Percutaneous nephrolithotomy in pediatric age group: Assessment of effectiveness and complications

Ender Ozden, Mehmet Necmettin Mercimek

Ender Ozden, Department of Urology, Faculty of Medicine, Ondokuz Mayis University, 55210 Samsun, Turkey
Mehmet Necmettin Mercimek, Department of Urology, Faculty of Medicine, Sanko University, 27090 Gaziantep, Turkey

Author contributions: Ozden E and Mercimek MN contributed equally to this paper, generated the tables and wrote the manuscript; and Ozden E designed the aim of the editorial and provided necessary corrections.

Conflict-of-interest statement: The authors have no relation with the companies and products mentioned in this study and authors declare nothing to disclose.

Open-Access: This article is an open-access article which was selected by an inhouse editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

Correspondence to: Ender Ozden, MD, FEBU, Associate Professor, Department of Urology, Faculty of Medicine, Ondokuz Mayis University, Kurupelit Campus, Atakum, 55210 Samsun, Turkey. eozden@omu.edu.tr
Telephone: +90-532-4467976

Received: August 28, 2015
Peer-review started: September 6, 2015
First decision: October 27, 2015
Revised: November 14, 2015
Accepted: December 13, 2015
Article in press: December 14, 2015
Published online: January 6, 2016

Abstract
Management of kidney stone disease in pediatric population is a challenging condition in urology practice. While the incidence of kidney stone is increasing in those group, technological innovations have contributed to the development of minimally invasive treatment of urinary stone disease such as mini-percutenous nephrolitotomy (mini-PCNL), micro-PCNL, ultra mini-PCNL. In this review we tried to evaluate the effect of new treatment techniques on pediatric kidney stones.

Key words: Percutaneous nephrolithotomy; Pediatric; Kidney stone; Urolithiasis

© The Author(s) 2016. Published by Baishideng Publishing Group Inc. All rights reserved.

Core tip: In this article, minimally invasive treatment options of pediatric kidney stone disease are examined. Also, the effectiveness and complication rates of these techniques were reviewed in the light of recent publications.

INTRODUCTION
The incidence of kidney stones in pediatric population is increasing and is reported that 50 cases per 100000 children[1]. The majority of kidney stones contain calcium. Most consist of calcium-oxalate but to a lesser extent calcium phosphate. Much less commonly kidney stones consist of urate, cysteine or struvite. Unlike adults, urinary stone disease in pediatric population is associated with genetic, metabolic and anatomical causes. Children with urolithiasis are considered high
risk for recurrent stone formation, and it is crucial for children to receive a treatment method that will provide them stone free\textsuperscript{20}.

Most pediatric urinary stones can be managed effectively by minimally invasive treatment modalities such as extracorporeal shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), retroperitoneal intrarenal surgery (RIRS)\textsuperscript{3}. However, PCNL can have a significant role in cases involving large and/or SWL resistant stones. According to the European Association of Urology guidelines, PCNL is recommended as primary treatment option for large renal stones (> 20 mm) and also for > 10 mm stones of the lower renal pole\textsuperscript{41}.

The surgical management of pediatric kidney stones with PCNL has been developed due to improvement of endourologic devices and acquired experiences. Standard PCNL required 24-30 F nephrostomy sheath for renal access. But this method is associated with complications such as hemoglobin drop, blood transfusion, damage of renal parenchyma, and postoperative analgesic requirement. In order to decrease morbidity associated with PCNL in pediatric patients small size instruments have been used. Thus, PCNL is performed with small size endoscopes via smaller percutaneous tract in diameters ranging from 11 F to 20 F and this was named as Miniperc or Mini-PCNL\textsuperscript{5}. Recently, Micro-PCNL or microperc has been described as another minimally invasive PCNL technique that is performed through a 4.8 F all-seeing needle\textsuperscript{6}.

The literature was reviewed for success and complication rates regarding recent PCNL techniques in pediatric age group.

**MINI-PCNL: SURGICAL TECHNIQUE, SUCCESS AND COMPLICATION RATES**

The first pediatric PCNL was described using a 15 F peel-away sheat and 10 F pediatric cystoscope by Helal et al\textsuperscript{5} in 1977. Yet, this technique was developed using an 11 F access sheat by Jackman et al\textsuperscript{8} in pediatric patients. Since then, the new form of PCNL has become a treatment option for adults as well\textsuperscript{9,10}. The first 12 F nephroscope was presented to perform mini-PCNL in 2001\textsuperscript{9}. The new device consisted of 15 F and 18 F sheats, a system of continuous low pressure irrigation, and a 6 F working channel. In time, this technique has developed and also accumulated in the pediatric patients for the treatment of renal stones regardless of the size of the stone. There is no common consensus as to exact size that is used for mini-PCNL, but usually access sheats below 20 F is accepted\textsuperscript{41}.

Mini-PCNL is performed under general anesthesia. After introduction of anesthesia with the patient in the lithotomy position, retrograde ureteral catheterization is performed with 3-5 F ureteral catheter to fill the collecting system during percutaneous access. Then, the patient is repositioned in the prone position with a 30\textdegree-45\textdegree upward tilt of the affected site. Adequate padding of the pressure points should be done to prevent pressure induced injuries and neuropaxias\textsuperscript{12,13}. Prone position is the most preferred technique but it has been reported that supine position vs prone position has equal safety and effectiveness\textsuperscript{14}. Percutaneous renal access is achieved under the fluoroscopic and/or ultrasonic guidance. A lower pole posterior calyx access is preferred, but site of renal puncture may vary depending on localization and burden of stone and renal anatomy. Puncture tract dilatation is performed with dilators, followed by placement of the sheath. According to the endoscopic equipment used in mini-PCNL different sheath size has been reported in literature. Although most preferred one is 16 F sheath, 15 F, 16 F, 18 F or 20 F sheaths have been used. Also, the most common endoscopes used are 9 F, 5 F ureteroscope, 12 F and 15 F mini-nephroscopes\textsuperscript{15,16}. According to the localization of the stone 7 F, 9 F and 14 F flexible ureteroscopes can be used. Stone disintegration is usually performed with laser and/or pneumatic lithotripsy that vary according to the surgeon preference\textsuperscript{17}.

PCNL is a challenging procedure in pediatric population because of the small kidney and the low tolerance to blood loss. The use of the mini-PCNL technique is becoming increasingly popular in the treatment of kidney stones in pediatric patients.

In the first publications, standart PCNL technique was performed for the treatment of kidney stone in children and stone-free rate (SFR) has been reported to be 47%–98%\textsuperscript{18,19}. Adult instruments were used with minimal complications. Badway et al\textsuperscript{19} reported their results of 60 children using a 26 F and 28 F Amplatz sheat. SFR was reported approximately 84% with PCNL monotherapy, with one only procedure being abandoned due to intraoperative bleeding. Samad et al\textsuperscript{18} performed 188 PCNLs using a 17 F or 26 F nephroscope in children aged 6-16 years. SFR was reported 47% after PCNL monotherapy and transfusion rate was 3%. Bilen et al\textsuperscript{20} compared the use of 26 F, 20 F and 14 F Mini-PCNL.

The mean patient age of the children in each group was 13.2 years, 5.9 years and 6.3 years, respectively. The stone burden, previous surgery and the mean hae-moglobin drop postoperatively did not change between the groups; however, the blood transfusion rate was higher in the 26 F and 20 F Amplatz sheath groups. The SFR was highest in the Mini-PCNL group, at 90%, compared to 69.5% in the 26 F and 80% in the 20 F group.

There is no consensus on definition of SFR. It is usually considered as stone fragments smaller than 3 or 4 mm. But untreated residual fragments can cause a stone related events. Due to the fact that pediatric patients have a risk for stone recurrence. It is important to achieve complete stone clearance by selected treatment methods in the treatment of kidney stones in pediatrics\textsuperscript{21}.

Wang et al\textsuperscript{22} reported their results of 247 renal units with calculi in 234 patients who underwent mini-PCNL aged under 3 years. All procedure were performed by
Table 1  Mini-percutaneous nephrolitotomy

| Ref.       | Year | Renal unit | Mean age | Stone size (mean) | Tract | Mean operative time (min) | Initial SFR % | Complications (% overall) |
|------------|------|------------|----------|-------------------|-------|--------------------------|---------------|--------------------------|
| Ozden et al\[25\] | 2010 | 100        | 9.5 yr   | 507.5 mm²         | 20.8 F (mean) | 79.1                     | 85            | 25                       |
| Zeng et al\[26\] | 2012 | 20         | 20.6 mo  | 2.2 cm            | 14-16 F     | 77.5                     | 95            | NR                       |
| Resoru\[a\] et al\[27\] | 2012 | 106       | 9.6 yr   | 23.7 mm           | 12-22 F     | 76.3                     | 85.8          | 17                       |
| Yan et al\[28\] | 2012 | 27         | 42.6 mo  | 1.85 cm           | 14-16 F     | 86.5                     | 85.2          | 15                       |
| Wals et al\[29\] | 2013 | 23         | 4.76 yr  | 3.44 cm²          | 16 F       | 109.4                    | 83.6          | 14                       |
| Omal et al\[29\] | 2013 | 1205      | 8.8 yr   | 4.09 cm²          | Cutoff size 20 F | 93.5                 | 81.6          | 27.7                     |
| Elderwy et al\[30\] | 2014 | 47        | 8 (median) yr | 2.3 cm (median) | 20-24 F | 90                      | 91.4          | 10.6                     |
| Desoky et al\[31\] | 2015 | 22        | 9.5 yr   | 2.4 cm            | 20 F       | 65.1                     | 90.9          | 3.6                     |
| Brodie et al\[32\] | 2015 | 46        | 7.3 yr   | NM                | 16 F       | NR                       | 76            | NR                       |

NR: Non reported; NM: Not measured; SFR: Stone-free rate.

Table 2 Modified clavien classification

| Grade | Description |
|-------|-------------|
| Grade I | Any deviation from the normal postoperative course without the need for treatment |
| Grade II | Requiring pharmacological treatment with drugs Blood transfusions and total parenteral nutrition are also included |
| Grade III | Requiring surgical, endoscopic or radiological intervention |
| Grade IIIa | Intervention not under general anesthesia |
| Grade IIIb | Intervention under general anesthesia |
| Grade IV | Life-threatening complication requiring ICU/ICU management |
| Grade IVa | Single organ dysfunction (including dialysis) |
| Grade IVb | Multiorgan dysfunction |
| Grade V | Death of a patient |

ICU: Intensive care unit.

single tract, including 24S 14 F tracts, 1 16 F tract and 1 12 F tract, respectively. 191 cases had stone burden 1-2 cm² and 30 cases stone burden > 2 cm², 26 cases < 1 cm². Mean operating time was 32.5 min (range 21-62 min). Complete stone free rate has been reported as 240 renal unit (97.2%). In another mini-PCNL study SFR rates has been reported as 90.8% in stone burden < 20 mm, but 76.3% in stone burden > 20 mm\[23\]. In Table 1, there is an overview of the recent published data of mini-PCNL.

Due to the minimally invasive nature of mini-PCNL in the case of providing complete stone clearance and a clear nephrostomy tract makes the procedure in tubeless manner. Bilen et al\[32\] evaluated result of tubeless (ureteral catheter but no nephrostomy drainage tube) vs conventional mini-PCNL (nephrostomy drainage tube) in infants and preschool children. In this study with 28 renal unit in 26 patients, the tubeless mini-PCNL group had significantly shorter surgery and fluoroscopy times. Complications rates were higher and duration of hospitalization were longer in the nephrostomy group. Stone-free rates were reported as 91.6% and 78.5% in tubeless and nephrostomy group, respectively.

The aim of the minimally invasive PCNL is to reduce complications such as blood loss, intraoperative -postoperative pain and hospital stay. On the other hand it is believed that a small calibre tract is less injurious to nephrons. But many authors have reported that 24-26 F dilatation does not cause significant morbidity in children, it has been reported that there is no advantage in using a small access based on renal scoring alone\[33\]. The caliber and number of tracts are associated with intraoperative hemorrhage during PCNL in children\[34\]. Complication rates have significantly reduced with the development of the smallest and least traumatic endoscopic appliances. Moreover, it is reported that there is a significant correlation of intraoperative bleeding with duration of surgery, stone burden and sheath size\[35\]. In addition that it is stated that operative time, sheath size, mid calyceal puncture and partial staghorn formation are independent predictors of complications\[36\].

It is important that using a common definition in the expression of complication to determine the risk factors for complications. Recently, the modified Clavien system for classifying surgical complications has been used for this purpose\[36\]. But complications are not always reported according to this system in recent publications (Table 2). Modified Clavien Classification has been shown.

The fist time, Ozden et al\[34\] indicated perioperative complications of PCNL in pediatric patients using the modified Clavien grading system. Transient fever (grade I) is one of the most frequent complication. But it is not always microbial in origin\[37\]. It is determined that transient fever rate is 31% in 188 PCNLs. However, postoperative infection is reported in approximately 6% of pediatric patients\[38\].

Bleeding is a serious complication during intraoperative and postoperative period in pediatric patients which is associated with sheath size, stone burden, number of tracts and operative time. Hemoglobin drop requiring transfusion (grade II) is reported in 0.4%-24% of patients\[39,40\]. In another study higher hemoglobin drop
has been determined in pediatric patients performed PCNL when size of the tract dilatation exceeded 22 F\cite{34}. There is a debate on the classification of grade III complication, is that auxiliary procedures such as RIRS, SWL and second look PCNL. It is recommended to consider them as part of treatment strategy. However, such as hydrothorax requiring chest tube or urine leakage requiring urinary diversion can be classified as Clavien grade III complication\cite{24}. It is said that grade III, IV, V complications should be quite rare and more likely associated with surgical techniques and experience\cite{41}. Complication rates have been shown in literature in Table 3.

### ULTRA-MINI PCNL: SURGICAL TECHNIQUE AND NEW REPORTS

In 2013, the new PCNL technique was described by Desai et al\cite{34} using a novel 6 F mini nephroscope through an 11-13 F metal sheath to perform holmium: YAG laser lithotripsy. The new procedure was performed in 36 patients with a mean stone size 14.9 mm. Two patient were preschool children. It was reported that mean operative time, stone free rate at postoperative 1st day and 1st month were 59.8%, 88.9%, and 97.2%, respectively. Complication rate were reported as 16.6% in 6 patients, according to Clavien classification, including 2 sepsis, 1 urinary extravasation, and 3 fever. The authors determined that there was no needed blood transfusion\cite{43}. In another study results of 62 patients were reported using a 3.5 F nephroscope. Nephrostomy tract was dilatated up to 13 F. Only four of the 62 patients were children. Mean stone size was 16.8 mm, stone free rate at the 1st month was reported approximately 87%\cite{44}. There is no sufficient data available to compare this new technique with other methods which use for the treatment of pediatric urinary stones. The new technique's effectivness and safety remain to be seen in larger prospective studies in pediatric patients.

### MICRO-PCNL: SURGICAL TECHNIQUES

Recently, Micro-PCNL or microperc has been described as another minimally invasive PCNL technique that is performed through a 4.85 F all-seeing needle. A three-way connector is attached to the latter, which admits a saline irrigation tube, 0.9 or a 0.6 mm-diameter micro-optic, a 272 μm laser fiber. The outher diameter of this modified needle is 1.6 mm (4.85 F). The first time this new technique was used in 15 adults. Mean stone size, operation time was 30.4 mm, 101.4 min, respectively. Postoperative complete stone clearance achieved in 11 patients\cite{45}. Since then this method has addedopted to the tretament of pediatric kidney stones. In a study, 24 infant treated with micro-PCNL. The mean age, stone size, operation time were 15.8 mo, 13.5 mm, 53.7 min, respectively. There is no major complication and hemorrhage drop requiring blood transfusion reported\cite{46}. More experience and more knowledge is needed for the effectiveness of this method.

### REFERENCES

1. Sas DJ, Hulsey TC, Shatat IF, Orak JK. Increasing incidence of kidney stones in children evaluated in the emergency department. *J Pediatr* 2010; 157: 132-137 [PMID: 20362300 DOI: 10.1016/j.jpeds.2010.02.004]
2. Tasian GE, Copelovitch L. Evaluation and medical management of kidney stones in children. *J Urol* 2014; 192: 1329-1336 [PMID: 24960469 DOI: 10.1016/j.juro.2014.04.108]
3. Tekgül S. Ureteroscopy versus shock wave lithotripsy for renal calculi in children. *J Urol* 2011; 185: 1188-1189 [PMID: 21334638 DOI: 10.1016/j.juro.2011.01.047]
4. Tekgül S, Dogan HS, Erdem E. Uinary stone disease, guidelines on pediatric urology. *EAU Urol Guidel* 2015; 56-58
5. Mishra S, Sharma R, Garg C, Kurien A, Sabnis R, Desai M. Prospective comparative study of miniperic and standard PNL for treatment of 1 to 2 cm size renal stone. *BJU Int* 2011; 108: 896-899; discussion 899-900 [PMID: 21477212 DOI: 10.1111/j.1464-410x.2010.09936.x]
6. Ramón de Fata F, García-Tello A, Andrés G, Redondo C, Melián E, Gimbernat H, Angulo JC. Comparative study of retrograde intrarenal surgery and micropercutaneous nephrolithotomy in the
treatment of intermediate-sized kidney stones. *Acta Urol Exp* 2014; 38: 576-583 [PMID: 24934458 DOI: 10.1016/j.acue.2014.09.007]

7 Helal M, Black T, Lockhart J, Figueroa TE. The Hickman peel-away sheath: alternative for pediatric percutaneous nephrolithotomy. *J Endourol* 2001; 15: 111-112 [PMID: 11380547 DOI: 10.1016/s0893-1381(01)00152-6]

8 Jackman SV, Hedican SP, Peters CA, Docimo SG. Percutaneous nephrolithotomy in infants and preschool age children: experience with a new technique. *Urology* 1998; 52: 697-701 [PMID: 9763096 DOI: 10.1016/s0090-4295(98)00315-x]

9 Lahme S, Bichler KH, Strohmaier WL, Götz T. Minimally invasive PCNL in patients with renal pelvic and calyceal stones. *Eur Urol* 2001; 40: 619-624 [PMID: 11805407 DOI: 10.1016/s0302-2838(01)00498-4]

10 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: 371-374 [PMID: 9870281 DOI: 10.1007/s0034598050083]

11 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-E349 [PMID: 22847041 DOI: 10.1111/j.1464-410x.2012.11098.x]

12 Xiao B, Zhang X, Hu WG, Chen S, Li YH, Tang YZ, Liu YB, Li JX. Mini-percutaneous Nephrolithotomy Under Total Ultrasonography in Patients Aged Less Than 3 Years: A Single-center Initial Experience from China. *Chin Med J (Engl)* 2015; 128: 1596-1600 [PMID: 26663360 DOI: 10.4103/0969-6669.158312]

13 Jeong CW, Yoon SY, Cho KS, Park JH, Seong JH, Hong SK, Byun SS, Lee SE. Seoul National University Renal Stone Complexity Score for Predicting Stone-Free Rate after Percutaneous Nephrolithotomy. *PLOS One* 2013; 8: e65888 [PMID: 23824752 DOI: 10.1371/journal.pone.0065888]

14 Ozden E, Li ZC, Zhou XF, Yang F, Huang JF, Lu MH. Supine percutaneous nephrolithotomy in children less than three years of age: five-year experience in 234 cases. *Urol Int* 2014; 92: 433-439 [PMID: 24732725 DOI: 10.1055/s-0035355573]

15 Abdelhafiz MF, Amend B, Bedke J, Kruck S, Nagele U, Stenzl A, Schilling D. Minimally invasive percutaneous nephrolithotomy: a comparative study of the management of small and large renal stones. *Urology* 2013; 81: 241-245 [PMID: 23374768 DOI: 10.1016/j.urology.2012.09.030]

16 Ozden E, Mercimek MN, Yakupoglu YK, Ozkaya O, Sarikaya S. Modified Clavien classification in percutaneous nephrolithotomy: assessment of complications in children. *J Urol* 2011; 185: 264-268 [PMID: 21074805 DOI: 10.1016/j.juro.2010.09.023]

17 Zeng G, Zhao Z, Zhao Z, Yuan J, Wu W, Zhong W. Percutaneous nephrolithotomy in infants: evaluation of a single-center experience. *Urology* 2012; 80: 408-411 [PMID: 22743259 DOI: 10.1016/j.urology.2012.04.058]

18 Resorlu B, Unsal A, Tepeler A, Atis G, Tokatli Z, Oztuna D, Armagan A, Gurbuz C, Caskurlu T, Saglam R. Comparison of retrograde intrarenal surgery and mini-percutaneous nephrolithotomy in children with moderate-size kidney stones: results of multi-institutional analysis. *Urology* 2012; 80: 519-523 [PMID: 22676346 DOI: 10.1016/j.urology.2012.04.018]

19 Yan X, Al-Hayek S, Gan W, Zhu L, Xi G, Huo H. Minimally invasive percutaneous nephrolithotomy in preschool age children with kidney calculi (including stones induced by melamine-contaminated milk powder). *Pediatr Surg Int* 2012; 28: 1021-1024 [PMID: 22729672 DOI: 10.1007/s00383-012-3112-8]

20 Wah TM, Kidger L, Kennish S, Irving H, Najmaldin A. MINI PCNL in a pediatric population. *Cardiovasc Intervent Radiol* 2013; 36: 249-254 [PMID: 22918446]

21 Onal B, Dogan HS, Satar N, Bilen CY, Güneş A, Ozden E, Ozturk A, Demirci D, Istanbuluğlu O, Gurock S, Nazli O, Tanriverdi O, Kefi A, Korgali E, Silay MS, Inci K, Izol V, Altintas R, Kilicarslan H, Sarikaya S, Yalcin V, Aygun C, Gevher F, Arıdogan IA, Tekgül S. Factors affecting complication rates of percutaneous nephrolithotomy in children: results of a multi-institutional retrospective analysis by the Turkish pediatric urology society. *J Urol* 2014; 191: 777-782 [PMID: 24095906 DOI: 10.1016/j.juro.2013.09.061]

22 Elderwy AA, Gadelmoula M, Elgammal MA, Osama E, Al-Hazmi H, Hammouda H, Ousman E, Abdullah MA, Neel KF. Percutaneous nephrolithotomy in children: A preliminary report. *Urol Int* 2014; 93: 187-191 [PMID: 25125889 DOI: 10.4103/0974-7796.134255]

23 Desoky EA, ElSayed ER, Eliesa A, Sleem M, Shabana W, Dawood T, Teleb M, Khalil S. Flank-free Modified Supine Percutaneous Nephrolithotomy in Pediatric Age Group. *Urology* 2015; 85: 1162-1165 [PMID: 25794427 DOI: 10.1016/j.urology.2015.01.030]

24 Bilen CY, Gunay M, Ozden E, Inci K, Sarikaya S, Tekgul S. Tubeless mini percutaneous nephrolithotomy in infants and preschool children: a preliminary report. *J Urol* 2010; 184: 2498-2502 [PMID: 20961572 DOI: 10.1016/j.juro.2010.08.039]

25 Traxer O, Smith TG, Pearle MS, Corwin TS, Saboorian H, Cadeddu JA. Renal parenchymal injury after standard and mini percutaneous nephrolithotomy. *J Urol* 2001; 165: 1693-1695 [PMID: 11342957 DOI: 10.1016/s0022-5347(05)66395-1]

26 Desai MR, Kukreja RA, Patel SH, Bapat SD. Percutaneous nephrolithotomy for complex pediatric renal calculus disease. *J Endourol* 2004; 18: 23-27 [PMID: 15066048 DOI: 10.1089/089827790432836613]

27 Zeren S, Satar N, Bayazit Y, Bayazit AK, Payasli K, Özköçer R. Percutaneous nephrolithotomy in the management of pediatric renal calculi. *J Endourol* 2002; 16: 75-78 [PMID: 11962558 DOI: 10.1089/0898277902753619546]

28 Tekfali A, Ali Karadag M, Tepeler K, Sari E, Berberoglu Y, Baykal M, Sarlar O, Muslimanoglu AY. Classification of percutaneous nephrolithotomy complications using the modified clavien grading system: looking for a standard. *Eur Urol* 2008; 53: 184-190 [PMID: 17651892 DOI: 10.1016/j.eururo.2007.06.049]

29 Xiao B, Hu W, Zhang X, Chen S, Li Y, Li J. Ultrasonoud-guided mini-percutaneous nephrolithotomy in patients aged less than 3 years: the largest reported single-center experience in China. *Urolithiasis* 2015; Epub ahead of print [PMID: 26232329 DOI: 10.1007/s10990-015-0089-x]
38 Samad L, Qureshi S, Zaidi Z. Does percutaneous nephrolithotomy in children cause significant renal scarring? J Pediatr Urol 2007; 3: 36-39 [PMID: 18947696 DOI: 10.1016/j.jpurol.2006.02.001]

39 Bogris S, Papatsoiris AG. Status quo of percutaneous nephrolithotomy in children. Urol Res 2010; 38: 1-5 [PMID: 19921165 DOI: 10.1007/s00240-009-0240-2]

40 Zeng G, Zhao Z, Wan S, Zhong W, Wu W. Comparison of children versus adults undergoing mini-percutaneous nephrolithotomy: large-scale analysis of a single institution. PLoS One 2013; 8: e66850 [PMID: 23826158 DOI: 10.1371/journal.pone.0066850]

41 Zeng G, Zhao Z, Wan S, Mai Z, Wu W, Zhong W, Yuan J. Minimally invasive percutaneous nephrolithotomy for simple and complex renal caliceal stones: a comparative analysis of more than 10,000 cases. J Endourol 2013; 27: 1203-1208 [PMID: 23924320 DOI: 10.1089/end.2013.0061]

42 Pan J, Chen Q, Xue W, Chen Y, Xia L, Chen H, Huang Y. RIRS versus mPCNL for single renal stone of 2-3 cm: clinical outcome and cost-effective analysis in Chinese medical setting. Urolithiasis 2013; 41: 73-78 [PMID: 23532427 DOI: 10.1007/s00240-012-0533-8]

43 Desai J, Zeng G, Zhao Z, Zhong W, Chen W, Wu W. A novel technique of ultra-mini-percutaneous nephrolithotomy: introduction and an initial experience for treatment of upper urinary calculi less than 2 cm. Biomed Res Int 2013; 2013: 490793 [PMID: 23984372]

44 Desai J, Solanki R. Ultra-mini percutaneous nephrolithotomy (UMP): one more armamentarium. BJU Int 2013; 112: 1046-1049 [PMID: 23841665 DOI: 10.1111/bju.12193]

45 Bader MJ, Gratzie 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: 1054-1059 [PMID: 21477921 DOI: 10.1016/j.eururo.2011.03.026]

46 Dede O, Sancaktutar AA, Bağ O, Dağgülli M, Utangaç M, Penbegul N, Soylemez H, Hatipoglu NK, Bodakci MN, Bozkurt Y, Atar M, Dede G. Micro-percutaneous nephrolithotomy in infants: a single-center experience. Urolithiasis 2015; Epub ahead of print [PMID: 26209010 DOI: 10.1007/s00240-015-0807-z]
