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Holmium: YAG laser lithotripsy for gallstones

A preliminary report

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Abstract
Background: Most retained gallstones can be extracted at the time of operative exploration or endoscopic retrograde cholangiopancreatography (ERCP). Infrequently, impaction or associated anatomic abnormalities may prevent their clearance. We assessed the efficacy of the holmium:YAG laser in managing retained biliary calculi that had proven refractory to the usual methods of extraction.
Methods: Two patients with calculi impacted in the intrapancreatic common bile duct and one patient with residual stones in a nonfunctional gallbladder were treated with holmium:YAG laser lithotripsy. Two of these patients were treated under conscious sedation, and one received a general endotracheal anesthetic. Laser energy was delivered by a 272-μm optical fiber inserted through a 7-Fr fiberoptic endoscope. The ablative effects were monitored continuously via videoscopic.
Results: All of the stones were cleared successfully in a single therapeutic setting. In one patient, fragments of the impacted intraductal stone were extracted with an endoscopic wire basket. In the other two patients, stone debris was completely cleared with saline irrigation. No complications developed, and all patients remained free of recurrence during a 6-month follow-up period.
Conclusions: The holmium:YAG laser is a multidisciplinary instrument that is safe and effective in the fragmentation of both urinary and biliary calculi. Because it can be delivered through a small-caliber fiberoptic endoscope, it should be particularly useful to laparoscopic surgeons who manage complicated biliary tract disease.

Key words: Lithotripsy — Holmium:YAG laser — Common bile duct — Biliary calculi — T-tube

Gallstones are found in the common bile duct (CBD) in 10–15% of all Western patients who undergo cholecystectomy [7]. Such calculi can usually be removed laparoscopically or at the time of preoperative or postoperative endoscopic retrograde cholangiopancreatography (ERCP) [9]. Rarely, retained stones are refractory to all of these approaches and require additional maneuvers. Extensive clinical experience with holmium:YAG lithotripsy in the management of urinary calculi has confirmed that this minimally invasive technique is safe and effective for all stone compositions tested [8]. Importantly, collateral damage to the wall of the ureter has been uncommon. These findings suggest that holmium:YAG lithotripsy could also become a useful adjunct in the biliary tract. In the following cases, we describe our preliminary experience with the use of holmium:YAG laser energy in the management of difficult CBD stones.

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Methods

Since January 1999, three patients with complicated biliary calculi have been treated with the holmium:YAG laser (VersaPulse Select, λ = 2100 nm, pulse duration 250 μsec; Coherent Medical Group, Santa Clara, CA, USA) at the University Hospital (Bexar County Hospital District, San Antonio, TX, USA). The demographic data and clinical courses of these patients are summarized in Table 1. In two patients, large solitary stones were found in the intrapancreatic portion of the CBD during laparoscopic cholecystectomy. Both patients underwent conversion to an open procedure, but multiple efforts to extract the stones were unsuccessful and a T-tube was placed. Postoperative ERCP also failed to dislodge the impacted stones. The third patient, a prisoner with Child's B cirrhosis, presented initially with acute cholecystitis. Laparoscopic cholecystectomy was attempted, but it was aborted because of the presence of very dense, vascular adhesions. A cholecystostomy tube was placed, and all symptoms rapidly improved. However, the cholecystostomy tube continued to produce purulent drainage over the next 3 months. A contrast study of the gallbladder confirmed the presence of multiple residual stones and demonstrated a stenotic cystic duct that did not communicate with the CBD.

The technical aspects of lithotripsy treatment were based on standard urological techniques. Two patients were managed with conscious sedation. One was treated under general anesthesia because of agitation associated with his mental retardation. In the patients with isolated CBD stones, access to the distal CBD was obtained by removing the T-tube and inserting a 0.035″ Bentson guidewire under fluoroscopic guidance. A 7-Fr flexible ureteroscope was then advanced over the guidewire under videoscopic control. After removal of the guidewire, a 272-μm optical fiber (Slimline-

Table 1. Characteristics of patients undergoing holmium:YAG laser lithotripsy for biliary stones

Age (yr)	Sex	Comorbidity	Access route	Stone characteristics
39	M	None	Choledochotomy	Single, cholesterol, 12-mm
46	M	Mental retardation	Choledochotomy	Single, cholesterol, 10-mm
47	M	Cirrhosis	Cholecystostomy	Multiple, pigment, 4–8-mm

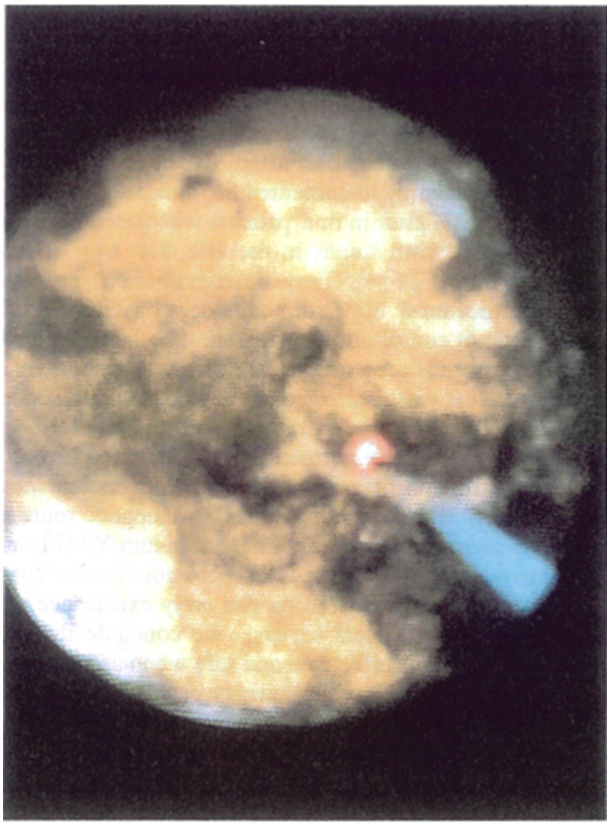

Fig. 1. The holmium:YAG laser beam is directed against the surface of a cholesterol stone that is impacted in the distal common bile duct. The red aiming beam is visible in an area already fragmented by the laser energy.

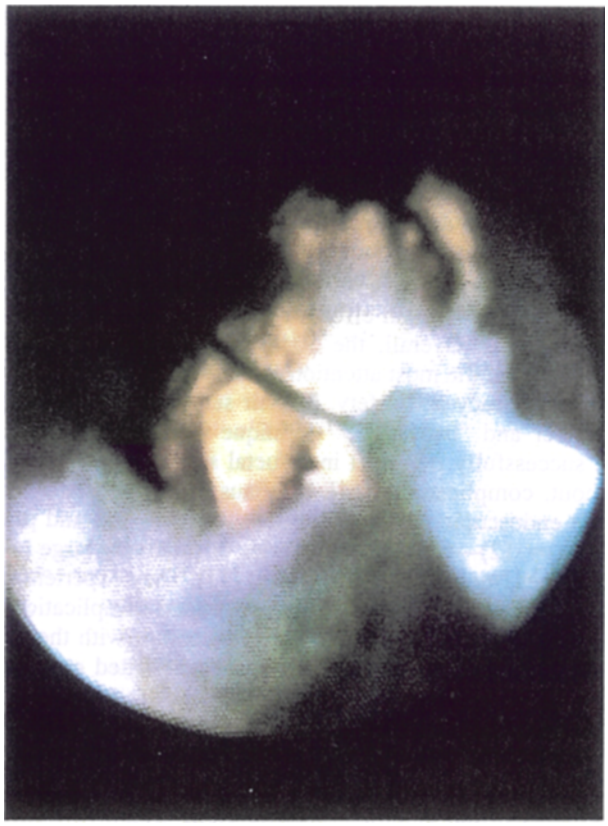

Fig. 2. Following the application of holmium:YAG laser energy, the remaining stone fragments are now small enough to be grasped in an endoscopic basket and extracted from the duct.

200; Coherent Medical Group) was advanced to the tip of the endoscope through the working port. The impacted stone was visualized (Fig. 1) and holmium:YAG energy was delivered using pulse energies of 0.6–1.0 J at 6–10 Hz. Lithotripsy was accomplished with the optical fiber in contact with the surface of the stone. In the patient with residual gallbladder stones, access was achieved by advancing the flexible ureteroscope through the cholecystostomy tract under videoscopic control. Multiple stones were identified and targeted separately using the same laser parameters as for the other cases.

Results

The two stones impacted in the distal CBD were fragmented quickly and efficiently with laser energy. In one patient, only endoscopic "dust" remained after the completion of laser lithotripsy. In the other, several small fragments were easily extracted using the endoscopic basket (Fig. 2). In both patients, postprocedure endoscopic inspection of the CBD revealed no further stones or debris and no evidence of mucosal injury. In addition, a completion cholangiogram demonstrated free flow of contrast into the duodenum without extravasation or filling defects. A small catheter was left in the T-tube tract for 2-3 days, then removed.

In the patient with multiple gallbladder calculi, all endoscopically visible stones were fragmented successfully by repeated activation of the holmium:YAG laser. Residual stone particles were then easily irrigated from the gallbladder. A small catheter was replaced through the cholecystostomy tract, and the mucopurulent drainage decreased rapidly. After 2 weeks, the catheter was removed without sequelae. At 6-months follow-up, no complications were seen.

There were no complications related to the laser treatments. All patients were discharged from the hospital within 24–48 h after lithotripsy. During a follow-up of ≥6 months in each case, no patient developed further symptoms related to his biliary tract.

Discussion

Since its introduction in 1974, the technique of endoscopic sphincterotomy has revolutionized the management of choledocholithiasis. Numerous studies have confirmed that ≤96% of all retained CBD stones can be removed successfully when either mechanical or electrohydraulic lithotripsy is available [3, 15]. Nevertheless, in patients with very large and/or impacted stones or severely altered anatomy, these methods can become impractical or unsafe. In such patients, the use of alternative strategies for stone clearance may become necessary.

One such approach, laser lithotripsy, was first described in 1981 by Orii et al., who used a continuous-wave Nd:YAG laser to successfully clear pigmented CBD stones from two patients [12]. However, further study suggested that the Nd:YAG laser would not be a universally acceptable lithotrite because of its tendency to drill rather than fragment most cholesterol stones [13]. In addition, it was observed that the Nd:YAG wavelength generated sufficient wall heat to be potentially damaging to bile ducts [5]. Subsequently, extensive laboratory and clinical investigations were conducted using a variety of laser wavelengths and delivery methods in an effort to determine the optimal approach [2, 6]. Overall, the 504-nm coumarin pulsed-dye laser received the most attention and appeared to exhibit the greatest efficacy and safety. In their series, Prat et al. used a mother and "babyscope" technique to accurately target and successfully fragment intraductal stones in 13 patients without, complications [14]. Neuhaus et al. used two different endoscopic routes—percutaneous ($n = 23$) and peroral ($n = 12$)—to fragment a series of relatively large biliary stones (mean diameter, 20 mm) [11]. They experienced two failures but no major lithotripsy-related complications.

In spite of such favorable initial outcomes with the use of the pulsed-dye laser, its high cost and limited range of applications have effectively precluded wider acceptance. Now, based on a growing number of reports in the urological literature, the holmium:YAG laser appears to be gaining acceptance as a more suitable alternative. Recent reports have shown that complete ureteral stone fragmentation is possible in >90% of all holmium:YAG lithotripsies, often after only a single endoscopic procedure; few related complications have been observed [15]. Urinary stones of all compositions can be reduced to substantially smaller residues than are usually found with other laser wavelengths [17]. Fragmentation by holmium:YAG lithotripsy occurs primarily by a photothermal mechanism whereby there is direct transmittance of energy from the laser to the stone [1, 18]. This mechanism is fundamentally different from other laser lithotripsy modalities. In particular, potentially hazardous cavitation bubbles or shock waves are not usually produced by holmium:YAG. This fact may explain the lower risk of collateral mucosal damage or stone retropulsion observed with the holmium:YAG laser.

In our three biliary cases, as in our urological cohort, the holmium:YAG laser has been used primarily as an endoscopic instrument. Thus, the optical fiber that delivered the laser energy was guided endoscopically to the targeted stone(s), and its cumulative effects were monitored endoscopically. In addition, visual/endoscopic cues were used to ensure that the tip of the laser fiber was kept in actual contact with the gallstones during laser activation, a requisite for optimal stone fragmentation and a safeguard against damage to adjacent structures. As recommended for intracorporeal urinary lithotripsy, judicious intraductal irrigation was used to dissipate the transmitted heat and to flush stone fragments from the field of view [8].

Several previous reports have validated the use of the holmium:YAG laser for the ablation of human gallstones. Nonetheless, clinical experience with this therapeutic modality remains limited. In 1992, Spindel et al. used an in vitro system to compare the holmium:YAG laser with the pulsed-dye laser. They found that lithotripsy could be performed satisfactorily using either method but suggested that collateral damage to adjacent tissues and to the laser fiber itself would be greater with the pulsed-dye system, [16]. In addition, they noted that the laser power required for stone fragmentation with the holmium:YAG laser was the same for all stones whereas it varied substantially among different stone compositions when the pulsed-dye laser was used. Das et al. subsequently documented the clinical efficacy of the holmium:YAG laser in four patients who presented with sepsis associated with stones in the bile duct ($n = 2$) or gallbladder ($n = 2$) [4]. They described seven separate lithotripsy procedures, all performed under conscious sedation and without complications. All stones, both cholesterol and pigment, were successfully cleared from three patients; one other patient was discharged with residual gallbladder stones after refusing further therapy. Monga et al. described a complex case of biliary obstruction that developed 7 years after the construction of a Roux-en-Y choledochojejunostomy [10]. They used a percutaneous, transhepatic route to completely fragment the stones with a holmium:YAG laser.

Similarly, our report concerns a spectrum of stone compositions and locations. Based on this early experience and the much larger urological surveys, we conclude that the holmium:YAG laser is effective and safe when used to fragment gallstones. Since laser lithotripsy can be easily performed and monitored through widely available videoscopic equipment, this approach should become increasingly useful to all laparoscopic surgeons who manage difficult biliary calculi.

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