

## Ultra-mini Percutaneous Nephrolithotomy (UM-PCNL) with a Semi-rigid Ureteroscope in Preschool Children: An Innovative Experience in Southern Iran

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**Purpose:** Percutaneous nephrolithotomy (PCNL) has undergone extensive modification to reduce complications. One of the recent advances in minimally invasive procedures is the advent of ultra-mini PCNL (UM-PCNL), which provides miniaturized access to the kidney. However, the specific instruments applied in UM-PCNL may not be found in centers with limited resources. This study evaluated the safety, feasibility, results, and short-term complication rates of performing UM-PCNL using a semi-rigid ureteroscope in preschool children.

**Materials and Methods:** Between September 2013 and September 2021, a total of 68 patients, including 42 boys and 26 girls with a mean age of  $3.2 \pm 2.4$  years, underwent UM-PCNL with a 4.5 French tip ureteroscope instead of an ultra-mini nephroscope in children aged less than 7 years old. The procedure was done under general anesthesia in the prone position. The nephrostomy tract was dilated to 12F. Stones were fragmented using a pneumatic lithotripter. Irrigation was done with normal saline.

**Results:** The early stone-free rate (SFR) was 91%, and the short-term total SFR was 97%. No statistically significant difference was found in pre-operative and post-operative Hb, BUN, Cr, Na<sup>+</sup>, and K<sup>+</sup>. Fever (11 patients) and ileus (5 patients) constituted the majority of complications, and only one patient required a blood transfusion. None of the cases undergoing UM-PCNL with this method required a re-do PCNL.

**Conclusion:** Our experience shows that with sufficient experience in handling semi-rigid ureteroscopes, urologists practicing in centers with limited resources could perform UM-PCNL with relatively favorable outcomes.

**Keywords:** ultra-mini percutaneous nephrolithotomy; renal calculi; ureteroscope; children

### INTRODUCTION

Pediatric urolithiasis has become more prevalent globally in the past few decades. This shift in the pattern of stone development can be attributed to changes in lifestyle and environmental conditions, which have led to an increase in the prevalence of kidney stones as opposed to bladder stones. Technological progress and widespread imaging use have also raised the possibility of stone detection<sup>(1)</sup>. Children account for approximately 2-3% of all stone formers<sup>(2)</sup>. Utilizing a 28-30F ureteroscope, percutaneous nephrolithotomy (PCNL) is the gold standard treatment for large renal and staghorn stones in children (more than 20 mm) and lower pole stones (greater than 10 mm) in adults<sup>(3)</sup>. However, it is still a backup option for minor renal calculi<sup>(4)</sup>. Over the past 45 years since its inception, PCNL has seen numerous changes and improvements. The main goal of these modifications has been to deliver a greater stone clearance rate while minimizing complications, morbidity, procedure length, and hospital stay<sup>(5)</sup>. Several different PCNL methods exist, such as standard (S-PCNL), mini-PCNL (or mini-perc), ultra-mini (UM-PC-

NL), and micro-PCNL. Complications and outcomes of PCNL procedures are affected by the size of the renal access and the corresponding specialized equipment<sup>(6-8)</sup>. While employing a 10F pediatric cystoscope on young children, Helal et al. were the first to design and publish the "mini-perc" technique, reducing the standard approach's complications. According to their results, this method had an SFR of 85 percent with minimum morbidity in infants and young children<sup>(9)</sup>. Additionally, it has been demonstrated to be effective against all sorts of upper tract stones<sup>(10)</sup>. The ureteroscope typically used in adults is replaced in UM-PCNL by a nephroscope encased in a small metal sheath. The final procedure uses unique equipment and a micro-PCNL. Because the 4.85F needle is inserted into the collecting system under direct visualization, micro-PCNL combines renal access and PCNL into a single procedure<sup>(11)</sup>. Our center did not possess the required nephroscope; therefore, we performed UM-PCNL with a 4.5 French tip semi-rigid ureteroscope in preschool children under seven.

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**Table 1.** Demographic characteristics of 68 preschool patients who underwent ultra-mini PCNL with a semi-rigid ureteroscope

Variables	n (%) or Mean (SD)
Gender	
Male	42 (61.8%)
Female	26 (38.2%)
Age (years)	3.2 ± 2.4
Previous failed ESWL	22 (32.3%)
Previous surgery on involved kidney	17 (25%)
Solitary kidney	2 (2.9%)
Stone size (mm)	14.0 ± 3.4
Stone location	
Pelvis	38 (55.9%)
Lower pole	21 (30.9%)
Partial staghorn (pelvis + upper or lower pole)	9 (13.2%)
Stone laterality	
Right	29 (42.6%)
Left	39 (57.3%)
Radiopacity of stone	
Opaque	53 (77.9%)
Lucent	15 (22.1%)
Hydronephrosis	
Mild	14 (20.6%)
Moderate	43 (63.2%)
Severe	11 (16.2%)
Pre-operation Hb (g/dL)	14.0 ± 2.6
Pre-operation BUN (mg/dL)	23.0 ± 4.5
Pre-operation Cr (mg/dL)	1.3 ± 0.3
Pre-operation Na <sup>+</sup> (mmol/L)	136.0 ± 3.6
Pre-operation K <sup>+</sup> (mmol/L)	4.4 ± 0.48

Data are presented as mean ± SD or number (percent)

**Abbreviations:** SD, standard deviation; ESWL, extracorporeal shock wave lithotripsy; Hb, hemoglobin; BUN, blood urea nitrogen; Cr, creatinine

## PATIENTS AND METHODS

### Study population and design

In this single-center study, we evaluated all recorded data of the short-term results and complications of UM-PCNL in preschool children under seven years old, done from September 2013 to September 2021 at our referral teaching center in Shiraz, Iran. One surgeon operated on all patients. The ethical committee approved this research study at Shiraz University of Medical Sciences (IR.SUMS.REC.1400.635).

All patients were referred by pediatric nephrologists for metabolic and imaging evaluation. Ultra-sonography or X-ray imaging was used to determine the size of the stone by determining its longest diameter. In the case of multiple stones, the sum of the longest diameters was measured. All children with an indication for PCNL were included in this study except those with complex staghorn renal stones and bleeding disorders. Short-term complications were those occurring within the first three post-operative weeks. In this analysis, the lack of stone particles or their size being less than 4 mm is considered stone-free.

Further assessments were done on each patient, including physical examination, hemoglobin level, complete blood count, urinalysis and urine culture, blood coagulation tests, blood urea nitrogen (BUN), creatinine (Cr), and electrolytes (Na<sup>+</sup> and K<sup>+</sup>) separately before and after the operation. All patients had negative pre-operative urine cultures.

### Surgical technique and outcome assessment

All surgeries were carried out under general anesthesia, following approval from the patient's guardian via informed consent at an interview with the physician and an adequate demonstration of UM-PCNL. A three-

four-French ureteral catheter was placed into the ureter of the affected kidney by cystoscope and fixed to a urethral Foley catheter. Then, the patient was repositioned in a prone position. The chest, abdomen, knee, and ankle were padded. Under fluoroscopy, ultrasound, or combination guidance, the intervention was initiated by inserting an 18-gauge Chiba needle into the target calyx. The fluid jet validated the location and penetration of the needle. Following that, a 0.035-inch J-tip guidewire was inserted via the needle sheath into the pelvicalyceal system (PCS) and, if possible, into the ureter. The nephrostomy tract was dilated to 12F, remaining as an Amplatz sheath in the PCS. The table height was adjusted for handling the long ureteroscope and lithotripter and preventing inadvertent bending, both designed for ureteroscopy. The Amplatz sheath was maintained in place by an assistant. We shortened the length of the Amplatz for better irrigation drainage and used a non-balloon ureteral catheter 3-4 Fr, which facilitated simultaneous downward irrigation flow to the bladder and Foley bag. To solve the irrigation problem, by increasing the height, we adjusted the pump speed to have a better view. In fact, using a pneumatic lithotripter 0.8 mm, tilting the table toward the affected side, handling the Amplatz by an assistant, and in some cases of large/hard stone (Complex staghorn not included in this study), we had to split the Amplatz longitudinally for better visualization and stone extraction with basket or forceps. The semi-rigid ureteroscope with a 4.5F tip was used as a substitute for an ultra-mini nephroscope (**Figure 1 & Figure 2**).

Stones were fragmented using a pneumatic lithotripter. Irrigation was done with normal saline. Most stone particles were removed by irrigation and tilting the table toward the surgeon, and some were extracted for analysis. A nephrostomy tube or JJ stent was used in some circumstances. Patients were monitored in the hospital for at least 24 hours. In addition to the final fluoroscopy for stone-free status, plain abdominopelvic (KUB) radiography and sonography for lucent stones were performed. The day after surgery, the ureteral stent and urethral Foley catheter were removed. If the patients were stable, they were discharged and returned one week later, then once a month through OPD follow-up. Any short-term complications occurring over the first three post-operative weeks were included in this study. Statistical analyses were performed using RStudio software version 1.2.5042 (Integrated Development for R. RStudio, Inc., Boston, MA). Based on the Shapiro-Wilk normality test, the paired sample t-test was used to evaluate continuous data with a normal distribution, whereas the Wilcoxon signed-rank test was used to compare non-normal variables. A *p*-value of < 0.05 was considered significant.

## RESULTS

A total of 76 available patient records were assessed, with 8 excluded due to insufficient data or missed follow-up. The clinical records of 68 children (42 boys and 26 girls) were reviewed. The average age for the study group at the time of intervention was 3.2 ± 2.4 years. There was unequal gender distribution among those undergoing this procedure (42 M: 26 F). All patients were Iranian and of Middle Eastern descent, and no racial disparity was observed among the study group. Our data revealed more procedures on the left kidney than

**Table 2.** Short-term outcomes of UM-PCNL with semi-rigid ureteroscope of 68 preschool patients

Variables	n (%) or Mean (SD)
<b>Stone clearance status</b>	
Early stone free	62 (91.1%)
Final stone free	66 (97.0%)
<b>Access method</b>	
Pure fluoroscopy	52 (76.5%)
Combined fluoroscopy/ultrasound	16 (23.5%)
Operation time (minutes)	45.0 ± 18.0
Fluoroscopy screening time (minutes)	1.3 ± 0.8
<b>Post-operation tube</b>	
Nephrostomy	9 (13.2%)
Without nephrostomy (tubeless:48/DJ:6)	54 (79.4%)
Totally tubeless	5 (7.3%)
Post-operation hospitalization (hours)	46.0 ± 8.0
Post-operation Hb (g/dL)	13.0 ± 2.6
Post-operation BUN (mg/dL)	25.0 ± 3.5
Post-operation Cr (mg/dL)	1.4 ± 0.4
Post-operation Na <sup>+</sup> (mmol/L)	134.0 ± 2.8
Post-operation K <sup>+</sup> (mmol/L)	4.6 ± 0.3
<b>Complications: Grade I</b>	
Fever	11 (16.2%)
Ileus	5 (7.3%)
<b>Complications: Grade II</b>	
Blood transfusion	1 (1.5%)
Rise of Cr	2 (2.9%)
Urine leakage	3 (4.4%)
Infection (UTI)	none
<b>Complications: Grade III</b>	
DJ placement for urine leakage	3 (4.4%)
Residual stone > 4 mm	1 (1.5%)
Distal ureteral stones need ureteroscopy	1 (1.5%)
Redo-PCNL	none
<b>Complications: Grade IV</b>	
Urosepsis	none
Visceral injury	none
<b>Complications: Grade V</b>	
Death	none

Data are presented as mean ± SD or number (percent)

**Abbreviations:** SD, standard deviation; Hb, hemoglobin; BUN, blood urea nitrogen; Cr, creatinine; UTI, urinary tract infection; DJ, double-J stent; PCNL, percutaneous nephrolithotomy

those on the right side (39 L: 29 R). No cases of bilateral kidney involvement were reported. The majority of stones were found in the renal pelvis (n= 38) or lower pole (n= 21), and the remainder were classified as incomplete staghorn calculi. The mean stone size was recorded at 14.0 ± 3.4 mm before intervention. One single kidney patient underwent percutaneous nephrostomy tube insertion two weeks before surgery due to fever, obstructive stone, and rising creatinine levels.

Seventeen patients had undergone previous surgery on the affected kidney, including previous pyeloplasty, PCNL, and transurethral lithotripsy (TUL), and twenty-two reported previously failed shock wave lithotripsy on the kidney selected for operation. Patients received treatment through single tract access; no supra-costal access was achieved. The mean surgery (PCNL) duration was 45 minutes (25-60 min). Pre-operative laboratory data included blood Hb, BUN, Cr, Na<sup>+</sup>, and K<sup>+</sup> levels. Prior surgical and other interventions on the affected kidney are recorded, as shown in **Table 1**.

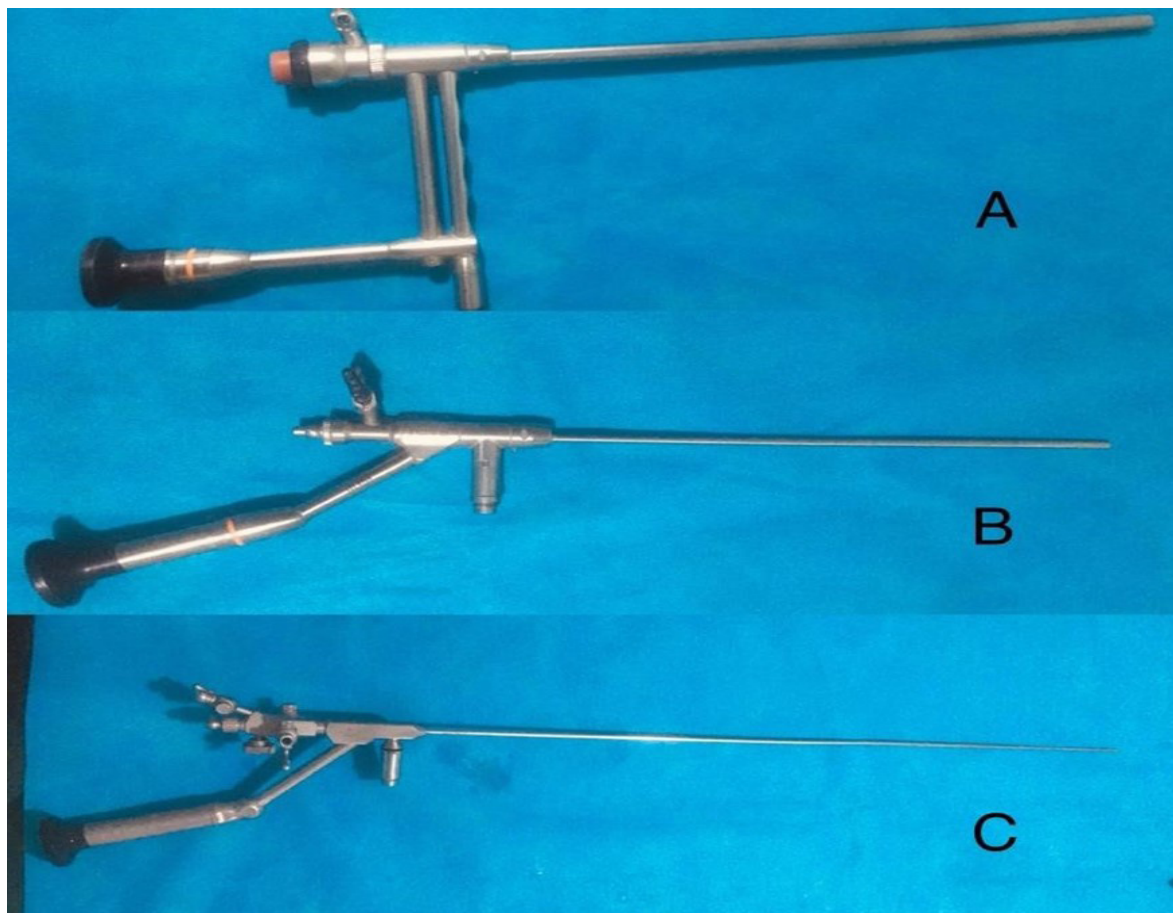
No conversion to open surgery was necessary, and there was no statistically significant difference between pre-operative and post-operative Hb, BUN, Cr, Na<sup>+</sup>, and K<sup>+</sup> levels. According to post-operative KUB X-ray and ultrasonography, sixty-six patients (91.1%) had an early stone-free rate (SFR) immediately after surgery. In contrast, one patient had a lower pole residual of 6 mm. Five patients had small fragments that passed in three weeks. One patient had a migrated stone fragment

to the distal ureter, which underwent Ureteroscopy. The final stone-free status was recorded after three weeks, and a 97% success rate was achieved. The average hospitalization lasted forty-six hours. The modified Clavien-Dindo scale was used to assess the complication rates. Although the total short-term complication rate was recorded at 39.37%, low-grade fever and ileus requiring conservative treatment were the most common findings among those undergoing surgery (16.1% and 7.3%, respectively). No cases of pyelonephritis were recorded. Only one patient required a blood transfusion after surgery. No patient underwent a re-do UM-PCNL using this protocol (**Table 2**).

Medical records indicate that patients did not present any significant concern at the last follow-up. A median follow-up of 31 months was recorded among the participants, with no considerable complication; however, our study criteria only included complications occurring during the first three post-operative weeks and after that followed by a pediatric nephrologist who referred them for surgery. Patients were followed in the nephrology clinic and referred to us if needed accordingly.

## DISCUSSION

Due to its prevalence, urolithiasis and its treatment are growing globally and are important<sup>(12)</sup>. Many intervention methodologies have been implemented based on the stone's size, location, and patient variables. Minimally invasive techniques are varied, including extra-



**Figure 1.** Comparison of three different nephroscope types. (A) Standard nephroscope (24/27 Fr.). (B) Miniature nephroscope (15 Fr.). (C) Semi-rigid ureteroscope used as nephroscope for ultra-mini PCNL.

corporeal shock wave lithotripsy (ESWL), conventional standard PCNL, mini-PCNL, retrograde intrarenal surgery (RIRS), and the recently introduced UM- and micro-PCNL. When PCNL is being considered as the surgical method, there is a choice to be made between surgery with fewer complications, less time in the hospital, less infection, and less need for blood transfusions, on the one hand, and surgery with a higher stone-free rate using a more practical instrument with a larger tract size, on the other. Compared to less intrusive techniques like ESWL, PCNL has a significantly greater success rate in achieving stone-free status but a higher complication rate<sup>(13-17)</sup>. Complications are primarily related to the access tract size. A decreased tract size could theoretically result in a less invasive operation with a lower rate of complications and morbidity. Contrary to this theory, sufficient evidence has demonstrated that the success rate is unaffected<sup>(11,18)</sup>. This diminution in tract size can explain the absence of any requirement for blood transfusion or placement of a nephrostomy tube, a conclusion consistent with earlier published research<sup>(18,19)</sup>. Development in technology has led to miniaturized equipment used in PCNL with a smaller nephrostomy tract size called standard PCNL, mini-PCNL, and the recently introduced UM-PCNL. Since its introduction by Desai et al. in 2011<sup>(1)</sup>, UM-PCNL has proved to be a less invasive method with

fewer peri and post-operative complications. Its safety and minimally invasive properties could lower bleeding rates and morbidity without affecting the procedure's success rate. RIRS should also be considered an advantageous method in endourology among minimally invasive methods. However, high equipment costs and variations in the renal system anatomy cast doubt on its popularity and success rate<sup>(20-22)</sup>. Moreover, lower calyceal remaining fragments can cause the recurrence of renal stones<sup>(22)</sup>. Our study aims to evaluate the safety, feasibility, and efficacy of UM-PCNL in preschool children (under seven years old) by using an innovative method using a 4.5 Fr. tip semi-rigid ureteroscope in centers where an ultra-mini nephroscope is not accessible and a less invasive procedure is planned by the surgeon. In our study, the early stone-free rate accounted for 91.1%, and the ultimate SFR stood at 97%, which is compatible with other studies. In the present study, the average operative time was forty-five minutes, and the average hospital stay was 2.6 days. There were no significant intraoperative or post-operative complications. Previous studies have indicated the feasibility of using the semi-rigid ureteroscope as an alternative to the conventional ultra-mini nephroscope. However, there have been reports of significant drops in post-operative hemoglobin values, which could raise concerns regarding the safety of this procedure. A study by Haghghi et al.



**Figure 2.** Semi-rigid ureteroscope applied as a nephroscope for ultra-mini PCNL.

demonstrated that applying a semi-rigid ureteroscope for UM-PCNL could significantly reduce hospitalization duration and visual analog scale (VAS) pain scores compared to standard PCNL. Furthermore, there were no significant differences in operation time for PCNL (from puncture to wound closure), need for auxiliary procedures, or stone-free rate (93.5%). Despite favorable findings regarding the applicability of the semi-rigid ureteroscope, a significant increase in blood transfusion rates was found to be a limiting factor in the success rate of this procedure<sup>(6)</sup>. In contrast, we found no significant difference among the evaluated laboratory parameters before and after surgery. Furthermore, our experience shows a higher short-term total SFR. However, the comparison of SFR between studies should be evaluated carefully by implementing the role different confounders may play in the final surgical outcome. It is imperative to outline the impact that prior surgical experience using the semi-rigid ureteroscope may have on complication rates. The semi-rigid ureteroscopes' length is more than the ultra-mini nephoscopes'; therefore, handling would require more expertise. In a study concentrated on UM-PCNL outcomes conducted by Desai et al., the mean surgical time was reported as  $59.8 \pm 15.9$  minutes and the mean hospital stay as  $3.0 \pm 0.9$  days. In this study, immediate SFR was 88.9%, and the total SFR after one month was 97.2%<sup>(11)</sup>. Sofimajidpour et al. conducted a study on applying UM-PCNL in children under the age of eight. They found an SFR of 95.5%, an average operation duration of  $58.6 \pm 5.7$  minutes, and an average hospital stay of  $44.7 \pm 15.3$  hours<sup>(23)</sup>. A systematic review conducted by Jones et al. revealed slightly higher overall complications in ultra-mini PCNL compared with mini-PCNL<sup>(5)</sup>. An overall blood transfusion rate of 2.1% in UM-PCNL was

reported. Stone-free status was greater in UM-PCNL than in M-PCNL, ranging from 85 to 100 percent for the former and 80 to 100 percent for the latter. Despite its reputation as a less invasive procedure, PCNL cannot be regarded as completely safe. However, it continues to be the conventional therapy for stones larger than 20 mm. The tract created to access the kidney explains operative complications, the most important of which is bleeding<sup>(5,16,24)</sup>. As the tract size remains an essential criterion affecting intra- and post-operative complications, it is considered that a smaller tract size can lead to less organ damage, bleeding, hospital stay, and further consequent complications. The findings in our study are in concordance with those reported in the aforementioned systematic review conducted by Jones et al.<sup>(5)</sup>

This study has several limitations that should be considered when assessing the results. First, this retrospective study lacks any comparison to a suitable control population. As with all retrospective studies, our work may have been subject to selection bias; however, we aimed to reduce the risk of bias by double-checking all available data. Certain confounders that may have influenced our results include gender, age, height, weight, the presence of anatomical abnormalities, and the presence of comorbidities. The two-dimensional measurement of stone size in our study could be replaced by 3D measurements, producing a more realistic estimate of stone size. As we lacked 3D measurement software during data gathering, we analyzed the results using two-dimensional measurements.

As stated in the methods section, we utilized a 4.5F semi-rigid ureteroscope, which is longer than a mini-nephroscope and more challenging to manipulate. The small body size of the children, the short distance

of kidney to skin, limited area of manipulation of instruments, and lack of LASER lithotripter, all were our faced problems. In addition, we could not undertake the dusting process since we lacked the Ho: YAG laser apparatus. This action may have affected our results, although the validity of this claim should be assessed in future randomized clinical trials with larger sample sizes.

## CONCLUSIONS

Regarding previous studies on minimally invasive PCNL, we performed ultra-mini PCNL on children under seven. We were not discouraged by the absence of an ultra-mini nephroscope in our center, and consequently, we used an innovative method, using a semi-rigid ureteroscope instead. Results obtained during this study explain the safety and feasibility of this method as a minimally invasive procedure in treating pediatric renal stones. Further studies and research will be needed to compare this method with other invasive and non-invasive methods mentioned in this article, especially the standard UM-PCNL.

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The authors declare that the above manuscript complies with Ethical Standards for research on human participants. This research was also approved by the ethical committee of Shiraz University of Medical Sciences (IR.SUMS.REC.1400.635). The authors of this study appreciate the cooperation of the operation theatre and urology ward staff at Ali-Asghar Hospital, Shiraz University of Medical Sciences. Furthermore, the authors wish to thank Prof. Nasrin Shokrpour, scientific writing and editing advisor of the Center for Development of Clinical Research of Namazi Hospital, Shiraz, Iran, for her invaluable comments in editing this manuscript.

## CONFLICT OF INTEREST

The authors report no conflict of interest.

## REFERENCES

- Mishra DK, Bhatt S, Palaniappan S, et al. Mini versus ultra-mini percutaneous nephrolithotomy in a paediatric population. *Asian J Urol.* 2022; 9:75-80.
- Schwarz RD, Dwyer NT. Pediatric kidney stones: long-term outcomes. *Urology.* 2006; 67:812-6.
- Sung YM, Choo SW, Jeon SS, Shin SW, Park KB, Do YS. The "mini-perc" technique of percutaneous nephrolithotomy with a 14-Fr peel-away sheath: 3-year results in 72 patients. *Korean J Radiol.* 2006; 7:50-6.
- Tekgöl S, Stein R, Bogaert G, et al. European Association of Urology and European Society for Paediatric Urology Guidelines on Paediatric Urinary Stone Disease. *Eur Urol Focus.* 2022; 8:833-9.
- Jones P, Bennett G, Aboumarzouk OM, Griffin S, Somani BK. Role of Minimally Invasive Percutaneous Nephrolithotomy Techniques-Micro and Ultra-Mini PCNL (<15F) in the Pediatric Population: A Systematic Review. *J Endourol.* 2017; 31:816-24.
- Haghighi R, Zeraati H, Ghorban Zade M. Ultra-mini-percutaneous nephrolithotomy (PCNL) versus standard PCNL: A randomised clinical trial. *Arab J Urol.* 2017; 15:294-8.
- Eslahi A, Ahmed F, Hosseini MM, et al. Minimal invasive percutaneous nephrolithotomy (Mini-PCNL) in children: Ultrasound versus fluoroscopic guidance. *Arch Ital Urol Androl.* 2021; 93:173-7.
- Eslahi A, Hosseini MM, Ahmed F, et al. Totally ultrasound-guided minimally invasive percutaneous nephrolithotomy in children: Is it safe? *Afr J Paediatr Surg.* 2022; 19:68-72.
- Helal M, Black T, Lockhart J, Figueroa TE. The Hickman peel-away sheath: alternative for pediatric percutaneous nephrolithotomy. *J Endourol.* 1997; 11:171-2.
- Li X, He Z, Wu K, et al. Chinese minimally invasive percutaneous nephrolithotomy: the Guangzhou experience. *J Endourol.* 2009; 23:1693-7.
- Desai MR, Sharma R, Mishra S, Sabnis RB, Stief C, Bader M. Single-step percutaneous nephrolithotomy (microperc): the initial clinical report. *J Urol.* 2011; 186:140-5.
- Scales CD, Jr., Smith AC, Hanley JM, Saigal CS. Prevalence of kidney stones in the United States. *Eur Urol.* 2012; 62:160-5.
- Albala DM, Assimos DG, Clayman RV, et al. Lower pole I: a prospective randomized trial of extracorporeal shock wave lithotripsy and percutaneous nephrostolithotomy for lower pole nephrolithiasis-initial results. *J Urol.* 2001; 166:2072-80.
- Srisubat A, Potisat S, Lojanapiwat B, Setthawong V, Laopaiboon M. Extracorporeal shock wave lithotripsy (ESWL) versus percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS) for kidney stones. *Cochrane Database Syst Rev.* 2014:Cd007044.
- Sabnis RB, Jagtap J, Mishra S, Desai M. Treating renal calculi 1-2 cm in diameter with minipercutaneous or retrograde intrarenal surgery: a prospective comparative study. *BJU Int.* 2012; 110:E346-9.
- Michel MS, Trojan L, Rassweiler JJ. Complications in percutaneous nephrolithotomy. *Eur Urol.* 2007; 51:899-906; discussion
- Tefekli A, Ali Karadag M, Tepeler K, et al. Classification of percutaneous nephrolithotomy complications using the modified Clavien grading system: looking for a standard. *Eur Urol.* 2008; 53:184-90.
- Bader MJ, Gratzke C, Seitz M, Sharma R, Stief CG, Desai M. The "all-seeing needle": initial results of an optical puncture system confirming access in percutaneous nephrolithotomy. *Eur Urol.* 2011; 59:1054-9.
- Jackman SV, Docimo SG, Cadeddu JA, Bishoff JT, Kavoussi LR, Jarrett TW. The "mini-perc" technique: a less invasive alternative to percutaneous nephrolithotomy. *World J Urol.* 1998; 16:371-4.
- Preminger GM. Management of lower pole renal calculi: shock wave lithotripsy versus

- percutaneous nephrolithotomy versus flexible ureteroscopy. *Urol Res.* 2006; 34:108-11.
21. Resorlu B, Oguz U, Resorlu EB, Oztuna D, Unsal A. The impact of pelvicaliceal anatomy on the success of retrograde intrarenal surgery in patients with lower pole renal stones. *Urology.* 2012; 79:61-6.
  22. Monga M, Best S, Venkatesh R, et al. Durability of flexible ureteroscopes: a randomized, prospective study. *J Urol.* 2006; 176:137-41.
  23. Sofimajidpour H, Zarei B, Rasouli MA, Hosseini M. Ultra-Mini-Percutaneous Nephrolithotomy for the Treatment of Upper Urinary Tract Stones Sized between 10-20 mm in Children Younger Than 8 Years Old. *Urol J.* 2020; 17:139-42.
  24. Skolarikos A, de la Rosette J. Prevention and treatment of complications following percutaneous nephrolithotomy. *Curr Opin Urol.* 2008; 18:229-34.