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SAFETY AND EFFICACY OF EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY VERSUS PERCUTANEOUS NEPHROLITHOTOMY FOR THE TREATMENT OF MODERET SIZE KIDNEY STONES IN THE MIDDLE AND UPPER POLE.

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Abstract

Introduction: Given the high incidence and recurrence of nephrolithiasis, technological advances have been made to dramatically improve minimally invasive techniques for treatment of kidney stone, such as extracorporeal shock wave lithotripsy (SWL) and percutaneous nephrolithotomy (PCNL). SWL is the standard method in the treatment of kidney stones smaller than 10 mm while PCNL methods of choice in the treatment of kidney stones larger than 20 mm. But for the choice of method for the treatment of 10 to 20 mm, upper and middle calices stones still there are conflicting opinions.

Objectives: The aim of the study was to evaluate the efficacy and safety of SWL and PCNL in the treatment of 10-20 mm kidney stonei in the middle and upper pole and to choose the optimal procedure.

Material and methods: The clinical study was designed as a randomized prospective study and conducted in GH "8th of September" - Skopje in the period from December 2023 to Januar 2025. During the study for both methods were analysed success rate, rate of re-treatment, the need for additional procedures, the degree of complications and the duration of the intervention and the hospital stay.

Results: The study included 81 patients randomized into two groups. The first group included 41 patients treated with SWL, and the second group included 40 patients treated with PCNL. SWL vs. PCNL success rate was 90% vs. 82.9% ($p = 0.29$); the rate of re-treatment of SWL was 39.02% versus 0% of PCNL. ($p = 0.00001$). The additional procedures were equally present in the two treatment groups 14.64% in SWL and 15% in PCNL ($p = 0.96$). PCNL was associated with a significantly longer duration of treatment versus SWL, 110.2 ± 17.7 minutes versus 47.1 ± 3.3 minutes respectively ($p = 0.00000$). Complications were less frequently detected in patients treated with SWL compared to patients treated with PCNL, 17.1% versus 32.5% respectively. ($p = 0.11$) The mean length of hospital stay was significantly shorter in patients treated with SWL compared to PCNL, 1.1 ± 0.4 versus 6.0 ± 1.7 days ($p < 0.0001$).

Conclusion: This study shows that PCNL and up to three SWL treatments are safe and comparatively effective in treating patients with stones in the upper and middle calices ranging 10–20 mm.

***Keywords*:** urolithiasis, nephrolithiasis, extracorporeal lithotripsy, percutaneous nephrolithotomy, kidney.

Introduction

Urolithiasis is a highly prevalent and increasingly common medical condition frequently encountered by urologists, with particularly high incidence rates reported in Western countries. Approximately 10% of the global population is estimated to experience kidney stones at some point in their lives. This growing prevalence is attributed to lifestyle and dietary factors, such as high sodium intake and inadequate fluid consumption. Other contributing etiological factors include global warming, urinary tract infections, and genetic predisposition.(1) Urolithiasis is not only one of the most common but also one of the most painful urological disorders, and severe cases can lead to serious complications, including infections and chronic kidney failure.(2) Due to its high incidence and recurrence, significant advancements have been made in minimally invasive stone treatment techniques, including extracorporeal shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), and retrograde intrarenal surgery (RIRS).(3).SWL is a noninvasive and anesthesia-free procedure with an average stone-free rate (SFR) of around 80%; however, it is associated with a relatively high retreatment rate and carry risks of incomplete clearance and complications. Conversely, PCNL delivers higher success rates (>90%), but is an invasive, anesthesia-requiring technique, associated with greater morbidity.(4) While SWL is the standard approach for stones under 10 mm and PCNL is preferred for those over 20 mm, the optimal treatment for 10–20 mm stones remains debatable. According to European Association of Urology (EAU) guidelines, both SWL and endourologic procedures are suitable for this group, with the choice depending on factors like stone size, location, composition, and pelvicalyceal anatomy.(5)

Objective:

The aim of the study was to evaluate the efficacy and safety of SWL and PCNL in the treatment of 10-20 mm middle and upper pole kidney stones and to choose the optimal procedure.

Material and methods:

This randomized prospective clinical study was conducted at the General Hospital "8th of September" in Skopje between December 2023 to Januar 2025. It included 81 patients with solitary kidney stones measuring 10 to 20 mm located in the upper or middle calyx. Patients were randomly divided into two groups: 41 underwent extracorporeal shock wave lithotripsy (SWL), and 40 were treated with mini percutaneous nephrolithotomy (PCNL). Inclusion criteria required patients aged 18–70 with a single 10–20 mm stone in the upper or middle calyx, BMI <30 kg/m², normal renal function, and no anatomical abnormalities. Exclusion criteria included BMI >30 kg/m², staghorn stone or multiple stones, untreated infections, congenital renal anomalies, solitary kidney, coagulopathies, prior renal/ureteral surgery, radiosensitive stones, ASA index >III, ureteral obstructions, and pregnancy. All participants provided informed consent. All patients were preoperatively assessed by detailed medical history; physical and laboratory examination; BMI, urinalysis; urine culture; renal ultrasonography (USG); Compiuter tomografy of urinary tract (CT urography), and anesthetic risk assessment per the ASA classification. Stone size was estimated using CT urography. Preoperative antibiotic prophylaxis with a third-generation cephalosporin was administered to all patients. The study evaluated patient and stone characteristics, treatment success rates, retreatment rates, the need for additional procedures, complication rates, operative duration, and length of hospital stay.

SWL

During extracorporeal shock wave lithotripsy (SWL), patients were treated using a third-generation electromagnetic lithotripter (Lithoskop®, Siemens Medical Systems, Erlangen, Germany). This device featured a focal length of 160 mm and a focal width of 8–12 mm, with maximum shock wave pressure ranging from 8.6 to 75.3 MPa and energy output up to 117 mJ. Its wide focal zone allowed high total energy delivery with reduced density, minimizing tissue damage. Patients were positioned supine, and stone localization was guided via X-ray and fluoroscopy. Treatment began with a low energy level (0.1 mJ), gradually increasing to 4 mJ as tolerated, following manufacturer guidelines. Shock waves were delivered at a frequency of 90 per minute, with a maximum of 4,000 shocks per session. Indicators of successful fragmentation included reduced radiodensity, blurred stone edges, and visible fragment movement. Pain management involved intravenous sedoanalgesia using fentanyl (1 µg/kg) and midazolam (0.05–0.1 mg/kg), tailored to patient-reported discomfort. Nonsteroidal anti-inflammatory drugs were used for their analgesic, anti-inflammatory, and smooth muscle-relaxing effects. Vital signs were monitored throughout the procedure. Ureteral stents were preemptively placed only in patients with upper urinary tract obstruction to preserve renal function. Most patients were discharged the same day with prescriptions for oral analgesics and medical expulsion therapy (tamsulosin 0.4 mg daily). Hospitalization was extended only for complications such as fever, severe renal colic, or gross hematuria. Up to two additional SWL sessions were allowed if complete fragmentation was not achieved initially. Treatment failure was defined as residual fragments >4 mm after three sessions, prompting consideration of alternative minimally invasive treatments, such as ureteroscopy (URS), retrograde intrarenal surgery (RIRS), or percutaneous nephrolithotomy (PCNL). Any post-SWL interventions, including JJ stent placement, were classified as additional procedures for active stone management.

PCNL

All procedures were performed under general anesthesia by a senior urologist with support from an experienced anesthesiology team. Patients were first placed in the dorsal lithotomy position for retrograde insertion of a 5 Fr ureteral catheter to allow calyceal opacification under fluoroscopy. The catheter was secured to a 14–18 Fr Foley catheter, after which patients were repositioned prone for percutaneous access. Calyceal puncture was achieved using the fluoroscopic triangulation technique, employing AP and 30° oblique projections for mediolateral and craniocaudal adjustments, respectively. Controlled apnea was used during intercostal puncture to minimize pleural injury.Once the collecting system was entered, urine aspiration and contrast injection confirmed correct positioning. A 0.035-inch hydrophilic guidewire was advanced into the ureter and subsequently exchanged for a super-stiff wire. The tract was dilated with Amplatz dilators up to 26 Fr, and a 24 Fr rigid nephroscope (Karl Storz Endoskope, Tuttlingen, Germany) was introduced. Stone fragmentation was performed using combined ultrasonic and pneumatic lithotripsy (Swiss Lithoclast, EMS, Nyon, Switzerland), with fragments retrieved by suction and forceps. At the end of the procedure, a double-J stent and an 18 Fr nephrostomy tube were placed. The nephrostomy tube was removed within 24–48 hours depending on drainage, and ureteral/Foley catheters were typically removed within 48–72 hours. Residual fragments >4 mm were managed with ESWL, and migrated ureteral stones with ureterorenoscopy (URS).

Postoperative monitoring included complete blood count, renal ultrasonography, and plain radiography (KUB) on day one; ultrasound and KUB at one month; and non-contrast CT at three months. Treatment success was defined as stone-free status or clinically insignificant residual fragments (CIRF <4 mm) at three months. Operative time was defined from ureteral catheter placement to nephrostomy tube fixation for PCNL, and as the total lithotripsy duration for SWL. Safety was assessed by intra- and postoperative complications, classified by Clavien-Dindo. Postoperative fever was defined as temperature >38.5°C without sepsis. Hospital stay was calculated from admission to discharge.

Statistical Analysis

Data were analyzed using SPSS version 23.0. Normality was assessed with the Kolmogorov-Smirnov and Shapiro-Wilk tests. Categorical variables were presented as frequencies and percentages, while continuous variables were summarized as mean ± standard deviation, median, interquartile range, and range. Comparisons between groups were performed using Fisher's exact test, Chi-square test, Student's t-test, and Mann-Whitney U test, as appropriate. A p-value <0.05 was considered statistically significant.

Results

Baseline characteristics were comparable between groups (Table 1). Gender distribution, age, BMI, and stone size and laterality did not differ significantly. A significant difference was noted in stone location: upper calyceal stones were more frequently treated with SWL, while middle calyceal stones were more common in PCNL ($p = 0.034$).

Table 1. Comparison of demography, stone characteristics and BMI between two groups

	SWL (n = 41)	PCNL (n = 40)	p-value
Age (years)			0,78
- Mean ± SD	58,73 ± 9,4	57,2 ± 12,2	
- Range	25 – 67	34 – 71	
Gender, n (%)			0,87
- Female	14 (34,15)	13 (32,5)	
- Male	27 (65,85)	27 (67,5)	
Stone Location, n (%)			0,034
- Upper calyx	24 (58,54)	14 (35)	
- Middle calyx	17 (41,46)	26 (65)	
Laterality, n (%)			0.30
- Right	18 (43.90%)	21 (52.50%)	
- Left	23 (56.09%)	19 (47.50%)	
Stone Size (mm²)			0,16
- Mean ± SD	235.0 ± 74.5	259.45 ± 81.3	
- Range	120 – 360	143 – 400	
BMI (kg/m²)			0,89
- Mean ± SD	25,49 ± 2,5	25,58 ± 2,8	
- Range	19,8 – 29,7	19,3 – 30,6	

Overall success rates were 82.9% for SWL and 90% for PCNL, with no statistically significant difference (p = 0.35) (Table 2).

Table 2. Comparative analysis of the overall success rate between the two methods

Treatment Outcome	SWL n (%)	PCNL n (%)	p value
Successful (SR)	34 (82.93%)	36 (90.00%)	p = 0.35
Failed Treatment	7 (17.07%)	4 (10.00%)	

By size, success rates were higher for 10–15 mm stones compared with 16–20 mm stones in both groups, though not significant (SWL: 90% vs. 76.2%, p = 0.41; PCNL: 94.4% vs. 86.4%, p = 0.61) By location, success rates were similar in the upper and middle calyces for both SWL (83.3% vs. 82.4%,p=1) and PCNL (85.7% vs. 92.3%) (p > 0.6). (Table 3).

Table 3. Success rate of SWL and PCNL in relation to stone location and stone size

	SWL (n = 41)	p-value	PCNL (n = 40)	p-value
Stone-Free Rate by Location (%)				
- Upper calyx	20/24 (83,33)	p=1,0	12/14 (85.71%)	p=0,602
- Middle calyx	14/17(82,35)		24/26 (92.31%)	
Stone-Free Rate by size (%)				
- 10-15mm	18/20 (90%)	p=0,41	17 /18(94.44%)	p=0,61
-16-20mm	16/21 (76.19%)		19/22 (86.36%)	

The cumulative success of SWL increased with repeated sessions: 60.9% after one, 75.6% after two, and 82.9% after three (Table 4). Single-session success was significantly higher with PCNL compared to SWL (90% vs. 60.9%, $p < 0.00001$), but differences were not significant after two or three SWL sessions (Table 5).

Table 4. Distribution of stone free status of the patients with SWLprocedure

Stone-Free Status	1st Session, n (%)	2nd Session, n (%)	3rd Session, n (%)
Stone-Free	25/41 (60,97)	31/41 (75,61)	34/41 (82,93)
Residual Stones	16/41 (39.02%)	10/41 (24.39%)	7/41 (17.07%)

Table 5. Comparative analysis of the success rate between the two methods in relation to the number of repeated SWL treatments versus a single PCNL treatment

Number of Treatments	SWL n (%)	PCNL n (%)	p value
1	25 (60.98%)	36 (90.00%)	**p = 0.00001**
2	31 (75.60%)	/	p = 0.056
3	34 (82.90%)	/	p = 0.35
Failed Treatment	7 (17.07%)	4 (10.00%)	

The retreatment rate in patients undergoing SWL was not significantly affected by stone location ($p = 0.81$). In contrast, stone size significantly influenced the likelihood of retreatment ($p = 0.015$). Patients with stones measuring 10–15 mm had a notably lower retreatment rate (20%) compared to those with stones measuring 16–20 mm (57.14%) (Table 6).

Table 6. Retreatment rate in SWL group

Variable	Subgroup	Number of Patients Needing Retreatment (n)	Retreatment Rate (%)	p-value
Stone Location	Upper calyx	9	37.5%	0.81
	Middle calyx	7	41.18%	
Stone Size	10–15 mm	4	20.0%	0.015
	16–20 mm	12	57.14%	

All 40 patients in the PCNL group underwent only one treatment. Of these, 36 patients (90%) were successfully treated, while the treatment was unsuccessful in 4 patients (10%).

The need for additional procedures was comparable in both groups ($p = 0.96$). In the SWL group, 6 patients (14.65%) required further intervention: 3 underwent ureterorenoscopy, 2 underwent mini percutaneous nephrolithotomy, and 1 had a JJ stent placed postoperatively. Similarly, 6 patients (15%) in the PCNL group required additional procedures: JJ stent placement in 3 cases and SWL in the remaining 3. (Table 7)

Table 7. Comparative analysis of the rate of additional procedures between the two methods.

Additional Procedures	n	SWL n (%)	PCNL n (%)	p value
No	69	35 (85.37%)	34 (85.00%)	$\chi^2 = 0.00$, $p = 0.96$ (ns)
Yes	12	6 (14.64%)	6 (15.00%)	
DJ Stent	4	1	3	
Additional ESWL	3	0	3	
URS	3	3	0	
Additional PCNL	2	2	0	

Mean operative time was significantly shorter with SWL (47.1 ± 3.3 min) compared to PCNL (110.2 ± 17.7 min, $p < 0.0001$)), indicating that SWL was notably less time-consuming. (Table 8)

Table 8. Comparative analysis of treatment duration between the two methods

Treatment	Mean ± SD (min)	Range (min–max)	p value
ESWL	47.1 ± 3.3	37 – 52	$t = 22.37$
PCNL	110.2 ± 17.7	52 – 138	$p = 0.00000$

Complication rates were lower in the SWL group (17.1%) compared with PCNL (32.5%), though not statistically significant ($p = 0.11$) (Table 9).

Table 9. Comparative analysis of the complication rates between the two methods

Complications	n	SWL n (%)	PCNL n (%)	p value
Absent	61	34/41 (82.93%)	27/40 (67.50%)	$\chi^2 = 2.59$
Present	20	7 /41(17.07%)	13/40 (32.50%)	$p = 0.11$ (ns)

In the SWL group, post-procedural complications were documented in 7 patients (17.1%). Among these, 3 patients developed "steinstrasse" due to residual stone fragments. Two of them were managed conservatively with hydration, tamsulosin, and analgesics, while one required ureterorenoscopy (URS). Two patients developed urinary tract infections characterized by leukocyturia and bacteriuria, accompanied by post-SWL fever in one patient , and were treated with culture-guided antibiotic therapy. One patient was readmitted due to pain caused by a migrated ureteral fragment, which was managed with nonsteroidal anti-inflammatory drugs (NSAIDs). Another patient developed a subcapsular hematoma, which was successfully managed conservatively. (Table 10)

Table 10. Complications Associated with SWL Treatment

Complications	n (%)
Absent	34 (82.93%)
Present	7 (17.07%)
Fever	1 (2.44%)
Steinstrasse (Stone street)	3 (7.31%)
Readmission due to pain	1 (2.44%)
Subcapsular hematoma	1 (2.44%)
Urinary tract infection	1 (2.44%)

In the PCNL group, one patient experienced severe bleeding that required blood transfusion, while three others had bleeding controlled conservatively. Pelvicalyceal system injury occurred in one patient, managed by nephrostomy tube placement and JJ stent insertion. Four patients developed postoperative fever, all of whom were treated with in-hospital antibiotic and antipyretic therapy. Prolonged urinary leakage was observed in two patients, and one patient developed pneumothorax, which was managed conservatively. Additionally, one patient developed an arteriovenous fistula as a late postoperative complication, successfully treated with selective angioembolization. (Table 11)

Table 11. Complications Associated with PCNL Treatment

Complications	Intraoperative Complicationsn (%)	Postoperative Complicationsn (%)	Late Complicationsn (%)
No complications	38 (95%)	30 (75%)	39 (97.5%)
Bleeding	1 (2.5%)	3 (7.5%)	–
Injury to the PCS*	1 (2.5%)	–	–
Elevated body temperature	–	4 (10%)	–
Pneumothorax	–	1 (2.5%)	–
Prolonged urinary leakage	–	2 (5%)	–
Arteriovenous fistula	–	–	1 (2.5%)

According to Clavien-Dindo grading, most were grade I–III, with no grade V events in either group (Table 12).

Table 12. Clavien-Dindo Grade of complication of SWL at PCNL

Clavien-Dindo Grade	SWL (%)	PCNL (%)
Grade I	4.8%	15.0%
Grade II	2.4%	5.0%
Grade IIIa	2.4%	10.0%
Grade IIIb	7.3%	–
Grade IV	–	2.5%
Grade V	0%	0%

Postoperative hemoglobin was significantly lower in PCNL patients, indicating greater blood loss ($p < 0.0001$) (Table 13).

Table 13. Preoperative and postoperative hemoglobin levels in SWL and PCNL treatment

Hemoglobin (g/dL)	Treatment	Mean ± SD	Range (min – max)	p value
Preoperative HGB	SWL	14.18 ± 1.38	11 – 16.5	t = 0.85
	PCNL	13.91 ± 1.45	11.5 – 16.4	p = 0.39
Postoperative HGB	SWL	14.05 ± 1.20	11.1 – 16.1	t = 6.76
	PCNL	12.87 ± 1.60	8 – 14.2	p = 0.00000

Hospital stay was also significantly shorter for SWL (1.1 ± 0.4 days) compared with PCNL (6.0 ± 1.7 days, $p < 0.0001$) (Table 14).

Table 14. Length of hospitalization for SWL and PCNL

Treatment	Mean ± SD (days)	Median (IQR)	p value
SWL	1.1 ± 0.4	1 (1 – 1)	t = 7.74
PCNL	6.0 ± 1.7	5.5 (5 – 7)	p = 0.000000

Discussion

Over the past three decades, the development of minimally invasive surgical techniques has profoundly changed the management of nephrolithiasis. Open surgery has been almost entirely replaced by extracorporeal shock wave lithotripsy (SWL) and percutaneous nephrolithotomy (PCNL), which are less invasive, safer, and associated with improved recovery [6,7]. The present study compared the efficacy and safety of SWL and PCNL for 10–20 mm stones located in the upper and middle calyces, focusing on stone size, location, and procedural outcomes. Both treatment groups were demographically homogeneous in terms of age, gender, BMI, stone surface area, and laterality, minimizing selection bias.

Our findings confirm that stone size is a critical predictor of SWL success. The stone-free rate was higher for 10–15 mm stones (90%) compared to 16–20 mm stones (76.2%). Abdel-Khalek et al. [6] reported similar results (89.7% vs. 78%). However, despite the notable percentage difference in our results, the variation was not statistically significant ($p = 0.41$), likely due to the smaller sample size and differing stone burdens compared to the aforementioned study, where a strong positive correlation was confirmed ($p < 0.001$).

Conversely Chung et al. [7] observed lower overall rates (70.4% vs. 53.1%), possibly due to inclusion of all calyceal stones and limitation to two treatment sessions. Philipraj et al. [8] also found a marked size effect (91.3% vs. 50%), for stones between 10–14 mm and 15–20 mm respectively though their stricter definition of success, counting any residual fragments as failures, likely reduced reported outcomes.In contrast, PCNL outcomes were less influenced by stone size. Our cohort showed 94.4% success for 10–15 mm stones and 86.4% for 16–20 mm stones ($p = 0.61$). Philipraj et al. [8] reported similar findings (91.3% vs. 96.1%), for stones between 10–14 mm and 15–20 mm also without statistical significance and Desai et al. [9] emphasized that size mainly affects PCNL results when treating stones >20 mm, particularly staghorn calculi. Thus, SWL is more sensitive to stone burden, whereas PCNL maintains stable outcomes within the 10–20 mm range.

Stone location did not significantly affect success in our series, with SFRs of 83.3% for upper calyceal stones and 82.4% for middle calyceal stones. These results align with Turna et al. [10], who found success rates of 82.8% vs. 83.4%, and Muniasamy et al. [13], who observed success rates of 80.6% and 95.4% for upper and middle calyceal stones, as well as Özgör et al. [14], who also reported no meaningful difference by calyceal location. Nielsen et al. [11] and Neisius et al. [12] observed even higher outcomes, (99% vs 95%) and (88%vs 100%) for upper and middle calyceal stones respectively, which may reflect inclusion of smaller stones and more sessions.

By contrast, Chung et al. [7] reported lower success rates of 65% and 64% for stones in the upper and middle calyces, respectively.For PCNL, our results similarly showed no significant effect of stone location (85.7% vs. 92.3%,$p=0.6$), consistent with Muniasamy et al. [13] who observed success rates of 80.6% and 95.4% for upper and middle calyceal stones, respectively, in the 10–20 mm size range and Özgör et al. [14] who) reported success rates of 88.1% for upper and 92.9% for middle calyceal stones Saxby et al. [15], however, reported lower clearance (78% vs. 75%), again reflecting inclusion of larger stone burdens.

The overall success rate was 82.9% for SWL and 90% for PCNL, consistent with Muniasamy et al. [13] (82.7% vs. 90.1%). Singh et al. [16] reported 73.2% vs. 95%, and Resorlu et al. [17] found 66.5% vs.

91.4%, within the same size range ,both highlighting PCNL's superior efficacy. Saxby et al. [15] similarly documented 75% vs. 91%. for stones of comparable size.Nevertheless, the gap narrows with multiple SWL sessions. In our study, SFR increased from 61% after one session to 83% after three, approximating PCNL outcomes. Aboelkher et al. [19] and Wiesenthal et al. [18] confirmed this trend, demonstrating significantly higher success for PCNL after a single procedure but comparable results after two or three SWL treatments.

The need for retreatment was significantly higher with SWL (39%) compared to PCNL (0%). Similar results were reported by Deem et al. (20) (35% vs. 0%), Muniasamy et al. (13) (19.8% vs. 4.3%), and Rao et al. (21) (17.1% vs. 0%). The higher retreatment rate observed in our study relative to these reports is likely attributable to our more aggressive treatment approach and institutional policy favoring multiple treatment sessions with early follow-up interventions, typically within three weeks, aimed at achieving a higher overall success rate.

In terms of additional procedures, 14.6% of SWL and 15% of PCNL cases in our cohort required further interventions. These findings align with Rao et al. (21) and Turna et al. [10], who reported 13 vs 16% after SWL. The higher rate reported by Deem et al. (20) (41.7%) likely reflects broader classification, counting repeat SWL as additional procedures. ,Wiesenthal et al. [18],found comparable additional procedures after PCNL of 9.4%. However, Deem et al.(20) and Rao et al.(21) reported lower rates of 5% and 1.3%, respectively. We attribute the relatively higher rate of additional procedures in our cohort to our limited experience in the beginning of procedure and smaller patient volume treated with PCNL.

PCNL required significantly longer operative times (110 min) than SWL (47 min),(P = 0.00000). Our values are consistent with Kurtulus et al. [22], who documented an average duration of 2.2 hours but longer than those reported by Resorlu et al. [17] and Özgör et al. [14] (~50–60 min), likely due to differences in how operative duration was defined. Muniasamy et al. (13) reported a mean PCNL operative time of 81.34 ± 30.9 minutes and were the only authors to provide SWL intervention time, which was 45 ± 0.0 minutes.

Hospital stay was also significantly longer for PCNL (6 vs. 1 day). Singh et al. [16] reported similar findings (5.7 vs. 0.2 days). Resorlu et al. [17] and Wiesenthal et al. [18] noted shorter stays (~2–3 days for PCNL, outpatient SWL). Muniasamy et al. [13] also reported shorter PCNL stays (4.6 days). Our longer stays likely reflect greater blood loss and a more cautious postoperative approach during the early phase of PCNL adoption.

Complications were more frequent with PCNL (32.5%) compared to SWL (17.1%), though most were minor (Clavien I–III). Singh et al. [16] reported similar differences (30% vs. 9.7%), while Resorlu et al. [17] (22.1% vs. 7.6%) and Muniasamy et al. [13] (7.5% vs. 7.4%) also demonstrated the same pattern. In our study, no patients treated with SWL experienced complications classified as grade IV or V according to the modified Clavien-Dindo scale. Postoperative complications were distributed as follows: grade I in 4.8%, grade II in 2.4%, grade IIIa in 2.4%, and grade IIIb in 7.3% of cases..Similarly, among patients treated with PCNL, no grade V complications were reported. Postoperative complications were classified as grade I in 15%, grade II in 5%, grade IIIa in 10%, and grade IV in 2.5% of cases.Our findings, classified by the modified Clavien-Dindo scale, align with most published studies, including Singh et al. (16), who reported grade I complications in 7.3% of SWL patients and 12.19% of PCNL patients; grade II complications in 2.4% and 12.19%, respectively; and grade III complications in 0% and 5%, respectively.Hemoglobin decline was significantly greater after PCNL (1.95 g/dL) compared to SWL (0.2 g/dL). Comparable results were observed by Aboelkher et al. [19] (0.96 g/dL), Akman et al. [25] (1.4 g/dL), and Özgör et al. [14] (1.6–1.7 g/dL). These findings confirm PCNL's higher risk of bleeding, consistent with its invasive nature.

Conclusion

Overall, PCNL provides superior single-session clearance with fewer retreatments, while SWL offers lower morbidity, shorter operative time, and minimal hospitalization.

When multiple SWL sessions are allowed, outcomes become comparable to PCNL, though at the expense of repeat interventions. Our findings support an individualized approach, with PCNL favored in patients seeking definitive single-session clearance and SWL preferred in those prioritizing minimal invasiveness.

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