Endoscopic management of stones in children

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Purpose of review

Management of pediatric urolithiasis has evolved from open surgery to minimally invasive techniques. With advancements in instrumention, endourological procedures are being performed more commonly in children. The current article reviews the literature published from January 2003 to September 2004 regarding endoscopic management of stones in children.

Recent findings

Whereas recent literature supports shock-wave lithotripsy as the preferred treatment option for pediatric stones, it also confirms the safety of percutaneous nephrolithotomy and ureteroscopy in all age groups. Retrograde intrarenal surgery and laparoscopic surgery are newer additions to the armamentarium of the endourologist but their role needs to be better defined.

Summary

The majority of stones in children can be managed using minimally invasive techniques. Proper treatment planning and use of appropriate instrumention are important to achieve optimal outcome.

Keywords

pediatric urolithiasis, percutaneous nephrolithotomy, shock-wave lithotripsy

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Abbreviations

PCNL	percutaneous nephrolithotomy
RIRS	retrograde intrarenal surgery
SWL	shock-wave lithotripsy

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Introduction

Technological advancements and miniaturization of endourologic instruments have significantly altered the management of pediatric stone disease. Currently, the majority of stones in children can be managed either with shock-wave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL) or ureterorenoscopy (URS), or a combination of these modalities. Open surgery is currently necessary in a few selected cases only. Pediatric nephrolithiasis has known to be associated with urinary infection and anatomic and metabolic abnormalities. This may explain the high recurrence rates with pediatric urolithiasis. As a result, management of stone disease in children necessitates complete calculus clearance, eradication of urinary infection and appropriate correction of any underlying metabolic or anatomical abnormalities.

Urinary lithiasis affects between 5 and 10% of the human population during their lifetime, only 1–3% of whom are children. There is a marked variation in pattern of urolithiasis in developed and developing countries. Various etiological factors implicated in pediatric urolithiasis include metabolic abnormalities (48–86%), urinary infection (14–75%), anatomical abnormalities (10–40%) and endemic factors (19–73.5%). Co-existent infection is present in 49% of children with metabolic abnormality [1–3].

The clinical manifestations of stone disease are often more subtle in children when compared with the more dramatic adult presentation. There is a preponderance of males (M/F 1.5–2:1) but less than that seen in adults (M/F 3:1).

Renal calculi

Management options for renal calculi are the same as those for adults. The majority of stones in children can be managed with either SWL, PCNL or a combination thereof. Retrograde intrarenal surgery (RIRS) and laparoscopic surgery are emerging as newer modalities.

Shock-wave lithotripsy

SWL is currently the procedure of choice for treating most urinary stones in children. However, the variable efficacy needed for ancillary procedures and complications are not as clearly defined in children as is in the adult population. Important concerns with pediatric SWL include radiation hazards, effect on renal function and alteration in renal growth.

Various short-term studies with SWL [4,5] have not shown any deleterious effect on renal function, renal growth and blood pressure. Important considerations for SWL are renal function, stone burden, composition and capability of distal urinary tract to successfully pass the fragments. Children pass stones fragments well, even with a large stone burden, and do not require routine stenting. Gofrit *et al.* [6] compared clearance rate in pediatric patients with that of adults after SWL for renal stones greater than 10 mm in diameter. The stone-free rate was 95% in the children and 78.9% in the adults. Technical modification in gantry or position is required to treat pediatric patients with SWL [7].

Since the first clinical report of SWL on children by Newman and associates in 1986, many studies on SWL have reported stone-free rates of 67–99% [8,9,10•–12•]. Younger children can also be treated with SWL. McLorie *et al.* [10•] treated children of less than 3.5 years with SWL and reported 66 and 86% success rates with single and multiple sessions respectively without any major complications. Success rates with SWL in younger children seem to be higher. Aksoy *et al.* [11•] reported a success rate of 93.3% in children of less than 5 years, 88.7% in 5–10 years and 76.5% in 11–14 years.

Shorter duration of stone disease, greater stone fragility and lower impedance to shock waves might be responsible for better stone fragmentation in children. Newer generation lithotriptors with smaller focal zones allows SWL to be performed using intravenous sedation only in select older children. Results of recent studies are elaborated in Table 1. Most authors use a relatively low power setting (15–20 kV) and fewer shock waves (<2000) in pediatric patients.

We performed SWL in 25 children (27 renal units) with a mean age of 4.6 years. The average stone size was 60 mm^2 (14–145 mm^2). 1023 average shock waves were given at less than 12.75 kV and 93% were stone free at 3 months (M R Desai, unpublished observations).

Variable outcome in SWL for inferior calyceal stones has been correlated to variation in lower pole anatomy. Onal *et al.* [15•] did not find any parameter or cutoff points of calyceal anatomy measurements predicting stone-free rate for inferior calyceal stones. There was a highly significant correlation between retreatment rates and stone burden [15•]. In contrast, Ozgur Tan *et al.* [16•] showed that the infundibulopelvic angle and infundibular length significantly affected the stone-free rates with SWL for inferior calyceal stones.

Staghorn calculi in children are infrequent and pose a special challenge to the urologist. They are generally made up of struvite and are usually not associated with significant hydronephrosis. Al-Busaidy *et al.* [12•] in their study of staghorn calculi reported a success rate of 79% and found no difference in stone-free rate in stented and non-stented groups, but complications were significantly higher in the non-stented group. The authors reported [12•] that pre-SWL stenting in staghorn calculi provided a greater margin of safety and shorten the hospital stay. In adults, results of SWL monotherapy for staghorn calculus are dismal (22–63%) [17]. In children, although the stone-free rate with SWL monotherapy is relatively high,

Table 1. Results of recent studies of extracorporeal shock-wave lithotripsy (ESWL)

Series	No.	Mean age (years)	Stone numbers	Mean size (mm)	Stone-free rate	Retreatment/ sessions	Ancillary procedure	Complication
Aksoy *et al.* [11•]	129	8.7	Total 134			53.7%	Stent 15	14.7%
			Renal 114	17.8	86.84%		URS 2	UTI 10
					<10 mm, 100%			Stienstrasse 7
					10–20 mm, 93.5%			Hematoma 1
					>20 mm, 66.6%			
			Ureteral 20	10.2	75.0%			
					<10 mm, 100%			
					>10 mm, 66.6%			
Al-Busaidy *et al.* [12•]	42	6.1	Staghorn 42	3.2 cm	79%	Mean sessions, 2.5	7/19	Minor 55%
			Partial 33					Sepsis and ureteral obstruction 2
			Complete 9					Partial obstruction 1
Tan *et al.* [13]	100	10.7	115	7.8 mm	60.2%	13.9%	10%	4.6%
Muslumanogolu *et al.* [14•]	344	8.7	Total 408		73.1%	53.9%	Stent 16	Stienstrasse 7.8%
			Renal 224		<1 cm, 92.3%	36.9%		Ureteral obstruction 14
					1–2 cm, 68.3%	71.6%		
					>2 cm, 50.0%	76.2%		
			Ureteral 168		90–100%			UTI 4
			Bladder 16					Colic 10

UTI, urinary-tract infection, Ureteroscopy.

the need for multiple sessions, for ureteral stenting and for higher adjuvant procedures are disadvantages. There is no comparative study of PCNL and SWL in children. Results of SWL in cases of large stone burden are highly variable (33–83%) whereas with PCNL they are 67–92% [8–12,21–25,29]. In children, the cumulative likelihood of stone recurrences is higher. Afshar *et al.* [18•] reported that 34.5% fragments grew in size at mean follow up of 48 months and a similar number of patients developed clinically significant symptoms. Nijman *et al.* [19] have also reported that 33% children with small fragments had evidence of calculus growth at 24 months. Patients who have a large stone or risk factor such as an anatomic abnormality are less likely to become stone free with SWL and should be managed using alternative endourological techniques.

SWL in children is well tolerated with minimal morbidity. Minor complications such as bruising, ecchymosis and renal colic may occur in 11–50% cases. Incidence of hematuria (40%) is less than that in adults [9]. Ureteral obstruction or sepsis requiring ureteral stenting or percutaneous drainage after SWL may occur with larger stones. The lungs of very small children and children with orthopedic abnormality need to be shielded during SWL to avoid lung contusion and hemoptysis [20].

Percutaneous nephrolithotomy

Since the first pediatric series reported by Woodside [21] and associates in 1985, PCNL has become an established technique in children as monotherapy, or as part of a multimodal approach for children with large stone burdens. The reluctance to perform PCNL in children previously was due to concerns regarding long-term renal damage, small kidney size, relatively large instruments, radiation exposure and risk of major complications such as bleeding.

Most studies demonstrate minimal scarring and insignificant loss of renal function after PCNL. Radioisotope scans before and after PCNL revealed unchanged differential function and no evidence of significant renal scars [22]. Dwaba *et al.* [23•] reported no scarring on Dimercaptosuccinic acid (DMSA) renal scanning and stabilization or improvement in function with Diethylene triamine penta acetic acid (DTPA) renal scanning after PCNL.

Earlier reports with PCNL in children described the use of adult-size instruments. Desai *et al.* [24] showed that intraoperative hemorrhage during PCNL in children is related to the calibre and number of tracts and emphasized the need of technical modifications. Zeren *et al.* [25] also showed significant association of intraoperative bleeding with operative time stone burden and sheath size. Gunes *et al.* [26•] performed PCNL with adult-size instruments and reported a higher incidence of complications in children aged <7 years or with staghorn calculi.

Advancements in instrumentation and availability of more-efficient energy sources for intracorporeal lithotripsy have revolutionized endourological procedures in children. With availability of smaller nephroscopes, miniperc procedures are feasible. Helal *et al.* [27] reported using a 15 Fr access sheath in a 2-year-old child. Jackman *et al.* [28] described an 11 Fr access sheath for pediatric PCNL.

With the availability of holmium:YAG laser, and smaller pneumatic lithoclast and ultrasound probes, PCNL can be performed using smaller nephroscopes. We [24] designed a smaller lithoclast probe with suction for use through a pediatric nephroscope and found it highly effective and safe in children.

The use of homium:YAG laser is appealing in children. As it involves the photothermal mechanism, there was concern regarding thermal injury to delicate urothelium in children. Various studies [29], however, have demonstrated the safety of holmium:YAG laser. With higher pulse energy, a wider bubble increases the risk of thermal injury. Therefore, in children higher laser energy levels should be avoided.

With increasing familiarity and availability of high-resolution ultrasonography, it is gaining popularity amongst urologists. Ultrasound-guided puncture is a good alternative to fluoroscopy and has the advantages of avoiding radiation, providing a straight peripheral calyceal puncture and preventing visceral injury [24].

Restricting the calibre of the percutaneous tract to 20–22 Fr compared to the conventional 30 Fr tract may significantly reduce morbidity. In 56 complex renal calculi, we achieved a stone-free rate of 89.8% using PCNL monotherapy. Although we [30•] used multiple tracts in 61% patients and required multiple stages in 45% patients, average hemoglobin drop was 1.9 g/dl and only four patients had significant intraoperative bleeding.

Indications for PCNL in children are similar to those in adults and include a large stone burden, significant renal obstruction, urinary infection, and failure of SWL and significant volume of residual stones after open surgery. Worldwide experience with percutaneous nephrolithotomy in children is summarized in Table 2.

Initially, PCNL was recommended only for children >8 years but Callaway *et al.* [33] demonstrated its safety in younger children also. Intraoperative bleeding

Table 2. Summary of recent studies of percutaneous nephrolithotomy (PCNL)

Series	No. of patients (renal units)	Mean age (range)	Stone size Mean (Range)	SFR (%)	Adjuvant procedure	Complications
Dwaba *et al.* [23•]	65 (72)	5.9 years (9 months–1 year)	260 mm^2 (60–2060 mm^2)	86	SWL 6	Bleeding 1, pelvic perforation 1, fever 2
Desai *et al.* [24]	40 (45)	9.2 years (11 months–15 years)	2.04 cm (9–4.5 cm)	91	SWL 3	Fever 15, pelvic perforation 1, urine leak 1
Zeren *et al.* [25]	55 (62)	7.9 years (10 months–14 years)	283 mm^2 (25–2075 mm^2)	86.9	SWL 1	Bleeding 16 (23.9%), fever 20 (29.8%)
Desai *et al.* [30•]	56	9.1 ± 4.7 years	337.6 mm (110–989 mm^2)	93.7	SWL 3	Persistent urinary leak 3, transfusion 8
Holman *et al.* [31]	134 (138)	8.9 years (8 months–14 years)	507 mm^2 (124–624 mm^2)	98.5	SWL1	10.8%
Badawy *et al.* [32]	60	6.0 years (3 months–13 years)	2.27 cm^2	83.3	Open 3, SWL 1	Fever 5, colonic injury 1, bleeding 1, extravasation 1

SFR, stone-free rate; SWL, shock-wave lithotripsy.

requiring blood transfusion, injury to the pelvicalyceal system and sepsis are major concerns with PCNL in children. To reduce complications in the initial part of one's learning curve, the procedure may be staged in select cases such as a non-dilated collecting system, associated urinary infection and large stone burden. Staging the procedure, wherein percutaneous access is obtained at the initial sitting and stone manipulation is performed subsequently through a mature tract, may decrease complications with PCNL in children.

Retrograde intrarenal surgery

With increasing experience of RIRS in adults, recently a few reports [29] of successful ureterorenoscopic management of inferior calyceal stones in children have been published. In future, RIRS may be used more frequently to treat residual stones after SWL, inferior calyceal stones and cysteine stones.

Laparoscopic surgery

The role of laparoscopy in management of pediatric stone disease still needs to be explored. Casale *et al.* [34•] performed laparoscopic pyelolithotomy in eight children with large stone burden after failed percutaneous access without any complications.

Ureteral calculi

Van Savage *et al.* [35] showed that most stones less than 3 mm in diameter in the distal ureter of children would pass spontaneously. Stones of 4 mm or greater in diameter are likely to require treatment. Ureteric stones can be managed with SWL or ureteroscopy. Stone-free rate with SWL varies from 75 to 100% depending on the size of stone. Landau *et al.* [36] found that 100% patients with stones of less than 10 mm were stone free regardless of location. Stone-free rate was 67% in stones larger than 10 mm following a single SWL session. The overall success rate of SWL was 97.3%. Ureteral catheters for better identification and localization of the stone during SWL were required in 15% patients [36].

Ureteroscopy for treating urolithiasis in prepubertal children has become more common with the advent of smaller instruments and laser lithotripsy. The early concern with larger calibre instruments included risk of damage to ureteral mucosa, ureteral meatus and the urethra in male children. With the availability of 4.5 and 6.0 Fr semirigid ureteroscopes and a 6.9 Fr flexible ureterorenoscope and holmium:YAG laser energy source, instrument-related complications are uncommon.

Table 3. Recent studies of ureteroscopy in children

Series	Patient no.	No. of procedures	Mean size (range)	Mean age (years)	Stone free (%)	Complications
Al-Busaidy *et al.* [38•]	26	28	12.1 mm (4–22)	6.5	88	Ureteral perforation 1, failure to access ureter 1, hematuria 4, fever 2
Satar *et al.* [39•]	33	35	5.3 mm (3–10)	7.4	94	Nil
Dogan *et al.* [40•]	35	35	8 mm (4–15)	6.2	82	Ureteric perforation 2
Schuster *et al.* [41]	25	27	2–12 mm	9.2	92	Stent migration 1, pyelonephritis 1, VUR 2
Bassiri *et al.* [42]	66	66	8 mm	9	88	Pyelonephritis 4.5%, hematuria 16.6%

There are concerns regarding ureteral dilatation prior to ureteroscopy in children. These include risk of stricture, need for indwelling stent, need for second procedure under anesthesia and the potential risk of development of vesico-ureteric reflux. It has been shown that ureteral dilatation does not increase the risk of stricture and significant reflux [37]. Moreover, with use of smaller-calibre ureteroscopes, ureteral dilation may not be required. Routine screening for reflux after ureteroscopy in children is not required and should be considered only in symptomatic children. Results of various studies with ureteroscopy in children are shown in Table 3.

Lam *et al.* [43] compared the efficacy of SWL with ureteroscopy using holmium:YAG laser lithotripsy in 67 patients with proximal ureteral calculi. The stone-free rates in patients with calculi of $\geq$10 mm were 93% with ureteroscopy and 50% with SWL, while for calculi of $<$10 mm, the stone-free rates were 100 and 80% for ureteroscopy and SWL, respectively [43].

SWL may require ureteral stenting in a large proportion of children with ureteral calculi, either to aid localization or stone clearance. Ureteroscopy may provide more-efficient stone clearance, and hence should be preferred for distal ureteral stones, larger stones and impacted stones.

Bladder calculi

Historically, bladder calculi have been reported as endemic in many developing nations. The incidence of bladder calculi after bladder augmentation and continent urinary diversion may approach 50%. Vesical calculi are usually large and hard, and can be managed by transurethral or percutaneous suprapubic lithotripsy or litholopaxy. The potential risk of damage to the male urethra makes the use of the transurethral route uncommon. Cain *et al.* [44] performed percutaneous extraction of bladder calculi in 13 children with bladder augmentation. Percutaneous extraction was successful in 12 of the 13 children (92%) [44]. Suprapubic cystolithotomy is a viable option in cases of large, hard, vesical calculi.

Conclusion

Pediatric urolithsiasis is relatively uncommon but poses a specific technical challenge to the urologist. Aims of the management should be complete clearance of stones, preservation of renal function and prevention of recurrence. Despite the consensus of SWL being the initial treatment of choice for most stones in pediatric patents, there are certain definite indications of endoscopic intervention. With improvements in instrumentation and technology, endoscopic management has become safer and effective. Because of small body habitus, delicate tissues and long-term implications of complications, proper and detailed planning of the surgical procedure is of utmost importance in the pediatric patient.

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