length of hospital stay, and time to return to normal activity. Written informed consent was obtained from all patients after a proper explanation of the study. Ethical approval was obtained from the Ethical Review Committee of SHNIBPS. Patient confidentiality was strictly maintained throughout the study.

Statistical Analysis: All data were recorded systematically in a preformed data collection form, and quantitative data were expressed as mean and standard deviation, and qualitative data were expressed as frequency distribution and percentage. Statistical analysis was carried out by using Statistical analysis was done by using SPSS (Statistical Package for Social Science) Version 20. Confidentiality was strictly maintained.

RESULT

Table I shows the baseline demographic and stone characteristics of patients in the three treatment groups. The mean age was comparable among the ESWL (42.6 ± 11.4 years), pneumatic URS (44.1 ± 10.8 years), and LU (45.3 ± 12.1 years) groups (p = 0.63). The male-to-female ratio was also similar across groups (28:12, 30:10, and 29:11, respectively; p = 0.88). Mean stone size did not differ significantly (13.4 ± 2.1 mm, 13.7 ± 2.3 mm, and 13.9 ± 2.0 mm; p = 0.68). Right-sided stones were

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present in 55.0%, 60.0%, and 57.5% of patients (p = 0.92). Hydronephrosis (65.0%, 70.0%, and 72.5%; p = 0.79) and impacted stones (45.0%, 50.0%, and 55.0%; p = 0.68) were similarly distributed among the groups.

Table – I: Baseline Demographic and Stone Characteristics of Patients (*n* = 120)

Variable	ESWL (n = 40), n (%)	Pneumatic URS (n = 40), n (%)	LU (n = 40), n (%)	P-value
Mean age (years)	42.6 ± 11.4	44.1 ± 10.8	45.3 ± 12.1	0.63
Male:Female	28:12:00	30:10:00	29:11:00	0.88
Mean stone size (mm)	13.4 ± 2.1	13.7 ± 2.3	13.9 ± 2.0	0.68
Side of stone (Right), n (%)	22 (55.0)	24 (60.0)	23 (57.5)	0.92
Hydronephrosis present, n (%)	26 (65.0)	28 (70.0)	29 (72.5)	0.79
Impacted stone, n (%)	18 (45.0)	20 (50.0)	22 (55.0)	0.68

Table II shows significant differences in treatment characteristics among the three groups. The mean number of sessions was highest with ESWL (2.1 ± 0.8) compared with pneumatic URS (1.3 ± 0.5) and LU (1.0 ± 0.0) (p < 0.001). Operative time increased from ESWL (48.6 ± 12.4 minutes) to URS (72.4 ± 18.6 minutes) and LU (108.3 ± 22.5 minutes) (p < 0.001). Double-J stent placement and anesthesia requirements were lowest in ESWL (15.0% and 20.0%) and highest in LU (100% each), with URS showing intermediate values (70.0% stent placement and 100% anesthesia) (all p < 0.001).

Table – II: Treatment Characteristics and Procedural Details

Parameter	ESWL (n = 40)	Pneumatic URS (n = 40),	LU (n = 40) =	P-value
Mean number of sessions/procedures	2.1 ± 0.8	1.3 ± 0.5	1.0 ± 0.0	<0.001
Mean operative time (minutes)	48.6 ± 12.4	72.4 ± 18.6	108.3 ± 22.5	<0.001
Double-J stent placed, n (%)	6 (15.0)	28 (70.0)	40 (100)	<0.001
Anesthesia required, n (%)	8 (20.0)	40 (100)	40 (100)	<0.001

Table III shows that stone-free rates were highest with LU, followed by pneumatic URS and ESWL. Immediate stone-free rates were 95.0% (LU), 75.0% (URS), and 55.0% (ESWL), increasing at 3 months to 100%, 85.0%, and 70.0%, respectively (p < 0.001). Residual fragments >4 mm was most frequent with ESWL (30.0%) and absent with LU, while retropulsion occurred only in the URS group (22.5%).

Table – III: Stone-Free Rates and Clearance Outcomes

Outcome	ESWL (n = 40)	Pneumatic URS (n = 40)	LU (n = 40)	P-value
Immediate stone-free, n (%)	22 (55.0)	30 (75.0)	38 (95.0)	<0.001
Stone-free at 3 months, n (%)	28 (70.0)	34 (85.0)	40 (100)	<0.001
Residual fragments >4 mm, n (%)	12 (30.0)	6 (15.0)	0 (0)	<0.001
Retropulsion of stone, n (%)	—	9 (22.5)	—	—

Table IV shows that repeat and auxiliary procedures were most frequent in the ESWL group and least frequent in the LU group. Repeat ESWL sessions were required in 45.0% of ESWL patients. Auxiliary URS was needed in 25.0% of ESWL, 10.0% of URS, and 2.5% of LU patients (p = 0.004), while auxiliary ESWL was required in 15.0% of URS and 2.5% of LU patients (p = 0.01). Overall, any auxiliary procedure was required in 35.0% of ESWL, 20.0% of URS, and 5.0% of LU patients (p = 0.003).

Table – IV: Auxiliary Procedures and Repeat Interventions

Parameter	ESWL (n = 40)	Pneumatic URS (n = 40)	LU (n = 40)	P-value
Repeat ESWL session required, n (%)	18 (45.0)	—	—	—
Auxiliary URS required, n (%)	10 (25.0)	4 (10.0)	1 (2.5)	0.004
Auxiliary ESWL required, n (%)	—	6 (15.0)	1 (2.5)	0.01
Any auxiliary procedure, n (%)	14 (35.0)	8 (20.0)	2 (5.0)	0.003

Table V shows that complication rates were comparable among ESWL, pneumatic URS, and LU, with no statistically significant differences in overall or major complications (p > 0.05). Any complication occurred in 15.0%, 25.0%, and 30.0% of patients, respectively. Individual complications were also similar across groups. However, mean hospital stay was significantly shorter with ESWL (0.8 ± 0.4 days) compared with URS (2.3 ± 0.9 days) and LU (4.6 ± 1.2 days) (p < 0.001).

Table – V: Complications and Postoperative Recovery

Outcome Parameter	ESWL (n = 40)	Pneumatic URS (n = 40)	LU (n = 40)	P-value
Any complication, n (%)	6 (15.0)	10 (25.0)	12 (30.0)	0.18
Major complications*, n (%)	1 (2.5)	2 (5.0)	3 (7.5)	0.55
Hematuria, n (%)	4 (10.0)	6 (15.0)	5 (12.5)	0.81
Febrile UTI, n (%)	2 (5.0)	4 (10.0)	5 (12.5)	0.42
Ureteral perforation, n (%)	0 (0)	2 (5.0)	1 (2.5)	0.35
Prolonged urine leak, n (%)	0 (0)	0 (0)	3 (7.5)	0.07
Mean hospital stay (days)	0.8 ± 0.4	2.3 ± 0.9	4.6 ± 1.2	<0.001

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DISCUSSION

In this study of 120 patients with large proximal ureteral stones, laparoscopic ureterolithotomy (LU) achieved the highest stone-free rates (95% immediate and 100% at 3 months), followed by pneumatic ureteroscopic lithotripsy (URS) (75% immediate and 85% at 3 months), while ESWL showed the lowest clearance (55% immediate and 70% at 3 months). Definitive stone extraction (LU) generally provides the greatest single-procedure success. Ureteroscopy provides high clearance but may be limited by proximal location and retropulsion. ESWL effectiveness decreases with increasing stone size and unfavorable anatomy [1]. Our ESWL stone-free rate at 3 months (70%) is comparable to outcomes reported in earlier in-situ ESWL series, where overall 3-month stone-free rates could be high for ureteric stones but failures were more common with larger stones. In the BJU International report by Gnanapragasam et al. (1999), 88% were stone-free at 3 months overall, and treatment failure was associated with larger stone size (e.g., >1.3 cm), supporting the size-dependent decline in ESWL success that we also observed in large proximal stones [10]. Importantly, the lower ESWL success seen in large proximal stones is biologically plausible and repeatedly documented. Hsiao et al. showed that in solitary proximal ureteral stones, outcomes after ESWL were poor when moderate-to-severe hydronephrosis was present, and for stones >10 mm stone-free rates dropped substantially as hydronephrosis increased. This helps explain why ESWL in our cohort required more repeat sessions and had a higher need for auxiliary procedures [11]. For pneumatic URS, our 3-month stone-free rate (85%) aligns with published ureteroscopic experiences in the pre-laser era. Tawfick (2010) directly compared ESWL with semirigid ureteroscopy using a lithoclast for large proximal ureteral stones and reported superior clearance for ureteroscopy compared with ESWL, with ESWL more often needing repeat treatment—findings that mirror our pattern of higher success and lower retreatment with URS than ESWL[12,13].However, we also observed retropulsion in a notable proportion of URS cases (about one-fifth), which likely contributed to residual fragments and the need for auxiliary procedures. Retropulsion is a known limitation of pneumatic lithotripsy in proximal stones, because ballistic energy can push the stone upward into the kidney, reducing single-session success and increasing secondary interventions. This procedural issue has been discussed widely in ureteroscopy literature of the period and remains a key technical explanation for why URS may not match LU in one-procedure stone-free rates for large proximal stones.[8] LU produced the best definitive clearance in our study (100% at follow-up), consistent with major series and comparative trials available up to 2012. Gaur et al. (2002) reported laparoscopic ureterolithotomy in a large cohort with mean stone size around the mid-teens (mm) and included many upper ureter stones, supporting LU as an effective method for large/impacted calculi when definitive extraction is desired [14]. More directly, Ko et al. (2011) compared primary LU with URS for large proximal ureteral stones and concluded that LU has a strong role as a primary modality in this setting, reflecting higher single-procedure stone-free rates at the expense of greater invasiveness [9]. A key finding in our results was the significantly higher need for repeat sessions and auxiliary procedures in the ESWL group. This is expected for stones ≥10 mm and in the presence of hydronephrosis/impaction—factors repeatedly associated with ESWL failure or prolonged clearance times. Studies from the era emphasize that alternative modalities (URS or surgical removal) may be appropriate after early ESWL failure or when predictors of poor ESWL success exist [11]. As anticipated, LU was associated with longer hospital stay and delayed return to normal activity compared with ESWL and URS in our study. This trade-off is consistent with the inherent differences in invasiveness: ESWL is non-invasive and commonly performed with minimal admission time, URS typically requires short hospitalization, and LU involves operative dissection and ureterotomy, often necessitating longer inpatient monitoring. The comparative literature similarly reports superior stone clearance for LU but longer operative time and hospital stay compared with URS [9]. Although LU showed the highest overall complication frequency in our dataset, differences in total and major complications were not statistically significant among groups. This pattern is consistent with the literature: ESWL complications tend to be minor and related to hematuria, colic, steinstrasse, or infection; URS complications include ureteral mucosal injury, perforation, febrile UTI, and later stricture; and LU may be associated with urine leak or wound-related morbidity, particularly early in the learning curve or without meticulous ureterotomy closure and stenting [15].

LIMITATIONS

This study was conducted at a single tertiary care center with a relatively modest sample size in each treatment group, which may limit the generalizability and statistical power of the findings. Treatment allocation was not randomized and depended on stone characteristics, patient preference, and resource availability, introducing potential selection bias. Follow-up was limited to three months, which may not have captured late complications such as ureteral stricture or long-term recurrence. In addition, stone composition and density were not routinely assessed, and newer technologies such as flexible ureteroscopy and laser lithotripsy were not evaluated.

CONCLUSION

This study demonstrates that laparoscopic ureterolithotomy provides the highest immediate and overall stone-free rates for large proximal ureteral stones, making it the most definitive treatment option when single-procedure success is the primary goal. Pneumatic ureteroscopic lithotripsy offers high effectiveness with shorter hospital stay and faster recovery than laparoscopic surgery, although its success may be limited by stone retropulsion and the need for auxiliary procedures. Extracorporeal shock wave lithotripsy remains the least invasive modality but is associated with lower stone-free rates and a higher requirement for repeat sessions and additional interventions in large proximal ureteral stones. Overall, treatment selection should be individualized based on stone size, degree of impaction, hydronephrosis, patient preference, and available expertise and resources. Laparoscopic ureterolithotomy is best suited for large, impacted, or ESWL-resistant stones, ureteroscopy with pneumatic lithotripsy represents a balanced minimally invasive alternative, and ESWL may be reserved for selected patients who prefer non-invasive treatment and accept the possibility of multiple sessions.

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