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Minimally Invasive Surgical Approaches to Kidney Stones in Children

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Abstract The existing treatment options for pediatric urolithiasis are endoscopic methods. Extracorporeal shockwave lithotripsy (SWL) is the first-line option for most of the kidney stones smaller than 1 cm in diameter. For larger stones or refractory cases, minimally invasive surgical methods are preferred. Percutaneous nephrolithotomy (PCNL) is a well-established treatment modality for most patients. This technique has shown evolution also in children so that miniaturized or tubeless methods could now be performed. Recent series show that flexible ureteroscopy is also becoming an important treatment option in the pediatric urology armamentarium for treating the calyceal and lower pole stones. Open surgery has a very limited role and it may be of use when there is a need to do an adjuvant reconstructive surgery. With the increasing experience, laparoscopic surgery is becoming an alternative option that may have potential to replace the open techniques.

Keywords Children · Pediatric · Kidney · Stone · Minimally invasive · Surgery · Percutaneous nephrolithotomy · Flexible ureteroscopy · Retrograde intrarenal surgery · Laparoscopy · Endoscopy

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Introduction

Pediatric urolithiasis is an important medical problem particularly in some geographic regions of the world. Although it was assumed as a major problem in Middle East, South Asia, and North Africa and a rare incidence in developed countries [1, 2], recent epidemiologic studies showed that the incidence of pediatric stone disease is also increasing in the Western world [3, 4] especially in girls, white race, and older children [5].

The stone locations shift from lower to upper urinary tracts in parallel to the socioeconomic improvements; bladder stones remained as a problem of underdeveloped countries. With technical advancements, the need for open stone surgery has exceedingly become rare. The treatment options for upper urinary tract stone disease are extracorporeal shockwave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), retrograde intrarenal surgery (RIRS), and laparoscopic and open operations. SWL is still the first-line treatment option for most of the cases, though for larger stones (> 20 mm) or in SWL-refractory cases, the alternative interventional modalities come up as an effective choice [6]. This review will focus on the surgical interventional treatment options for upper urinary tract stones in children.

Percutaneous Nephrolithotomy

The first series of pediatric PCNL has been reported by Woodside et al. [7]. Since then, pediatric PCNL has gained a wide popularity and become the standard choice of treatment for the renal stone cases requiring surgical intervention. Although the preoperative evaluation, indications, and surgical technique are based on similar principals as in adults, the concerns on the smaller anatomy and requirement for appropriate sized instruments as well as debates on radiation hazards and effects on renal function are unique considerations for the pediatric population.

Effects on Renal Parenchyma

The effects of this procedure on the renal parenchyma were investigated by a few clinical studies. In one of them, it was shown that there was no evidence of renal scarring in any renal unit on dimercaptosuccinic acid scans (DMSA) and stabilization or improvement of selective glomerular filtration rate with diethylene triamine pentaacetic acid scans (DTPA) in all but 4 of 72 renal units [8]. Samad et al. [9] reported that 5 % (3/60) of patients had renal scar on DMSA postoperatively, although in that study, preoperative scans were absent. Moreover, two studies investigating the effects of endourological treatment methods on renal functions revealed that minimally invasive methods do not cause morphological or functional alterations [10, 11]. Therefore, the available data in the literature suggests that PCNL does not produce renal damage as a method for kidney stone treatment in children.

Access Size and Mini-perc

Although the initial pediatric PCNL series were successfully performed with adult instruments [12, 13], the complication rates (especially transfusion rates) were significantly higher than the modern series [14–17]. Recently, Unsal et al. [18] compared the use of different size instruments in different age groups and commented that endourologic intervention in children usually required instruments specific for preschool aged children; however, in older children with dilated collecting system, the use of adult instruments and techniques may achieve equal results. This finding was similar to the recommendations of Dogan et al. [19], who found that the use of adult-type instruments might have a positive impact on stone-free rate, operation time, and fluoroscopy time without increasing the complication rate, particularly in children with a high stone burden. Despite these satisfactory results, the search for small-caliber instruments with the aim of decreasing the renal and abdominal wall injury, postoperative pain, postoperative hospital stay, and transfusion rates continued. Jackman et al. [20] introduced a new approach, the *mini-perc* technique, firstly with the use of 13 F ureteral sheath (11 F inner diameter), and then described the use of 11 F peel-away vascular access sheath as a working sheath [21], which enabled them to perform the procedure successfully, even without nephrostomy in one case, with no significant postoperative complication. Recently, 14 F renal sheaths were manufactured, and a retrospective study that analyzed the outcomes regarding the sheath diameters (26 F, 20 F, and 14 F) showed the similar results according to the operative and fluoroscopy times, mean hemoglobin decrease, and hospitalization time; however, low blood transfusion rates were associated only with the use 14 F sheath [22]. The miniaturization of the technique was further advanced to the use of 16 G (4.85 F) *all-seeing needle*, which has a three-way connector for a 0.9 mm microoptic, irrigation, and laser fragmentation that enables single-step PCNL (*microperc*). The stone is only fragmented and left in place for spontaneous passage. Desai et al. [23] performed this technique in two children, which might be an alternative for stone sizes less than 20 mm. Besides the mentioned potential benefits of miniature instruments, the direct vision may easily be disturbed by bleeding due to the lesser irrigation fluid flow and smaller fragments can be extracted because of the narrow working sheath. Therefore, one should choose this approach after balancing the benefits and limitations by considering the age of the child and stone burden.

Tubeless PCNL

These advancements encouraged the surgeons to perform *tubeless* PCNLs. The suitable cases for tubeless PCNL were described as follows: neglected double-J stent with stone formation; stone size 2–5 cm or less than 2 cm if failed ESWL as primary treatment; pelvicaliceal anatomy not favorable for clearance after ESWL as in the case of lower calyceal stones; or parents preferring PCNL as the first line of treatment and radiolucent stones after failure of medical treatment [24]. Bilen et al. [25], in their series of mini-PCNL, left only the ureteral catheter in kidney unless a significant parenchymal bleeding or significant residual fragments were present. In this comparative study, the outcomes of two groups (with and without percutaneous nephrostomy) with a similar mean age and preoperative stone burden (nephrostomy group: 416 mm^2 vs tubeless group: 192 mm^2, $P=0.189$) were investigated. Analysis revealed a stone-free rate of 91.6 % in tubeless group (versus 78.5 % in nephrostomy groups [$P=0.395$]) with a significantly decreased operative and fluoroscopy time, complication rates, and postoperative hospital stay. As mentioned above, an indwelling catheter or a double-J stent is left in place in most of the cases. However, a very recent prospective randomized study investigated the feasibility of totally tubeless PCNL in 23 children and stated that it yields decreased hospital stay and analgesic use with no more complications [26•].

Other Conditions

The innovations mentioned above have enabled miniaturization and flexibility of the instruments and accumulation of experience such that concerns on age limitations faded away so that even 5-month-old infants could have undergone PCNL [27–29]. It has now become possible to perform PCNL in any size of stones [30–32], through difficult accesses [33, 34], for anomalous kidneys [35] and even bilateral simultaneously after gaining a significant experience [36, 37].

Therapeutic Outcome

As a monotherapy, PCNL is a very effective treatment modality. Reviews of the current literature demonstrate a stone-free rate over 85 % and approaches 100 % with auxiliary procedures as SWL, ureteroscopy (URS), and second-look PCNL [38–40]. Some authors use these auxiliary procedures or staged operations to decrease the number of tracts and bleeding. Samad et al. [12] reported an increased stone-free rate from 47 to 90 % after the primary PCNL to 90–100 % cumulative stone clearance following the post-PCNL auxiliary SWL. In another study, 30 renal units were treated with PCNL in which 16 needed at least one more sessions and ended up with a stone-free rate of 87 % with no blood transfusion postoperatively [41].

Technical Aspects

PCNL is optimally adapted to children after gaining significant experience in adults. Allen et al. [42] showed that the learning curve of a single surgeon suggests that competence at performing PCNL is reached after 60 cases and excellence after 115. Therefore, some suggest performing at least 100 adult PCNLs before attempting pediatric cases or involving an experienced practitioner who has that level of experience.

Preoperative radiologic imaging and sterile urine is important as in adults. Many urologists prefer to establish the access by themselves under fluoroscopy, though the rational use of fluoroscopy should be established to limit radiation exposure. Use of ultrasonography to establish an access before or during the surgery may be a good alternative that has been shown to have high success and low complication rates in adults [43–45]. However, in pediatric cases, to establish the access under ultrasonography guidance before the surgery will require an additional session under anesthesia, and in cases that require intraoperative additional access, an interventional radiologist should be ready in the operation room, which is not always practically possible. Moreover, if the surgeon would make the intraoperative ultrasonography guided access, he should be experienced in this technique. There are a few articles in the literature that showed the feasibility of ultrasonography guided access in pediatric PCNL series, which can be a practical alternative [46, 47•].

The choice of access establishment should be based on the preference of a posterior calyx to an anterior one, a dilated calyx if possible, a calyx with a long and wide infundibulum, which should offer the extraction of maximum amount of stones on a straight line with pelvis [15]. Despite these similarities, PCNL in children carries some characteristics that deserve special attention. Intraoperatively, dilation should not be larger than 24 F, and particularly for children younger than 3 years old, not larger than 20 F. The smallest caliber instrument that is available and will offer the optimum stone extraction should be preferred. Flexible nephroscope, if available, may be useful for stones in difficult localizations. The dilation may be more difficult than adults because of the hypermobility of kidney in children due to the lesser amount of perirenal fatty tissue. Relatively thin parenchyma and under-recognition of the mucosa–parenchyma border may cause easier unintended sheath dislocation and difficult orientation. Children are more prone to temperature changes and volume loads. Therefore, irrigation fluid should be warm and at low pressure flow to prevent hypothermia and hypervolemia. Additionally, maximum effort for leaving no residual fragment is of utmost importance because of the high recurrence rates in children.

Complications

Range and diversity of complications are similar and complication rates are comparable to adult series [48]. In one unique study, factors affecting the complication rates in pediatric PCNL have been analyzed and regression analysis showed that stone burden and operative time were independent risk factors for complications [49••].

Bleeding is one of the most commonly reported perioperative complications and blood transfusion rate is reported to be up to 24 % [8, 12–15, 36, 50, 51]. In the modern series, it is less than 10 % [17, 18, 24, 29, 48, 49••]. Inappropriate site of entry to kidney (ie, calyceal neck, directly to pelvis, medial entry) may be the initial causes of bleeding. However, intraoperative bleeding mostly occurs due to levering the nephroscope, which causes uncontrolled parenchymal laceration. Instead, for stones at a difficult localization, use of flexible nephroscope, making another access, or leaving the stone in place for auxiliary SWL or second-look PCNL may be less invasive and probably better options. In a study evaluating the outcome of PCNL for staghorn stones in children revealed that blood loss was significantly associated with the use of multiple tracts and dilation more than 24 F [32]. A significant bleeding that disturbs vision most of the times can be stopped by placing the working sheath into the kidney to compress the parenchymal vessels. Increasing the irrigation flow with the hand pump may be used intermittently; however, the risk of extravasation out of collecting system and absorption to systemic circulation risk should be kept in mind. Fulguration of the vessel, if apparent, is also possible after replacing the irrigation fluid with a nonelectrolyte containing fluid; this should be reserved as a last resort. If these conservative measures are not adequate, operation should be halted and a nephrostomy left in the kidney. Clamping the nephrostomy catheter for a time approximately 1 h in association with forced diuresis will be helpful. Conversion to open surgery because of bleeding is rare and reported to occur less than 5 % [14, 27, 52].

Minor renal pelvis extravasation is reported to occur in 5 %, whereas apparent *renal pelvis perforation* is 2–4 % [8, 17, 53]. It can occur as a result of inadvertent manipulation with the nephroscope or during disintegration of the stone. It is managed conservatively by leaving the nephrostomy catheter longer or placement of double-J stent in long-lasting cases. Renal pelvis perforation also can cause the migration of stone out of the kidney. In this case, no attempts to retrieve the stone from the extrarenal area should be done, as it is possible to injure the renal pedicle.

Extrarenal fluid collection is mostly retroperitoneal, but in some instances, intraperitoneal collection may occur. Small perirenal retroperitoneal collections are common and do not require any additional intervention. However, large fluid collections are reported to occur in 1 % of cases and easily managed by a percutaneous drainage catheter [50].

Fever with or without documented urinary tract infection (UTI) is also a commonly reported postoperative complication with a wide range between 2 % and 49 % [8, 12–15, 27, 36, 50–52]. In recent studies, it is reported less than 15 %, which might be attributed to an increased awareness of postoperative infections and subsequent preoperative preventative measures [17, 18, 25, 29, 38, 48, 49••]. Preventive measures are similar for all endoscopic stone surgeries, as described previously. Having a sterile preoperative urine culture is very important. Prophylactic parenteral antibiotics should be given during the anesthetic induction. However, in cases with unresolved preoperative bacteriuria, surgery should be performed under antibiotic treatment.

Prolonged *urinary leakage* through the nephrostomy tract after the removal of nephrostomy catheter is reported to happen in up to 8 % of cases [13, 15, 22, 29, 49••, 50, 52]. This complication mostly occurs due to ureteral obstruction or an unnoticed residual fragment. An internal double-J stent placement will normally resolve this problem.

Neighboring organ injury is a subject of special interest that is actually one of the most bothersome complications. These complications are relatively rare, probably due to surgeons' achievement of a significant experience before the pediatric cases and more cautious approach to a pediatric patient. *Hydrothorax* is one of the neighboring organ injuries. It is reported to occur less than 2 % [22, 49••, 52] and treated with chest tube placement

Colonic injury is another devastating complication. It has been reported three times in the pediatric PCNL literature [27, 29, 53]. The incidence of retrorenal or posterolateral colon location is about 1 % in normal population, whereas it can increase up to 19 % in patients with horseshoe kidneys [54, 55]. The colonic injury in adult PCNL literature varies between 0.2 % and 0.8 % and the risk factors are presence of horseshoe kidney, previous history of renal surgery, colonic distention, and lower pole access to left kidney [56–58]. The situation can be recognized during the operation, on the antegrade pyelography at the end of the procedure, or postoperatively gas/colonic content coming within the nephrostomy or colocutaneous fistula. If the injury is retroperitoneal, it can be treated conservatively by diverting the urinary tract from colon. The nephrostomy can be withdrawn into colon to create a controlled colocutaneous fistula, a stent is placed into the urinary tract, the oral intake is stopped, and the patient is put on antibiotics. Intraperitoneal injuries should be repaired with open surgery because of the peritonitis risk due to fecal contamination. Two of these three patients have been treated conservatively [27, 29] while the other one underwent open surgery [53]. The presence of a retrorenal colon can only be recognized by computerized tomography. However, the routine use of tomography cannot be advocated because of the relatively rare incidence of this pathology, as compared to risks associated with ionizing exposure to radiation and financial costs. Therefore, it would be logical to consider tomography in patients with known risk factors. However, Gedik et al. [53] recommend routine preoperative tomographic imaging since they experienced two retrorenal colon related events (1 injury, 1 open surgery) within a population of 48 patients.

Retrograde Intrarenal Surgery

Since its first use for pediatric stone disease in a case report [59], the effectivity of semirigid ureteroscopy has been shown in details for treatment of ureteric stones and it has been the first-line therapeutic option for ureteral stones in children [6]. As well as the distal and middle ureteral stone cases, several studies also showed the use of nonflexible instruments for the treatment of stones located in proximal ureter, kidney, and calyces [60, 61]. With the significant improvements in the miniaturization and flexibility of endoscopic instruments, flexible ureterorenoscopy (FUR) has become a more attractive option for upper tract stones as in adult counterparts.

There are several reports on ureteroscopic stone treatment; these include a few cases of FUR [62, 63] for which the number of FUR was not reported [64]. The first series with a considerable patient population was reported by Minevich et al. [65] in a heterogeneous group including both rigid and flexible instruments. They used a 7 F flexible ureterorenoscope without a sheath for treatment of stone and ureteral or ureteropelvic strictures. Unfortunately, it is not possible to retrieve the data specifically for stone disease patients from the presented series. One year later, the use of FUR with a 14 F ureteral access sheath for dilation and access of the ureter in eight (five bilateral) children was reported, which showed that routine use of a ureteral access sheath in children facilitated FUR [66]. Smaldone et al. [67] presented a series of 100 consecutive pediatric ureteroscopy series including the use of FUR in 65. Although they didn't give the details on FUR, the authors were favoring the use of ureteral access sheath mostly for the peripubertal age group, avoiding the routine active dilatation of the orifice, instead recommending passive dilatation with preprocedural stent placement. In 2007, Cannon et al. [68] reported a pure FUR series for treatment of lower pole stone disease in 21 children with a success rate of 76 % (93 % for stones <15 mm and 33 % for > 15 mm). They used a ureteral access sheath in 43 % of patients and experienced no intraoperative or postoperative complication. The authors concluded FUR can be considered a primary treatment option for children with lower-pole calculi smaller than 15 mm.

The largest pediatric FUR series was published at the end of 2008. This study included 170 FUR procedures in 167 children in which 60 % of stones were located above ureteropelvic junction [69]. No active dilation was performed in this series. Retrograde access couldn't be obtained in 57 % of patients and they were stented for a couple of weeks for passive dilatation. The preference for ureteral access sheath was the discretion of the surgeon and the percent of access sheath use was not given. The stone-free rate for kidney stones was 97 % after first and 100 % after second session with no intra- or postoperative complications. Because the given data implies that 86 % of renal stones were located in the lower pole, FUR seems to be a good candidate to replace the role of SWL at least for lower pole stones. Another study evaluated the factors that can affect the need for passive dilation in patients who underwent FUR. The study included 30 patients with stones located at proximal ureter or above. In 40 % of patients, it was impossible to reach the stone with flexible instruments despite the dilation attempts and stent placement for passive dilatation was necessary in these patients. The stone-free rate was 93 % with two ureteral perforations during the procedure but no complication in the long term. However, there was no significantly affecting factor to predict the preoperative stenting in terms of age, height, or weight [70].

Despite the aforementioned high stone-free rates, Tanaka et al. [71] reported 50 % stone clearance immediately after the first session, which increased to 58 % with extended follow-up, though with secondary FUR, 78 % of children were rendered stone-free with no significant intra- or postoperative complications. The authors showed that initial stone-free status was dependent on preoperative stone size but not stone location, and younger patient age and larger preoperative stone size were associated with the need for additional procedures. Additional procedures were required in more than half of the stones 6 mm or larger but in no stone smaller than 6 mm. A single-institution study on the efficacy of URS and/or FUR for treatment of kidney stones in 21 patients showed that URS/FUR can be considered as a primary modality for pelvic stones, whereas it has no therapeutic role for partial staghorn cases [72]. There are three more recent studies mentioning the feasibility of FUR in children. In one of them, 12 patients out of 13 were rendered stone-free [73]. The latter one evaluated the outcomes of FUR in preschool children and infants. The success rate was 88 % and with 5.8 % (1/17) complication rate, which was an intraoperative extravasation during balloon dilation [74]. The second largest series on FUR has been published recently with 80 children with upper ureteral calculi. The stone-free state was achieved in 90 % of cases after the first session and an additional 7.5 % became stone-free following the second session [75]. Moreover, several case reports revealed that FUR can be a good option for patients in whom other treatment options are not possible as type 1 glycogen storage disease with a significant hepatomegaly or von Willebrand disease [76, 77]. As a result, although RIRS seems beneficial, comparative studies are needed to reveal the advantages of its use in children as mentioned by Tekgul [78].

Technical Aspects

Technique is similar as in the adults as well as the used instruments (6.9/7/7.5 F flexible ureterorenoscopes). Use of guidewires and working under direct vision are of no controversy. The universally preferred energy source through the flexible ureterorenoscope is the holmium:yttrium aluminum garnet (YAG) laser. There are some practical differences changing regarding the surgeons' preference; those most of the time are not evidence based. These are choice of orifice dilatation techniques, use of ureteral access sheaths and placement of postoperative stents.

There are several techniques for orifice dilation: 1) routine passive dilatation as a staged procedure; 2) Routine intraoperative active dilatation with coaxial or balloon dilatators; 3) Insertion of the ureterorenoscope without any dilation and in failed cases, placing a double-J stent as a passive dilatation method. Authors who advocate the passive dilation method claim the possible trauma of active dilation technique where the active dilation supporters underscore the need for an additional session under anesthesia. On the other hand, need for an extra session for preoperative stent placement in fact decreases the efficacy quotient of the procedure, which should be considered when the stone-free rates of RIRS are interpreted. All these arguments unfortunately lack scientific evidence and tend to reflect the personal beliefs and experiences.

A ureteral access sheath provides an easy tract to reach the desired level of ureter, which prevents the possible injuries due to the multiple entries, facilitates the stone disintegration and extraction, and improves the irrigation fluid flow by decreasing the intraluminal pressure. In other words, placing an access sheath practically means an active dilation of the orifice and use of a sheath use is also at surgeon's discretion regarding the stone burden and predicted number of entries to the ureter.

The decision to place a stent postoperatively is based on complexity and duration of procedure, use of a ureteral access sheath, number of entries with the ureteroscope, and degree of visible ureteral trauma or edema at the end of the procedure.

Complications

The complication rates are very low when the purely FUR series are considered. The most reported complications are related to the distal ureter though the ureteral perforation, which is less than 5 %, and ureteral stricture, which is less than 1 % (Table 1). These low complication rates may be attributed to the smaller caliber of instruments now available and selective application of active dilatation.

Laparoscopy

In the modern era, most stone diseases in children are treated by endourological modalities such as SWL, URS (flexible/semirigid), and PCNL. The role of laparoscopy for urinary stone disease treatment in some indications has been well defined in adults [79]. In cases of failed endoscopic procedures, complex renal anatomy (ectopic or retrorenal colon), concomitant ureteropelvic junction obstruction or caliceal diverticula, or megaureter, large impacted stones can be counted as the indications for laparoscopic pyelo/nephro/ureterolithotomy. The adult literature yielded some recommendations according to the evidence-based medicine that laparoscopic ureterolithotomy has a level of evidence IIa and grade of recommendation A, whereas laparoscopic pyelolithotomy/nephrolithotomy has a III/B evidence level [79].

The role of and experience on laparoscopic stone surgery in children is very limited and composed of several case series with limited number of patients. The first marked case report was a laparoscopic-extended pyelolithotomy accomplished in a 16-month-old child with a large cystine stone that occupied the child's entire renal pelvis [80]. The other few case-reports are on the feasibility of laparoscopic approach for stones located in ectopic locations [81, 82]. In 2004, Casale et al. [83] reported the largest series of pediatric laparoscopic transperitoneal pyelolithotomy in eight children (ages 3 months to 10 years) who had previously undergone failed percutaneous access with a long-term stone-free rate of 87.5 %. The second-largest series reflects

Table 1 The modern series of flexible ureterorenoscopy interventions for kidney stones

Study	Patient, *n*, Renal unit, *n*	Mean age, *y*	Mean stone size, *mm*	Renal localization, %	Mean operative time, *min*	Active dilatation, %	Ureteral access sheath, %	Postoperative stent, %	Stone-free, %	Mean follow-up, *mo*	Complication (*n*)
Singh et al. [66]	8, 14	9.3	9	20	99	0	100	100	100	10	0
Smaldone et al. [67]	100 (65 FUR)	13.2	8.3	23	NA	70	24	76	91	10.1	Perforation (5) Stricture (1)
Cannon et al. [68]	21	15	12	100			43	71	76 (93 % for <15 mm, 33 % for >15 mm)	11	0
Kim et al. [69]	167	5.2	6.12	60	NA	0	NA	NA	100 (<10 mm) 97 (>10 mm)	19.7	0
Corcoran et al. [70]	30	9.7	8.8	63	NA	97	72	100	93 %	8	Perforation (2)
Tanaka et al. [71]	50, 52	7.9	8	100	NA	35	48	98	50, 58, 78*	NA	N/V (1)
Dave et al. [72]	19	6.9	17+staghorn	100	NA	0	42	100	75 (pelvic),100(polar), 14 (staghorn)	NA	Perforation (1) Urinoma (1)
Yeow et al. [73]	13	8.2	10.3	92	NA	0	100	100	92	20	Conversion to open (2)
Unsal and Resorlu [74]	17	4.2	11.5	100	52	27	17	100	100 % (<10 mm) 81.8 % (>10 mm)	10.3	Perforation (1)

FUR flexible ureterorenoscopy; *NA* not available; *N/V* nausea and vomiting

* please look into the text for details

the experience of robot-assisted pyelolithotomy in adolescents with staghorn calculi [84]. Conversion to open surgery was required in one of five patients, whereas three of four cases completed laparoscopically were rendered stone-free. Flexible renoscope was used in two cases in association with laparoscopic graspers to extract the residual fragments.

As mentioned above, laparoscopy has a limited role in pediatric urolithiasis treatment. However, it was shown to be feasible in patients who had previous failed endoscopic intervention, abnormally located kidneys, and stone with concomitant ureteropelvic junction obstruction.

Conclusions

Minimally invasive surgical approaches for stone disease in children continue to evolve. Use of pediatric nephroscope became standard for PCNL, and instrument sizes continue to drop in association with the present tendency to avoid larger tract dilatations. Use of RIRS, particularly for calyceal and lower pole stones, opened a new insight and seems to be a serious alternative for SWL and PCNL in the near future. Laparoscopy for cases in which endoscopic methods failed or were contraindicated stands as a good alternative for open approaches.

Disclosures None.

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