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Complications of Percutaneous Nephrolithotripsy versus Retrograde Intrarenal Surgery for Patients with Pelvic Renal Stones

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ABSTRACT

Background: Renal stones are a global health issue, affecting nearly 12% of the population. With the evolution of minimally invasive urological procedures, percutaneous nephrolithotripsy (PCNL) and retrograde intrarenal surgery (RIRS) have become the primary treatments for managing renal stones. However, each procedure carries distinct complications, particularly in challenging patient groups such as those with obesity.

Aim: This study aimed to compare the complication rates of PCNL versus RIRS in the management of unilateral pelvic renal stones.

Cases and methods: This prospective randomised study was conducted on 228 patients with unilateral pelvic renal stones. Patients were divided into two equal groups: Group A underwent PCNL (n=112) and group B underwent RIRS (n=116). Intraoperative and postoperative complications, operative time, hospital stay, and analgesic requirements were evaluated.

Results: PCNL demonstrated a significantly higher rate of bleeding (6.3% vs 0%), increased postoperative pain requiring NSAIDs (100% vs 22.4%), and longer hospitalisation (3.27 vs 1.12 days). RIRS had fewer severe complications but required significantly longer operative times (120.6 vs 82.5 minutes).

Conclusion: PCNL is associated with increased morbidity. RIRS presented fewer complications and may be preferable in high-risk individuals.

Keywords: Renal stones, PCNL, RIRS, Complications, Stone surgery.

INTRODUCTION

Renal stone disease represents a considerable public health concern, affecting an estimated 10–12% of the global population over their lifetime. The prevalence has been rising due to lifestyle changes, dietary habits, and increasing rates of obesity and metabolic syndrome. The recurrence rate is also high, with approximately 50% of patients experiencing a recurrence within five years of the initial episode [(1)].

Management of renal stones has evolved substantially, transitioning from open surgical techniques to minimally invasive methods such as extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotripsy (PCNL), and retrograde intrarenal surgery (RIRS). Among these, PCNL and RIRS are now commonly employed for medium- to large-sized renal stones. Both techniques offer distinct advantages and complications, particularly in obese patients where access, anesthetic risks, and postoperative outcomes can be significantly influenced by body habitus [(2)]. PCNL involves direct access to the renal collecting system through a small incision in the flank, allowing efficient removal of large stone burdens. It is recommended as the first-line of treatment for renal calculi larger than 2 cm, offering high stone-free rates with a single procedure. However, it is associated with complications such as bleeding, infection, renal injury, and longer recovery times, especially in high-risk patients [(3)].

RIRS, in contrast, uses a retrograde approach via the natural orifice and the ureter, with flexible ureteroscopy and laser lithotripsy to fragment and extract stones. It has gained popularity due to its reduced morbidity, shorter hospital stay, and suitability for patients with comorbid conditions. However, limitations include the need for multiple sessions in cases of larger stone burdens and the risk of ureteric injury or infection [(4)].

With the global obesity epidemic contributing to increased risk for stone formation and complicating surgical access, it is vital to understand the safety and efficacy of these procedures in individuals. This study aimed to compare the complications of PCNL and RIRS in the treatment of unilateral renal pelvic stones.

MATERIALS AND METHODS

Study design: This prospective, randomised comparative study was conducted at the Department of Urology, Helwan University Hospital, from December 2020 to December 2022.

Patient selection: In this study, 364 patients were assessed for eligibility, 124 patients were excluded, 96 of whom did not meet our inclusion criteria, and 28 patients declined to participate in the study as detailed in the CONSORT flowchart **(Figure 1).**

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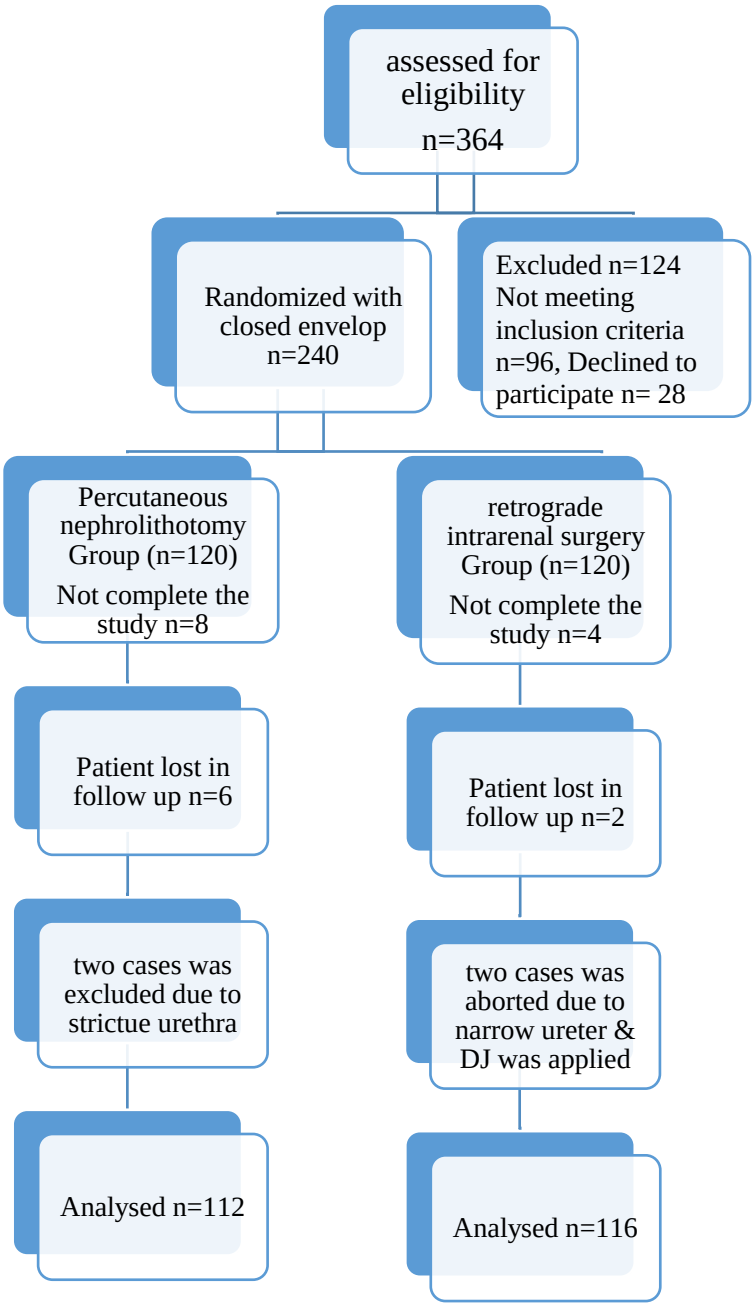

Figure (1) CONSORT flowchart.

A total of 240 patients, aged 18 years and older, with unilateral pelvic renal stones were enrolled. Patients were evaluated with a thorough clinical history and physical examination, complete blood count, renal function tests, urinalysis, urine culture, ultrasonography, plain abdominal radiography (KUB), and non-contrast CT (NCCT) to assess stone size, location, and density.

Inclusion Criteria: Age ≥ 18 years, Single pelvic renal stone, serum creatinine < 1.4 mg/dL and no prior surgical intervention on the affected kidney

Exclusion Criteria: Single kidney, anatomical urinary tract abnormalities, active urinary tract infection, coagulopathy or bleeding disorders, pregnancy, severe skeletal deformities and known ureteral strictures.

Randomisation: After meeting our inclusion and exclusion criteria, using a sealed envelope technique, eligible patients were randomly assigned to: Group A (PCNL): 120 patients (112 completed and analysed) and group B (RIRS): 120 patients (116 completed and analysed).

SURGICAL PROCEDURES

PCNL technique: Patients were put in the prone posture after receiving general anesthesia. An 18G access needle was used to accomplish a posterior calyceal puncture under fluoroscopic supervision. Sequential Amplatz dilators were used to widen the tract up to 30 Fr after a guidewire was introduced into the collecting system. A 26 Fr rigid nephroscope was used, and a pneumatic lithotripter was used to break up the stones. Stone shards were either watered out or removed using graspers. In every instance, a 30 Fr nephrostomy tube was inserted.

RIRS Technique: Patients were placed in the dorsal lithotomy position while under general anesthesia. A ureteral access sheath (12–14 Fr) was introduced following ureteral dilatation to 14 Fr during cystoscopy and guidewire implantation. Holmium: YAG laser lithotripsy was delivered using a 272 µm fiber after the stone was seen using a computerized flexible ureteroscope. Stone fragments were either allowed to pass naturally or extracted with a nitinol basket. After surgery, a double-J stent was implanted in each patient.

Outcome measures: Primary Outcomes included the information on the patient's characteristics (age and gender), the characteristics of the kidney stones (size and laterality), incidence and nature of intraoperative and postoperative complications.

Secondary Outcomes included operative time, length of hospital stay, need for analgesics (NSAIDs), and requirement of blood transfusion.

Postoperative care and follow-up: Serum creatinine levels, hemoglobin monitoring, and clinical observation were all part of the postoperative evaluations. At one month, KUB and ultrasonography were used to evaluate stone clearance. NCCT was saved for unclear results. The use of NSAIDs during hospitalization was used to measure pain control.

Ethical approval: The study received approval from Helwan University's Institutional Review Board (approval number: HU-72-2020). Prior to taking part in the study, each patient gave written informed consent. The Declaration of Helsinki, the World Medical Association's Code of Ethics for research with humans, has been followed in the conduct of this study.

Statistical Analysis

Data were analysed using IBM SPSS version 23. Continuous variables were presented as mean ± standard deviation (SD), and categorical variables as frequencies or percentages. Student's t-test was used for comparing continuous variables, and the Chi-square or Fisher's exact test for categorical variables. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS

Demographic characteristics showed no significant differences between groups in age, sex, stone side, or size. 76 patients were males (67.9%) & 36 patients were females (32.1%) in PCNL group. In RIRS group, 64 patients were males (67.9%) & 52 patients were females (32.1%). The mean age for PCNL and RIRS groups was 32.18 ± 13.4 and 34.05 ± 8.9 years respectively. 60 patients were right-sided (53.6%) & 52 patients were left-sided (46.4%) in PCNL group. In RIRS group, 53 patients were right-sided (45.7%) & 63 patients were left-sided (54.3%). The mean diameter of stones for PCNL and RIRS was 2.1 ± 0.4 cm and 1.9 ± 0.3 respectively (Table 1).

Table (1): Demographics characteristics

Parameter	PCNL Group (n = 112)	RIRS Group (n = 116)	p-value
Sex (male, female)	76/36	64/52	
Age (years, mean ± SD)	32.18 ± 13.4	34.05 ± 8.9	0.463
Stone side (Right/Left)	60/52	53/63	0.616
Stone size (cm, mean)	2.1 ± 0.4	1.9 ± 0.3	0.113

The mean operative time was significantly shorter for PCNL (82.5 ± 13.09 minutes) compared to RIRS (120.6 ± 10.4 minutes, p=0.026). The hospital stay was significantly longer for PCNL patients (3.27 ± 0.67 days) than for RIRS patients (1.12 ± 0.59 days, p<0.001) **(**Table 2 and figures 2 & 3).

Complication Rates: Bleeding requiring transfusion occurred in 7 PCNL patients (6.3 %) and none in the RIRS group (p=0.372). Fever > 38 °C occurred in 12 PCNL (10.7%) and 9 RIRS patients (7.76%) (p=0.114). Pelvicalyceal injury was seen in one PCNL patient. Stone migration occurred in four patients in each group. 100% of PCNL patients required NSAIDs post-operatively vs only 20.7% in the RIRS group (p<0.001) (Table 2 and figures 4 & 5).

Table (2): Perioperative Outcomes and Complications

Outcome /Complication	PCNL Group (n = 112)	RIRS Group (n = 116)	p-value
Operative time (min)	82.5 ± 13.09	120.6 ± 10.4	0.026
Hospital stay (days)	3.27 ± 0.67	1.12 ± 0.59	<0.001
Bleeding requiring transfusion	6.3 % (7 patients)	0 %	0.372
Fever >38°C	10.7 %	7.76 %	0.114
Postoperative NSAID requirement	100 %	22.4 %	<0.001
Stone migration incidence	3.6 %	3.4 %	0.965

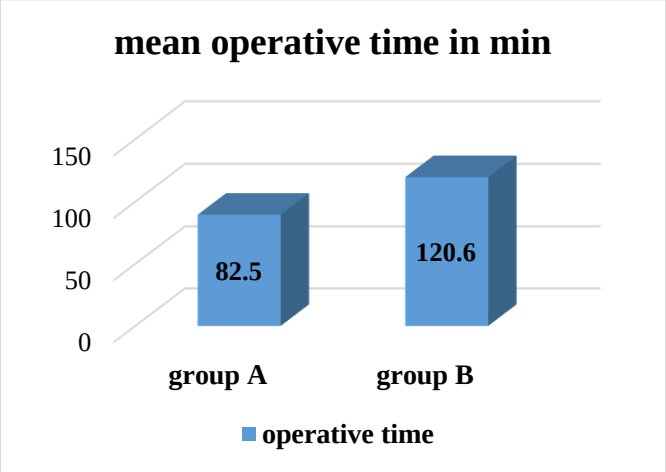

Figure (2): Comparison between mean operative time in PCNL group and RIRS group.

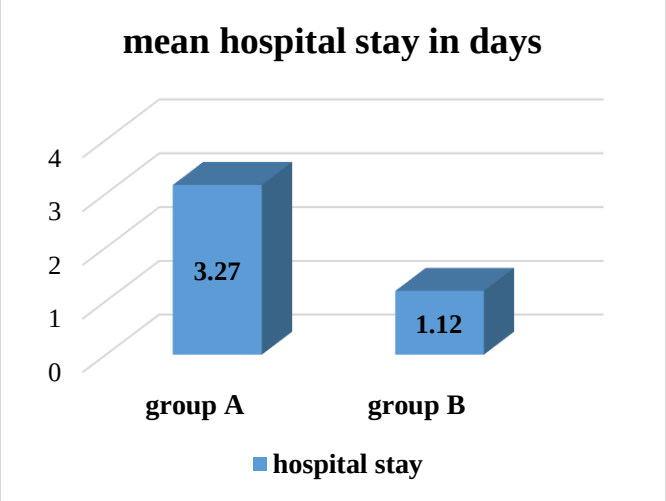

Figure (3): Comparison between mean hospital stay in PCNL group and RIRS group.

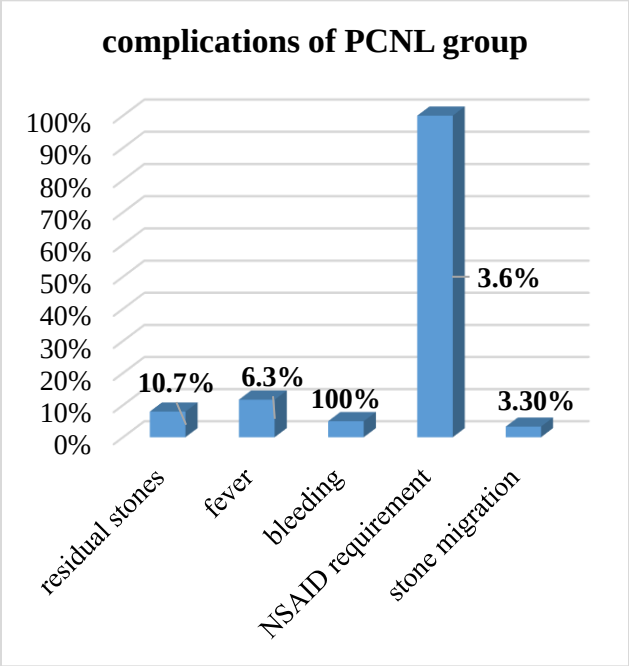

Figure (4): Complications of PCNL group.

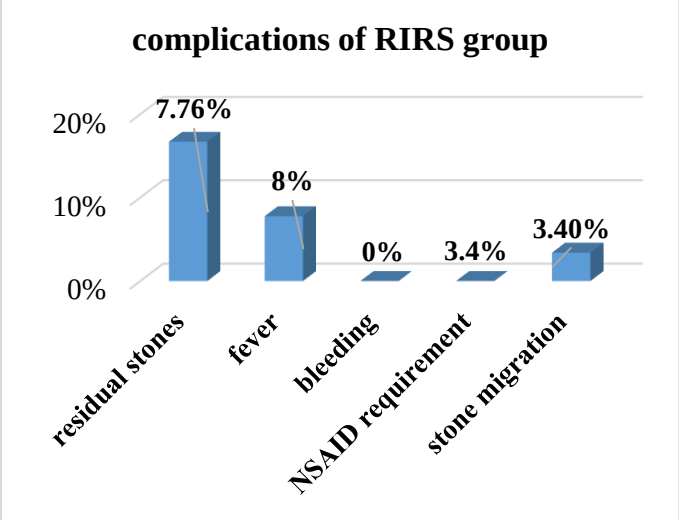

Figure (5): Complications of RIRS group

DISCUSSION

This comparative study confirmed that PCNL comes at the cost of increased perioperative morbidity. The statistically significant differences in hospital stay and analgesic requirement clearly prefer RIRS, highlighting its better tolerability and faster recovery profile.

Mechanisms of complications: Why bleeding is higher in PCNL

One of the most serious side effects of percutaneous nephrolithotripsy (PCNL) is bleeding. The renal parenchyma, which contains segmental arteries and veins that could be unintentionally harmed during access or tract dilatation, must be penetrated in order to create a percutaneous tract. These vascular injuries frequently show up as postoperative hematuria or intraoperative

bleeding. Furthermore, obese people have thicker adipose layers at presentation, which makes it harder to achieve appropriate calyceal access and raises the risk of vascular misdirection [5].

Tissue damage may be exacerbated by the stiff nephroscope used in PCNL, high-pressure irrigation, and extended manipulation to fragment large stones. In addition to impeding venous return, elevated intrarenal pressure has the potential to rupture delicate capillaries in the collecting system. Moreover, obesity is frequently linked to endothelial dysfunction, chronic inflammation, and a prothrombotic state, all of which might increase the likelihood and intensity of hemorrhagic episodes [5].

In our study, 7 patients (6.3 %) in the PCNL group required blood transfusion, while none in the RIRS group did, aligning with the premise that PCNL, while effective, carries a significantly higher bleeding risk. These findings advocate for heightened caution and expertise in performing PCNL on obese individuals, where small deviations from standard technique can lead to major vascular complications.

In contrast, RIRS avoids percutaneous access entirely, using natural orifices and flexible instruments to reach and treat stones. This endoluminal strategy greatly reduces parenchymal trauma and has consistently demonstrated lower rates of bleeding-related complications across multiple studies [6].

Bleeding is a well-documented complication of PCNL and was observed in our study with a transfusion rate of 5.4%, consistent with existing literature. Several mechanisms contribute to this higher bleeding risk:

1. **Percutaneous access tract injury:** It is inevitable that vascular structures will be disrupted when a nephrostomy tube is created through renal parenchyma. Because of its relatively avascular plane, the posterior lower pole is usually preferred, nevertheless anatomical differences in obese patients may make optimum calyceal access more challenging, raising the risk of vascular injury [7].
2. **Renal parenchymal trauma:** Both arterial and venous bleeding are more likely when the tract is dilated up to 30 Fr and hard tools are inserted because they can directly damage the renal tissue. Microvascular tears or, in more extreme situations, arterial lacerations result from dilatation's forceful stretching of parenchymal and vascular tissues. Additionally, prolonged irrigation during nephroscopy may worsen coagulation by raising intrarenal pressure [8].
3. **Stone burden and manipulation:** Larger stones frequently require more extensive manipulation, which puts more mechanical strain on the collecting system and vessels as well as increased intra-renal pressure. This necessitates considerable fragmentation inside the collecting system. Diffuse oozing or arterial bleeding could result from these activities accidentally damaging the mucosa, fornices, or even deeper parenchymal layers [9].
4. **Obesity-related factors:** During PCNL, obesity poses unique technical challenges. The thicker layers of fat in the abdomen and retroperitoneum can hinder accurate angulation of access and reduce fluoroscopic vision. Furthermore, deeper puncture paths are needed, which may be more likely to cause vascular disruption since they naturally pass through more tissue planes [10].
5. **Coagulopathy and inflammatory response:** Low-grade systemic inflammation and altered coagulation profiles, such as increased fibrinogen, plasminogen activator inhibitor-1 (PAI-1), and prothrombotic states, are frequently linked to obesity. These elements could worsen bleeding or lessen the efficiency of post-trauma local vasoconstrictive processes [11].
6. **Operator learning curve:** PCNL is an operator-dependent process that calls for a high level of technical proficiency. Inexperienced operators could struggle to achieve the best calyceal puncture, which could lead to several tries or less-than-ideal tract formation. Both make vascular problems more likely [12].
7. **Absence of real-time Doppler imaging:** Standard fluoroscopic or ultrasound-guided PCNL does not provide real-time visualization of vessels, in contrast to certain sophisticated centers that use Doppler-guided access to avoid vascular structures. This restriction raises the risk of unintentional vascular puncture [13].

When comparing retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PCNL) for patients with medium-sized renal stones, **Akman *et al.*** [14] found that while none of the patients undergoing RIRS needed blood transfusions, 10.7% of those treated with PCNL experienced significant bleeding. **Michel *et al.*** [15] reported a similar pattern in a multicenter assessment, showing that 11.2% of PCNL episodes involved bleeding that required a transfusion. Additionally, in a randomized controlled trial assessing stones larger than 2 cm, **Bryniarski *et al.*** [16] found that 15.6% of patients in the PCNL group needed transfusion. With 32 participants in each treatment arm, their research offered more convincing proof of PCNL's comparatively higher bleeding risk than RIRS.

Infection risk and operative duration in RIRS

Even though RIRS is less invasive, problems can still arise. In both groups, our investigation discovered a noteworthy but non-significant incidence of postoperative fever. However, because of the complexity of flexible ureteroscopy and laser fragmentation, RIRS requires a

longer operating time. This could lead to greater irrigation fluid absorption through the pyelovenous and pyelolymphatic systems, increasing the risk of urosepsis and a systemic inflammatory reaction. Thus, even though the risk of infection is still minimal overall, the length of the operation should be reduced and preoperative antibiotics should be closely followed [11].

In contrast to 24% of patients treated with flexible ureteroscopy, 28% of patients treated with percutaneous nephrolithotomy (PCNL) experienced postoperative fever surpassing 38 °C [14]. However, **Akman *et al.*** [15] discovered that no incidences of febrile episodes were documented among patients who had flexible ureteroscopy, and only one patient in the PCNL group experienced a high-grade fever.

Postoperative pain: A comparative analysis

One important factor influencing healing and patient satisfaction is postoperative pain. According to our data, all PCNL patients needed NSAIDs, while the RIRS group only needed them in 22.4% of cases. This discrepancy is explained by the percutaneous tract in PCNL, which causes somatic pain as a result of renal capsule dilatation and flank incision. RIRS, on the other hand, mostly causes visceral discomfort because it is completely endoluminal. Patients with RIRS required less analgesia, which allows for earlier mobilization, shorter hospital stays, and better overall recovery [17].

Cost-effectiveness and hospital stay:

Hospital stay was significantly longer in the PCNL group, a finding consistent with international literature. This has direct implications on healthcare cost, resource allocation, and patient throughput. Although RIRS may involve higher equipment costs and potentially multiple sessions for complete clearance, the shorter hospitalization, faster return to activity, and reduced complication management may balance overall costs [18]. **Akman *et al.*** [14] found that patients receiving flexible ureteroscopy spent 26.5 hours in the hospital on average, while those getting percutaneous nephrolithotomy (PCNL) spent an average of 60 hours. Similarly, **Bryniarski *et al.*** [15] found that patients treated with flexible ureteroscopy had a lower mean stay of 3.4 days, while those treated with the PCNL cohort had longer hospitalizations, with a mean hospital stay of 4.4 days.

STRENGTHS AND LIMITATIONS: A notable strengths of this study is its prospective design, a demographic often underrepresented in urological trials. The randomised grouping and standardized surgical techniques further enhance the reliability of the findings. However, limitations included its single-center nature, lack of long-term follow-up data on recurrence and quality of life, and the absence of validated pain scales (e.g., VAS or NRS) in assessing postoperative discomfort.

Implications for clinical practice:

These results support an individualized approach to stone management in patients. For larger, single pelvic stones, PCNL may still offer the most efficient clearance, albeit with higher morbidity. RIRS is a viable alternative for patients at increased surgical or anesthetic risk, offering a safer profile with reasonable efficacy. Surgeon experience, patient anatomy, and hospital resources should all inform the treatment pathway. PCNL comes at the cost of increased perioperative morbidity. The statistically significant differences in hospital stay and analgesic requirement clearly favour RIRS, highlighting its better tolerability and faster recovery profile. In contrast, RIRS avoids the risk of bleeding by relying on a natural orifice and endoluminal navigation, thereby eliminating the need for renal puncture. This significantly reduced the risk of parenchymal and vascular injury, which was reflected in the absence of transfusion events in our RIRS cohort. The statistically significant differences in hospital stay and analgesic requirement clearly favour RIRS, highlighting its better tolerability and faster recovery profile. RIRS, while taking longer intraoperatively was associated with a shorter hospital stay and fewer severe complications. These advantages are particularly important in obese patients who often have cardiopulmonary comorbidities that increase perioperative risks. Consistent with **Bozkurt *et al.*** [15], we found significantly longer operative times with RIRS, yet these did not correlate with increased major complications. Notably, fever was observed in both groups, suggesting that even minimally invasive procedures carry a risk of infection, especially in prolonged procedures and obese individuals.

CONCLUSION

Both PCNL and RIRS were effective for treating pelvic renal stones. PCNL carried a higher risk of bleeding, postoperative pain, and longer hospital stay. RIRS offered a safer complication profile, making it an ideal option for patients at high anesthetic or surgical risk. Individualized treatment selection, based on patient comorbidities, stone characteristics, and surgeon experience, is essential to optimizing outcomes.

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Conflict of interest: None.

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