Percutaneous Nephrolithotomy in Pediatric Patients

Jun Li, Bo-Yu Yang, and Hui-Min Zhao

Abstract Pediatric urolithiasis is a relatively rare disease in urology. According to the American Urological Association (AUA) 2016 Surgical Treatment Guidelines, surgery is recommended for patients who are unable to pass stones spontaneously after 4–6 weeks of observation and who are unresponsive to 4–6 weeks of medical therapy. Extracorporeal shock wave lithotripsy (ESWL) is the treatment of choice in most cases involving upper urinary tract stones, while percutaneous nephrolithotripsy (PCNL) is appropriate for more complex or unique types of kidney stones. Pediatric patients require a thorough assessment and preparation prior to undergoing PCNL. Age is not a limiting factor for surgery and infants as young as a few months can safely undergo PCNL as long as appropriate surgical equipment and adjunctive therapy are used. As 75%–84% of kidney stones in children are associated with genetic metabolic disorders, and 50% of children have symptomatic recurrences within three years of their first occurrence, the number of surgeries performed throughout a child's lifetime should be minimized. Since children are growing and developing, an ultrasound-guided technique is preferred because it avoids the harmful effects of radiation. The literature reports stone-free rates after PCNL ranging from 68 to 100%. Any remaining stones can be treated with a second phase of surgery or a combination of extracorporeal shock wave lithotripsy and flexible ureteroscopy lithotripsy.

Keywords Percutaneous nephrolithotom · Kidney stones · Nephrolithiasis · Urolithiasis · Minimally invasive surgery · Stone removal · Renal calculi · Percutaneous access · Nephroscope · Endourology · Lithotripsy · Stone fragmentation · Kidney anatomy · Renal pelvis · Calyces · Staghorn calculi · Fluoroscopy · Ultrasound-guided access · Tubeless percutaneous nephrolithotomy · Postoperative care

J. Li (✉) · B.-Y. Yang · H.-M. Zhao
Department of Urology, Capital Medical University Affiliated Beijing Friendship Hospital, Beijing 100050, China
e-mail: lljun@yeah.net

J. D. Denstedt and E. N. Liatsikos (eds.), *Percutaneous Renal Surgery*,
https://doi.org/10.1007/978-3-031-40542-6_21

1 Indications and Contraindications

Indications and contraindications for PCNL in children are similar to those in adults (Grivas et al. 2020).

(1) Indications
(2) Staghorn calculi
(3) Renal pelvis stone > 2 cm
(4) Lower calyceal stones > 1 cm
(5) Cystine stones unsuitable for flexible ureteroscopy lithotripsy (FURS)

For special types of kidney stones, such as cystine or uric acid stones, the effectiveness of extracorporeal lithotripsy is often limited due to a high recurrence rate. In cases where being stone-free is critical, PCNL may be a preferred option. PCNL can also be used for upper ureteral stones with severe obstruction or a diameter greater than 1.5 cm in patients who have failed ureteroscopy or extracorporeal lithotripsy. It is important to select surgical instruments and PCNL methods appropriate for children, considering factors such as stone location, stone burden, age, and kidney size.

(B) Contraindications

In summary, contraindications for PCNL surgery in children are similar to those in adults:

1. Uncorrected systemic bleeding;
2. Patients with medical comorbidities precluding aanethesia;
3. Patients with untreated severe urinary tract infection;
4. Patients with renal tuberculosis;
5. Patients with untreated primary hyperoxaluria (PHO) type I/II.

2 Operative Position

PCNL can be performed in a variety of surgical positions, including prone, supine, and lateral. The prone position allows a wider range of equipment to be used and is the most common position for children with PCNL in China. However, it can be difficult for anesthesiologists to control tracheal intubation and is not convenient for resuscitation. The supine position was first used in adults by Valdivia et al. in 1987 and has many potential advantages in pediatric PCNL techniques. Data on the use of supine PCNL in children support its safety and high efficacy in stone clearance rates, even for infants under 1 year of age Vaddi et al. (2021). The modified Valdivia position, used in a small number of pediatric patients with the MicroPerc technique, has also shown satisfactory success and safety. In supine PCNL, the urinary tract is level or slightly upwardly inclined relative to the operating table, allowing rapid drainage of irrigating fluid and stone debris from the body, reducing the risk of hypothermia and severe postoperative infection. This position also addresses anesthesia limitations associated with the prone position. Lateral lithotomy at PCNL was first performed in morbidly obese patients in 1994 and has proven anesthetic advantages in patients with severe medical risk factors or comorbidities, as well as in patients with morbid obesity or kyphosis (Sultan et al. 2019).

3 Preoperative Preparation

In pediatric patients, it is critical to minimize bleeding during surgery due to smaller kidneys and correspondingly lower blood volume, making them less tolerant to bleeding. The use of adult surgical instruments can result in renal injury and massive bleeding, emphasizing the need for minimally invasive techniques in pediatric PCNL. Technological advances have led to the development of several minimally invasive PCNL techniques with reduced surgical channel size, including mini-PCNL (14–20 Fr), ultra-mini PCNL (11–13 Fr), ultra-mini PCNL (14 Fr) and micro-PCNL (4.8Fr), have all been successfully used in the treatment of children with kidney stones. Smaller tracts result in less renal injury and less bleeding. Standard PCNL (sPCNL) using 24–30 Fr channels is associated with high stone clearance rates (>90%) but also carries the risk of kidney injury and excessive bleeding requiring blood transfusion, particularly in children (Sultan et al. 2019). While sPCNL is recommended for staghorn stones in adults, it is not suitable for the growing and developing kidneys of children, especially those of infants with a renal size of only 5 to 6 cm. Compared to mini PCNL associated complications with standard PCNL are more common and more severe according to some studies (Tefekli et al. 2008). Therefore, minimally invasive techniques such as mini-PCNL and micro-PCNL are preferred in pediatric patients to minimize bleeding and reduce the risk of complications.

Mini-PCNL is a modified version of sPCNL, which utilizes a smaller access channel of 14 to 20 Fr, compared to the larger 24–30 Fr channel used in sPCNL. Surgical endoscopes typically consist of 8.0–9.8 Fr rigid ureteroscopes or 8.5–12.5 Fr nephroscopes with high-pressure endoscope perfusion pumps. Fascial dilators are used to dilate the percutaneous renal channel, starting at 8 Fr and gradually expanding to 14 to 20 Fr. Compared with sPCNL, mini-PCNL has several advantages, including reduced incidence of complications such as bleeding, less perioperative pain, shorter hospital stay, and lower treatment costs (Bodakci et al. 2014). Mini-PCNL is recommended for the management of kidney stones smaller than 2.5 cm, although multiple tracts can be established to treat larger stones (Ganpule et al. 2016a). Studies (Utangac et al. 2016) have shown that mini-PCNL has a much lower complication rate than sPCNL, with an overall complication rate of 12% compared to 24% in sPCNL ($P = 0.048$). The incidence of bleeding requiring blood transfusion is also significantly lower in mini-PCNL patients (2.4% vs. 12.9%, $P = 0.013$). Even with the smaller channel size, mini-PCNL has a high stone clearance rate, making it a safe and effective treatment option for pediatric patients with kidney stones.

To improve the safety and efficacy of mini-PCNL while minimizing complications, Desai et al. (2013) introduced Ultra-Mini-PCNL (UMP). UMP adopts 3 Fr optical system, 7.5 Fr nephroscope and 11–13 Fr metal channel, with high stone-free rate and low complication rate. Desai et al. (2013) compared UMP with RIRS for the treatment of kidney stones ranging from 1.0 to 3.5 cm, and both techniques were found to have a high stone-free rate and a low rate of complications. Additionally, Dede et al. (2015) reported that UMP achieved a final SFR of 87.1% in the treatment of 39 children with renal calculi, with no children requiring blood transfusions during the perioperative period. In 2015, Zeng et al. (2016) suggested the use of a super mini PCNL {SMP} involving an 8 Fr micronephroscope, and 12 Fr and 14 Fr irrigation and suction sheaths. The unique design of the flushing suction sheath tube allows for separate irrigation and aspiration, thereby improving the efficiency of stone clearance despite the use of a smaller instrument. With an incision size of only 3 mm, the stone can be directly aspirated through the suction device after being fragmented to 2 mm using a laser. The SMP's suction sheath is double-layered, with the sandwich filling the patient's pelvis while also absorbing water and debris without the need for additional tubing. Bleeding in the kidney is stopped through autologous tissue compression and an autologous coagulation mechanism after the operation, and pain is minimized for the patient, making SMP a minimally invasive surgery. The procedure is performed under fluoroscopic guidance in the prone position using a 7 Fr nephroscope with an outer channel sheath ranging from 10 to 14 Fr. SMP has been successfully performed on 141 adult patients with a mean stone size of 2.2 cm, resulting in a reported SFR of 90.1% (Zeng et al. 2016). No major complications were reported, and 72.3% of the patients were catheter-free.

MicroPerc is a novel hybrid surgical instrument, which consists of a 4.8 Fr puncture needle and a surgical channel. The first part is the working outer sheath with a circumference of 4.8 Fr. The second part is the connection device, equipped with three channels that can simultaneously accommodate the imaging fiber, the perfusion device, and the 200–270 μm laser fiber. The preoperative preparation for MicroPerc surgery is similar to conventional nephroscopic surgery, and the patient is placed in a prone position after ureteral catheter or ureteral stent placement. The needle-shaped nephroscope (all-seeing needle) allows for direct visualization of the puncture route after insertion of the optical fiber. Under B-ultrasound guidance, the target renal calices are punctured and the position of the needle is monitored in real time. Once the needle enters the collection system, the working path is established and the working outer sheath is maintained. The inner needle portion is then retracted and a cross connector installed to allow placement of the 200–270 μm holmium laser fiber and lithotripsy perfusion device. The use of MicroPerc's small working channel reduces intraoperative bleeding and injury, thereby eliminating the need for external drainage tubes after surgery. Internal stents can be placed retrogradely according to the intraoperative situation. In comparison to traditional PCNL, MicroPerc minimizes the risk of kidney injury, bleeding, infection, and other surgical complications Ganpule et al. (2016b).

When MicroPerc is combined with holmium laser lithotripsy, a channel can be established through one-step puncture, so that the stones can be crushed and then fragmented and discharged. If the pulverization is complete and the ureter is in good condition, only a 5 Fr ureter catheter is necessary 24–48 hours after the operation.

Fig. 1 a, b: Multi-channel pediatric PCNL, a 14Fr peel-away sheath and two MicroPerc channels, during operation (1a), only a 12Fr nephrostomy tube was needed after operation (1b)

This eliminates the need for stents and external drains after surgery, greatly reducing potential damage to the kidneys and risk of bleeding (Fig. 1). Additionally, secondary anesthesia to remove the stent is not required. Previous clinical research has demonstrated the potential of this approach to improve the quality of life for children, save money on treatment and be effective. For stones smaller than 2 cm in diameter, mPCNL, UMP, and SMP are more appropriate treatment options. These stones can be crushed by pneumatic ballistics or holmium lasers, and then quickly removed from the body using water pressure or a negative pressure device. For older children, children with large volume of hydronephrosis collection system, or children with large stone load and long operation time, the standard channel combined with negative pressure stone removal system can also be used to quickly remove stones, which improves the operation efficiency, shorten the operation time and reduce the incidence of postoperative complications. For relatively simple calculi with a small stone burden, it is possible to avoid the use of an indwelling nephrostomy tube or even a ureteral stent to improve postoperative comfort (Choi et al. 2014).

For conventional percutaneous nephrolithotomy, the following surgical instruments are needed:

1. The renal puncture and dilation set contain a puncture needle with an outer sheath, metal guide wire, fascia dilater, peel-away sheath, nephrostomy tube and cap.
2. Nephroscope and ureteroscope.
3. Lithotripsy equipment and instruments: holmium laser, pneumatic ballistic, stone-removal basket, and stone-removal forceps.
4. Liquid infusion pump.
5. Video observation system, camera system, video conversion system, and monitor.

4 Surgical Procedures

(1) Preoperative preparation

a b

Fig. 2 a, b: Position during pediatric PCNL, lithiotomy position (2a), prone position (2b)

The patient is placed in the lithotomy position, and a 5 Fr ureteral catheter is inserted into the ipsilateral ureter leading to the kidney under the guidance of a cystoscope. The catheter is secured, and the end is connected to an infusion device for continuous perfusion and filling the collection system. Additionally, a 5 Fr double pigtail stent may be inserted according to the patient's body length and estimated ureter length (age number + 10 cm). The bladder (volume estimated as (number of age + 2) * 30 ml) is then filled with saline to provide reflux hydronephrosis. Finally, the chest and abdomen are elevated and the surgical field is exposed (Fig. 2).

(B) Puncture under ultrasound guidance

To prepare for the procedure, the B ultrasound probe is directed parallel to the long axis of the kidney in order to observe the overall outline of the kidney, the location of the stone, and its relationship with the collecting system. Usually, the area between the posterior axillary line and the scapular line is the best area for puncture, and the posterior calyx puncture in the middle group is usually selected first. The needle can be inserted within the plane of B-ultrasound (both end parts of the probe), and for patients with a high stone position, the needle can be inserted from outside the plane of B-ultrasound (lateral part of the probe). The direction of puncture was chosen to be the dorsal calices closest to the dorsal skin, providing the shortest access. Pediatric patients typically have less subcutaneous and perinephric fat, making it easier to lose access when the needle is outside the kidney. During the puncture process, B-ultrasound is used to clarify the path of the puncture needle and prevent deviation. When the puncture needle is successfully inserted into the renal calyceal, urine overflow can be seen after retracting the core of the needle. For some patients with low renal pelvis pressure or mild hydronephrosis, the correct position of the needle tip can be determined by negative pressure suction with a syringe.

(C) Establishment of tracts

Once the needle position is confirmed by B-ultrasound, an ultrastiff guide wire with a "J" tip is inserted along the outer sheath of the puncture needle. The skin and subcutaneous tissue are then incised with a sharp knife, approximately 0.5–1 cm in length. After removing the outer sheath of the indwelling guidewire, the channel is gradually expanded along the guidewire using a fascial dilator. There are two methods to expand the channel: the "step-by-step method" and the "one-step" dilation with a high-pressure balloon. The former involves gradual enlargement of the channel to the desired size using a fascial dilator or a telescoping antenna-style metal dilator. The latter involves expanding the channel to the desired size in one step using a high-pressure balloon. Kidney stones in children form quickly, have a brittle texture, and have a good crushing effect. As a result, after channel establishment, the procedure is usually straightforward. The specific channel specifications should be determined based on the patient's individual circumstances.

(D) Stone removal

After the peel-away sheath is established, a nephroscope or ureteroscope is placed in an antegrade manner, and continuous saline perfusion is used to flush the visual field maintain a clear field of view. The location and general texture of the stones are observed, and the stones are fragmented and removed using lithotripsy devices. Any remaining stones should be extracted. If a ureteral catheter is used for artificial hydronephrosis before the operation, a ureteral stent will be placed at the conclusion of the procedure. Additionally, a nephrostomy tube will be placed.

5 Operation Tips and Tricks

Children have a lower body weight and lower blood volume, and their tolerance to blood loss is poor. During the access procedure, it is critical to emphasize the accuracy of the target and the direction of the needle. The accuracy of the puncture needle point is the key factor in preventing severe bleeding during the perioperative period of percutaneous nephrolithotomy.

When performing infant nephropuncture under ultrasound guidance, the quality of the imaging device is crucial. High-frequency linear array probes are superior to low-frequency convex array probes for infant puncture guidance. Due to the short distance between the kidney and the skin, a high-frequency linear array probe can offer a clear visualization of the kidney structure, particularly the vessels, with the assistance of Doppler technology (Tzeng et al. 2011) (Fig. 3). However, in older and obese children, high-frequency probes may not provide any significant visualization advantage.

When performing infant nephropuncture, it is important to consider the unique anatomical features of children, especially infants, such as their thin skin, subcutaneous tissue, and perirenal tissue. The short distance between the target calyx and the skin provides limited space for adjusting the needle direction and securing the ultra-stiff guidewire. Thus, it is crucial to accurately determine the direction of the needle from the target calyx to the uretero-pelvic junction and ensure that the puncture pathway is long enough to securely hold the guidewire and prevent the loss of the channel during the operation. When expanding the channel, the principle of

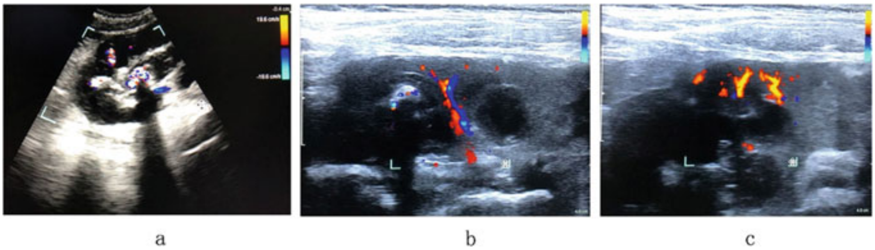


Fig. 3 a, b, c: Infant kidney structure and vessels under ultrasound san. Image from low-frequency convex array probe (3a), image from high-frequency linear array probe (3b, c)

"prefer shallow rather than deep" should be followed. Children have smaller kidney volumes than adults, and basing dilation depth on experience in adults may result in a deep channel that could damage the contralateral collecting system or even the renal pedicle. Therefore, when using facial dilators for channel expansion, it is important to avoid creating channels that penetrate too deeply.

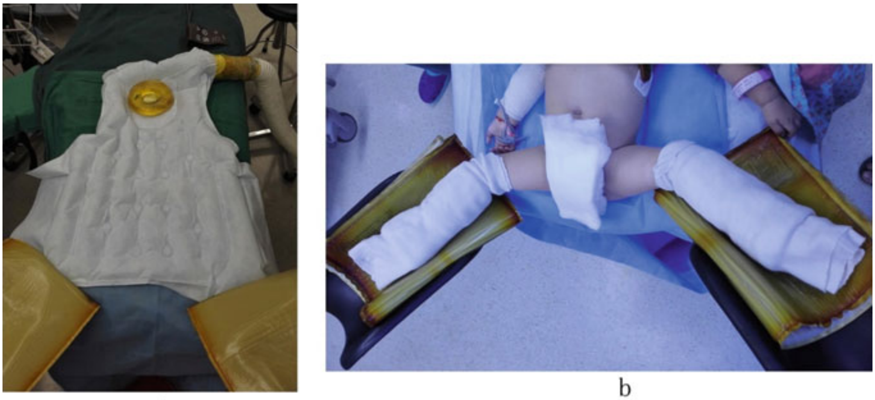
Children's kidneys are more brittle in texture but more compliant, and often multiple adjacent calices can be explored through the target calices. During lithotripsy, attention should be given to solving the main problem through a single channel. If the calyx where the stone is located cannot be explored due to a challenging angle, another channel should be established if necessary to prevent laceration of the renal parenchyma or a calyceal neck caused by excessive exploration.

To ensure the health of children during PCNL, special care must be taken to maintain their body temperature. It is important to note that children are more susceptible to rapid temperature drops due to the use of hypothermic saline during the procedure, which can lead to decreased blood pressure, heart rate, and even endanger their lives. To prevent this, all fluids used during the procedure, including perfusion saline, must be heated to 37 °C. Additionally, a warm blanket should be used to maintain a steady temperature. If possible, the monitor should be equipped with a body temperature monitoring module to allow for continuous tracking of any changes in the child's body temperature (Fig. 4).

6 Postoperative Management

Perioperative management in children is a team effort with physicians and allied health members familiar with the special needs of pediatric patients. Infant patients are unable to express their feelings, and they need to rely on their parents to relay their wishes. Postoperative complications need to be addressed by professional pediatricians and nursing teams.

In pediatric patients, fever, bleeding, and pain are common complications following PCNL. The external drainage tube is typically thin in children, and regular monitoring is necessary to detect any potential obstructions caused by blood clots or



a b

Fig. 4 a, b: Insulation measure, warm blanket for children (4a), arms and legs proof (4b)

stone fragments. Infants and young children have low immune resistance, which can easily cause postoperative fever. Inadequate drainage should be excluded first, and symptomatic drug treatment should be provided according to the cause. Children have low pain tolerance and may require analgesic medication to prevent postoperative pain-induced uncooperative behavior.

When the general condition of the child is stable, the imaging data can be reviewed to observe the position of the internal stent and the residual stone. If reoperation is not needed, the nephrostomy tube and urinary catheter can be removed. The ureteral stent can be removed 2 to 4 weeks after surgery. After the drainage tube is removed, patients and their families should be advised to rest and not engage in strenuous activities to reduce the occurrence of delayed bleeding.

7 Complications and Their Prevention

In children, bleeding, postoperative fever or infection, and persistent urinary fistula are the most frequently reported complications following percutaneous nephrolithotomy. Bleeding is generally associated with stone burden, location, operation time, size of the working sheath, and number of working channels. The need for blood transfusions is reported to be less than 10% in the literature (Ozden et al. 2011; Onal et al. 2014). The proportion of severe bleeding requiring blood transfusion is gradually decreasing with the miniaturization of current access. Accurate puncture and appropriate channel size remain the most important strategies to prevent intraoperative and postoperative bleeding. The use of B-ultrasound-guided puncture not only avoids radiation exposure but also identifies possible blood vessels along the puncture path, which helps the surgeon avoid and prevent injury. In infants with small kidney volumes, a larger channel increases the risk of bleeding and exacerbates kidney injury. Conversely, smaller access reduces the probability and risk of major bleeding. Recent studies have shown that postoperative fever generally occurs in less than 15% of patients, and most early-onset fever is often unrelated to urinary tract infection. Compared to adults, children have poorer self-immunity and resistance, lower tolerance to trauma, and are more likely to develop a fever after surgery. For children, maintaining urine drainage unobstructed after surgery and administering timely and sufficient antibiotics to prevent infection are critical. Adequate drainage during surgery and open drainage after surgery can help prevent a persistent urinary fistula.

8 Recent Advances in PCNL

Nephrostomy is the most commonly employed drainage method following PCNL. Some surgeons also insert a double-J tube in the ureter to enhance drainage into the bladder. The presence of a nephrostomy tube may result in increased postoperative pain and prolonged hospital stay for patients. To address this issue, some surgeons have introduced the concept of tubeless mini-PCNL. Completely tubeless PCNL in children was evaluated and found to be a safe procedure (Softness and Kurtz 2022). A controlled trial comparing tubeless mini-PCNL with mini-PCNL in 70 children under 3 years of age concluded that tubeless mini-PCNL had similar outcomes and safety (such as stone clearance rate, postoperative fever, and hemoglobin decrease) but significantly reduced recovery time (Song et al. 2015).

Endoscopic combined intrarenal surgery (ECIRS) is a novel and promising surgical approach for the treatment of urolithiasis. ECIRS combines RIRS with PCNL and requires two surgeons to operate simultaneously. Specifically, RIRS is utilized to identify stones that may have been missed by PCNL, and these stones are subsequently flushed or grasped and delivered to the renal pelvis for removal via the PCNL channel. This technique leverages the strengths of both PCNL and RIRS, which results in a reduction of the bleeding risk associated with multiple channels and an improvement in stone clearance rates. ECIRS is a viable option for the treatment of complex kidney stones. In a systematic review published in 2020, Cracco and Scoffone (2020) reported that ECIRS boasts a high stone-free rate and a low incidence of Clavien-Dindo grade I and II complications. Moreover, the incidence of grade III, IV, and V complications is minimal. In this study, postoperative bleeding risk was also low, with hemoglobin decreases ranging from 0.8 to 2.1 g/dL.

9 Summary and Future Prospects

The development of pediatric PCNL technology has mainly focused on miniaturization. This is of significant importance in the surgical treatment of pediatric calculi as it can avoid large renal parenchyma injuries in children. Its safety and effectiveness have been established in the pediatric population. PCNL has proven beneficial in the treatment of staghorn and large kidney stones, and pediatric PCNL technology offers a variety of surgical access, locations, and combinations of endoscopic and intrarenal procedures that can eliminate the need for tubes. However, the success rates of stone-free rate (SFR) and stone clearance rate (CR) remain critical factors that surgeons must consider when applying PCNL technology to children with urinary calculi. Currently, there is a lack of expert consensus or an appropriate risk prediction model to help surgeons choose the most suitable surgical approach for individual children. The choice of surgical position will also affect the postoperative SFR and CR of children. Future technical improvements should not only increase the efficiency of existing procedures but also reduce the incidence of complications. Additionally, research on the applicability of various surgical methods for PCNL and the exploration of prediction models for children with stones can assist clinicians in making informed decisions and achieving accurate, personalized treatment. Furthermore, future studies should investigate whether the choice of surgical method needs to be tailored to the stone composition and improved surgical methods for patients with recurrent stones.

References

Bodakci MN, Daggulli M, Sancaktutar AA, Soylemez H, Hatipoglu NK, Utangac MM, Penbegul N, Ziypak T, Bozkurt Y. Minipercutaneous nephrolithotomy in infants: a single-center experience in an endemic region in Turkey. Urolithiasis. 2014;42(5):427–33.

Choi SW, Kim KS, Kim JH, Park YH, Bae WJ, Hong SH, Lee JY, Kim SW, Hwang TK, Cho HJ. Totally tubeless versus standard percutaneous nephrolithotomy for renal stones: analysis of clinical outcomes and cost. J Endourol. 2014;28(12):1487–94.

Cracco CM, Scoffone CM. Endoscopic combined intrarenal surgery (ECIRS)—Tips and tricks to improve outcomes: a systematic review. Turk J Urol. 2020;46(Supp. 1):S46–57.

Dede O, Sancaktutar AA, Dagguli M, Utangac M, Bas O, Penbegul N. Ultra-mini-percutaneous nephrolithotomy in pediatric nephrolithiasis: both low pressure and high efficiency. J Pediatr Urol. 2015;11(5):253 e251–256.

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.

Ganpule A, Chhabra JS, Kore V, Mishra S, Sabnis R, Desai M. Factors predicting outcomes of micropercutaneous nephrolithotomy: results from a large single-centre experience. BJU Int. 2016b;117(3):478–83.

Ganpule AP, Vijayakumar M, Malpani A, Desai MR. Percutaneous nephrolithotomy (PCNL) a critical review. Int J Surg. 2016a;36(Pt D):660–4.

Grivas N, Thomas K, Drake T, Donaldson J, Neisius A, Petrik A, Ruhayel Y, Seitz C, Turk C, Skolarikos A. Imaging modalities and treatment of paediatric upper tract urolithiasis: a systematic review and update on behalf of the EAU urolithiasis guidelines panel. J Pediatr Urol. 2020;16(5):612–24.

Onal B, Dogan HS, Satar N, Bilen CY, Gunes A, Ozden E, Ozturk A, Demirci D, Istanbulluoglu O, Gurocak 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, Aridogan IA, Tekgul 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(3):777–82.
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(1):264–8.
Softness KA, Kurtz MP. Pediatric stone surgery: what is hot and what is not. Curr Urol Rep. 2022;23(4):57–65.
Song G, Guo X, Niu G, Wang Y. Advantages of tubeless mini-percutaneous nephrolithotomy in the treatment of preschool children under 3 years old. J Pediatr Surg. 2015;50(4):655–8.
Sultan S, Aba Umer S, Ahmed B, Naqvi SAA, Rizvi SAH. Update on surgical management of pediatric urolithiasis. Front Pediatr. 2019;7:252.
Tefekli A, Ali Karadag M, Tepeler K, Sari E, Berberoglu Y, Baykal M, Sarilar O, Muslumanoglu AY. Classification of percutaneous nephrolithotomy complications using the modified clavien grading system: looking for a standard. Eur Urol. 2008;53(1):184–90.
Tzeng BC, Wang CJ, Huang SW, Chang CH. Doppler ultrasound-guided percutaneous nephrolithotomy: a prospective randomized study. Urology. 2011;78(3):535–9.
Utangac MM, Tepeler A, Daggulli M, Tosun M, Dede O, Armagan A. Comparison of scoring systems in pediatric mini-percutaneous nephrolithotomy. Urology. 2016;93:40–4.
Vaddi CM, Ramakrishna P, Pm SS, Anandan H, Ganesan S, Babu M. Supine percutaneous nephrolithotomy in a 9-month infant. Urol Case Rep. 2021;34:101424.
Zeng G, Wan S, Zhao Z, Zhu J, Tuerxun A, Song C, Zhong L, Liu M, Xu K, Li H, Jiang Z, Khadgi S, Pal SK, Liu J, Zhang G, Liu Y, Wu W, Chen W, Sarica K. Super-mini percutaneous nephrolithotomy (SMP): a new concept in technique and instrumentation. BJU Int. 2016;117(4):655–61.