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ORIGINAL PAPER

Efficacy and safety of endoscopic laser lithotripsy for urinary stone treatment in children

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Abstract We reviewed our 6 years of experience with endoscopic holmium: yttrium aluminum garnet (YAG) laser lithotripsy for treatment of urinary stones in different locations in 111 children. A retrospective review was performed on endoscopic holmium: YAG laser lithotripsy procedures performed to treat stones in children between March 2006 and March 2012. In total, 120 laser lithotripsy procedures were performed to treat 131 stones in 111 children (80 males and 31 females; age range, 11 months to 16 years; median age, 6 years). Stones were located in the kidney in 48 cases (36.7 %), ureter in 52 (39.7 %), bladder in 21 (16.0 %), and urethra in 10 (7.6 %). Stone size ranged from 4 to 30 mm (mean, 12.8 mm), and anesthesia duration was 10–170 min (mean, 56 min). Forty-four ureters required balloon dilation, and 61 double J stents were inserted. Follow-up ranged from 3 to 75 months (mean, 35 months). Complete stone clearance was achieved at the end of the procedure in 102 (91.9 %) patients (age $<$ 7 years, 93.3 % vs. age $\geq$ 7 years, 90.2 %; $p > 0.05$). The success rate was 81.3 % for kidney stones (<10 mm, 90.9 % vs. $\geq$ 10 mm, 78.4 %; $p > 0.05$) and 100 % for the ureter, bladder, and urethral stones. Overall success rate with extracorporeal shockwave lithotripsy was 100 %. No major complications were encountered during or after the procedures. These results confirm the effectiveness and safety of holmium laser lithotripsy for treating all urinary stone locations in children of all ages.

Keywords Children · Stone · Retrograde intrarenal surgery · Ureteroscopy · Laser · Lithotripsy

Introduction

Urolithiasis in children remains of clinical importance because of the management challenge and high incidence. Although urolithiasis prevalence is 1–8 % in developed countries, it is 30 % in developing countries [1–7]. Urolithiasis is a common problem in Turkey, particularly in the Southeastern Anatolia Region, which is where our hospital is located [3, 4]. Turkish epidemiological studies have reported that urolithiasis is endemic, with an overall prevalence of 14.8 %, an incidence of 2.2 %, and a pediatric prevalence of 0.8 %. Pediatric urolithiasis comprises 17 % of all urolithiasis cases [4, 6, 7].

Treatment of urinary stone disease in children is challenging [5]. However, in the past few years, small instruments and technological developments have improved urolithiasis management and have made possible the use of endoscopic procedures, instead of open surgery, in adults and children [5, 8–10]. Today, ureterorenoscopic lithotripsy (URSL) and extracorporeal shockwave lithotripsy (ESWL) are the most common treatment options for urinary stones [11, 12]. Ultrasonic, pneumatic, electrohydraulic, and laser lithotripters have been used for URSL. Additionally, the use of thin ureteroscopes during laser lithotripsy has supplied a safer treatment procedure with lower complication rates in children [8–13].

Herein, we present our 6 years of experience with endoscopic holmium: yttrium aluminum garnet (YAG) laser lithotripsy to treat urinary stones located in different locations in children.

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Patients and methods

The records of all patients ≤16 years old who underwent endoscopic holmium: YAG laser lithotripsy procedures for treatment of stones at the Ministry of Health Dumlupinar University Kutahya Evliya Celebi Education and Research Hospital and Dicle University Hospital from March, 2006 to March, 2012 were reviewed retrospectively. We included patients with urinary stones in different locations in whom only endoscopic lithotripsy was performed using a holmium: YAG laser. Patients treated with ESWL alone, percutaneous nephrolithotomy (PCNL) and stone extraction by forceps, medical treatment, and endoscopic lithotripsy by other energy sources (pneumatic, electrohydraulic, and ultrasonic) were excluded. The information recorded included patient demographics, stone size and location, operative technique, anesthesia duration, and postoperative outcomes. Stone size was defined as the longest diameter measured on plain X-rays. Parental informed consent was obtained for the surgical and anesthetic procedures. Prophylactic perioperative antibiotics were administered to patients.

All patients were radiologically and clinically evaluated and treated by the same team. All procedures were performed by Uygun (109, 91 %) and Okur (11, 9 %) using various endoscopes, including a flexible ureterorenoscope (URS) (Flex-X™ flexible ureteroscope, 7.5 Fr. × 6000 mm; Karl Storz GmbH, Tuttlingen, Germany), a semi-rigid cystoscope (Pediatric OES Pro Compact Cystoscope OP Telescope™, 11 Fr. × 220 mm; Olympus KeyMed Ltd., Southend, UK), a semi-rigid pediatric URS (Pediatric OES Pro Ureteroscope™, 6.4/7.8 Fr. × 430 mm; Olympus KeyMed), and a miniature URS (Ultra-Thin Uretero-Renoscope™, 4.5/6.5 Fr. × 430 mm and 4.5/6.5 Fr. × 315 mm; Richard Wolf GmbH, Knittlingen, Germany). The semi-rigid cystoscope was used mostly for diagnostic routine urethrocystoscopy, ureteral balloon dilatation, double J stent insertion and removal, urethral and bladder lithotripsy, and some distal ureteral lithotripsy when the ureter orifice had a sufficient opening. The semi-rigid pediatric URS previously and the miniature URS currently (for the last 2 years) were used mostly for ureteral and renal lithotripsy. The flexible URS was used only for renal lithotripsy and usually with ureteral access sheaths (Flexor® ureteral access sheath, 9.5 Fr. × 28 cm; Cook Medical Inc., Bloomington, IN, USA). When the ureteral orifice was narrow and allowed for smooth, easy access into the ureter and renal pelvis, ureteral balloon dilatation was performed using a ureteral balloon dilatator (UroMax Ultra™ high-pressure balloon, 12 Fr. × 4 cm; Boston Scientific Co., Boston, MA, USA) inserted into the ureter over the guide-wire and inflated to 10 atm for 1 min using an inflator (Encore 26 Inflator™; Boston Scientific) under endoscopic and fluoroscopic guidance. Ureteral balloon dilatation was often used before using miniature URS and when needed. We entered through the ureter directly with or without guide-wires (Standard double J stent guide-wire or Roadrunner® PC Wire Guide; Cook Medical) and/or using a 180° rotation of the endoscopes. We used a holmium: YAG laser lithotripsy unit (StoneLight® Holmium Laser System; AMS Inc., Minnetonka, MN, USA) with various sizes (150–550 μm) of laser fibers as the energy source. Based on the stone features, laser fibers generating 0.5–1.5 Joules at a frequency of 5–12 Hz were used. The stones were fragmented until they were deemed small enough to pass spontaneously. In some patients, residual fragments were removed by forceps or baskets for chemical analysis. The extraction of residual fragments by baskets or forceps was not routinely performed, except for large bladder stones. A double J stent was placed in cases of a high stone load, a large residual stone (after inadequate treatment, inability to reach the stone or stone migration), an obstruction, edema, presence or suspicion of leakage, internal damage, or ureteral injury. A Foley catheter was routinely placed in cases of the presence or suspicion of urine leakage for decompression of the urinary system and in cases of internal damage of the urethra or multiple entrances through the urethra, especially in male patients. Foley catheters were removed on the postoperative first or second day, if they were not required. The double J stents were removed 4 weeks after the procedure, if no residual stones were found. The patients were discharged on the first postoperative day after radiological and clinical monitoring if they were stable and had no uncontrolled complications. All patients were evaluated at the postoperative first and third months by urinalysis, plain abdominal X-rays, and ultrasonography. When large residual stones were observed, a second laser lithotripsy or ESWL was planned. Stone-free status was determined by the absence of residual fragments on follow-up imaging. After treatment, all patients were followed every 6 months by urinary ultrasonography for recurrence of urolithiasis and long-term complications.

The Mann–Whitney *U* test was used to determine the significance of differences between groups. The data were statistically analyzed with SPSS version 15.0 for Windows (SPSS Inc., Chicago, IL, USA), and a p value ≤0.05 was considered to indicate significance.

Results

A total of 120 laser lithotripsy procedures to treat 131 stones were performed in 111 children [80 (72.1 %) males and 31 (27.9 %) females; 60 (54 %) infants and preschool-age children (aged < 7 years) and 51 (46 %) school-age children and adolescents (aged ≥ 7 years); 93 (83.8 %) single and 18 (16.2 %) multiple stones; median age, 6 years; age range, 11 months to 16 years]. Stones were located in the

Table 1 Features of preoperative findings of patients

No. of patients	111
Male	80 (72.1 %)
Female	31 (27.9 %)
Median age, years (range)	6 (11 months to 16 years)
Single stone	93/111 (83.8 %)
Multiple stones	18/111 (16.2 %)
No. of stones	131
Stone location	
Kidney	48 (36.7 %)
Renal pelvis	32 (66.7 %)
Upper pole calices	11 (22.9 %)
Lower pole calices	5 (10.4 %)
Ureter	52 (39.7 %)
Proximal ureter	3 (5.8 %)
Distal ureter	49 (94.2 %)
Bladder	21 (16.0 %)
Urethra	10 (7.6 %)
Stone side	
Left	29 (32.6 %)
Right	49 (55.0 %)
Bilateral	11 (12.4 %)
Mean stone size, mm (range)	12.8 (4–30)
Kidney stone	13.1 (8–25)
Other stone	12.4 (4–30)

Table 2 Features of postoperative findings

No. of procedures	120
Mean anesthesia, min (range)	56 (10–170)
Dilatation of ureteral orifice	44/100 (44 %)
Double J stent insertion	61/100 (61 %)
Mean hospitalization, days (range)	2.3 (1–5)
Complications	6/120 (5 %)
Minor abdominal leakage	2
Suspicion of ureteral puncture	1
Urinoma	1
Renal puncture with guide-wire	1
Split coil fragment in kidney	1
Sepsis	–
Major complication	–
Stone-free rate	102/111 (91.9 %)
Age < 7 years	56/60 (93.3 %)*
Age ≥ 7 years	46/51 (90.2 %)
Success rate	
Kidney stones	39/48 (81.3 %)
Stones < 10 mm	10/11 (90.9 %)#
Stones ≥ 10 mm	29/37 (78.4 %)
Other stones	83/83 (100 %)±
Stone-free rate with ESWL	111/111 (100 %)
Mean follow-up, months (range)	35 (3–75)

* $p > 0.05$ compared with age ≥ 7 years

\# $p > 0.05$ compared with stones ≥ 10 mm

± $p < 0.05$ compared with kidney stones

kidney in 48 cases (36.7 %), the ureter in 52 (39.7 %), the bladder in 21 (16.0 %), and the urethra in 10 (7.6 %). Stone size was 4–30 mm (mean, 12.8 mm). The preoperative findings of the patients are summarized in Table 1.

Anesthesia duration was 10–170 min (mean, 56 min). Forty-four (44 %) ureters required balloon dilation of the ureteral orifice for 100 ureteral accesses, and 61 (61 %) double J stents were inserted. Follow-ups ranged from 3 to 75 months (mean, 35 months). Complete stone clearance was achieved at the end of the procedure in 102 (91.9 %) patients (aged < 7 years, 93.3 % vs. ≥ 7 years, 90.2 %; $p > 0.05$). The success rate was 81.3 % (<10 mm, 90.9 % vs. ≥ 10 mm, 78.4 %; $p > 0.05$) for kidney stone and 100 % for other stones (ureter, bladder, or urethra; $p < 0.05$). The overall success rate of URSL together with ESWL was 100 %. No major complications were encountered during or after the procedure, although six minor complications (5 %) occurred. Two minor abdominal leakages, one a suspicious ureteral puncture with a laser fiber and one a renal puncture with a guide-wire, were identified and treated with a double J stent. A split retrieval coil (Stone Cone™ Nitinol Urological Retrieval Coil; Boston Scientific) fragment was noticed in a kidney after the procedure; this required a second intervention. The mean duration of hospitalization was 2.3 days (range, 1–5 days). Recurrence of urolithiasis was a long-term complication in two patients; no other long-term complications were revealed by ultrasonography. The postoperative findings are summarized in Table 2.

Discussion

Urolithiasis is a common problem in adults and children in Turkey, particularly in the Southeastern Anatolia Region [3, 4]. However, treatment of urinary stones in children is challenging because they have a relatively narrow urinary tract. Thus, minimally invasive treatments such as URSL, ESWL, and PCNL are more essential in children [1, 14, 15]. The miniaturization of instruments and technological developments such as laser lithotripsy have improved urolithiasis treatment in children [9, 10, 12, 15].

ESWL and URSL procedures are recommended by the European Association of Urology as first-line ureteroscopic management alternatives for pediatric patients [16]. URSL is preferred as first-line treatment for pediatric urolithiasis by many pediatric urologists [9, 10, 17]. URSL seems to be an effective and safe procedure with minimal complication rates and high stone-free results [8–10, 17]. We also prefer using URSL and ESWL alone or together to treat almost all pediatric urolithiasis cases for stones located anywhere in the urinary tract.

Lithotripters with various energy sources such as ultrasonic, pneumatic, electrohydraulic, and laser sources are used for URSL lithotripsy procedures. Pneumatic lithotripters are effective, safe, and reliable for pediatric ureteral stones; however, they have the disadvantage of higher rates of stone migration into the upper urinary system [9]. Laser lithotripters are also effective, safe, and reliable for removal of pediatric stones from any location in the urinary tract. This procedure can be conducted through flexible and ultrathin instruments and in all endoscopic lithotripsy procedures, including mini- or micro-PCNL [18, 19]. Laser lithotripsy also has a shorter operative time, higher stone-free rates (77–100 %), and lower complication rates [8–10, 13, 20, 21]. We have been using a laser lithotripter for pediatric stone treatment since 2006, and only one fragmented proximal ureteral stone has migrated to the renal pelvis; this was fragmented in a second procedure by double J stent removal using a laser lithotripter. Our data confirm the effectiveness and safety of holmium laser lithotripsy for treatment of urinary stones in children.

Intraoperative and postoperative minor and major complications occur during endoscopic lithotripsy procedures in 0–17 % of patients [5, 8–15, 17, 20, 22]. We did not detect any major complications in our series, but we experienced six (5 %) minor complications (Table 2), which was comparable to other recent reports in children and adults. Five of these cases were easily treated with a double J stent. The other complication, a split fragment of a retrieval coil in the kidney, required a second intervention. We have used several accessory instruments such as stone extractors (NCompass®, NCircle®, and NGage®; Cook Medical) and retrieval devices (Stone Cone™, Boston Scientific and NTrap®; Cook Medical). However, all are resistant to stray, but not direct, laser energy, and retrieval devices restrict handling of the endoscope. Thus, care should be taken not to damage them or the ureter during laser lithotripsy.

If required, we gently dilate the ureter, using only controlled ureteral balloon dilatators via endoscopic and fluoroscopic guidance. Thus, complications regarding this procedure may not be seen. Nevertheless, this is usually not needed with the use of a miniature URS. We gently enter directly through the ureter without guide-wires in some patients, although this approach should be performed with extreme care by only experienced clinicians, particularly in children who may develop severe complications requiring additional interventions.

The advent of smaller instruments and other technological developments have made URSL available for older children and infants in most pediatric urological centers [5, 8–10]. In our study, the stone-free rate in <7 year old children versus those ≥7 years old was not significantly different. Therefore, we believe that laser URSL may be useful in children of all ages when guided by experienced hands with appropriately thin instruments. Unsal et al. [8] reported that the success rate for kidney stones <10 mm was significantly higher than that for stones ≥10 mm during retrograde intrarenal surgery (100 % vs. 81.8 %) in 16 children ≤7 years old. Our kidney stone size success rates were similar, but the difference between the rates for different sizes was not significant. PCNL also has high stone-free rates compared with those of ESWL, but PCNL is usually reserved for larger stones such as staghorn stones. ESWL and/or retrograde intrarenal surgery treatment failures may occur more often owing to the more invasive nature of the procedures. In addition, complications such as sepsis, bleeding, renal pelvis perforation, and damage to the closest organs are not uncommon [14, 23]. Our success rate for kidney stones (mean size, 13.1 mm; range, 8–25 mm) was 81.3 % (<10 mm, 90.9 % vs. ≥10 mm, 78.4 %), which was comparable to the rates of PCNL for treating mid-sized kidney stones.

In adults, laser lithotripsy via URSL or PCNL had been used for large stones (>2 cm), but use of this procedure in children is limited [24–27]. We used laser lithotripsy to treat two children with large stones: a 30-mm stone in the bladder and a 25-mm stone in the kidney. Patients with urolithiasis should be rendered stone-free in one procedure, with the fewest complications and least amount of damage possible. Although our success rate for all non-renal stones was 100 %, our success rate for kidney stones ≥10 mm was lower (78.4 %). One reason for the lower rate for kidney stones may be that we were not forced to break the whole stone during only one procedure; given the long operating time or invasiveness of the procedure for larger kidney stones (≥10 mm), we placed a double J stent instead, particularly in cases of obstruction and friability, to avoid injury and sepsis. In such cases, residual stones may wholly and spontaneously pass through the ureter and be more easily treated by extraction during the removal of the double J stent from the ureter, or may be treated during subsequent ESWL and/or URSL procedures. Finally, the complication rate in our patients was only 5 %, and the overall success rate of URSL together with ESWL was 100 %. However, we should not forget that complications can increase with multiple procedures.

There were limitations in this study. First, vesicoureteral reflux and ureteral stricture were not evaluated routinely. Second, all procedures were not performed by one surgeon, although 91 % were performed by the same surgeon.

This study confirms the effectiveness and safety of holmium laser lithotripsy for treatment of all urinary stone locations in children of any age. Further prospective randomized studies are required to explain and compare minimally invasive stone treatment procedures in children.

Conflict of interest The authors have no financial disclosures relevant to this article.

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