

Outcomes of Retrograde Intrarenal Surgery versus Mini-Percutaneous Nephrolithotomy for Renal Stones

Regmi P, Singh CK

Department of Surgery (Urology),

Devdaha Medical College and Research Institute,

Rupandehi, Nepal.

Corresponding Author

Prabodh Regmi

Department of Surgery (Urology),

Devdaha Medical College and Research Institute,

Rupandehi, Nepal.

E-mail: Prabodhregmi2142@gmail.com

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ABSTRACT

Background

Percutaneous nephrolithotomy (PCNL) and retrograde intrarenal surgery (RIRS) are common minimally invasive procedures for the management of upper urinary tract stones.

Objective

To compare the efficacy and safety of percutaneous nephrolithotomy and, retrograde intrarenal surgery both using thulium fibre laser, in patients with solitary renal stones measuring 15–30 mm.

Method

This prospective comparative study carried out after ethical approval. A total seventy-eight patients with single stone 1.5-3 cm in longest diameter were compared. The primary endpoint was stone-free rate at 4 weeks, assessed by kidney–ureter–bladder radiography and ultrasonography. Secondary outcomes included operative time, hospital stay, hemoglobin drop, transfusion requirement, and postoperative fever.

Result

A total seventy-eight patients with single stone 1.5-3 cm in longest diameter were included. Retrograde intrarenal surgery group (Group-A) had 41 patient and mini-percutaneous nephrolithotomy group (Group-B) had 37 patients. RIRS demonstrated significantly shorter operative time (64.3 ± 23.1 vs. 79.4 ± 26.3 min; $p = 0.01$), reduced hospital stay (2.1 vs. 3.5 days; $p = 0.001$), and lower hemoglobin drop (1.33 ± 0.92 vs. 2.17 ± 1.30 g/dL; $p = 0.002$) compared with mini-percutaneous nephrolithotomy. Blood transfusion was required only in the mini-percutaneous nephrolithotomy group. Stone-free rate was similar in both groups (90.2% vs. 91.9%; $p = 0.82$). Postoperative fever rates were similar in both groups (4.9% vs. 2.7%; $p = 0.58$).

Conclusion

RIRS achieved comparable stone-free rates to mini-percutaneous nephrolithotomy group, with the advantages of shorter operative time, reduced hospital stay, and lower blood loss. Retrograde intrarenal surgery may represent a safe and effective minimally invasive alternative to mini-percutaneous nephrolithotomy in selected patients.

KEY WORDS

Mini-percutaneous nephrolithotomy, Renal stone, Retrograde intra-renal surgery, Thulium laser lithotripsy

INTRODUCTION

Advances in imaging and technology have transformed the treatment of urinary tract stones.¹ The open surgery previously performed has largely replaced by minimally invasive techniques such as percutaneous nephrolithotomy (PCNL), retrograde intrarenal surgery (RIRS), and extracorporeal shockwave lithotripsy (ESWL), which offer less pain, shorter hospital stay, faster recovery, and high stone clearance rates.²

For renal stones larger than 20 mm, current European Association of Urology (EAU) and American Urological Association (AUA) guidelines recommend percutaneous nephrolithotomy (PCNL) as the first line treatment.³ The modern flexible ureteroscopes and lithotripters like the holmium or thulium laser make RIRS a safe and effective option for treating large and complex urinary stones.⁴ The Thulium Fiber Laser (TFL) is an emerging competitor for urinary stones treatment with some advantages of higher stone free rate over Holmium:yttrium-aluminum-garnet (Ho:YAG) laser.⁵

Various studies have reported the discordant outcome results between the PCNL, and RIRS surgeries.⁶⁻⁸ PCNL, with its larger working channel, provides a high stone-free rate in a single session, even for complex and staghorn calculi, whereas RIRS, owing to advancements such as miniaturized flexible ureteroscopes, high-power Ho:YAG lasers, newer thulium fiber lasers (TFL), and ureteral access sheaths, has expanded its indications to include stones larger than 2 cm.⁹ RIRS avoids a renal puncture, thus potentially reducing bleeding complications and hospital stay.¹⁰ Nevertheless, data directly comparing RIRS and PCNL for stones in the range of 15–30 mm remain limited. Therefore, the present study was designed to compare RIRS and mini-PCNL using TFL specifically for renal stones from 15 to 30 mm.

METHODS

This prospective comparative study was conducted to find out the outcome after M-PCNL and RIRS in the patients with stone size from 15 to 30 mm in the surgical department of Devdaha Medical College and Research Institute (DMCRI), Western Region of Nepal, from April 2025 to March 2026. All patients, before undergoing surgery either M-PCNL or RIRS, who fulfil the inclusion and exclusion criteria were recruited in the study. Sample size was taken from similar study⁽¹¹⁾ (with calculation/formula); $n = (Z\alpha/2 + Z\beta)^2 [P_1(1-P_1) + P_2(1-P_2)] / (P_1 - P_2)^2$; PCNL stone-free rate (P_1) = 0.90; RIRS stone-free rate (P_2) = 0.75; $Z\alpha/2 = 1.96$ for 95% confidence; $Z\beta = 0.84$ for 80% power. A written informed consent was taken from all patients after explaining the procedure. A computer-based sampling method was used. The study was approved by the institutional ethics committee (approval number Ref. no: 1303/081/082; 21 March, 2025). RIRS group (Group-A) had 41 patient and PCNL group (Group-B) had 37 patients. Three patients lost follow up in M-PCNL

group were excluded. Inclusion Criteria: the patients more than 18 years undergoing urological surgery M-PCNL or RIRS with stone size from 15 to 30 mm. Exclusion Criteria: patients less than 18 years, multiple stones, previous renal surgeries, anomalous kidney, trauma case, associated with cancer of urinary tract, pregnancy, and chronic renal failure.

All patients underwent preoperative assessment for urine routine and microscopic, urine culture and sensitivity, complete blood count (CBC), random blood sugar, coagulation profile: bleeding time (BT), clotting time (CT), prothrombin time (PT) and international normalized ratio (INR), blood urea nitrogen (BUN), serum creatinine (Cr), Sodium, Potassium, chest x-ray, abdominal ultrasonography (USG), and computed tomography of kidney ureter and bladder (CT-KUB) or CT intravenous urography (IVU).

Working Definition

A. M-PCNL: mini percutaneous nephrolithotomy with the tract size from 16 to 22 Fr.

B. RIRS: retrograde intra-renal surgery performed with flexible digital uretero-roscope using energy source Thulium Fibre Laser 200/365 micro mm with variable frequency 10-30 Hz and energy from 400 -1200 Joules.

C. Stone clearance was defined as no identifiable stone or residual fragments < 4 mm on plain abdominal X-ray of kidney, ureter and bladder (KUB) and USG abdomen after 2-4 weeks after Double J stent removal.

D. Operation time

1. PCNL: time taken from the puncture of PCNL to the placement of DJ stent.

2. RIRS: time taken from the Ureteric Access Sheath (UAS) placement and lasing the stone to completion of the placement of DJ stent

E. Post-operative fever: Axillary temperature >100.4 F recorded twice or more than two times using digital thermometer.

F. Stone free rate (SFR), defined as the absence of any residual fragment > 4 mm on X-ray (KUB) and USG abdomen at 2 to 4 weeks postoperatively.

G. Hemoglobin loss will be calculated the difference between pre-operative and post-operative hemoglobin according to laboratory reports.

Technique: According to standard hospital procedure, patients with a negative pre-operative urine culture, a single prophylactic dose of 1 gram of intravenous ceftriaxone was given within 1 hour before surgery. RIRS was performed under general anesthesia. A 6.0 French semi-rigid ureteroscope (Wolf) was used to examine the ureter and kidney. A conventional ureteral access sheath was used. RIRS performed using a 7.5-8.5 French flexible ureteroscope (Hugemede, China). The stone was fragmented using a dusting technique (0.4–1.2 J/15–30 Hz) with a 60-watt thulium laser (Quanta, Italy). At the

end of the procedure, the entire pelvicalyceal system was assessed to ensure no residual stone fragments larger than the fiber size remained. A 6 French/26 cm double-J stent was placed in all cases. Patients were discharged on the first postoperative day if they had no fever, no significant red urine, and a normal leukocyte count (less than 11,000/mm³).

PCNL was performed with the patient in either the supine or prone position. The tract created under fluoroscopic guidance using an Amplatz sheath with a dilator size of 16–20 French. A 11.0 French nephroscope (Wolf, Germany) was used in all cases. The stone was fragmented using a dusting technique (0.8–1.2 J/15–30 Hz) with a 60-watt thulium laser (Quanta, Italy). At the end of the procedure, the entire collecting system was examined by direct endoscopic examination and fluoroscopy to confirm complete stone clearance. A 6 French/26 cm double-J stent was inserted in all cases after the procedure. A 14 or 16 French urinary bladder catheter was placed in all cases. The bladder catheter was removed on the first postoperative day if there was no gross hematuria.

According to standard hospital practice, patients undergoing RIRS were discharged on the first postoperative day. Following PCNL, patients were discharged on the second postoperative day, provided there is no complications.

Patient follow-up

Follow-up was included X-ray of kidney, ureter, and bladder (KUB) and USG abdomen after 2–4 weeks. At the 2–4 week follow-up visit, the double-J stent was removed if no residual fragments of more than 4 mm were noted. Otherwise, the patients were scheduled for an additional procedure or follow up as hospital protocol. Residual fragments ≤ 4 mm or the absence of a radio-opaque shadow on follow-up imaging was defined as stone-free status.

Outcome measurements

The primary endpoint was stone-free rate (SFR) at 2–4 weeks, assessed by kidney–ureter–bladder radiography and ultrasonography. Secondary outcomes included operative time, hospital stay, hemoglobin drop, transfusion requirement, and postoperative fever.

Data analysis performed using the Statistical Package for the Social Sciences (SPSS), Windows version 20 (SPSS Inc., Chicago, IL). The following parameters were analyzed in number and frequency (percentage): demographic parameters (age and sex); stone characteristics (size,); operative details: duration of surgery}. The postoperative outcomes (stone clearance rate, length of hospital stay, hemoglobin loss, blood transfusion rate, and any additional endoscopic, radiological, or surgical procedures) were analyzed using descriptive statistics (numbers and frequencies), and their relationships were assessed using Fisher's exact or t-test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 41 patients in the RIRS group and 37 patients in the PCNL group were compared. Baseline characteristics, including sex distribution ($p = 0.68$) and stone laterality ($p = 0.18$), were comparable between the two groups. The mean stone size was similar in both groups, with 23.09 ± 4.67 mm in the RIRS group and 21.91 ± 6.24 mm in the PCNL group ($p = 0.91$). RIRS group shows a slightly higher mean stone size (23.09 mm) with lower variability ($SD \approx 4.67$). PCNL group has a similar mean stone size (22.72 mm) but greater variability ($SD \approx 7.55$), indicating a wider range of stone burden including very small and very large stones. Operative time was significantly shorter in the RIRS group (64.27 ± 23.07 minutes) compared to the PCNL group (79.35 ± 26.31 minutes; $p = 0.01$). Similarly, hospital stay was significantly reduced in the RIRS group (2.1 days vs 3.5 days; $p = 0.001$). Hemoglobin drop was also significantly lower following RIRS (1.33 ± 0.92 g/dL) compared to PCNL (2.17 ± 1.30 g/dL; $p = 0.002$). Although transfusion requirement was observed only in the PCNL group (2.7%), this difference was not statistically significant ($p = 0.42$). The stone-free rates were comparable between RIRS and PCNL (90.2% vs 91.9%, respectively; $p = 0.82$). Postoperative fever was slightly higher in the RIRS group (4.9%) compared to PCNL (2.7%), but this difference was not statistically significant ($p = 0.58$), (Table 1).

Table 1. Comparison of Baseline Characteristics and Perioperative Outcomes between RIRS (n = 41) and PCNL (n = 37).

Parameter	RIRS (n=41)	PCNL (n=37)	p-value
Baseline Characteristics			
Age (years)	42.83 ± 12.95	43.92 ± 15.08	0.74
Sex (M/F)	17 (41.5%) / 24 (58.5%)	16 (43.2%) / 21 (56.8%)	0.68
Stone laterality (Rt/Lt)	24 (58.5%) / 17 (41.5%)	27 (73.0%) / 10 (27.0%)	0.18
Stone size (mm)	23.09 ± 4.67	23.19 ± 6.84	0.91
Perioperative Outcomes			
Operative time (min)	64.27 ± 23.07	79.35 ± 26.31	0.01
Hospital stay (days)	2.15 ± 0.48	3.27 ± 0.83	0.001
Hemoglobin loss (g/dL)	1.33 ± 0.92	2.17 ± 1.30	0.002
Stone-free rate	37 (90.2%)	34 (91.9%)	0.82
Fever	2 (4.9%)	1 (2.7%)	0.58
Blood transfusion	0 (0%)	1 (2.7%)	0.42

DISCUSSIONS

In this study, a total of 78 patients were analyzed, with 41 undergoing RIRS and 37 undergoing PCNL. The study population was with similar baseline demographic and clinical characteristics, including sex distribution, stone size, and laterality, between the two groups. This comparability

is crucial in minimizing confounding variables and ensuring that differences in outcomes can be attributed primarily to the intervention rather than underlying patient or stone characteristics.

The present study showed significantly shorter operative time associated with RIRS compared to PCNL. The mean operative time in the RIRS group was 64.27 ± 23.07 minutes, whereas it was 79.35 ± 26.31 minutes in the PCNL group ($p = 0.01$). This difference can be explained by the basic procedural variations between the two techniques. PCNL requires the creation of a percutaneous tract into the renal collecting system, followed by tract dilation and nephroscope insertion. These steps are technically demanding and time-consuming, particularly in cases with complex anatomy or difficult access.¹² In contrast, RIRS utilizes natural orifices, thereby eliminating the need for tract creation and reducing procedural complexity. The findings of shorter operative time with RIRS are consistent with several previous studies.^{13,14} Moreover, RIRS can be completed more efficiently with improved surgeon's experience, advanced modern equipments such as high-power holmium:YAG or newer Thulium Fiber Laser (TFL)s and digital flexible ureteroscopes.¹⁵

Another important outcome observed in present study was the significantly shorter hospital stay in patients undergoing RIRS compared to PCNL (2.15 ± 0.48 versus 3.27 ± 0.83 days, $p=0.001$). This finding reflects the minimally invasive nature of RIRS, which results in reduced postoperative pain, faster recovery, and earlier mobilization. In contrast, PCNL is associated with greater tissue trauma due to renal puncture and tract dilation, necessitating longer postoperative monitoring and hospitalization.¹⁶ Shorter hospital stay is not only beneficial from a patient perspective but also has significant implications for healthcare resource utilization and cost-effectiveness. Studies have emphasized the economic advantages of minimally invasive approaches like RIRS, particularly in healthcare systems with limited resources.¹⁷ Reduced hospitalization leads to lower costs, decreased risk of hospital-acquired infections, and higher patient satisfaction.

In this study, the hemoglobin loss was another parameter that differed significantly between the two groups. The patients undergoing PCNL had greater hemoglobin decline (2.17 ± 1.30 g/dL) compared to those undergoing RIRS (1.33 ± 0.92 g/dL), with a statistically significant difference ($p = 0.002$). This finding is similar to other study.¹¹ This observation is consistent with the known risk profile of PCNL, which involves renal parenchymal injury and potential vascular damage during tract creation leading to more bleeding complication. Although only one patient (2.7%) in the PCNL group required blood transfusion, the trend toward higher blood loss in PCNL is well-documented in the literature. Studies have reported transfusion rates ranging from 3% to 7% in PCNL, depending on factors such as stone size, number of access tracts, and surgeon

experience.¹⁸ In contrast, RIRS is associated with minimal blood loss due to its endoscopic approach, making it a safer option in patients with bleeding disorders or those on anticoagulant therapy.¹⁹

The ultimate goal of stone removal surgery is to achieve a high stone-free rate. In the present study, the stone-free rates were comparable between the two groups, with 90.2% in the RIRS group and 91.9% in the PCNL group ($p = 0.79$). This findings are similar to other recent studies.^{20,21} It challenges the traditional notion that PCNL is superior in terms of stone clearance, especially for larger stones. The comparable efficacy of RIRS observed in this study can be attributed to technological advancements and improved surgical techniques.^{22,23} Modern flexible ureteroscopes offer enhanced deflection and visualization, allowing access to all calyces of the kidney. Additionally, laser lithotripsy types (Ho:YAG versus TFL) and techniques such as dusting and fragmentation enable effective stone disintegration and clearance.^{24,25}

There was low rate of postoperative fever and no statistically significant difference in both procedures. Fever occurred in two patients in the RIRS group and one patient in the PCNL group ($p = 0.61$). This suggests that both procedures are relatively safe when performed under appropriate conditions and with proper perioperative care. Infection-related complications are a known concern in endourological procedures, particularly due to increased intrarenal pressure during irrigation in RIRS.²⁶ However, adherence to proper sterilization protocols, use of ureteral access sheaths, and appropriate antibiotic prophylaxis can significantly reduce the risk of such complications.²⁷

Therefore, the choice between RIRS and PCNL should be individualized based on multiple factors, including stone size, location, patient comorbidities, anatomical considerations, surgeon's expertise and the inclusiveness of various predictive scoring systems.^{14,28,29}

The present study has several strengths, including a well-matched study population and comprehensive evaluation of both efficacy and safety outcomes. Additionally, the study design does specify comparative, which reduces selection bias. However, certain limitations must be acknowledged. The relatively small sample size may limit the statistical power of the study, particularly for detecting differences in rare complications. Additionally, the study is monocentric. Another limitation is the lack of long-term follow-up data. Stone recurrence is an important consideration in the management of urolithiasis, and future studies should aim to assess long-term outcomes, including recurrence rates and the need for repeat interventions. Furthermore, parameters such as postoperative pain scores, quality of life, and cost analysis were not evaluated in this study but could provide valuable insights in future research.

Despite these limitations, the findings of this study contribute to the growing body of evidence supporting the

use of RIRS as an effective and safe alternative to PCNL. With ongoing technological advancements and increasing surgeon experience, the role of RIRS is likely to expand further in the management of renal calculi.

CONCLUSION

Our findings suggest that for renal stones of 15 to 30 mm, RIRS using TFL is a valid alternative to PCNL, offering

comparable efficacy with significantly less morbidity. The shorter hospital stay and lower blood loss are particularly relevant in the era of newer innovative technology. RIRS should be considered a first line option for renal stones sized up-to 3 cm, particularly when rapid recovery and minimization of bleeding risk are priorities.

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