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# Laser lithotripsy in the treatment of renal stones in children.
## A single-center experience

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**Laser lithotripsy in the treatment of renal stones in children. A single-center experience**

AIM: *To evaluate the effectiveness and safety of laser lithotripsy in the treatment of renal stones in children in a single center.*
MATERIAL AND METHODS: *We retrospectively analysed patients (n=36) who were treated with laser nephrolithotripsy (LL group) between 2011 and 2014. We compared those results with results of pneumatic nephrolithotripsy in patients (n=32) who were treated from 2007 to 2011 (PL group). The patients were evaluated in respect of gender, age, stone location, stone size, complications and stone-free rate.*
RESULTS: *The duration of anesthesia, the need for retreatment, the mean hospitalization and the occurrence of minor complications (perirenal haematoma, urinoma, minimal ureteral perforation) were significantly lower in LL group ($p < 0.05$). We found statistically significant difference in stone-free rate between two groups – stone-free rate was significantly higher in LL group (LL: 94.4% vs. PL: 62.5%) ($p < 0.05$).*
DISCUSSION: *Analyzing the stone-free rate after lithotripsy and the occurrence of complications, it is shown that the laser lithotripsy is more efficient than pneumatic lithotripsy and that endoscopic procedure proved safer, in terms of complications. Majority of the studies showed different successful rate after laser lithotripsy for stones located in the kidney. In particular cases, there is the need for ureteral orifice dilatation and ureteral stent insertion.*
CONCLUSIONS: *Laser endoscopic lithotripsy is minimally invasive, effective and safe surgical procedure for the treatment of renal stones in children with minimal complication rate. The effectiveness is partially limited to stones in lower pole calices of the kidney.*

KEY WORDS: Laser lithotripsy, Urolithiasis, Ureterorenoscopy

## Introduction

Urolithiasis in children is much more frequent than it used to be [1]. Pediatric patients make 1-2% of all patients with urinary stone disease [2,3]. The rate of recurrence is very high, especially in patients who weren't adequately treated from metabolic abnormalities [3]. Principles of surgical treatment are basically the same as in adults, but some technical aspects are more difficult in children [4]. Instruments for the endoscopic treatment in pediatric patients have smaller calibre. Those instruments are greatly required for the instrumentation and they can be used only in the hands of experienced surgeons. At the same time, the price of those instruments is much higher then those for adult patients [4,5]. There is no consensus in current literature about the most effective treatment of renal stones in children [2,3,6] (Fig. 1). The options are: open surgery, extracorporeal shock-wave lithotripsy, percutaneous lithotripsy and endoscopy [6,7]. Nowadays, we

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Fig. 1: KUB radiography in patient with cystine stone in the left kidney.

Fig. 2: Endoscopic view of laser lithotripsy.

can state that open surgery is an out of date approach. Extracorporeal shock-wave lithotripsy is one of the least invasive surgical technique, but in some types of calculi, like cystine and oxalate, it doesn't give good results [8,9]. In the recent past, the use of percutaneous lithotripsy was controversal in children, but advances in technical equipement, like construction of small caliber instruments with minimal tissue damage, make that technique very useful in children [10]. Endoscopy is technique of choice for ureteral stones [11,12]. If the stones are located in cavities of the kidney, ureterorenoscopy is very demanding [13]. Semirigid instruments could be useful only when the stone and the instrument are in the same direction. When the stone is deep inside cavities of the kidney, only flexible instruments could be used [14,15]. The most useful lithotripters are pneumatic and laser. Combining flexible ureterorenoscopy and laser lithotripsy, stones in all segments of the kidney could be reached. It is published that all types of stones could be disintegrated with laser beam [2,3,16] (Fig. 2).

## Material and Method

We retrospectively analyzed results of laser lithotripsy (LL group) in 36 patients with renal stones, treated between August 2011 and September 2014 at our institution (17 girls and 19 boys, mean age 9.5 years, range 2-17). Patients with stones in other segments of urinary tract (ureter, bladder, urethra) were excluded. Control group consisted of 32 patients who were treated with pneumatic lithotripsy (PL group) from July 2007 to July 2011 (16 girls and 16 boys, mean age 9.1 years, range 2-17). In both groups semirigid 6.5-F and 8-F ureterorenoscopes were used. In LL group flexible 7.5-F ureterorenoscope was also used. The sources of energy in study and control group were holmium: YAG laser and pneumatic lithotripter, respectively. Before the surgery, we evaluated urinalysis, urine culture and kidney function tests. Also, metabolic screening of urine was performed to identify the causes of the disorder which led to the formation of stones. Ultrasound and kidney, ureter and bladder radiography (KUB) were performed, and also urography, if it was necessary. We measured stone size by ultrasound and radiography. Surgical procedures were done under general anesthesia, and all patients received routine antibiotic prophylaxis. In majority of patients dilatation of ureteral orifice was not needed, but in some number of them there was the need for it. Ureteral dilation balloon cathether 4 mm was used. After passing the ureteral orifice ureterorenoscope was placed through the ureter to the renal pelvis. In PL group semirigid ureterorenoscope was used in all patients. Air pressure of pneumatic lithotripter was set at 3 bars and frequency at 12 Hz. In LL group both semirigid and flexible ureterorenoscopes were used. When the stone was located in renal pelvis or in upper pole renal calices, semirigid ureterorenoscope was used. When the stone was located in lower pole calices or if it could not be visualized with semirigid ureterorenoscope in any part of the kidney, the flexible ureterorenoscopy was performed. In PL group

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0.8 mm and 1 mm probes were used for fragmentation of the stone. In laser lithotripsy group a 550 m and 200 m probes with a 3 mV green helium light guide were used for the lithotripsy. We used micro laser fibers generating 0,2 to 2 J at a frequency of 5-10 Hz. In both groups, the lithotripsy was being carried out until stone was fragmented in particles with the size of 3 mm or less. Larger stone particles (2-3 mm) were removed by stone-basket, while smaller particles were left for spontaneous passage. In case of mucosal damage and in case there was a risk of ureteral stone particles obstruction, ureteral stent was placed. We used double J stents 4-F and 4.7-F, depending on the age and constitution of the patient. Those stents were removed after 2 to 5 days. Postoperatively all patients were assessed by ultrasound in the first two days. They were discharged after one to three days, depending on the severity of surgical procedure, presence of complications and the general state of a patient. All patients were evaluated after one, three and six months after the surgery by urinalysis, ultrasound and, if needed, KUB radiography. The presence of residual stones (> 3mm) indicated the need for retreatment. The Mann-Whitney *U* test was used to determine the differences between groups. The data were statistically analyzed with SPSS 22.0 for Windows software, and a $p$ value < 0.05 was considered to indicate statistical significance.

## Results

Ureterorenoscopy (semirigid or flexible) and laser-nephrolithotripsy were performed in the total number of 44 procedures in 36 patients in LL group. In PL group semirigid ureterorenoscopy and pneumatic lithotripsy were performed in the total number of 47 procedures in 32 patients. The female/male ratios (17:19 and 16:16, respectively) and mean ages of the patients (9.5, range 2-17 and 9.1, range 2-17, respectively) in both groups were similar ($p > 0.05$). Single/multiple stones ratios (30:6 and 27:5, respectively) were also similar in both groups ($p > 0.05$). Location of the stone in LL group was: renal pelvis in 10 (27.8%), upper pole calices in 10 (27.8%) and lower pole calices in 16 (44.4%) patients. In PL group: renal pelvis in 17 (53.1%), upper pole calices in 10 (31.3%) and lower pole calices in 5 (15.6%) patients. In LL group stones were located in left kidney in 12 (33.3%), in right kidney in 18 (50%) and in both kidneys in 6 (16.7%) patients. In PL group in left kidney in 11 (34.4%), in right kidney in 15 (46.9%) and in both kidneys in 6 (18.7%) patients. There was no significant difference in terms of stone side between the groups. Mean stone sizes were similar in LL and PL group (13.5 mm, range, 8-32 mm and 13 mm, range, 8-28 mm, respectively) ($p > 0.05$) (Table I).

Mean duration of general anesthesia in study group was 65 minutes (range, 40-90) and 75 minutes (range, 40-105) in control group, with statistically significant difference between the groups ($p < 0.05$). There was the need for retreatment in 8 (22.2%) patients in LL group: in four patients with bilateral calculosis and in four patients whose initial stone size was 20 mm or more. In PL group, there was the need for retreatment in 12 (37.5%) patients: in six patients with bilateral calculosis and in six patients whose initial stone size was 20 mm or more. In three (9.4%) patients in PL group with very large stones the third treatment (retreatment No 2) was necessary. The need for retreatment was significantly lower in LL group ($p < 0.05$). In both LL and PL groups, there was the need for ureteral orifice dilatation in 7 (19.4%) and 6 (18.8%) patients, respectively. Ureteral stent was inserted in 14 (38.9%) and in 12 (37.5%) patients, respectively. There was no statistically significant difference in the need for ureteral orifice dilatation and ureteral stent insertion ($p > 0.05$) between the two groups. Duration of hospitalisation was significantly lower in LL group: 1-3 days (mean, 1.6 days) and 1- 4 days (mean, 2 days) in PL group, respectively ($p < 0.05$). Complications were presented after two (4.6%) surgical procedures in LL group: perirenal haematoma in one (2.3%) and urinoma in one (2.3%) patient. There were complications after 4 (9.1%) surgical procedures in PL group: perirenal haematoma in 2 (4.5%) cases and minimal ureteral perforation after 2 (4.5%) procedures. The occurence of complications was significantly lower in LL group ($p < 0.05$). After the treatment, overall stone-free rates in study and control groups were 94.4% (34 of 36) and 62.5% (20 of 32), respectively. All patients in LL group with stones in renal pelvis (10 of 10, 100%) and upper pole calices (10 of 10, 100%) were free of stone after the laser lithotripsy procedure. In 14 of 16 (87.5%) patients with the stone in lower pole calices, the stone was completely fragmented, while in two (12.5%) patients, the stone was incompletely fragmented. In PL group, in 12 of 17

TABLE I - *Preoperative findings of patients.*

| | LL group | PL group |
|---|---|---|
| No. of patients | 36 | 32 |
| Female | 17 (47.2%) | 16 (50%) |
| Male | 19 (52.8%) | 16 (50%) |
| Mean age, years (range) | 9.5 (2-17) | 9.1 (2-17) |
| Single stone | 30 (83.3%) | 27 (84.4%) |
| Multiple stones | 6 (16.7%) | 5 (15.6%) |
| Location of stone | | |
| Renal pelvis | 10 (27.8%) | 17 (53.1%) |
| Upper pole calices | 10 (27.8%) | 10 (31.3%) |
| Lower pole calices | 16 (44.4%) | 5 (15.6%) |
| Stone side | | |
| Left | 12 (33.3%) | 11 (34.4%) |
| Right | 18 (50%) | 15 (46.9%) |
| Bilateral | 6 (16.7%) | 6 (18.7%) |
| Mean stone size, mm (range) | 13.5 (8-32) | 13 (8-28) |

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Table II - *Postoperative findings of patients*

| | LL group | PL group |
|---|---|---|
| No. of procedures | 44 | 47 |
| Mean anesthesia, min (range) | 65 (40-90) | 75 (40-105) |
| Retreatment No 1 | 8/36 (22.2%) | 12/32 (37.5%) |
| Retreatment No 2 | 0/36 (0%) | 3/32 (9.4%) |
| Ureteral orifice dilatation | 7/36 (19.4%) | 6/32 (18.8%) |
| Ureteral stent insertion | 14/36 (38.9%) | 12/32 (37.5%) |
| Mean hospitalization, days (range) | 1.6 (1-3) | 2 (1-4) |
| Complications | 2/44 (4.6%) | 4/44 (9.1%) |
| Perirenal haematoma | 1/44 (2.3%) | 2/44 (4.5%) |
| Urinoma | 1/44 (2.3%) | 0/44 (0%) |
| Minimal ureteral perforation | 0/44 (0%) | 2/44 (4.5%) |
| Stone-free rate (overall) | 34/36 (94.4%) | 20/32 (62.5%) |
| Stone-free rate (location) | | |
| Renal pelvis | 10/10 (100%) | 12/17 (70.6%) |
| Upper pole calices | 10/10 (100%) | 7/10 (70%) |
| Lower pole calices | 14/16 (87.5%) | 0/5 (0%) |
| Mean follow-up, months (range) | 14 (6-31) | 15 (6-36) |

(70.6%) patients with location of stone in renal pelvis, stones were completely fragmented after the treatment. Also, in 7 of 10 (70%) patients with the stone in upper pole calices, stones were completely fragmented. In all patients with the stone in lower pole calices, pneumatic lithotripsy was completely unsuccessful (0 of 5). There was statistically significant difference in stone-free rates in relation of localization of stones between the two groups ($p < 0.05$). Mean follow up in LL and PL groups was similar: 14 (range, 6-31) months and 15 (range, 6-36) months, respectively ($p > 0.05$). (Table II).

## Discussion and Commentary

Although urolithiasis is not as frequent in children as in adults, some questions about the efficacy of the treatment are similar. It is very difficult to determine which kind of treatment is the most effective [3,4]. On the other hand, charachteristics of children's body make the problem more complicated. A narrow urinary tract is one of specificities of pediatric age [17]. Construction of endoscopic instruments has to be adapted for every age group. For younger age there is the need for instruments which have to be sufficiently small and, at the same time, sufficiently effective. Also, instrumentation must be safe. Sometimes, handling those instruments is very demanding. Technological improvements with the construction of small-calibre ureterorenoscopes ensure safer instrumentation in very young children [5,18].

Extracorporeal shock-wave lithotripsy (ESWL) and ureterorenoscopic lithotripsy procedures are recommended as the first-line treatment alternatives for pediatric urolithiasis by the European Association of Urology [19].

In many pediatric centers ureterorenoscopic lithotripsy is the first-line treatment [20]. Being a safe and effective procedure with the lowest complication rate, that kind of treatment is considered to be the least invasive procedure in children [21]. Many authors suggest combination of ESWL and ureterorenoscopy as the most effective way of treatment [5].

Various types of lithotripters are used for stone disintegration. There are: ultrasonic, electrohydraulic, pneumatic and laser lithotripters [22]. Atar et al. reported that efficacy of pneumatic and laser lithotripsy in the treatment of bladder and ureteral calculosis is similar [23]. Possibility of stone migration in renal pelvis is higher during pneumatic lithotripsy and ureteral perforation is cited as the complication during that kind of lithotripsy [24]. But, when the stone is located in renal cavities, the efficacy of laser lithotripsy is much higher. Laser lithotripsy can be conducted through flexible ureterorenoscopes and almost any part of urinary tract can be available for lithotripsy. Laser lithotripsy has a shorther operative time, lower complication rate and higher stone-free rate in comparison with pneumatic lithotripsy [3,4,18,25]. The preferred type of laser lithotirpters is Holmium: YAG (yttrium-aluminium-garnet) laser. This is a pulse laser with a wavelenght spectrum of 2140 μm. Each pulse of energy generated within the 0.2 to 2 J range for 350 μs is rapidly absorbed by water. The termal effect penetrates to a 0.5 mm depth soft tissue. In stones composed from calcium, cystine, oxalate and struvite, the effectiveness of laser lithotriptor comes to the fore [23,25,26]. Our experience with Holmium: YAG laser also prove the effectiveness of that kind of lithotripsy.

Different minor and major complications were described during endoscopic lithotripsy procedures, such as: perforation of ureter, perirenal haematoma, urinoma, renal puncture with guide-wire, sepsis, split coil fragment in kidney, etc. The occurence of complications could be 0 to 17% [16,18,27]. In our series, in study group we found two (4.6%) minor complications: perirenal haematoma in one patient and urinoma also in one patient. Both were treated conservatively: intravenous antibiotic therapy and bed rest, with daily ultrasound examination. After three days ultrasound findings were normal. In control group minor complications were found in 4 (9.1%) patients: perirenal haematoma in two patients and minimal ureteral perforation in two patients. Patients with perirenal haematoma were treated in the same way as patients in study group. In other two patients minimal ureteral perforation was noticed during the pneumatic lithotripsy procedure. Complications were treated by placing double J stent at the end of the procedure. Those stents were removed after three weeks. Although major complications were not noticed in both groups, we can state that the occurence of complications is directly related to surgeons' experience in ureterorenoscopy and to the choice of lithotripsy type [27,28]: the occurence of complications is lower in patients who were treated with laser

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lithotripsy. Thus, it is very important for the safety of these procedures to be performed by an experienced surgeon.

Generally, there is no need for ureteral dilatation if small-calibre instruments are used. Sometimes, especially in younger age patients, dilatation is needed. That procedure has to be done gently, using ureteral balloon dilatators with endoscopic guidance [2,12,29]. In our series in LL group in seven (19.4%) patients (4 girls and 3 boys, aged 2 to 11 years) we performed ureteral orifice dilatation, using ureteral 4 mm balloon-dilator. In PL group that procedure was necessary in 6 (18.8%) patients (2 girls and 4 boys, aged 2 to 13 years). We did not have any complications regarding that procedure. We can state that the need for ureteral orifice dilatation is not related to the choice of lithotripsy type.

After the lithotripsy procedure, a surgeon has to estimate if ureteral stenting is required. If there is excessive mucosal damage, ureteral wall stricture, risk of obstruction with stone particles, ureteral stenting is required [29]. We performed it in 14 (38.9%) patients in LL group (5 girls and 5 boys of all age groups), using 4-F and 4,7-F double J stents. Also, we performed ureteral stenting in 12 (37.5%) patients (5 girls and 7 boys of all age groups) in PL group.

In various publications, stone-free rate after laser nephrolithotripsy has been reported between 77 and 100%. Uygun et al. report stone-free rate for kidney stones of 91.9%, while Straub et al. report stone-free rate of 94% [16,17,25,27,30]. In our series overall stone-free rates in LL and PL groups were 94.4% and 62.5%, respectively. Also, we realized that it takes less time to perform procedure during laser lithotripsy than pneumatic lithotripsy and that the total number of required surgical interventions is lower. It is very clear that the possibility for stone disintegration with laser lithotripsy is significantly higher than with pneumatic lithotripsy.

We found that all patients with stones in every part of the kidney were successfully treated with laser lithotripsy, with the exception of two patients with the stone in lower pole calices. We couldn't solve the problem because stones were located deep in lower pole calices. The deflection of flexible ureterorenoscope, with laser fiber within, was insufficient and stones could not be reached with laser fiber, even using the laser 200 m probe. In those two cases, fragmentation of calculi was only partial and patients were selected for alternative treatment options - extracorporeal shock-wave lithotripsy vs. percutaneous lithotripsy. On the other hand, stone-free rate after pneumatic lithotripsy was significantly lower in all segments of the kidney. Moreover, in lower pole calices, pneumatic lithotripsy was comletely unsuccessful.

Nevertheless, stone-free rate after laser lithotripsy in our series represents good success rate and it is in accordance with current literature. In our following studies we will have to evaluate which elements of the procedure are responsible for limitations of success rate.

## Conclusion

Laser endoscopic lithotripsy is minimally invasive, effective and safe surgical procedure for the treatment of renal stones in children in all age groups. The effectiveness is partialy limited when stones are located in lower pole calices of the kidney. Complication rate is very low. Further clinical studies and development in construction of endoscopic instruments and technical devices will ensure more effective and safer outcome of surgical treatment for pediatric urolithiasis.

## Riassunto

L'urolitiasi nell'infanzia è molto più frequente di un tempo. I principi del trattamento chirurgico sono essenzialmente gli stessi di quelli dell'età adulta, ma alcuni aspetti tecnici sono più difficili da realizzare nel bambini. Nella letteratura corrente non c'è consenso riguardo al trattamento più eficace della calcolosi renale nel bambino. Utilizzando associati l'ureterorenoscopio flessibile e la litropsia laser è possibile raggiungere i calcoli in tutti i recessi renali.

Abbiamo esaminato retrospettivamente i risultati della litotripsia laser (gruppo LL) in 35 pazienti con calcolosi renale trattati tra Agosto 2011 e Settembre 2014 nel nostro istituo (17 ragazze e 19 ragazzi, dell'età media di 9,5 anni, compresa tra 2 e 17 anni). Il gruppo di controllo è rappresentato da 32 pazienti sottoposti a trattamento litotriptico pneumatico (gruppo PL) tra Luglio 2007 e Luglio 2011 (16 ragazze e 16 ragazzi, dell'età media di 9,1 anni, compresa tra 2 e 17 anni). Per determinare la differenza tra i gruppi è stato usato il test U di Mann-Whitney.

Il rapporto F/M, l'età media dei pazienti ed il rapporto tra calcolosi singola e multipla erano simili tra i due gruppi ($p > 0.05$). Non c'erano differenze significative circa il lato della calcolosi tra i due gruppi. Il colume medio dei calcoli erano simili nei gruppi LL e PL ($p > 0.05$). La durata dell'anestesia, la necessità di reintervenire, la durata dei ricoveri e l'incidenza di complicanze minori (ematoma perirenale, urinoma, perforazione ureterale minima ) sono state significativamente minori nel gruppo LL ($p < 0.05$). Non c'è stata differenza statisticamente significativa per l'effettuazione di dilatazione dell'orificio ureterale e l'inserimento di stent ($p > 0.05$) tra i due gruppi.

Abbiamo trovato invece differenze statisticamente significative nell'incidenza della completa bonifica dalla litiasi tra i due gruppi, con bonifica totale più numerosa nel gruppo LL (LL: 94.4% vs. PL: 62.5%) ($p < 0.05$). Differenze statisticamente significative di bonifica totale sono state rilevate tra i due gruppi in rapporto alla localizzazione dei calcoli – considerando tutte le localizzazioni intrarenali (pelvi, calici di entrambi i poli) – con bonifica completa più elevata nei gruppo LL ($p < 0.05$).

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È molto difficile stabilire quale è il tipo di trattamento più efficace nell'urolitiasi in età pediatrica. La litotripsia extracorporea shock-wave (ESWL) è una delle procedure meno invasive, ma in alcuni tipi di calcoli, come quelli cistinici e di ossalato, non è sufficientemente efficace. L'efficacia della litotripsia pneumatica e la litotripsia laser nel trattamento della calcolosi vescicale ed uretrale è simile. Ma quando il calcolo è localizzato nelle cavità renali, l'efficacia della litotripsia lasewr è molto superiore, ed ha un tempo di esecuzione più breve, minore incidenza di complicazioni e maggiore incidenza di bonifica totale a paragone con la litotripsia pneumatica.
La litotripsia laser endoscopica è minimamente invasiva, efficace e sicura per il trattamento chirurgico della calcolosi renali nell'infanzia di tutti i gruppi di età. L'efficacia è parzialmente limitata quando i calcoli sono localizzati nei calici del polo renale inferiore. L'incidenza delle complicazioni è molto bassa.
Ulteriori studi e nuovi sviluppi nella costruzione di strumentario endoscopico e supporti tecnici assicureranno risultati migliori e più sicuri nel trattamento chirurgico della urolitiasi in età pediatrica.

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