Ureteroscopic Treatment of Ureteral Calculi with Holmium:YAG Laser Lithotripsy

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ABSTRACT

Purpose: We evaluated the effectiveness and safety of holmium:YAG laser lithotripsy with a semirigid ureteroscope for ureteral calculi in a prospective cohort of 697 patients.

Patients and Methods: Holmium:YAG laser lithotripsy was performed with a semirigid ureteroscope in 697 inpatients between September 2002 and January 2006. Calculi were located in the distal ureter in 382 patients (54.8%), the midureter in 143 (20.5%), and the proximal ureter in 172 (24.7%). Patients were assessed 2 to 24 weeks postoperatively with repeat plain radiography, ultrasonography, intravenous urography, or some combination.

Results: The overall stone-free rate was 92.2%, the rate being 100% for calculi in the distal ureter (N = 382), 97.9% for calculi in the midureter (N = 140), and 70.3% for calculi in the proximal ureter (N = 121). Complications occurred in 13 patients (1.9%). Postoperative ureteral stricture developed in five patients (0.72%) and was managed surgically.

Conclusions: Holmium:YAG laser lithotripsy with a semirigid ureteroscope is a highly effective and safe treatment for ureteral calculi, especially those in the distal ureter and midureter.

INTRODUCTION

VARIOUS TREATMENT OPTIONS are available for ureteral calculi in China, including medication with Chinese traditional medicine, extracorporeal shockwave lithotripsy (SWL), ureteroscopy and percutaneous nephrolithotomy using different intracorporeal lithotripters, and open ureterolithotomy. The holmium:YAG laser, which was introduced into practice in the early 1990s, can fragment all types of urinary calculi regardless of their composition in a fluid environment via endoscopes. We report our experience with a prospective series of patients managed ureteroscopically with the holmium:YAG laser for ureteral calculi.

PATIENTS AND METHODS

Between September 2002 and January 2006, a prospective cohort of 697 consecutive patients with ureteral calculi were evaluated, including 425 men and 272 women 19 to 82 years old (mean age 47 years). All patients were treated by retrograde ureteroscopy with a Wolf 8F/9.8F 10° semirigid ureteroscope and a holmium:YAG laser after informed consent was obtained. The ureteroscopic procedure was performed by one of two staff urologists alternately (HJ and ZW). Sixty-five patients underwent bilateral procedures during the same session. There were multiple and solitary stones in 127 and 570 patients, respectively. The calculi were in the distal ureter in 382 patients (54.8%), the midureter in 143 (20.5%), and the proximal ureter in 172 (24.7%). The mean stone size was 12.0 mm (range 4–32 mm), as measured on preoperative intravenous urograms (IVUs) and ultrasonograms and recorded as the maximum diameter. A renogram was required in 479 patients (68.72%) who had hydronephrosis and pyclectasia >2 cm. In the total series, 231 patients had a history of upper urinary-tract stone disease: 47 (20.3%) had had an open ureterolithotomy, 62 (26.8%) had had medical treatment, and 122 (52.9%) had had SWL. One fourth of the patients (N = 177; 25.4%) had a history of failure of SWL. Among these patients, there were 79 calculi located in the upper ureter, 74 in the midureter, and 24 in the dist-
tal ureter. Anatomic abnormalities were present in 54 patients, including a solitary kidney in 9 and concurrent ureteral stricture or ureteropelvic junction obstruction in 45.

Ureteroscopic procedures were performed on an inpatient basis using a Wolf semirigid 8F/9.8F ureteroscope with the patient under general anesthesia in 612 cases (87.8%) and epidural anesthesia in 85 (12.2%). Patients were placed in the standard lithotomy position. The ureteroscope was passed into the bladder through the urethra under visual monitoring, and a 0.035-inch guidewire was inserted into the ureteral orifice to facilitate passage of the ureteroscope. Balloon dilation was not performed. Continuous low-pressure fluid flow was necessary to maintain visibility.

Laser lithotripsy was delivered using a pulsed 100 W holmium laser (Luminas, Coherent VersaPulse). A 365-μm fiber was used in 319 patients (45.8%) and a 550-μm fiber in 378 (54.2%), who had stones >1.5 cm. Laser energy generally was applied at an initial setting of 0.8 J at a pulse rate of 10 Hz and increased incrementally by 0.2 J as necessary. The maximum power was 12 W. Stones were fragmented to a particle size of 0.2 to 0.3 cm. In an early series of 55 cases, forceps were used to extract stone fragments of about 0.3. Inflammatory strictures around or under stones were observed in 217 patients (31.1%).

A 4.5F stent (Optimed) with both ends open was inserted into the ureter through the working channel of the ureteroscope under monitoring and left indwelling for 2 to 4 weeks. Postoperative radiographs were then taken. Stents were removed with a Wolf 20F cystoscope under topical urethral anesthesia. Most (N = 671; 96.3%) of the patients were followed with IVU, ultrasonography, or both 2 weeks to 6 month after lithotripsy. A renogram was used in the follow-up of 77 patients (11.0%) who had severe preoperative renal function loss.

RESULTS

Most patients (643/697; 92.2%) were stone free after a single ureteroscopic procedure. The stone-free rate stratified by stone location was 100% in the distal ureter, 97.9% in the midureter, and 70.3% in the proximal ureter (Table 1). Fragmentation was incomplete during laser lithotripsy in 49 patients (7.03%) because of retrograde stone migration, and SWL was used postoperatively. Laser lithotripsy could not be performed in five patients because of ureteral perforation in two and inability to reach the stone in a sharply angulated ureter in three.

Open surgery was performed in these five patients to remove calculi, repair the ureter, or both.

The intraoperative complication rate was 1.15%, including ureteral perforation by the ureteroscope in two, the guidewire in three, and the laser in three. Minimal injury was managed by ureteral stenting. Postoperative IVU and urinary ultrasonography were required at 3 months for these patients, and no ureteral stricture was observed. The other five patients (0.72%) demonstrated ureteral stricture by IVU or MRI at follow-up at 3 and 6 months postoperatively. All of these patients had undergone laser resection of surrounding inflammatory polyps during lithotripsy. Among them, three patients were followed on an outpatient basis every 6 months by IVU for 2 years without surgical intervention because of the mild extent of the narrowing and subsequent hydronephrosis. The other two patients underwent holmium laser incision of the stricture. The overall complication rate was 1.87%.

The mean operative time was 25.2 minutes (range 10–60 minutes). The setting of pulse energy was at 0.8 to 1.2 J at a frequency of 10 Hz, and the total energy ranged from 0.8 to 1.2 J. All patients were hospitalized for 24 to 48 hours for medical observation.

DISCUSSION

In the 1980s, the advent of SWL revolutionized the treatment of most renal and ureteral calculi, but it is not as effective as previously believed for all upper-tract urolithiasis according to current clinical experience. The development of the holmium:YAG laser represents a new mode of intracorporeal lithotripsy.4 The holmium laser is a solid-state system that operates at a wavelength of 2140 nm in the pulsed mode. The active medium is the rare-earth element holmium combined with an yttrium–aluminum–garnet crystal. The holmium laser has a pulse duration ranging from 0.25 to 0.35 seconds, and its energy is highly absorbed by water. Because tissues are composed mainly of water, the majority of the energy is absorbed near the surface, resulting in superficial cutting or ablation. The zone of thermal injury associated with laser ablation ranges from 0.5 to 1.0 mm.3

The mechanism for holmium:YAG lithotripsy is different. The long pulse duration produces an elongated cavitation bubble that generates only a weak shockwave compared with the strong shockwave produced by short-pulse lasers. Holmium lithotripsy starts before the bubble collapses and produces a

<table>
<thead>
<tr>
<th>Site</th>
<th>No. pts</th>
<th>No. having laser lithotripsy</th>
<th>Mean stone size (mm) (range)</th>
<th>Percent (no.) stone free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal ureter</td>
<td>382</td>
<td>382</td>
<td>11.5 (4–22)</td>
<td>100 (382)</td>
</tr>
<tr>
<td>Midureter</td>
<td>143</td>
<td>140</td>
<td>12.5 (6–25)</td>
<td>97.9 (140)</td>
</tr>
<tr>
<td>Proximal ureter</td>
<td>172</td>
<td>170</td>
<td>12.7 (8–32)</td>
<td>70.3 (121)</td>
</tr>
</tbody>
</table>

*Ureteroscope was unable to reach stone because of ureteral stricture in three.

*Ureteral perforation in two; open surgery was required.

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The technique of holmium laser lithotripsy is relatively straightforward and involves placing the fiber on the stone surface before activating the laser. Lithotripsy depends on the pulse energy output and the diameter of the optical delivery fiber, implying that lithotripsy efficiency correlates with energy density.\(^5\) Pulse energies of 0.6 to 1.2 J and pulse rates of 5 to 15 Hz are used.\(^3\) Because high pulse energy narrows the safety margin and may increase stone retropulsion as well as fiber damage, it is recommended that treatment be commenced using low pulse energy (e.g., 0.6 J) with a pulse rate of 6 Hz and that the pulse frequency (rather than the energy) be increased as needed to speed fragmentation.\(^9\) Success in the treatment of ureteral stones of all compositions is reported in 91% to 100% of cases, with a mean stone-free rate of 95%.\(^10\) Failures are attributable mostly to stone migration. Holmium laser lithotripsy results in small particles, which are easily irrigated out of the urinary tract, reducing the need for basketing.\(^11\)

In our series, the mean stone-free rate was 92.0% with a single ureteroscopic procedure. Holmium laser lithotripsy is most indicated for calculi in the distal ureter and midureter. Retrograde migration is possibly an unavoidable problem for calculi in the proximal ureter, which occurred in 49 cases in this series. Some migration is secondary to high-pressure irrigation and increased pulse energy. The distance of calculi from the ureteropelvic junction seems to be important when attempts are made to minimize retropulsion such as using low-pressure irrigation and decreased pulse energy. Lacking a flexible ureteroscope, we applied SWL for displaced stones, and it proved to be a good complementary option.

Chen and colleagues\(^12\) reported a high success with a 6F/7.5F semirigid tapered ureterorenoscope and holmium:YAG lithotripsy for impacted upper-ureteral stones >2 cm. Maislos and associates\(^13\) called attention to the efficacy of the Stone Cone for the treatment of proximal-ureteral stones. All 19 patients were rendered stone free after holmium:YAG laser lithotripsy in conjunction with a Stone Cone. A flexible ureteroscope was used to treat upper-ureteral and renal calculi.

The intraoperative complication rate was low, as reported by others,\(^11\) with most complications being ureteral perforation. Perforation can be caused by the ureteroscope, guidewire, or laser. The risk of perforation from the laser is negligible, because the depth of thermal injury is only 0.5 to 1 mm.\(^1,14,15\) Clear vision is essential at all times to avoid perforation. Ureteral stenting is able to manage this condition, and open surgical repair is rarely necessary. In these cases, a postoperative IVU and urinary ultrasonography are required at 3 months to detect any ureteral stricture and changes in the degree of hydronephrosis.

Ureteral stenting was performed directly through the working channel of the ureteroscope in our series. A 4.5F pigtail stent is suitable and is kept for 2 weeks, mainly to avoid sudden ureteral obstruction by stone fragments and blood clots. Mild back discomfort during urination and hematuria are common. Review of a plain film is required before removal of stents.

Some endourologists think that routine stenting can be reserved for complicated cases because of the minimally invasive nature of holmium laser lithotripsy. Slight patient discomfort and a low incidence of postoperative complications are reported.\(^16-18\) Postoperative upper-tract imaging is not necessary in uncomplicated cases. In a randomized study of whether stents may be eliminated after uncomplicated ureteroscopy for ureteral stones, Denstedt and coworkers\(^19\) reported that patients in whom a stent was not placed were not at higher risk for complications and had fewer postoperative symptoms than those with a stent. In addition, eliminating a ureteral stent postoperatively did not compromise the ability to render a patient stone free. Our team has begun to avoid ureteral stents for patients in whom the calculus is relatively small and nonimpacted and in the distal ureter. Karod et al\(^19\) questioned routine upper-tract radiologic surveillance for obstruction after uncomplicated ureteroscopic lithotripsy in asymptomatic patients. In a review of their experience with 183 patients, they observed that all cases of postoperative obstruction were heralded by an episode of flank pain. Furthermore, none of the patients who were asymptomatic at the routine follow-up radiologic procedure had evidence of obstruction. Sofer and colleagues\(^20\) endorsed the elimination of routine postoperative upper urinary-tract imaging by ultrasonography or IVU in asymptomatic patients because of the extremely low (0.35%) incidence of stricture in their series of patients who had no evidence of stone impaction, significant ureteral edema, or preoperative ureteral narrowing. Postoperative clinical assessment, urinalysis and culture, and plain films at 1 and 6 weeks are recommended for asymptomatic patients with radiopaque nonimpacted calculi who underwent an uncomplicated holmium:YAG ureteroscopic procedure.

CONCLUSION

Our experience shows that holmium:YAG laser lithotripsy with a semirigid ureteroscope is a highly effective and safe treatment for ureteral calculi and is particularly indicated for calculi in the distal ureter and midureter.

REFERENCES


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ABBREVIATIONS USED
IVU = intravenous urogram; MRI = magnetic resonance imaging; SWL = extracorporeal shockwave lithotripsy.