

# A Comparative Analysis of Mini-Percutaneous Nephrolithotomy and Retrograde Intrarenal Surgery for the Management of 10–20 Mm Pediatric Kidney Stones

 Recep Burak Degirmen-tepe,<sup>1</sup>  Yasir Muhammed Akca,<sup>1</sup>  Deniz Gul,<sup>1</sup>  Hacı Ibrahim Cimen,<sup>1</sup>  Muammer Bozkurt,<sup>2</sup>  
 Tuncay Toprak,<sup>3</sup>  Fikret Halis<sup>1</sup>

<sup>1</sup>Department of Urology, Sakarya University, Faculty of Medicine, Sakarya, Türkiye

<sup>2</sup>Department of Urology, Health Sciences University, Prof. Dr. Cemil Tascioglu City Hospital, Istanbul, Türkiye

<sup>3</sup>Department of Urology, University of Health Sciences, Fatih Sultan Mehmet Training and Research Hospital, Istanbul, Türkiye

## ABSTRACT

**Objective:** This study compares the clinical outcomes of mini-percutaneous nephrolithotomy (m-PNL) and retrograde intrarenal surgery (RIRS) in managing 10–20 mm renal stones in pediatric patients. The primary objective is to evaluate stone-free rates (SFRs), operative parameters, and complications to provide insights into optimal treatment strategies for pediatric nephrolithiasis.

**Materials and Methods:** A retrospective analysis of 39 pediatric patients under 18 years of age who underwent m-PNL (Group 1) or RIRS (Group 2) for renal stones between 10 and 20 mm from January 2016 to March 2024 was conducted. Patients were assessed for demographic data, operative time, hospitalization duration, fluoroscopy time, hemoglobin reduction, SFRs, and complications. Statistical analyses were performed to compare the two groups.

**Results:** The mean operative time, hospitalization duration, and fluoroscopy time were significantly shorter in the RIRS group ( $p < 0.001$ ), with lower post-operative hemoglobin reduction compared to the m-PNL group. At the 1-month follow-up, SFRs were comparable between groups (m-PNL: 95.2%, RIRS: 94.9%,  $p = 0.710$ ). Minor complications were observed in both groups without significant differences. RIRS demonstrated advantages in hospital stay and reduced radiation exposure, while m-PNL required fewer anesthesia sessions.

**Conclusion:** Both m-PNL and RIRS are effective and safe for treating pediatric kidney stones. While RIRS offers shorter operative and hospitalization times with reduced hemoglobin loss, m-PNL avoids the need for routine double-J stenting and additional anesthesia. Treatment choice should be individualized, considering clinical factors and family preferences, to optimize outcomes in pediatric nephrolithiasis management.

**Keywords:** Mini-percutaneous nephrolithotomy, Pediatric nephrolithiasis, Retrograde intrarenal surgery

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**Address for correspondence:** Recep Burak Degirmen-tepe. Department of Urology, Sakarya University, Faculty of Medicine, Sakarya, Türkiye

**E-mail:** burakdegirmen-tepe@gmail.com **ORCID ID:** 0000-0002-2875-5750

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## INTRODUCTION

Pediatric nephrolithiasis is an infrequent condition; however, its incidence has increased significantly over the past few decades, with a dramatic annual rise of approximately 10%.<sup>[1]</sup> Managing renal stones in children presents greater challenges compared to adults, encompassing complexities in diagnosis, metabolic evaluations, surgical interventions, and prognosis.<sup>[2]</sup> To address this significant health issue, technological advancements in endourology have progressed rapidly over the years, aiming to achieve maximum success with minimal morbidity.<sup>[3]</sup>

Percutaneous nephrolithotomy (PNL) was first performed in the pediatric population in 1985 on a 14-year-old child.<sup>[3]</sup> PNL offers significantly high stone-free rates (SFRs) and requires fewer auxiliary procedures and sessions compared to other treatment methods. However, its application in children poses challenges due to the smaller size of their kidneys and collecting systems, the fragility of renal parenchyma, and the increased mobility of the pediatric kidney. Over time, the introduction of smaller instruments, as utilized in mini-PNL (m-PNL), has led to reduced parenchymal and vascular damage, making the procedure more suitable for this population.<sup>[4]</sup>

Currently, retrograde intrarenal surgery (RIRS) has emerged as a less invasive option to PNL for the treatment of renal calculi and has been performed with safety and efficacy. However, depending on the location and size of the stones, RIRS may necessitate multiple sessions.<sup>[3,5]</sup> With advancements in technology and increasing experience, both m-PNL and RIRS have demonstrated comparable success rates in achieving stone clearance.<sup>[3,6]</sup> Ideally, pediatric kidney stone treatments should aim for the highest SFRs with minimal complications, while also striving to minimize the number of surgical and anesthesia sessions required.<sup>[4,5]</sup>

We present a comparative clinical analysis of m-PNL and RIRS in the management of 10–20 mm renal stones in pediatric patients.

## MATERIALS AND METHODS

A retrospective analysis was conducted on adolescents and children (<18 years) undergoing m-PNL or RIRS for kidney stones (10–20 mm) over an 8-year period (2016–2024). All patients under the age of 18 with 10–20 mm kidney stones who underwent m-PNL or RIRS during the specified period were selected for evaluation. Participants were stratified into two distinct cohorts based on the minimally invasive surgical technique employed: Group 1 (m-PNL) and Group 2 (RIRS). Demographic and clinical parameters, including gender, stone size, age, stone location, duration of hospitalization, operative time, fluoroscopy time, hemoglobin reduction, complications, and SFRs, were retrospectively reviewed, analyzed, and compared.

The study was conducted retrospectively, and the choice of surgical technique was not randomized. Operative management was standardized through single-surgeon performance for both techniques. The patients included in the study did not have any pathology that could alter the success of treatment, such as urinary obstruction, bleeding diathesis, ectopic kidney, malrotation, or ureteropelvic junction obstruction. All patients included in the study had unilateral renal stones. All patients' parents were given detailed information about kidney stone treatments before surgery. Ethical clearance was granted by Sakarya University's Institutional Review Board (No: 123, Date: 15/04/2024). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Preoperative evaluations included routine biochemical and microbiological testing. All procedures were conducted only after confirmation of negative urine cultures. Patients with positive urine cultures were treated with targeted antibiotics. Radiological assessments, as necessary, were performed using renal ultrasonography (US), intravenous urography, or computed tomography (CT). Stone size was defined as the longest axis of each stone measured using preoperative US, kidney-ureter-bladder (KUB) radiography, or CT. Stone size was defined as the longest axis of each stone based on preoperative imaging. Due to the retrospective design and variation in imaging modalities over the years, consistent data on the second axis were not available. Therefore, volume or surface area calculations could not be applied uniformly across all cases, which is a noted limitation of the study. In cases of multiple stones, the total stone burden was calculated by summing the longest axes of each individual stone.

Intravenous cephalosporin was administered to all patients as prophylaxis before the endoscopic procedure, with the dosage adjusted based on age and weight. For m-PNL, patients were initially positioned in the dorsal lithotomy position, where a ureteral catheter was inserted over a guidewire to the targeted kidney. The external portion of the catheter was secured to the inserted urethral catheter using a silk suture. Patients were then repositioned to the prone position, and the kidney was visualized using a C-arm fluoroscope by administering contrast material through the pre-inserted ureteral catheter. Access to the renal pelvicalyceal system was achieved through an 18-gauge Chiba needle inserted into the appropriate calyx, followed by guidewire advancement into the renal pelvis and calyces. Tract dilation was performed over the guidewire, and an access sheath was positioned. A 12Fr nephroscope (Richard Wolf, Knittlingen, Germany) was introduced through a 15/18 Fr sheath to access the pyelocalyceal system. Calculi were disintegrated utilizing a 550-micron holmium: YAG laser fiber and pneumatic lithotripters, and the resulting fragments were retrieved with forceps. Upon achieving stone clearance, a nephrostomy catheter was placed in all m-PNL patients, clamped on post-operative day 1, and removed on day 2. The total operation time for m-PNL

encompassed patient positioning, ureteral catheter placement through cystoscopy, percutaneous access, tract dilation, stone fragmentation, and nephrostomy placement.

The RIRS procedure involved general anesthesia, lithotomy positioning, and fluoroscopically-guided insertion of a 9.5 Fr ureteral access sheath (28/35 cm, Cook Medical) through which a 7.5 Fr flexible ureterorenoscope (Flex X2, Karl Storz) was advanced. After the stone was once identified, the stone was fragmented into smaller pieces to facilitate spontaneous passage, utilizing a 270  $\mu$ m fiber holmium:YAG laser set at 0.6 J and 6–8 Hz. Following stone fragmentation, a guidewire was advanced into the renal collecting system through the UAS. A double-J (DJ) stent was routinely placed under cystoscopic guidance over the guidewire in all patients. This stent was scheduled for removal under general anesthesia 4-week post-procedure. Preoperative stenting was not routinely performed before RIRS procedures. The total operation time for RIRS was defined as the duration encompassing the induction of general anesthesia, patient positioning, cystoscopic placement of a guidewire into the ureter, UAS placement, stone fragmentation, and DJ stent placement at the end of the procedure.

Post-operative follow-up was conducted using KUB radiography and US. The patients were routinely checked for residual stones with KUB radiography on the 1<sup>st</sup> day post-operatively and KUB radiography and US on the 1<sup>st</sup> month post-operatively. Treatment success was objectively defined as complete stone-free status, confirmed by imaging modalities at the 1-month post-operative follow-up. Post-operative complications were evaluated for each patient using the Clavien–Dindo classification system.<sup>[7]</sup> Treatment efficacy was principally assessed through SFR, where success mandated the absence of any radiologically detectable stone fragments larger than 4 mm. Secondary analyses focused on procedure-related adverse events, which were prospectively documented and severity-stratified according to Clavien–Dindo classifications (Grades I–V).

### Statistical Analysis

All data processing utilized the Statistical Package for the Social Sciences 16.0J software (IBM). Nonparametric approaches (Mann–Whitney U for continuous data;  $\chi^2$  tests for proportions) were selected due to small cohort size and distributional concerns. The alpha threshold for significance was established at 0.05.

### RESULTS

The mean age of the patients was 7.6 $\pm$ 2.8 years in the m-PNL group and 8.2 $\pm$ 2.7 years in the RIRS group ( $p=0.600$ ). Group 1 included 12 males (57%) and 9 females (43%), while Group 2 comprised 10 males (55%) and 8 females (45%). The mean stone size was 13.9 $\pm$ 0.9 mm in Group 1 and 13.6 $\pm$ 1.2 mm in Group 2 ( $p=0.349$ ), respectively. The demographic data of the patients are summarized in Table 1.

**Table 1.** Demographic values of the patients

	Mini-PNL	RIRS	p
Number	21	18	
Male/female	12/9	10/8	
Age (y)*	7.6 $\pm$ 2.8	8.2 $\pm$ 2.7	0.600
Stone size (mm)*	13.9 $\pm$ 0.9	13.6 $\pm$ 1.2	0.349
Stone locations**			
Lower	11	3	
Middle	2	0	
Upper	1	7	
Pelvic	5	7	
Multicalyceal	2	1	

PNL: Percutaneous nephrolithotomy; RIRS: Retrograde intrarenal surgery;

\*Mean $\pm$ standard deviation; \*\*Distribution of stones in the kidney.

The mean operation time was 66.8 $\pm$ 10.6 min for Group 1 and 49.2 $\pm$ 7 min for Group 2, showing a statistically significant difference ( $p<0.001$ ). The mean hospitalization time was shorter in the RIRS group (26.3 $\pm$ 4.6 h) compared to the m-PNL group (77.7 $\pm$ 18.4 h), as expected with a less invasive procedure ( $p<0.001$ ). Fluoroscopy exposure during surgery averaged 138.6 $\pm$ 19.5 s for Group 1 and 30.4 $\pm$ 28.1 s for Group 2, with the difference again being statistically significant ( $p<0.001$ ).

The post-operative hemoglobin decrease was 1.65 $\pm$ 0.31 g/dL in the m-PNL group and 0.5 $\pm$ 0.29 g/dL in the RIRS group, with a statistically significant greater decrease observed in the m-PNL group. Stone location distribution differed significantly between groups: Lower pole stones predominated in the m-PNL group (52.3% vs. 16.6% in RIRS), while upper pole stones were more frequent in the RIRS group (38.8% vs. 4.7% in m-PNL). The SFRs on the 1st post-operative day were 95.2% for the m-PNL group and 88.9% for the RIRS group, with no statistically significant difference ( $p=0.630$ ). In the m-PNL group, two patients had multicalyceal stones. One patient was managed with a single lower pole access, while the second required two access tracts due to anatomical constraints. Both cases achieved stone-free status postoperatively. One RIRS case (5.6%) required staged treatment due to failed initial UAS placement. After deferred DJ stenting and a 3-week interval, UAS placement and stone fragmentation were successfully completed. At the 1-month follow-up, the SFRs were 95.2% for the m-PNL group and 94.9% for the RIRS group, with no significant difference between the groups ( $p=0.710$ ).

No major complications were observed in the post-operative period. In the m-PNL group, a DJ stent was placed in one patient due to symptomatic ureteral stones detected during

**Table 2.** Comparison of post-operative outcomes

	Mini-PNL	RIRS	p
Operation time* (min)	66.8±10.6	49.2±7	<0.001
Hospitalization* (h)	76.7±18.4	26.3±4.6	<0.001
Fluoroscopy time* (s)	138.6±19.5	30.4±28.1	<0.001
Hemoglobin drop* (g/dL)	1.65±0.31	0.5±0.29	<0.001
Stone-free rate,** n (%)	19/21 (90.5)	16/18 (88.9)	0.630
Success rate,*** n (%)	20/21 (95.2)	17/18 (94.9)	0.710
Post-op complications			0.551
Clavien grade I	5	2	
Clavien grade II	2	2	
Clavien grade III	1	0	
Clavien grade IV-V	0	0	

PNL: Percutaneous nephrolithotomy; RIRS: Retrograde intrarenal surgery;

\*Mean±standard deviation; \*\*Outcomes on post-operative day 1; \*\*\*Stone-free rate at 1st month.

follow-up. No cases of bleeding requiring blood transfusion occurred. Minor post-operative complications, such as hematuria, urinary infection, ecchymosis, and paralytic ileus, were observed in some patients in either group and were managed appropriately. The comparison of complications between the groups, according to the Clavien–Dindo classification, is summarized in Table 2.

## DISCUSSION

Technological advancements in urology have revolutionized therapeutic approaches for nephrolithiasis, replacing open surgeries with minimally invasive techniques such as Extracorporeal Shock Wave Lithotripsy (ESWL), PNL, and RIRS.<sup>[2]</sup> ESWL is particularly effective for 10–20 mm kidney stones in selected cases; however, its success rate declines as stone size increases. Achieving higher SFRs often requires multiple sessions, leading to additional anesthesia and radiation exposure.<sup>[8]</sup> The miniaturization of instruments and the development of flexible devices have facilitated easier access to renal stones, thereby expanding the applicability of m-PNL and RIRS procedures in the pediatric population.<sup>[2]</sup>

Compared to adults, pediatric kidneys are more mobile, have a narrower pelvicalyceal system, and possess more fragile renal parenchyma and mucosa, making it challenging to balance complete stone clearance with the preservation of renal parenchyma.<sup>[9]</sup> The primary goal in pediatric urolithiasis treatment is to employ a minimally invasive surgical technique that minimizes impact on kidney function while achieving a high stone clearance rate on the first attempt, without the need for re-treatment or auxiliary procedures.<sup>[10]</sup>

The rising prevalence of pediatric nephrolithiasis in recent years highlights the need for a thorough assessment of surgical techniques employed in its treatment.<sup>[11]</sup> Accordingly, we aimed to contribute to this field by presenting our clinical study, which compares m-PNL and RIRS in the pediatric patients.

There is comparatively limited research comparing m-PNL and RIRS in children. Resorlu et al.<sup>[6]</sup> conducted a multi-institutional analysis focused on kidney stones between 10 and 30 mm in size, reporting an overall SFR of 85.8% in the m-PNL group and 84.2% in the RIRS group after one session. Their analysis demonstrated significantly different success rates between modalities: RIRS achieved 87.3% SFR for stones <20 mm versus 50% for >20 mm calculi, whereas m-PNL showed superior efficacy (100% and 83.9% SFR for respective size categories). The final SFR was improved to 94.3% in the m-PNL group and 92.6% in the RIRS group. Although they found longer mean fluoroscopy time, operation time, and hospitalization duration in the m-PNL group, their findings indicated that the morbidities associated with PNL could be significantly reduced using the RIRS technique. In a similar study, Saad et al.<sup>[12]</sup> conducted a randomized controlled study comparing the outcomes of PNL and RIRS in 38 pediatric patients with kidney stones larger than 2 cm. They found 71% and 95.5% SFRs for RIRS and PNL, respectively. According to the study results, there were higher SFRs for PNL, less radiation exposure, shorter hospital stay, and fewer complications for RIRS. They suggested that RIRS was a preferred surgical option but not an innocent procedure. These findings, however, were applicable to larger stone sizes, while our study focused on stones ranging from 10–20 mm. In addition, while we used a 12Fr nephroscope in our study, Saad et al.<sup>[12]</sup> employed a 22Fr nephroscope, which further differentiates the two studies.

Recently, several researchers have compared m-PNL and RIRS as surgical techniques for treating kidney stones ranging from 10 to 20 mm in children. Wang et al.<sup>[13]</sup> investigated children under 3 years with solitary 10–20 mm stones, demonstrating both techniques as clinically effective, though m-PNL proved superior by requiring fewer anesthesia sessions. Corroborating these findings, Özçift et al.<sup>[4]</sup> reported comparable outcomes in their pediatric cohort (stone size 10–20 mm), where RIRS offered advantages in reduced hospitalization duration and shorter fluoroscopy exposure - aligning with our institutional experience. However, their cost-benefit analysis favored m-PNL for its economic efficiency and reduced anesthetic burden. In our study, which focused on pediatric kidney stones ranging from 10 to 20 mm, we found a statistically significant difference between the m-PNL and RIRS groups regarding operation time, hospitalization duration, fluoroscopy time, and hemoglobin decrease, all favoring RIRS. However, no significant differences were observed in terms of SFR, overall suc-

cess rate, or post-operative complications. Besides, our study revealed a disparity in stone location between groups, with lower pole stones more common in the m-PNL cohort and upper pole stones in the RIRS cohort. This imbalance may have influenced outcomes, as lower pole stones are technically more challenging to treat with RIRS due to difficulties in ureteroscope deflection and fragment clearance, while upper pole stones pose access challenges for percutaneous approaches. Despite this, both techniques achieved comparable SFRs, suggesting that surgeon expertise and instrument selection (e.g., flexible nephroscopes in m-PNL) may mitigate anatomical constraints. Future studies should stratify outcomes by stone location to control for this bias.

The ongoing Pediatric Kidney Stone Care Improvement in Children and Teens (PKIDS) study, a large comparative effectiveness trial in the United States, is further investigating the outcomes of PNL, ureteroscopy, and shock wave lithotripsy in over 1000 pediatric patients. This study aims to provide robust data on the optimal management of pediatric nephrolithiasis and may offer additional insights into the comparative efficacy of these techniques.<sup>[14]</sup> Our findings align with the preliminary trends observed in PKIDS, particularly in terms of the safety and efficacy of minimally invasive techniques like RIRS and m-PNL in children.

The neurodevelopmental consequences of anesthesia exposure in infants and young children remain incompletely understood, despite millions of pediatric procedures performed annually under general anesthesia. Preclinical studies demonstrate that common anesthetic agents induce dose-dependent neurotoxicity through mechanisms including apoptotic neurodegeneration, synaptic dysfunction, and impaired neurogenesis – particularly during peak synaptogenesis (6–24 months postnatally). While human cohort studies report conflicting associations with later cognitive deficits (e.g., learning disabilities), current evidence suggests that repeated or prolonged exposure may elevate neurodevelopmental risks, warranting judicious use of anesthesia in early childhood. This underscores the importance of technique selection (e.g., regional adjuncts), duration minimization, and adherence to evolving consensus guidelines for elective procedures in high-risk developmental windows.<sup>[15,16]</sup> The study by Ebert et al.<sup>[17]</sup> highlights the preference for spinal anesthesia as a strategy to mitigate the potential neurocognitive risks associated with general anesthesia in children, aligning with these findings. In addition, the study conducted by Jia et al.<sup>[15]</sup> further indicates that factors such as more frequent exposure to surgery and anesthesia, younger age at the time of exposure, and lower body weight may have detrimental effects on cognitive and behavioral development. It has been reported that repeated exposure to anesthesia may impact brain development in chil-

dren, potentially affecting their intellectual growth and cognitive abilities.<sup>[13]</sup> While some studies suggest potential risks associated with repeated or prolonged exposure to general anesthesia, large population-based studies indicate that a single brief exposure is not linked to long-term neurodevelopmental deficits.<sup>[18]</sup> In our study, the comparable SFRs achieved by the RIRS group with a shorter operation time suggest that RIRS could be a valuable option for pediatric patients with 10–20 mm kidney stones.

Our study has several limitations. Its retrospective design introduces potential bias. The absence of randomization, the relatively small sample size in each group, and the lack of comprehensive stone analysis for all patients represent significant constraints. The heterogeneity in imaging modalities used for stone size measurement is another limitation of our study. While we prioritized CT measurements for accuracy, variations in imaging techniques may have introduced some bias. Future studies should standardize imaging protocols to ensure more consistent and reliable comparisons. Another important limitation of our study is the measurement of stone size based solely on the longest axis. This approach may not accurately reflect the actual stone burden, particularly in cases of irregularly shaped or elongated stones. Due to the retrospective design and variability in imaging methods, consistent measurements of the second axis or volumetric assessments could not be performed. Furthermore, data regarding stone hardness, including Hounsfield Unit values or compositional analysis, were not consistently available and could not be incorporated into our analysis. Given the potential influence of stone hardness on fragmentation and procedural efficiency (especially in RIRS), this represents an additional limitation. An additional limitation is that the non-randomized design led to uneven distribution of stone locations between groups, potentially favoring m-PNL for lower pole stones and RIRS for upper pole stones. While this reflects real-world clinical decision-making, it may have confounded operative outcomes. This imbalance may have introduced a selection bias, as anatomical location can influence both access and fragmentation efficiency depending on the surgical approach. Future prospective, randomized studies with larger patient cohorts are necessary to obtain more robust and meaningful findings. On the other hand, the fact that all surgical procedures were performed by a single surgeon is a strength of our study, as it ensures consistency in surgical technique and minimizes variability in outcomes.

## CONCLUSION

M-PNL and RIRS are endoscopic surgical techniques proven to be effective and safe for pediatric kidney stone management. RIRS has demonstrated advantages such as shorter hospital stays and operation times, reduced post-operative hemoglobin loss compared to m-PNL, and lower fluoroscopy expo-

sure during surgery. However, despite achieving comparable stone-free and success rates with m-PNL, the routine use of DJ stents after RIRS, the need for additional anesthesia during stent removal, and the potential requirement for further minimally invasive procedures should be carefully considered. These factors underscore the importance of individualized treatment decisions, particularly in pediatric patients, with the preferences of the child's family taken into account.

#### DECLARATIONS

**Ethics Committee Approval:** The study was approved by Sakarya University Ethics Committee (No: 123, Date: 15/04/2024).

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**Peer-review:** Externally peer-reviewed.

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