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Outcomes of Flexible Ureteroscopic Lithotripsy with Holmium Laser for Upper Urinary Tract Calculi

Marcello Cocuzza, Jose R. Colombo Jr, Antonio L. Cocuzza, Frederico Mascarenhas, Fabio Vicentini, Eduardo Mazzucchi, Miguel Srougi

Division of Urology, University of Sao Paulo, USP and Department of Urology, Syrian-Lebanese Hospital, Sao Paulo, Brazil

ABSTRACT

Objective: To assess the perioperative and financial outcomes of flexible ureteroscopic lithotripsy with holmium laser for upper tract calculi in 44 patients.
Materials and Methods: Between February 2004 and September 2006, 44 patients treated for upper tract stone with flexible ureteroscopic lithotripsy were evaluated. Renal stones were associated with collecting system obstruction in 15 (34%) patients, failed extracorporeal shock-wave lithotripsy (SWL) occurred in 14 (32%) patients, unilateral multiple stones in 18 (41%) patients, and multiple bilateral stones in 3 (7%). In 29 (66%) patients, the stone was located in the inferior calyx. Perioperative and financial outcomes were also evaluated.
Results: 50 procedures were performed in 44 patients. The mean stone burden on preoperative CT scan was 11.5 ± 5.8 mm. The mean operative time was 61.3 ± 29.4 min. The stone free rate was 93.1% after one procedure and 97.7% after a second procedure, with overall complication rate of 8%. Therapeutic success occurred in 92% and 93% of patients with lower pole stones and SWL failure, respectively. Treatment failure of a single session was associated with presence of a stone size larger than 15 mm (p = 0.007), but not associated with inferior calyx location (p = 0.09). Surgical disposables were responsible for 78% of overall costs.
Conclusion: Flexible ureteroscopy using holmium laser is a safe and effective option for the treatment of upper urinary tract calculi. In addition, it can be considered an attractive option as salvage therapy after SWL failure or kidney calculi associated with ureteral stones. Stone size larger than 15 mm is associated with single session treatment failure.

Key words: *ureter; calculi; Lithotripsy; Holmium laser*
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INTRODUCTION

Ureteroscopy has evolved as the most minimally invasive approach to the ureter and kidney since it was first used in 1912 by Hampton, who accidentally entered a massive dilated ureter with a 12F cystoscope (1). The management of upper tract stone disease has shifted from the invasive nephrolithotomy to methods with more effective therapeutic options and lower morbidity. SWL has revolutionized the treatment of upper tract stones and has become the most employed option for these types of stones as well (2). However, its success rates are far from satisfactory and may vary from 80% for those smaller than 1 cm to 54% for stones greater than 2 cm (3). Percutaneous nephrostolithotomy (PCNL) has made it possible to achieve a stone free rate of more than 90%, with inherent risks of the percutaneous access (4). Recognition of the limitations of SWL and PCNL has allowed the increased popularity of ureteroscopic treatment of renal stones.

Flexible ureteroscopy became clinically available after the development of the small diameter ureteroscope with passive and active deflection allowing access to the entire collecting system in up to 94% of the procedures (5). Its ability to access the upper tract collecting system, associated with the development of a safe, reliable, and flexible endoscopic lithotripsy source, combined with more efficient extraction instruments made the flexible ureteroscopic laser lithotripsy more attractive to effectively treat renal stones with high success rates and low morbidity.

This study evaluates the outcomes of holmium laser lithotripsy for upper tract calculi performed via flexible ureteroscopy.

MATERIAL AND METHODS

Between February 2004 and September 2006, 44 consecutive patients who underwent flexible ureteroscopy with holmium laser lithotripsy for upper tract stone disease were evaluated. Relevant demographic data and operative outcomes were retrieved from medical records with institutional review board approval.

Patients - The patient cohort presented a mean age of 42.2 ± 12 years, with the male gender in 28 (63%) patients. The indication for surgical treatment was renal stones associated with collecting system obstruction in 15 (34%), failure of SWL in 14 (32%) patients, unilateral multiple stones in 18 (41%), and multiple bilateral stones in 3 (7%), Table-1. All patients underwent a preoperative non-contrast CT scan with images acquired at 5.0- mm collimation thickness at 5.0- mm interval width. Collecting system obstruction was defined in patients presenting with flank pain and hydronephrosis associated with ureteral stones demonstrated by CT scan.

The mean stone size treated was 11.5 +/- 5.8 mm, located only in the right kidney in 23 (52%) cases, left kidney in 18 (41%), and bilaterally in 3 (7%). Nine patients presented with at least one stone > 15 mm in diameter. Twenty-nine only had intrarenal stones and 15 had combined ureteral and renal stones. Twenty-nine (66%) patients had at least one stone located in the lower pole, 8 (20%) had the stone in the renal pelvis and 18 (41%) in more than one location (Table-1).

Table 1 *– Demographics of patients treated with flexible ureteroscopy lithotripsy with holmium laser for upper tract calculi.*

N	44
Age (years)	42.2 ± 12.5
Male (%)	28 (63%)
Symptomatic (%)	40 (91%)
Associated ureteral stone (%)	15 (34%)
SWL Failure (%)	14 (32%)
Mean stone size (mm)	11.5 ± 5.8
Bilateral stones (%)	3 (7%)
Multiple stones (%)	18 (41%)
Lower calyx (%)	29 (66%)

Surgical procedure - All patients received prophylactic parenteral third generation cephalosporin antibiotics prior to the procedure. In each case, intervention was performed under general anesthesia and endotracheal intubation or laryngeal mask associated with neuromuscular blockage, allowing respiratory motion to be interrupted for short periods.

Briefly, after the retrograde pyelography, a safety guide wire was smoothly positioned in the kidney to avoid bleeding into the pelvis due to urothelial lesion that could alter visibility during the procedure. Ureter dilatation was performed with the inner part of the access sheath for 2 minutes, with complete insertion of the sheath over the wire under fluoroscopic guidance (Figure-1). The presence of a preexisting stent or ureteral dilatation due to ureteral stone obstruction obviated the need for dilatation. When ureteral stones were not associated, the authors employed a 12/14F, 35 cm, (Applied Medical) access sheath for female patients and a 12/14F, 55 cm (Applied Medical) access sheath for males yielding direct access to the renal pelvis. As upper ureteral stones were associated, 12/14F, 20 cm (Applied Medical)

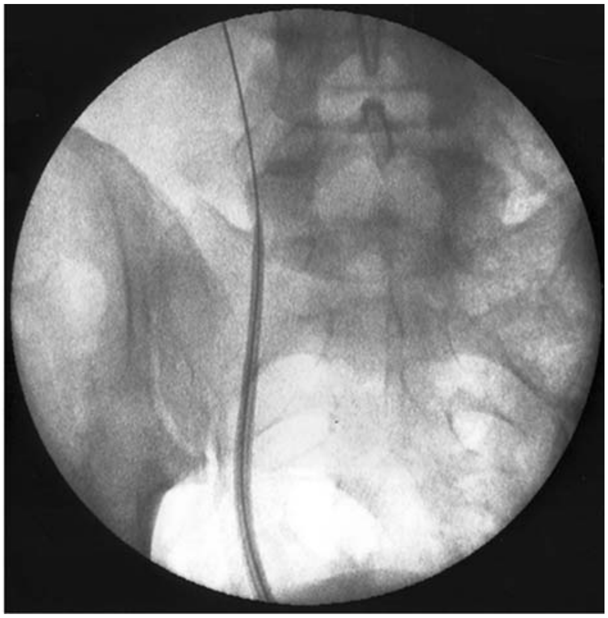

Figure 1 – Access sheath placed over a guide wire in the right ureter.

and 36 cm (Navigator, Boston Scientific) sheaths were employed for females and males, respectively, allowing larger fragment removal and better irrigation flow. We attempted to use the access sheath in all cases. When resistance at the iliac vessel level was encountered, the flexible ureteroscope was introduced without an access sheath via its placement over a guide wire under fluoroscopic guidance to avoid further dilation of the mid-ureter. If an access sheath was not used, a small-caliber Foley catheter was inserted into the bladder to assist in upper tract drainage.

The flexible ureteroscope (7.5F Karl Storz Flex-X or 6.8F ACMI DUR-8) was introduced over the guide wire to the renal pelvis. The wire was then withdrawn to optimize irrigant flow and a complete inspection of the collecting system was performed. Holmium:YAG laser lithotripsy was performed through a 200 μm core sized fiber (Dornier Lightguide Super 200) for fragmentation until only very small stone fragments (< 2 mm) were observed, avoiding the need for basket stone retrieval. Our current settings for the laser (Medilas H, Wave Light Laser Technology, Germany) were 1 Joule at 8 Hertz with a total power of 8 Watts. If the lower pole calyx stones could not be fragmented in spite of a fully deflected ureteroscope, it was moved to a less dependent calyx position by using a 2.4 zero-tip nitinol basket or water flush, thus facilitating stone fragmentation. All collecting systems were inspected at the end of fragmentation. A double J stent was placed in all patients at the conclusion of surgery and was removed after approximately 2 weeks. Stents attached with pull-strings were used in a few cases where small stones were completely fragmented and the access sheath was not used. In these cases, stent removal was performed 1 week later on an outpatient basis.

Operative outcomes - Stone-free status was determined after stent removal by CT scan at approximately 2 months postoperatively in all patients. Results were classified by the largest single fragment as stone-free (no residual fragments observed or residual fragments smaller than 3 mm), residual stones greater than 3 mm requiring a second procedure, and failure when it was not possible reach stone free due to intraoperative complications or technical problems. Complications were categorized into intraoperative complications limited to ureteral perforation or postoperative complications characterized by consistent hospitalization for pain that required a patient hospital stay for more than 1 night.

Financial analysis - Detailed surgical cost data from one private institution (SLH) was available for 25 selected patients with no perioperative complication. The data was collected from patients' billing statements and categorized in material and operating room costs. The first one included the regularly used disposables (ureteral sheath, basket, guide wire, and ureteral stent), and the second included operating room, laser and video units, and fluoroscopy/x-ray using time for each procedure. The costs of anesthesia supplies, laboratory, medication, and nursing were not analyzed, and no adjustment for inflation was made. When a patient stayed overnight due to a late surgical schedule and they were discharged early in the next morning, and the overnight stay was not charged. Costs for SWL were not available in our Institutions.

Statistical analysis - Univariable analysis to identify all potential predictors of treatment failure was performed. It was conducted using the Pearson χ^2 statistic or Fisher's exact test for categorical data, the Student's-t-test for continuous normally distributed data, and the Wilcoxon rank sum test for continuous, non-normally distributed data. All statistical tests were two-tailed and $p < 0.05$ was considered statistically significant.

RESULTS

Fifty procedures were performed in 44 patients, with a mean operative time of 61.3 ± 29.4 min. The ureteral sheath was used in 88% of the procedures. The stone free rate was 93.1% after one procedure, and 97.7% after a second procedure. Three patients required two procedures in order to become stone free. Treatment success occurred in 92% of patients with lower pole stones. In the patients with salvage therapy after SWL failure and multiple stones the stone free rate were achieved in 93% and 90%, respectively. However, therapeutic success occurred in 70% and 66% of patients with stone size > 15 mm and > 20 mm, respectively. Operative data are shown in Table-2.

Ninety-two percent of the patients were discharged 1 day after the procedure. The overall complication rate was 8%. Intraoperative complications consisted of two proximal ureteral perforations caused by the guide wire and confirmed by the recognition of contrast leakage under fluoroscopic evaluation. In one case, the inner part of the ureteral sheath was passed over the wire and mistakenly dilated through the perforation, hence the procedure was suspended. Both cases were treated with ureteral stenting for 30 days and no further complications occurred thereafter until one year of mean follow up. Postoperative complications consisted of two patients, who required postoperative hospitalization for pain control during 2 days. No patient presented symptoms of urinary tract infection nor was readmitted to the hospital until follow-up with CT scan at approximately 2 months after the procedure.

Table 2 – *Operative data of flexible ureteroscopy lithotripsy with holmium laser for upper tract calculi.*

Procedures	50
Operative time (min.)	61.3 ± 29.4
Ureteral sheath (%)	39 (88%)
Stone free/1 procedure (%)	93.1 %
Stone free/2 procedures (%)	97.7%
Stone free/ Stone size > 15 mm (%)	70%
Stone free/ Stone size > 20 mm (%)	66%
Stone free/ Lower calyx (%)	92%
Stone free/ Multiple stones (%)	90%
Stone free/ SWL Failure (%)	93%
Intraoperative complications (%)	2 (4%)
Postoperative complications (%)	2 (4%)

Treatment failure of one single session was associated with the presence of stone greater than 15 mm ($p = 0.007$) but not associated with the inferior calyx stone location ($p = 0.09$), nor the presence of multiple stones ($p = 0.45$). When considering stone location, no significant differences were found between intraoperative parameters and multiple versus solitary stones.

The mean overall cost (± SD) for procedure was US$ 5042 ± 352. Surgical disposables were responsible for 78% of the total (US$ 3942 ± 476) and the remaining 22% (US$ 1100 ± 179) were due to operating room expenses.

COMMENTS

Technological advances over the past 2 decades were responsible for the flexible ureteroscopy evolution from a simple diagnostic procedure to a basic therapeutic tool. These changes included downsizing the ureteroscope, upsizing working channels, modern stone extraction tools and holmium laser as an energy source. With the actively deflectable ureteroscopes, all calyces can be accessed in up to 95% of kidneys, including lower pole (6).

Flexible ureteroscopy for upper urinary tract stones is a delicate procedure comprised of intricate details. These details must be respected since they may be the difference between success or failure. The procedure is best performed under general anesthesia, since it allows temporary respiratory motion interruption enhancing the precision of the laser probe as well as reducing the rate of urothelial lesions and operation time.

The proposed advantages of the ureteral sheath allow fast, safe, and multiple accesses to the upper urinary tract. The sheath also increases ureteroscope life span, decreases intrarenal pressure, and provides improved visibility as a result of more effective irrigant flow (7).

The other major factor that made it possible to expand the flexible ureteroscopy use for upper tract stones was the introduction of holmium:YAG laser energy. This energy is rapidly absorbed by water and has minimal tissue effect through a 200 µm core sized fiber while allowing for greater ureteroscope deflection without compromising irrigant flow and consequently visibility (4). In few cases where the 200 µm core sized fiber caused a deflection angle loss, the fragmentation of lower pole stones could be facilitated after repositioning the stone to a more cephalic calyx. Auge et al. reported reduced strain on endoscopes and improved stone-free rates when using the repositioning technique (8).

Minimally invasive techniques should be considered an attractive option for asymptomatic renal stones when associated ureteral stone obstruction is present, requiring intervention. Treatment for asymptomatic calyceal calculi is recommended based on the premise that 70% of these stones increase and will cause symptoms requiring treatment during a 5-year period (9).

Stone-free status after a single procedure appears directly related to stone burden. SWL should be considered the first line of therapy for stones ≤ 10 mm, with stone-free rate reports as high as 85% after one procedure (10). Although success rates of flexible ureteroscopy may be similar, the more invasive nature of endoscopic surgery counteracts this advantage. The presence of residual fragments following SWL, necessitating multiple procedures, is often associated with stones greater than 20 mm and lower calyceal location (11). Flexible retrograde ureteroscopy can be considered for salvage therapy after SWL failure, based on the universal effect of the holmium laser in fragmenting unresponsive stones (4).

Stones greater than 20 mm may be considerer a limitation for SWL and flexible ureteroscopy, with approximately 30% and 60% stone free rates, respectively, with PCNL being considered the first line therapy in this situation (12). However, Grasso et al. showed successful treatment for stones greater than 20 mm with retrograde flexible ureteroscopy, with an average of 1.6 procedures per patient (13).

Although technical efforts were made to increase ureteroscope durability, Afane et al. reported an average of 6 to 15 procedures in the first generation of small-caliber ureteroscopes before requiring some sort of repair. The loss of deflection during treatment of lower pole stone was the most frequent defect (14). These repairs are expensive, and the durability of these instruments represents a major financial concern (14,15). During 50 procedures, a disruption in the laser fiber during a lower pole stone fragmentation with full deflection damaged the working channel of one ureteroscope. Lower-pole ureteronephroscopy requires transmission of holmium:YAG energy along a deflected fiber. There is also a risk of fiber fracture from thermal breakdown and laser-energy transmission to the endoscope. The performance and safety of laser fibers differs both between manufacturers and as regards manufacturer's line of fibers (16).

The new generation of ureteroscopes as the DUR-8 Elite ACMI (Southborough, MA.) has secondary active deflection improving access to lower pole calyx and also exhibiting improved durability (17). Carey et al. reported that newer model flexible ureteroscopes less than 9F provided more than 40 uses before an initial repair was needed (15).

Two ureteral perforations occurred during the use of a standard wire (non-hydrophilic) prior to the insertion of an access sheath. Both of them occurred in a dilated ureter setting due to distal stones. We currently recommend the use of hydrophilic guide wires before inserting the access sheath. The overall complication rate of 8% observed in this study is comparable to that reported in the literature (4). Ureteral stricture rate of 1% has been reported, however the postoperative follow-up is not long enough to determine its incidence in this series. Although, the standard care for ureteroscopy is to discharge patients the same day, our patients remained in hospital overnight as the procedure was performed under general anesthesia late in evening.

The current study presented stone-free rates slightly better than the major series presented in the literature (4,18). This result may be due to the smaller mean stone size and longer operative time in our series, which could indicates longer laser firing time to achieve small residual fragments. The use of ureteral sheath in the majority of cases could possibly have a role in the overall results, and should be investigate further in a randomized study context. Also, stone free rates were strongly influenced by definition of success (residual fragments smaller than 3 mm) and only 36 out of 44 patients (81.8%) were found to be completely stone free. Portis et al. reported 94.6% stone free rate when success was defined as achieving fragments smaller than 4 mm (19). In addition, our protocol used 5.0-mm sections for non-contrast CT scan, however small calculi (< 3 mm) may be missed on 5.0-mm thick sections (20).

Holmium laser flexible ureteroscopy is an economically viable treatment modality and demonstrates an acceptable financial analysis profile. Material costs, excluding operating room expenditure, has accounted for the majority of treatment related expenses in this study. There is some reluctance to accept this procedure due to high equipment costs and by the inherent learning curve related to a new surgical technique. Some series have demonstrated that flexible ureteroscopy is as effective as SWL in the treatment of renal stones with low complications rates, but in an era of cost containment, it is also necessary to evaluate the financial differences of the treatments (4,12). Although in the United States ureteroscopic laser stone treatment is considered more cost-effective than SWL, in Brazil the costs related to SWL are much lower, hence, a prospective study is still needed to determine the cost effectiveness of each technique in our country (21).

The limited number of patients is a drawback in this series. However, the data were collected prospectively, and all patients received a close and pre-established follow-up, which could be considered strengths of this study.

The authors believe the data presented herein support the minimally invasive treatment with flexible ureteroscopy and holmium laser of upper tract stones. Precise indication, knowledge of capability and limitations of flexible endoscopes are crucial for a high success rate while preserving the equipment for a long life span.

CONCLUSION

Flexible ureteroscopy with Holmium:YAG laser is a safe and effective option for the treatment of upper urinary tract calculi. The procedure should be considered an attractive treatment option for associated kidney calculi with obstructing ureteral stones as well as salvaging therapy after SWL failure as well. Stone size larger than 15 mm is associated with single session treatment failure.

CONFLICT OF INTEREST

None declared.

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Correspondence address:
Dr. Marcello Cocuzza
Division of Urology
University of São Paulo, USP
Rua Adma Jafet, 50 151/152
Sao Paulo, SP, 01308-050, Brazil
Fax: + 55 11 3256-9511
E-mail: mcocuzza@uol.com.br

EDITORIAL COMMENT

While shockwave lithotripsy has been the first-line treatment for upper ureteral calculi < 2.0 cm over the last twenty years, there appears to be an increasing number of urologists performing flexible ureteroscopy with holmium:YAG laser lithotripsy for these stones. The miniaturization of the flexible ureteroscope, the development of the holmium:YAG laser, ureteral access sheaths, and small caliber tipless nitinol stone baskets have led to safer, more efficacious procedures (1,2). Furthermore, a recent report suggesting a link between shockwave lithotripsy and diabetes mellitus has raised concerns (3). However, further refinement of flexible ureteroscopy is required to both improve patient outcome and reduce costs. The development of durable < 7.0 Fr sized digital ureteroscopes, improvements in holmium:YAG laser fiber technology to reduce fiber failure during lower pole procedures, and updated stent designs that minimize symptoms are all needed to further advance this field.

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Dr. Bodo Knudsen
Department of Urology
The Ohio State University Medical Center
Director, Ohio State University
Comprehensive Kidney Stone Program
Columbus, Ohio, USA
E-mail: bodo.knudsen@osumc.edu