# Ureteral Calculi in Children
## What is Best as a Minimally Invasive Modality?

Abbas Basiri, Samad Zare, Nasser Shakhssalim, Seyed Mohammadmehdi Hosseini Moghaddam

**Introduction:** Minimally invasive treatment of ureteral calculi in children is a challenging topic. In an evidence-based review, we evaluated the efficacy and safety of extracorporeal shock wave lithotripsy (SWL) and ureteroscopic modalities for this group of patients.

**Materials and Methods:** In this study, we performed a comprehensive systematic review on articles appeared in the PubMed from 1998 to March 2008. We selected all papers addressing SWL or ureteroscopic management of the ureteral calculi in children and determined the level of evidence of the presenting data.

**Results:** Thirty-nine articles were reviewed and 24 with valid information on SWL or ureteroscopic management of the pediatric ureteral calculi were analyzed. Six articles (25%) were randomized controlled trials and 18 (75%) were retrospective case-controls or case series. The following data were extracted from the 24 articles: in SWL groups, overall success rate was 84.1% (range, 71% to 100%) for the upper ureteral calculi and 76.2% (range, 19% to 91%) for the lower ureteral calculi. Only 61% of the patients had only 1 treatment course, while 8% and 31% of the cases required 2 and more than 2 sessions of treatment, respectively. With ureteroscopic management, the overall success rates were 93.2% (range, 81% to 100%) and 74.4% (range, 20% to 100%) in the lower and upper ureteral calculi, respectively.

**Conclusion:** The main limitations of the series on minimally invasive treatment of pediatric ureteral calculi are lack of powerful randomized controlled trials or prospective data and insufficient patient numbers. Therefore, it is difficult to draw absolute conclusions about successful treatment based on current knowledge.

*Keywords: urinary calculi, child, shock wave lithotripsy, ureteroscopy, treatment, randomized control trials*

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*Urology and Nephrology Research Center and Department of Urology, Shahid Labbafinejad Medical Center, Shahid Beheshti University (MC), Tehran, Iran*

*Corresponding Author:*
*Abbas Basiri, MD*
*Urology and Nephrology Research Center, No 44, 9th Boustan, Pasdaran, Tehran 1666668111, Iran*
*Tel: +98 21 2256 7222*
*Fax: +98 21 2256 7282*
*E-mail: basiri@unrc.ir*

## INTRODUCTION

Management of ureteral calculi in children is usually a challenge to the treating urologist. Fortunately, ureteral calculi are less frequent in children than in adults; only 7% of the total urinary calculi are seen in children.[1] More than 80% of the ureteral calculi pass spontaneously and do not require any intervention.[2] For those in whom the calculus is unlikely to pass, treatment methods can be invasive or noninvasive, depending on the presence of ureteral obstruction, intractable pain, urosepsis, persistent gross hematuria, degree of impaction, patient expectations, and surgeon's experience.[3,4] Initially, ureteral calculi in the pediatric age group was one of the contraindications

for extracorporeal shock wave lithotripsy (SWL). After the study of Newman and colleagues in 1986, SWL was started on for children in some centers, and even infants as young as 6 months have been treated successfully.[5,6] Important rules that have to be obeyed in the treatment of children are protecting the lung and the adjacent organs as much as possible, diminishing the number of SWL sessions or auxiliary measures, and using ultrasonography more frequently than radiography for locating the calculus in order to avoid ionizing radiation.[7]

During the last quarter of the 20th century, developments in endourology led to the safe use of ureteroscopy, and consequently, this form of treatment has become widely accepted for ureteral calculi in adults. However, the use of ureteroscopy in children has been limited.[8,9] The first reported ureteroscopy in children was performed by Young and McKay with a standard pediatric cystoscope in a patient with a posterior urethral valve and a gross dilated upper tract.[10] Early ureteroscopy procedures in children were performed using large-caliber ureteroscopes; this caused difficulties in advancement through the intramural tunnel, leading to injury of the ureteral mucosa.[11] Although ureteroscopy has become a powerful diagnostic and therapeutic tool in children with the introduction of small-caliber ureteroscopes, there have been few studies conducted on the safety and long-term effectiveness of ureteroscopy for the treatment of ureteral calculi in these patients.[12]

In this article, we performed a systematic review on the minimally invasive treatment options for ureteral calculi in children. A comprehensive search was done via the MeSH term and Non-MeSH term search protocol on the PubMed for the relevant articles that appeared from January 1998 to March 2008. The keywords were *extracorporeal shock wave lithotripsy*, *transureteral lithotripsy*, *pediatric ureteral calculi*, *ureteral calculi*, *safety*, and *efficacy*. Other specific words were researched during the study if needed.

## LEVELS OF EVIDENCE

Classification of the levels of evidence was performed on the basis of a simplified Oxford scaling system[13,14]:

Level 1 evidence: good-quality randomized controlled trials (RCTs) or meta-analyses of RCTs

Level 2 evidence: low-quality RCTs, clinical trials with pseudorandomized allocation or 1 arm, or meta-analyses of good-quality cohort studies

Level 3 evidence: good-quality retrospective case-control studies or good-quality case series

Level 4 evidence: low-quality retrospective case-control studies or low-quality case series

We reviewed 39 articles and analyzed 24 of those with valid information about SWL or ureteroscopic management of pediatric ureteral calculi.[1-4,7-9,11,12,15-29] Ureteroscopy and SWL for ureteral calculi had been reported in 20 (83.3%) and 9 (37.5%) articles, respectively. Nineteen papers (79.2%) had a single-arm (clinical trials or case series) on either ureteroscopy or SWL, and 5 papers (20.8%) had compared these two options in a double-arm fashion (RCTs or case series).[11,12,15,16] Only 1 article (4.2%) was an RCT. All of the calculi in this study were located in the lower ureter. The levels of evidence were determined for these 24 articles. There were 1 (4.2%), 3 (12.5%), 10 (41.7%), and 10 (41.7%) articles classified in levels 1 to 4, respectively. Details of the papers are outlined in Table 1.

## RESULTS

Totally, treatment of 1027 children with ureteral calculi, consisting of 555 boys (54.1%) and 472 girls (45.9%), had been reported in the reviewed articles. The median age of the patients was 7.5 years (range, 1 to 17 years). In 380 patients (36.8%), the calculi were located in the upper ureter (above the pelvic brim) and in 647 (63.2%), the calculi had been detected in the lower ureter (under the pelvic brim). The median sizes of the upper and lower ureteral calculi were 7.7 mm (range, 4 mm to 15 mm) and 7.5 mm (range, 4 mm to 14 mm), respectively. Extracorporeal shock wave lithotripsy and transureteral lithotripsy had been performed in 422 (41.1%) and 605 (58.9%) patients (Table 1). Follow-up had been done with plain abdominal radiography, ultrasonography, intravenous urography, and

**Table 1.** Summarized Data of 24 Selected Articles on Treatment of Ureteral Calculi in Children*

| No | Article | Level of Evidence | Article Type | Modality | Patients | | Calculus Location, % | | Calculus Size, mm | Energy Source | Stent, % | Ureteral Dilation, % | Ureteroscope, type, F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Girls | Boys | Lower | Upper | | | | | |
| 1 | De Dominicis et al[12] | 1 | RCT | TUL & SWL | 21 | 10 | 100 | 0 | 5 to 9 | Ballistic, Laser | 0 | 0 | Semirigid, 5 |
| 2 | Dogan et al[20] | 2 | CT | TUL | 15 | 20 | 92 | 8 | 4 to 15 | Laser | 100 | 100 | Rigid, 8 to 11.5 |
| 3 | Rauchenwald et al[7] | 2 | CT | SWL | 41 | 39 | 58 | 42 | 9 to 15 | … | 0 | 0 | |
| 4 | Sofer et al[2] | 2 | CT | TUL | 7 | 5 | 83 | 17 | 5 to 20 | Laser | 90 | 10 | Semirigid, 6.5 to 11.5 |
| 5 | Ozgur et al[24] | 3 | case series | SWL | 18 | 23 | 63 | 37 | … | … | 20 | 0 | |
| 6 | Ozbey et al[22] | 3 | case series | SWL | 11 | 18 | 100 | 0 | 4 to 18 | … | 0 | 0 | |
| 7 | Tan et al[15] | 3 | case series | TUL & SWL | 32 | 35 | 100 | 0 | 5 to 10 | Pneumatic | 0 | 0 | Semirigid, 8 |
| 8 | Delakas et al[23] | 3 | case series | TUL & SWL | 12 | 13 | 44 | 56 | 5 to 14 | Laser | 25 | 0 | Semirigid, 8 |
| 9 | El- Assmy et al[18] | 3 | case series | TUL | 16 | 17 | 88 | 12 | 4 to 15 | Laser | 85 | 0 | Semirigid, 6.5 to 10 |
| 10 | Thomas et al[9] | 3 | case series | TUL | 16 | 17 | 73 | 27 | 3 to 14 | Laser | 70 | 0 | Semirigid, 8 to 11.5 |
| 11 | Satar et al[19] | 3 | case series | TUL | 17 | 18 | 74 | 26 | 3 to 10 | Pneumatic | 35 | 0 | Rigid, 6.5 to 10 |
| 12 | Kurzrock et al[21] | 3 | case series | TUL | 17 | 0 | 77 | 23 | 5 to 11 | Laser | 29 | 6 | Semirigid, 6 |
| 13 | Bassiri et al[8] | 3 | case series | TUL | 35 | 31 | 89 | 11 | 5 to 15 | Laser, Pneumatic, EH, Basket | 0 | 38 | Semirigid, 8 to 11.5 |
| 14 | Tan et al[25] | 3 | case series | TUL | 10 | 13 | 67 | 33 | 5 to 12 | Laser , EH | 91 | 17 | Semirigid, 6.5 to 8 |
| 15 | Brinkmann et al[17] | 4 | case series | SWL | 19 | 21 | 0 | 100 | 5 to 17 | … | 43 | 0 | |
| 16 | Raza et al[1] | 4 | case series | TUL | 25 | 27 | 77 | 23 | 7 to 10 | EH, Laser, Basket | 0 | 0 | Semirigid, 6.8 |
| 17 | Jayanthi et al[11] | 4 | case series | TUL & SWL | 24 | 17 | 100 | 0 | 7 to 12 | Laser | 9 | 0 | Semirigid, 8 to 10 |
| 18 | Wollin et al[3] | 4 | case series | TUL | 9 | 10 | 69 | 31 | 7 to 9 | Laser | 0 | 0 | Flexible, 8 to 11.5 |
| 19 | Landau et al[28] | 4 | case series | TUL & SWL | 17 | 21 | 50 | 50 | 6 to 9 | … | 39 | 0 | … |
| 20 | Romero et al[26] | 4 | case series | TUL | 3 | 4 | 29 | 71 | 4 to 7 | Pneumatic | 0 | 0 | Semirigid, 8 |
| 21 | Lesani et al[29] | 4 | case series | TUL | 10 | 12 | 0 | 100 | 5 to 9 | Laser | 12 | 25 | Rigid, 6.5 to 11.5 |
| 22 | Aridogan et al[27] | 4 | case series | TUL | 31 | 25 | 65 | 35 | 5 to 12 | Pneumatic | 41 | 25 | Rigid, 6.9 to 10 |
| 23 | Al-Busaidy et al[4] | 4 | case series | TUL | 12 | 14 | 58 | 42 | 4 to 22 | Laser | 25 | 0 | Rigid, 8 |
| 24 | Smaldone et al[16] | 4 | case series | TUL | 35 | 32 | 56 | 44 | 5 to 10 | Laser | 76 | 44 | Semirigid, 6.9 & Flexible, 7.2 |

*RCT indicates randomized controlled trial; CT, clinical trial; TUL, transureteral lithotripsy; SWL, shock wave lithotripsy; and EH, electrohyraulic. Ellipses indicate not available or not applicable.

voiding cystourethrography in a few studies. The follow-up durations ranged from 3 months to 18 months.

## Extracorporeal Shock Wave Lithotripsy

In almost all reports, SWL had been performed by Siemens or Dornier lithotripters plus devices at prone position usually under dissociative anesthesia using ketamine (0.5 mg/kg) for most children, and sedation was sufficient for some children older than 14 years old. The devices were 1st-, 2nd-, and 3rd-generation lithotripters in 20%, 30%, and 50% of the cases, respectively. The shock wave had been delivered by undertable piezoelectric, electromagnetic, and electrohydraulic sources in 20%, 25%, and 55% of cases. The mean number of shock waves per session and power were 2724.68 ± 507.34 kV and 17.46 ± 1.13 kV, respectively. Ninety-eight percent of SWLs had been done in an outpatient setting. Contraindications for SWL were coagulation disorders, pyelonephritis, and obstruction distal to calculi, nonfunctioning kidney, and hypertension.[17] Extracorporeal shock wave lithotripsy procedures were carried out under ultrasonographic and fluoroscopic controls in 65% and 35% of cases, respectively. The overall success rates were 84.1% (range, 71% to 100%) in the upper ureteral calculi and 76.2% (range, 19% to 91%) in the lower ureteral calculi. Only 61% of the patients had 1 treatment course, while 8% and 31% of cases required 2 and more than 2 sessions of treatment, respectively. De Dominicis and associates reported the efficacy quotient of 30% and 70% for SWL and ureteroscopic management of the lower ureteral calculi, respectively.[12] They reported steinstrasse in 4.2% of the patients who underwent SWL.

Transient microscopic hematuria (100%) and bruising of the skin (80%) were the most common complications after SWL (Table 2).

**Table 2.** Complications of Extracorporeal Shock Wave Lithotripsy (SWL) and Ureteroscopic Management of Pediatric Ureteral Calculi

| Complications | Ureteroscopy, % | SWL, % |
|---|---|---|
| Major | | |
| Ureteral perforation | 1.7 | 0 |
| Ureteral stricture | 1.0 | 0 |
| Urosepsis/pyonephrosis | 0.5 | 0.7 |
| Ureteral avulsion | 0.4 | 0 |
| Nonfunctioning kidney | 0.1 | 0.2 |
| Minor | | |
| Microscopic hematuria | 100 | 100 |
| Skin bruising | 0 | 80.0 |
| Gross hematuria | 15.0 | 21.0 |
| Renal colic | 7.1 | 7.9 |
| Fever (> 38°C) | 4.3 | 10.0 |
| Urinary retention | 7.0 | 0 |
| Mucosal tearing | 3.5 | 0 |

## Ureteroscopic Management of Ureteral Calculi

Ureteroscopy had been performed by rigid, semirigid, and flexible ureteroscopes in 5 (26.5%), 11 (57.8%) and 3 (15.7%) of the articles. The sizes of the ureteroscopes were between 6.5 F and 11.5 F. The calculi had been fragmented by holmium laser (60%), pulsed-dye laser (8%), ultrasonic lithotripsy (5%), electrohydraulic lithotripsy (7%), and pneumatic lithotripsy (20%). The use of grasping forceps was limited to 3.5% of the ureteroscopic procedures. Ureteral dilation had been performed in 18.6% of the cases, usually not required for ureteroscopes smaller than 8 F. Thirty percent of the patients required ureteral drainage via a ureteral catheter or a double-J stent, and the most frequent indications for this intervention where calculi greater than 1 cm in diameter, obstructing calculi, complicated ureteroscopy, and malfunctioning kidney.[18-21] In almost all patients, treatment had been performed under general anesthesia. The overall success rate in the lower ureteral calculi was 93.2% (range, 81% to 100%), and it was 74.4% (range, 20% to 100%) in the upper ureteral calculi. The efficacy quotient for ureteroscopic management of pediatric ureteral calculi was 38% and 42% in 2 articles.[9,18] In El-Assmy and colleagues' study, the calculi were located in the lower ureter and upper ureter in 29 (88%) and 4 (12%) of the cases,[18] and in Thomas and colleagues' study, they were located in the lower ureter and upper ureter in 24 (73%) and 9 (27%) of the cases.[9] The need for repeated treatment were reported in 17% of ureteroscopic modalities. Calculus migration was reported in 5.3% of the patients. Transient hematuria was the most common minor complication (Table 2).

## DISCUSSION

Although SWL offers the patient a less-invasive modality, it is associated with some inherent drawbacks. The success of the procedure is variable, with some large series reporting stone-free rates between 76% and 84% and repeated treatment rates of zero to 36%.[8,22,23] Most children require general anesthesia for SWL, which means if SWL fails, the child will again be exposed to general anesthesia to undergo a salvage endourologic procedure. Large calculi, cystine calculi, and radiolucent calculi are not suitable for treatment with SWL.[16,24]

Ureteroscopy could be performed as an outpatient procedure in adults and the cost-effectivity was reported to be similar or even less than those for SWL using a first-generation lithotripter.[11] However, this is rather controversial as there is wide variability in the success rate, the type of equipment, experience, and medical expenses among different countries and even institutions. The safety of ureteroscopy in pediatric age group has not been fully established.[23,25] It is difficult to draw conclusions on successful treatment based on calculus location in children due to the small patient numbers in most reports. However, success rates of treatment in proximal ureteral calculi in adults are lower than those for distal calculi, although the increased use of the holmium laser has improved these success rates dramatically.[19] Depending on the location of the calculus, the success rate of ureteroscopy varies (range, 20% to 100% for calculi in the upper ureter, 36% to 83% for those in the middle ureter, and 81% to 100% for those in the lower ureter). Although SWL is more effective for upper ureteral calculi, ureteroscopy provides a favorable outcome for those in the middle ureter and the lower ureter. In addition, without question, ureteroscopy was more effective in the treatment of nonopaque ureteral calculi.[22] The main limitations of these series are selection bias, lack of powerful RCTs or prospective data, insufficient patient numbers, limited follow-up information, and lack of a standard definition for stone-free status. The success rates for ureteroscopic laser lithotripsy and calculus extraction in children range from 86% to 100% in the literature, and secondary procedures usually increase this rate to nearly 100%.[9] Although the size of the calculus in addition to its location may affect treatment efficacy and success, they did not affect the results of some studies, which may be due to the small number of patients with calculi in the upper ureter.[26] With an excellent technique and meticulous attention to details, significant complications occur in 0 to 7% of the cases.[5] Overall, the incidence of ureteral stricture after ureteroscopy is 1% to 4% in adults, but rates specific to children are unknown due to the small patient numbers in most series. Nonetheless, it has been documented that the recent advent of smaller instrumentation has decreased this risk to less than 1%.[4] Shroff and Watson described a child who developed a ureteral stricture after holmium laser lithotripsy. This complication was treated by holmium laser at a second ureteroscopy.[30]

Duration of ureteroscopy should be short, unnecessary manipulations should be avoided, and warm irrigation fluids should be used to avoid complications. The most frequent early complications of pediatric ureteroscopy are hematuria, renal colic, and urinary retention. According to this literature review, there is no need for dilation of the intramural ureter before each ureteroscopy. When dilation is required, it should be done only to the smallest size that will allow introduction of the ureteroscope. Some reports suggested vesicoureteral reflux (11% to 17%) as a late complication of pediatric ureteroscopy secondary to dilation of the ureteral orifice when a large-caliber ureteroscope is used. However, because this complication is almost temporary and low-grade, it is not necessary that cystography be performed routinely after ureteroscopy.[24,27] In the earliest series of pediatric ureteroscopy, postoperative stents were inserted and tolerated well in all cases.[3,11,28] In 1996, Kurzrock and colleagues reported that stent was not needed to be inserted in all patients and only 29% required it, which were removed after a short time.[21] Sometimes, insertion of a stent may be advantageous although removal of the stent requires general anesthesia.[21]

Calculus analysis was available only in few

patients of the reviewed series. A comparison of calculus composition by ureteral and kidney location showed a significant preponderance of ureteral calcium calculi (92% versus 44%), and a trend toward more intrarenal cystine calculi (33% versus 8%) and sturvite calculi (22% versus zero).[2] Metabolic abnormality was present in nearly 40% of the children in these series.[25] Satisfaction of the patients is an important predictor of treatment efficacy that was not referred in these literatures.

## CONCLUSION

Based on these data, SWL is more effective for upper ureteral calculi, and ureteroscopy provides a favorable outcome for calculi in the middle and lower ureter. The main limitations of these series were selection bias, lack of powerful RCTs or prospective data, insufficient patient numbers, limited follow-up information, and lack of a standard definition for stone-free status. Therefore, it is still difficult to draw final conclusions about safety and efficacy of these modalities. In order to help shedding light on this subject, we have designed a nation-wide RCT, the results of which will be released in the near future.

## CONFLICT OF INTEREST

None declared.

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