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ELECTROHYDRAULIC VERSUS HOLMIUM LASER LITHOTRIPSY FOR BLADDER AND URETHRAL STONES IN CHILDREN

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Objective: To compare the efficacy and safety of electrohydraulic and Holmium laser lithotripsy in the treatment of bladder and/or urethral stones in children.

Patients and Methods: Between January 2000 and January 2006, 112 children (102 boys and 10 girls) aged between 2 and 13 years presented to our department with vesical (n=72) and urethral (n=40) stones. Previous surgery for bladder stones was reported in 28/112 (25%) cases. The stone burden ranged from 4-22 mm. The stones were radiolucent in 12 (10.7%) cases. Multiple bladder and combined urethral and vesical stones were recorded in 14 (12.5%) cases. The children were divided into two groups according to the treatment modality: 50 children (Group A) were treated by electrohydraulic lithotripsy (EHL) using either pediatric cystoscopes or the short ureteroscope, 7 F, while in 62 children (Group B) Holmium laser was used through a 7.5 F pediatric endoscope without any modification. Follow up range was 1-1.5 years.

Results: In Group A, disintegration was successful in 48/50 (96%) cases. The mean operative time was 18.3 minutes. The urethral catheter was maintained for 24-72 hours (mean 36 hours). Conversion into open surgery was necessary in two cases. No other major operative or postoperative complications were encountered. In Group B, complete disintegration was achieved in all cases including impacted urethral stones. The mean operative time was 15.7 minutes. The urethral catheter was left for one day only in 36 (58.1%) cases.

Conclusions: In our series, Holmium laser lithotripsy used for the treatment of bladder or urethral stones in children caused no complications and achieved slightly better results than electrohydraulic lithotripsy. Nevertheless, electrohydraulic lithotripsy remains an effective and a viable option despite its rare - yet sometimes serious - complications.

Key Words: children, vesical stones, urethral stones, Holmium laser, electrohydraulic lithotripsy.

INTRODUCTION

In developing countries there is still a high incidence of bladder stones in children which has been attributed mainly to dietary factors, particularly the dependence on cereals and rice.[1] Currently, bladder stones represent about 5% of all urinary calculi and are 2-3 times more common in males than females.[2] The rate of recurrent stones in children has been reported to be 6.5% to 54%.[3] In the past, patients of such young age would be subjected to multiple surgical interventions until minimally invasive treatment options became available.[4] The continuous evolution in the evaluation and management of stone disease and the advent of small caliber endoscopes and different types of intracorporeal lithotriptors (per interim electrohydraulic (EHL), ultrasonic, laser and pneumatic lithotripsy) have enabled urologists to treat an increasingly large number of urinary stones in children via a minimally invasive approach.[5-6]

The aim of lithotripsy is to fragment a stone into several extractable pieces or to reduce its size allowing spontaneous passage of the stone particles.[7] However, obviously each type of lithotriptor carries its own advantages as well as its peculiar shortcomings making each one more suitable for specific applications.[8]

This study was designed to compare the clinical utility, efficacy and safety of electrohydraulic and Holmium laser lithotripsy in children with bladder and/or urethral stones.

PATIENTS AND METHODS

Between January 2000 and June 2006, 112 children (102 boys and 10 girls) aged between 2 and 13 years were treated for urinary stones at our department. At presentation 82 children (73.2%) suffered from lower urinary tract symptoms with or without hematuria, while 30 children (26.8%) presented with acute urinary retention. Previous surgery for bladder stones was reported in 28/112 (25%) cases. Three patients (2.7%) had reconstructed bladders.

Preoperative evaluation included plain radiography of the urinary tract, abdominal ultrasonography, urine analysis with culture sensitivity, complete blood picture and bleeding profile assessment.

Bladder stones were found in 72 (64.3%) and urethral stones in 40 (35.7%) patients, among them 14 (12.5%) with multiple vesical and/or urethral stones. Radiolucent stones were detected in 12 cases (10.7%).

The stone size in both groups ranged from 4 to 22 mm in diameter. The stone characteristics in both groups are presented in Table 1.

Fifty children (Group A), 32 with primary vesical and 18 with primary urethral calculi, were treated by EHL using a RIWOLITH 2280 Electrohydraulic Lithotripter (Richard Wolf GmbH). In 47 cases, including 15/18 urethral stones (83.3%) that could be pushed back to the bladder by endoscopic hydraulic irrigation, the stones were disintegrated inside the bladder in a way to achieve a particle size <2 mm without attempting its retrieval. The remaining 3 urethral stones were impacted and necessitated partial in-situ disintegration; particles >3 mm were further disintegrated inside the bladder. Stones were multiple in 6 (12%) children including one girl with an augmented bladder who needed two sessions with 3 days apart due to the high stone burden and the marked turbidity of the field.

The lithotripter power was adjusted between 1 J down to 500 mJ/pulse. The desired frequency (pulse rate) was adjusted between 6-20 Hz. The mode of discharge was either single pulse, pulse sequence or continuous pulse, but the latter was found to be hazardous and was therefore not used. The probe sizes used were 2.4 F and 3.5 F. Larger or smaller probes were available but not used. These parameters were adjusted on an individual basis. The procedures were done through a pediatric endoscopic set, 6 / 7.5F or a short ureteroscope, using normal saline for irrigation. No targeting of the stone was done unless the tip of the probe was at least 1-2 mm away from the bladder wall and 4-5 mm away from the tip of the endoscope. The time of lithotripsy was calculated. A Foley urethral catheter was inserted in all cases.

Sixty-two children (Group B), 40 with vesical and 22 with urethral calculi, were treated with a VersaPulse Power Suite 20 Watt Holmium laser which has a wave length of 2.1 microns, a repetition rate of 5-20 Hz, an energy/pulse range from 0.5 to 2.5 J. and 3 intensity speeds. These parameters were adjusted on an individual basis. The energy was delivered through reusable 200 um quartz fibers. We used a pediatric endoscopic set 7.5 F without modification. Fifty-seven cases underwent vesical disintegration of the stones, including 17/22 (77.3%) urethral stones that could be pushed back to the bladder. The remaining 5 urethral stones were impacted and were completely powdered in-situ. The laser was precisely fired to the stone under direct protected vision; the aiming beam had a red diode. The fiber was adjusted at a distance of 1 mm from the stone aiming at complete powdering of the stones and leaving only insignificant fragments for

Table 1: Stone characteristics in both groups

Characteristics	Group A - EHL n=50		Group B - Laser n=62		Total n=112	
Primary vesical stones	32/50	64.0%	40/62	64.5%	72/112	64.3%
Primary urethral stones	18/50	36.0%	22/62	35.5%	40/112	35.7%
- pushed into the bladder	15/18	83.3%	17/22	77.3%	32/40	80.0%
- impacted in the urethra	3/18	16.7%	5/22	22.7%	8/40	20.0%
Multiple vesical/urethral stones	6/50	12.0%	8/62	12.9%	14/112	12.5%

EHL: electrohydraulic lithotripsy

spontaneous passage. The time of lithotripsy was calculated.

Urethral catheterization was needed only in 36 children (58.1%), including cases with urethral stones, hematuria and some cases with a relatively longer operative time.

All children were managed under general anesthesia. Antibiotics were administered prophylactically before and two days after the intervention. In both groups, the stones were manipulated in a wide area of the bladder cavity part of which was extending well cephalic to the stone. Urethroscopy was initially carried out to assess the caliber of the urethra as well as to push urethral stones back to the bladder by irrigation.

Follow-up one week after catheter removal and then again every 6 months for 1.5 years included clinical assessment, evaluation of the urinary stream, abdominal ultrasonography and plain radiography. Success was defined as the perurethral endoscopic disintegration of stone/s down to passable gravels without any sonographic or radiographic evidence of the stone/s one week after spontaneous voiding regardless of the method of lithotripsy.

RESULTS

In Group A (EHL) disintegration was successful in 48/50 (96%) cases. Intraperitoneal bladder perforation occurred in two cases (4%), which were converted to open surgery with an uneventful post-operative course. One patient, a girl with multiple stones in an augmented bladder, needed two sessions due to the large stone burden and marked turbidity of the field during the first trial. Injury of the bladder mucosa occurred in 5 cases (10%). The time of lithotripsy ranged from 11 to 37 minutes (mean: 17.3 minutes). The smallest stone (4 mm) required 15.6 minutes for treatment which was not the shortest time required compared to other – virtually larger - bladder stones. Different probe sizes were used: a 3.5 F probe was used in 42 (84%) cases, while the 2.4 F probe was used in 8 cases. The 51 treatment sessions called for 55 probes in use (1.1 probes/ case). On 3 occasions, two probe sizes/case were used. In one case, the metallic tip of the probe was fractured, the missed tip was endoscopically retrieved and the damaged probe was then replaced.

The power setting used in 48 (96%) cases ranged from 500 mJ to 1 J. A smaller power (< 500 mJ) was tried in the initial two cases and was not effective. The mode of discharge was single pulse for testing, then pulse sequence mode in all cases. The mean hospital stay was 1.1 days. Postoperative catheterization for 24 -72 hours (mean 36 hours) was required for all patients. Mild hematuria was noted in 7 (14%) cases and relieved spontaneously. Postoperative fever occurred in 4 (8%) children and responded well to medical treatment.

In Group B (Holmium laser lithotripsy), 17 (77.3%) of 22 urethral stones could be pushed back to the bladder and, thus, stone disintegration inside the bladder could be achieved in 57/62 cases. The remaining

5 urethral stones were impacted, and complete powdering was achieved in-situ without thermal injury and within a short time not exceeding 9 minutes. All cases treated by Holmium laser needed a single treatment session only, even the 8 children with multiple stones. Complete disintegration was achieved in all cases within 9 to 31 minutes. Thermal mucosal injury occurred in 5 cases (8.1%). The mean operative time was 15.3 minutes. Postoperative fever and mild hematuria were recorded in 5 (8.1%) cases each. Urethral catheterization was needed for one day in 36 (58.1%) children; cases without catheterization experienced no problems in postoperative voiding. The mean hospital stay was one day.

No retained gravels, stone recurrence or urethral stricture were detected postoperatively and during one and a half years of follow-up in both groups. The comparative results are shown in Table 2.

DISCUSSION

The main goal of any treatment modality for urinary stones is to render the patient stone-free under one anesthetic with the least morbidity and risk possible.[9] A balance has to be created between achieving efficacy and maintaining safety. Safety is actually given higher priority though efficacy is an obligation.

Controversy exists about transurethral treatment of bladder calculi in young boys. The delicacy of the urethra must be a primary consideration; for this reason open surgery for urolithiasis in children is still commonly practised.[10] However, because of the high incidence and recurrence of bladder stones in non-industrialized countries[1] (25% in our study), those children may be subjected to open surgery too frequently. This relatively contraindicates percutaneous cystolithotomy and diverts the opinion away from open surgery[11], especially when taking into consideration the success of less invasive techniques and the possibility of moving most urethral stones to the bladder where they can be managed.

In this study, 83.3% and 77.3% of urethral stones could be moved to the bladder in the EHL group and in the Holmium laser group, respectively, so that the need for urethral manipulation was limited.

With EHL, our general strategy was to start with the smallest probe, the least frequency and the lowest stage to assure safety, and to adjust these variables on demand thereafter to achieve efficacy. As regards the 3 impacted urethral stones, our aim was to produce partial in-situ fragmentation which could be achieved by minimal application of EHL in the form of one or three pulses. All stones in this series proved to be fragile, and a power stage from 500 mJ to 1J was sufficient for complete fragmentation. It is noteworthy that electrohydraulic lithotripsy has been used since 1978 to fragment ureteral calculi with proved efficacy[12].

The single-shot mode was actually used to test the initial response of the stone to EHL. However, the multiple-shock mode was the most suitable one accounting for more than 84% of our applications. We did not use the continuous-pulse mode as it requires great operator attention and carries a risk of bladder perforation which has been reported to occur with only one discharge if the EHL probe is in contact with the vesical wall.[13] In our work conversion to open surgery was necessary in two cases due to this problem.

The 3.5 F probe size proved to be the most suitable one with respect to efficacy, safety and to being used with the small endoscopes. The 2.4 F probe size was used for the resultant gravels and when there was an obligation to deal with the stone inside the urethra. However all the probes fit into any standard rigid endoscope without an offset eyepiece, which is considered a real advantage of EHL.[14]

Mucosal injury from misdirected lithotripsy energy or from propulsion of stone fragments

Table 2: Comparative results in both groups.

Results	EHL Group (n=50)		Laser Group (n=62)		Total (n=112)	
	No	%	No	%	No	%
Disintegration details:						
- Complete disintegration in the bladder	47	94.0%	57	91.9%	104	92.9%
- Complete disintegration in the urethra	0	0	5	8.1%	5	4.5%
- Coarse urethral disintegration	3	6.0%	0	0	3	2.7%
- Total successful disintegration	48	96.0%	62	100%	110	98.2%
Number of sessions:						
- Cases done in one session	49	98.0%	62	100%	111	99.1%
- Cases done in two sessions	1	2.0%	0	0	1	0.9%
Complications:						
- Bladder perforation	2	4.0%	0	0	2	1.8%
- Fractured probes	1	2.0%	0	0	1	0.9%
- Mucosal injury	5	10.0%	5	8.1%	10	8.9%
- Hematuria	7	14.0%	5	8.1%	12	10.7%
- Postoperative fever	4	8.0%	5	8.1%	9	8.0%
Postoperative catheter for one day	50	100.0%	36	58.1%	86	76.8%
Mean hospital stay (days)	1.1		1			
Mean operative time (minutes)	17.3		15.3			
Costs	low		high			

* EHL: electrohydraulic lithotripsy

is a potential risk[15]. In our study it was encountered in 5 cases (10%). The metallic tip of the probe was fractured in another case; this, however, did not hinder the procedure or interfere with good visibility. Marked turbidity was seen in one case with multiple stones and a reconstructed bladder and made two sessions necessary. Considering these issues, postoperative urethral catheterization was needed for all children treated with EHL, while it was needed only in 58% of the laser-treated group. Other drawbacks of EHL compared to laser lithotripsy are the relatively longer operative time, the longer hospital stay, the increased incidence of mucosal injury and hematuria.

The unique advantages of Holmium laser lithotripsy reported in the literature could be confirmed in our study[14-16]. In all our patients the disintegration was complete and was achieved more rapidly. Not more than one session was required in all cases, even in those with multiple stones. In the impacted 5 urethral stones, laser produced complete powdering in situ, without thermal or mechanical injury to the urethra.

No damage to the quartz fiber or the endoscope was encountered.

The small caliber of the optical fiber makes laser appealing in children, and its energy does not depend on fiber size as in EHL, in other words, the stone is literally melted with minimal retropulsion of the target stones and minimal forward scattering of laser energy.[17] These factors obviate the need for the retrieval of gravel and minimize the time of laser lithotripsy when compared with EHL.

The optional supply of automatic coupling devices, which were not available in our system, allows differentiation of stones and mucosal surfaces in nanoseconds prior to firing, which is a reliable safety criterion preventing many side effects, although it may not influence the rate of perforation[18]. In our study, accidental photo-thermal injury from an improperly directed laser beam to the urothelium occurred in 5 children (8.1%), which is similar to the findings of Razvi et al.[19]. When working with Holmium laser we maintain a good irrigation flow to dissipate heat and to prevent the snow storm effect of the powdered fragments which was found to increase the risk of mucosal injury by Zhong et al.[20].

In this study, we found no significant difference between radio-opaque and radiolucent calculi as regards the time or power of disintegration.

Taking into consideration that the wide cavity of the bladder would allow a smaller stone to escape in front of the irrigation fluid, we reduced the irrigation flow just before disintegrating small stones. The position of the patient was also manipulated in a way to allow the stone to gravitate towards the tip of the probe or laser fiber. Finally we kept a distance of 1-2 mm between the probe or the quartz fiber and the stone prior to initiating lithotripsy.[21-22].

In conclusion, the results of this study show that Holmium laser represents an important and reliable treatment modality for bladder and/or urethral stones in children with regard to safety and efficacy. Nevertheless, the electrohydraulic lithotriptor remains an effective and a viable option despite its rare - yet sometimes serious - complications. The 96% success rate achieved with EHL in our study compared favorably with the 92% success rate reported by Bulow and Frohmuller[23]. As regards the costs, it is known that EHL probe failure often occurs after less than 50 shocks, but that EHL nevertheless has a relatively low cost when compared with laser systems.[24]

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RESUME

La lithotripsie électro-hydraulique contre le laser Holmium pour les calculs de vessie chez les enfants

Objectifs: Comparer l'efficacité et la sûreté de la lithotripsie électrohydraulique à ceux de la lithotripsie au laser Holmium dans le traitement des calculs de la vessie et/ou urétrales chez les enfants.

Patients et méthodes: De janvier 2000 à janvier 2006, 112 enfants (102 garçons et 10 filles) âgés entre 2 et 13 ans se sont présentés à notre service avec des calculs de vessie (n=40) et de l'urètre (n=72). Une chirurgie antérieure pour des calculs de vessie a été enregistrée chez 28/112 cas (25%). La masse lithiasique moyenne s'est étendue de 4 à 22 millimètres. Les calculs étaient radio-opaques dans 12 (10.7%) cas. Les calculs multiples de la vessie et les calculs urétraux et vésicaux combinés ont été enregistrés dans 14 cas (12.5%). Les enfants ont été divisés en deux groupes selon la modalité de traitement: 50 enfants (groupe A) ont été traités par lithotripsie éléctro-hydraulique (EHL) en utilisant les cystoscopes pédiatriques ou l'urétéroscope court, 7 F, alors que chez 62 enfants (groupe B) le laser Holmium était utilisé par un endoscope pédiatrique de 7.5 F sans n'importe quelle modification. Le recul était de 1-1.5 ans.

Résultats: Dans le groupe A, la désintégration était réalisée chez 48 patients (96%). La durée moyenne était de 18.3 minutes. Le cathéter urétral a été gardé pendant 24-72 heures (moyenne=36 heures). La conversion en chirurgie ouverte a été réalisée dans deux cas. Aucune autre complication per ou postopératoire n'a été notée. Dans le groupe B, la désintégration complète a été réalisée dans tous les cas comprenant les calculs urétraux. La durée moyenne était de 15.7 minutes. Le

cathéter urétral a été laissé pour un jour seulement chez 36 patients (58.07%).
Conclusion: Dans notre série, la lithotripsie au laser Holmium dans les calculs de vessie ou de l'urètre chez l'enfant n'a causé aucune complication et a réalisé des résultats légèrement meilleurs que la lithotripsie électro-hydraulique. Néanmoins, la lithotripsie électrohydraulique représente une option pertinente et viable en dépit de ses complications rares pourtant parfois sérieuses.

Editorial Comment:

The relative pros and cons of electrohydraulic and Holmium laser lithotripsy approaches are well presented in this study. I did have a question regarding the author's cost analysis. There is no question that the initial capital cost of the holmium laser is much more than an electrohydraulic generator. However, with careful use and reuse of the laser fiber, this could potentially be used for dozens of such cases, and thus the ongoing, day-to-day cost of the disposables associated with laser lithotripsy should be less than those associated with the electrohydraulic device.

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