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RESEARCH ARTICLE

Comparative Outcomes of Retrograde Intrarenal Surgery versus Percutaneous Nephrolithotomy in the Management of Renal Calculi: A Study of 120 Cases

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Abstract

Background: Renal calculi represent a significant urological burden globally, affecting up to 10% of the population and demonstrating increasing prevalence. Management strategies have evolved from open surgery to minimally invasive techniques. Retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PCNL) are two widely adopted minimally invasive procedures. While both are effective, differences in efficacy, safety, complication profile, and resource utilization persist.

Objective: To compare the clinical outcomes, safety, efficacy, and perioperative parameters of RIRS and PCNL in treating renal calculi in a cohort of 120 patients.

Methods: This prospective comparative study included 120 patients diagnosed with renal stones between July 2023 to June 2025. Patients were randomized into two groups: Group A (RIRS; n = 60) and Group B (PCNL; n = 60). Key endpoints included stone-free rate (SFR), operative time, hospital stay, analgesic requirement, and complications classified by Clavien-Dindo.

Results: The overall SFR at 3 months was 85% for RIRS and 92% for PCNL ($p = 0.21$). PCNL demonstrated a higher SFR for stones >2 cm ($p < 0.05$). RIRS showed shorter operative time, reduced analgesic requirement, and shorter hospital stay ($p < 0.01$). Complications were more frequent in PCNL, notably bleeding requiring transfusion (5%) compared to RIRS (0%). Minor complications (fever, transient hematuria) were comparable. No mortalities were observed.

Conclusion: Both RIRS and PCNL are effective for renal calculi. PCNL achieves higher SFR for larger stones, while RIRS offers advantages in terms of hospital stay, pain profile, and complication rates. Tailored treatment selection based on stone burden, patient comorbidity, and resource availability is recommended.

Keywords: Retrograde Intrarenal Surgery (RIRS), Percutaneous Nephrolithotomy (PCNL), Renal Calculi, Stone-Free Rate, Minimally Invasive Urology.

1. Introduction

Renal calculi, commonly referred to as kidney stones, are one of the most frequently encountered urological disorders, affecting approximately 10–15% of the global population, with a rising incidence reported in recent decades [1]. Environmental factors, dietary

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habits, metabolic abnormalities, dehydration, obesity, and genetic predisposition have all been implicated in stone formation [2]. The clinical presentation of renal calculi varies widely, ranging from asymptomatic incidental findings to severe flank pain, recurrent urinary tract infections, and progressive renal deterioration if left untreated [3]. Management of nephrolithiasis has undergone a paradigm shift over the past four decades. Historically, open renal surgery was the mainstay of treatment and was associated with prolonged hospitalization, significant postoperative pain, and considerable morbidity [4]. The advent of minimally invasive techniques revolutionized treatment, first with extracorporeal shock wave lithotripsy (ESWL) in the 1980s, followed by percutaneous nephrolithotomy (PCNL) and later retrograde intrarenal surgery (RIRS) [5]. Among these modalities, PCNL has traditionally been the gold standard for the treatment of large renal stones (>2 cm), staghorn calculi, and complex stone burdens due to its superior stone clearance rates [6]. However, PCNL is not without disadvantages, including bleeding, visceral injury, sepsis, postoperative pain, nephrostomy-related morbidities, and longer length of hospital stay [7]. Retrograde intrarenal surgery emerged as a refined alternative with the evolution of flexible ureteroscopy, digital imaging technologies, smaller-caliber instruments, and laser lithotripsy systems such as Holmium: YAG laser [8]. RIRS provides stone access via the natural ureteric pathway, avoiding renal puncture and parenchymal trauma. This technique is particularly useful for stones <2 cm, patients with bleeding tendencies, children, elderly, and those with a solitary kidney [9]. Despite its advantages, RIRS may have limitations in accessing lower pole stones, potential increase in intrarenal pressure causing infection risk, and reduced efficacy in large volume burden without staged procedures [10]. As both procedures are widely practiced today, determining their relative benefit in different patient populations remains essential. Numerous studies suggest that while PCNL provides higher stone-free rates (SFR), particularly for larger stones, RIRS offers reduced morbidity, shorter recovery, and better quality-of-life outcomes [11,12]. However, comparative studies analyzing both modalities in the same cohort under uniform clinical conditions remain limited. Given this background, the present study aims to conduct a comparative evaluation of RIRS and PCNL in the management of renal calculi, focusing on operative time, stone-free rate, complication profile, postoperative pain, and hospital stay. Using a prospective cohort of 120 cases, this study seeks to offer clinically meaningful guidance on individualized modality selection, optimizing patient outcomes while minimizing procedural risk.

2. Materials and Methods

This prospective comparative observational study was conducted in the Department of Urology at Dinajpur Medical College and Hospital & Check-Up Specialized Hospital, Dinajpur, Bangladesh over a 24-month period extending from July 2023 to June 2025. Ethical approval was obtained prior to commencement, and each participant provided written informed consent. A total of 120 patients diagnosed with renal calculi were enrolled and subsequently divided into two equal groups: Group A underwent Retrograde Intrarenal Surgery (RIRS) and Group B underwent Percutaneous Nephrolithotomy (PCNL). Patient allocation was performed using a computer-generated randomisation list to minimize selection bias.

2.1 Study Population and Eligibility Criteria

All participants were aged between 18 and 75 years. Renal calculi were confirmed radiologically using non-contrast computed tomography of the kidney, ureter, and bladder (NCCT-KUB). Inclusion criteria consisted of single or multiple renal stones ≤3 cm in maximum dimension, symptomatic stones unresponsive to conservative or medical expulsive therapy, and patients with functional contralateral kidneys. Patients were excluded if they had uncorrected coagulopathy, active urinary tract infection, pregnancy, obstructive anomalies such as ureteropelvic junction obstruction, serum creatinine >2.0 mg/dL, or a history of previous major open renal surgery on the affected side.

2.2 Preoperative Evaluation

Baseline laboratory tests including complete blood count, renal function panel, serum electrolytes, coagulation profile, and urine culture were performed for all patients. Those with positive urine cultures were treated with appropriate antibiotics prior to surgery. Radiological data such as stone size (maximum diameter), number of stones, and anatomical location (upper pole, middle calyx, lower calyx, renal pelvis) were recorded.

2.3 Surgical Technique — RIRS

Patients underwent general anesthesia. A guidewire and ureteral access sheath were gently inserted through cystoscopy. A flexible ureteroscope was advanced into the renal pelvis and calyces, where stone visualization

and fragmentation were performed using Holmium: YAG laser lithotripsy. Small fragments were retrieved using a Dormia basket as required. A double-J ureteral stent was routinely placed at the conclusion of the procedure.

2.4 Surgical Technique — PCNL

Under general anesthesia, patients were positioned prone. Retrograde ureteric catheter insertion was achieved, followed by percutaneous renal access using fluoroscopy or ultrasonography guidance. The access tract was dilated up to the nephroscope size, and stones were fragmented using pneumatic or ultrasonic lithotripters. Larger fragments were removed via suction or graspers. A nephrostomy tube was placed based on bleeding risk or surgeon preference.

2.5 Outcome Measures and Follow-up

Primary outcome was stone-free rate (SFR), defined as absence of residual stone fragments >4 mm on radiological imaging at 3 months. Secondary outcomes included operative duration, intraoperative fluoroscopy time, postoperative analgesic requirement, length of hospital stay, complications categorized by Clavien-Dindo classification, and need for secondary procedures. Follow-up imaging with ultrasound and X-ray KUB or CT was performed at 1 week and 3 months postoperatively.

3. Results

A total of 120 patients were recruited for the study, with 60 undergoing Retrograde Intrarenal Surgery (RIRS) and 60 undergoing Percutaneous Nephrolithotomy (PCNL). Both groups were comparable in their baseline characteristics, ensuring homogeneity for comparative analysis. The mean age of patients in the RIRS group was 45.8 ± 12.4 years, while in the PCNL group it was 47.1 ± 10.6 years, indicating no statistically significant age difference ($p = 0.46$). The gender distribution also showed no marked difference, with a male-to-female ratio of 34:26 in the RIRS group and 36:24 in the PCNL group ($p = 0.72$). Evaluation of initial clinical characteristics revealed that patients undergoing PCNL presented with slightly larger stones, with a mean diameter of 2.3 ± 0.5 cm, compared to 1.9 ± 0.7 cm in the RIRS group. This size disparity was statistically significant ($p = 0.02$), indicating a slightly heavier stone burden in the PCNL arm. The proportion of multiple stones and lower pole location stones was similar between both groups, suggesting both cohorts shared comparable stone complexity patterns.

Analysis of operative parameters demonstrated key procedural differences between the two modalities. The average operative duration was significantly shorter for RIRS (72.4 ± 18.8 minutes) in comparison to PCNL (92.1 ± 25.6 minutes), showing a statistically meaningful difference ($p < 0.01$). Fluoroscopy exposure was drastically lower in RIRS, averaging 3.2 ± 1.1 minutes, whereas PCNL required 12.8 ± 3.4 minutes of fluoroscopy ($p < 0.01$). This reflects the inherently minimally invasive nature of RIRS and underscores PCNL's need for tract access visualization. Access creation in PCNL required an average of 1.3 puncture attempts, while RIRS required no such intervention. Furthermore, stone retrieval via basket manipulation was more frequently required during PCNL procedures (85%) compared to RIRS (65%) ($p = 0.03$). Double-J stent placement was universal in RIRS procedures (100%) to prevent ureteral edema and ensure drainage, while it was required only in 20% of PCNL patients, typically based on intraoperative bleeding or anticipated risk of obstruction.

Postoperative stone-free outcomes revealed that the overall Stone-Free Rate (SFR) at 3-month follow-up was slightly higher among PCNL patients. PCNL achieved an SFR of 92% (55 out of 60 patients), compared to 85% (51 out of 60 patients) for RIRS. Although this trend favored PCNL, the difference was not statistically significant ($p = 0.21$). However, subgroup analysis based on stone size demonstrated clinically meaningful differences. In cases with stones ≤2 cm, both techniques achieved identical SFR of 90%, indicating equivalent efficacy for smaller stones. However, for stones >2 cm, PCNL achieved a significantly superior SFR of 95%, compared to only 75% for RIRS ($p < 0.05$). Four patients (6.7%) from the RIRS group required repeat procedures due to persistent fragments, whereas only two PCNL patients (3.3%) required secondary intervention.

Postoperative recovery parameters demonstrated that RIRS offered a more favorable convalescence profile. Hospital stay duration was significantly shorter for RIRS patients, averaging only 1.5 ± 0.6 days, while PCNL patients remained hospitalized for a mean of 3.2 ± 1.1 days ($p < 0.001$). Pain control analysis further emphasized the difference: RIRS patients required only 1.3 ± 0.8 doses of analgesics postoperatively, whereas PCNL patients averaged 3.1 ± 1.2 doses ($p < 0.001$). Time to return to routine activities was also markedly shorter in the RIRS group (3.5 ± 1.2 days), compared with PCNL where normalization

of daily activity took approximately 7.2 ± 2.5 days, illustrating the greater invasiveness and associated recovery burden of PCNL.

Complication patterns were assessed using Clavien-Dindo classification. Minor complications such as transient hematuria, fever, and mild nausea occurred similarly across both groups (Grade I: 5 cases in RIRS, 6 in PCNL). Grade II complications, mainly UTI requiring antibiotics or mild anemia requiring iron therapy, were observed slightly more in the PCNL group (8 vs. 4 cases). Major clinical complications demonstrated a stark difference. PCNL reported significantly higher Grade III–IV complication rates (15%) compared with RIRS (1.7%). Six PCNL patients required surgical or procedural intervention (Grade III), including clot evacuation or stent repositioning or renal arterial embolization, whereas only one RIRS patient experienced a similar complication. Three patients in the PCNL group developed sepsis requiring ICU care (Grade IV), while no severe complications of this type occurred in the RIRS cohort. Importantly, no mortality (Grade V) occurred in either group.

3.1 Patient Demographics and Baseline Characteristics

Table 1. *Baseline Demographic & Clinical Features*

Parameter	RIRS (n = 60)	PCNL (n = 60)	p-value
Mean Age (years)	45.8 ± 12.4	47.1 ± 10.6	0.46
Gender (M/F)	34 / 26	36 / 24	0.72
Mean Stone Size (cm)	1.9 ± 0.7	2.3 ± 0.5	0.02*
Multiple Renal Calculi	24 (40%)	27 (45%)	0.59
Lower Pole Stone Location	18 (30%)	17 (28%)	0.82
Previous History of Renal Stone Surgery	8 (13.3%)	10 (16.7%)	0.61

**Statistically significant*

3.2 Operative and Intraoperative Parameters

Table 2. *Operative Characteristics*

Parameter	RIRS	PCNL	p-value
Mean Operative Time (minutes)	72.4 ± 18.8	92.1 ± 25.6	<0.01*
Fluoroscopy Time (minutes)	3.2 ± 1.1	12.8 ± 3.4	<0.01*
Access Attempts Required	–	1.3 ± 0.5	–
Need for Stone Fragment Retrieval Basket	39 (65%)	51 (85%)	0.03*
DJ Stent Placement	60 (100%)	12 (20%)	–

3.3 Stone-Free Rates (SFR)

Table 3. *Post-operative Stone Clearance*

Group	Stone-Free Rate at 3 Months	Residual Fragments (>4 mm)	Repeat Procedure Required
RIRS (n = 60)	51 (85%)	9 (15%)	4 (6.7%)
PCNL (n = 60)	55 (92%)	5 (8.3%)	2 (3.3%)
p-value	0.21 (NS)	–	–

Subgroup Stone Size Analysis

Stone Size	RIRS SFR	PCNL SFR	p-value
≤ 2 cm	90%	90%	1.00
> 2 cm	75%	95%	<0.05*

3.4 Hospital Stay and Post-operative Recovery

Table 4. *Postoperative Morbidity Parameters*

Variable	RIRS	PCNL	p-value
Length of Hospital Stay (days)	1.5 ± 0.6	3.2 ± 1.1	<0.001*
Post-operative Analgesic Doses Needed	1.3 ± 0.8	3.1 ± 1.2	<0.001*
Time to Resume Normal Activities	3.5 ± 1.2 days	7.2 ± 2.5 days	<0.001*

3.5 Post-operative Complications

Table 5. *Complication Profile – Clavien-Dindo Classification*

Complication Grade	RIRS (n)	PCNL (n)
Grade I (mild fever, nausea, transient hematuria)	5	6
Grade II (UTI requiring antibiotics, anemia)	4	8
Grade III (intervention – ureteral stent reposition / clot evacuation) Renal arterial segmental embolization	1 0	5 1
Grade IV (life-threatening complications – ICU care for sepsis)	0	3
Grade V (Death)	0	0
Total Significant (Grade III-IV)	1 (1.7%)	9 (15%)

4. Discussion

The findings of this comparative study provide important insights into the clinical outcomes of RIRS and PCNL in treating renal calculi. In the present cohort, RIRS was associated with shorter operative time, reduced post-operative pain, minimal fluoroscopy exposure, shorter hospital stay, and significantly fewer high-grade complications. Conversely, PCNL achieved a higher stone-free rate (SFR), particularly in patients with stones larger than 2 cm. These results align closely with previously published evidence highlighting PCNL's superiority for large stone burdens [6,12]. The stone-free rate (SFR) remains one of the most clinically relevant endpoints in stone management. In this study, the overall SFR at 3 months was 92% for PCNL and 85% for RIRS. Although this difference was not statistically significant overall, subgroup analysis demonstrated clear superiority of PCNL for stones >2 cm (95% vs. 75%). This observation corroborates the recommendations of the American Urological Association and European Association of Urology guidelines, which designate PCNL as first-line therapy for stones exceeding 20 mm [13]. RIRS, however, achieved near-equivalent SFR for ≤2 cm stones, suggesting its suitability as a primary alternative for smaller renal stones [14]. Complication profile is a critical clinician- and patient-centered factor in selecting a surgical modality. Major complications (Clavien-Dindo grade ≥III) occurred in only 1.7% of RIRS patients compared to 15% in the PCNL group. This difference is clinically important as PCNL-related morbidity such as bleeding requiring transfusion, renal parenchymal trauma, and septic complications continues to be a recognized limitation of the technique [7,15]. In contrast, RIRS's minimally invasive approach, with access via natural urinary tract pathways, results in fewer complications and faster postoperative recovery [8]. Length of hospital stay and analgesic requirement also significantly differed. RIRS patients resumed normal activities in approximately three to four days, compared to one week or more after PCNL. This suggests RIRS may confer socioeconomic benefits, particularly in working-age populations and in healthcare-limited settings where inpatient bed-availability is constrained.

Despite these advantages, RIRS has inherent limitations. The procedure requires greater endoscopic expertise, longer learning curve, and expensive consumables including flexible ureteroscopes and laser fibers [9,10]. Additionally, for large-volume stones, staged procedures may be required, increasing overall treatment burden [16]. PCNL, meanwhile, provides definitive clearance in a single session in most cases but requires interventional radiology support and nephrostomy-care expertise. Taken together, these findings support a selective and individualized clinical approach rather than competition between modalities. PCNL remains the optimal choice for stones >2 cm, staghorn calculi, or complex multi-calyceal burden. RIRS serves as an excellent alternative in patients with high surgical risk, bleeding tendencies, solitary kidneys, and those prioritizing quicker recovery. Future studies may benefit from larger multicenter cohorts, cost-effectiveness analysis, long-term recurrence outcomes, and randomized controlled design to strengthen generalizability. Nonetheless, the current study contributes valuable comparative data supporting strategic modality choice based on stone metrics and patient health profile.

4.1 Limitations

- Two-center study may limit generalizability.
- Follow-up imaging modality (e.g., CT vs ultrasound) could influence SFR assessment.
- Need for longer follow-up to assess recurrence.

5. Conclusion

Both RIRS and PCNL are effective modalities in the management of renal calculi. PCNL demonstrates

superior stone clearance for larger stones, while RIRS offers significant advantages in reduced morbidity, shorter hospitalization, and enhanced patient comfort. Clinical decision-making should integrate stone characteristics, patient risk profile, surgeon expertise, and institutional resources.

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