

Effectiveness of laser lithotripsy-assisted bile duct surgery for complex choledocholithiasis: A prospective study

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ABSTRACT

Background: Choledocholithiasis remains a prevalent condition in hepatobiliary surgery, particularly in Southeast Asia. While several treatment modalities exist, achieving complete stone clearance remains challenging, especially in cases with intrahepatic or impacted stones. Intraoperative cholangioscopy combined with laser lithotripsy has emerged as a promising approach to improve outcomes. **Materials and methods:** This prospective study included 28 patients with intra- or extrahepatic bile duct stones who underwent open bile duct surgery combined with flexible cholangioscopy and holmium:YAG laser lithotripsy at Hai Phong University of Medicine and Pharmacy Hospital from June 2023 to April 2025. Demographic data, clinical and laboratory findings, operative details, complications, and treatment outcomes were recorded and analyzed descriptively. **Results:** The mean patient age was 52.3 ± 9.9 years, with 64.3% having a history of biliary surgery. All patients experienced right upper quadrant pain, and Charcot's triad was observed in 35.7%. Multiple stones were present in 82.1% cases, and 53.6% had cast-like stones. Intraoperatively, complete stone clearance was achieved in 85.6% of cases. Residual stones were predominantly located in the intrahepatic ducts. The mean operative time was 98.2 ± 21.1 minutes, and the mean hospital stay was 11.4 ± 4.8 days. Postoperative complications occurred in 21.4% of patients, with bile leakage being the most common (7.1%). Overall, 78.6% of patients achieved good clinical outcomes. **Conclusions:** Open bile duct surgery combined with intraoperative cholangioscopy and laser lithotripsy is a safe and effective method for managing complex choledocholithiasis, offering a high stone clearance rate and acceptable complication profile. Broader implementation of this technique may require increased access to specialized equipment and surgical expertise.

Keywords: bile duct stones, choledocholithiasis, intraoperative cholangioscopy, laser lithotripsy, flexible endoscopy, stone clearance

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INTRODUCTION

Choledocholithiasis remains a common and challenging condition in hepatobiliary surgery, particularly in regions with a high prevalence of biliary tract diseases such as

Southeast Asia. In Vietnam, bile duct stones are frequently encountered and are often associated with bacterial infection and a high risk of recurrence. Traditional treatment strategies, including open surgery, laparoscopic bile duct exploration, and

endoscopic retrograde cholangiopancreatography (ERCP), have been widely used. However, each technique has limitations in terms of stone clearance rate, invasiveness, and recurrence.

In recent years, the incorporation of intraoperative cholangioscopy during biliary surgery has gained traction as a method to enhance visualization and facilitate complete stone removal. Despite this advancement, stone extraction using standard techniques such as Dormia baskets or saline irrigation alone may not be sufficient, particularly in cases of impacted or intrahepatic stones. To overcome this limitation, energy-based fragmentation methods such as electrohydraulic or laser lithotripsy have been introduced. Holmium:YAG laser lithotripsy, in particular, allows for precise stone fragmentation under direct visualization and has been reported to achieve high rates of duct clearance. Patel et al. demonstrated a 97% intraoperative stone clearance rate using single-operator cholangioscopy and laser lithotripsy [1].

Flexible cholangioscopy has been utilized in several tertiary hospitals in Vietnam since the early 2000s, with reported stone clearance rates ranging from 54.8% to 93.5% depending on technique and stone characteristics [2]. However, evidence from regional centers remains limited, particularly regarding the use of laser lithotripsy in combination with open or laparoscopic biliary surgery. This study aimed to evaluate the clinical outcomes of bile duct stone surgery combined with laser lithotripsy.

MATERIALS AND METHODS

Study design and subjects

This was a prospective study conducted at Hai Phong University of Medicine and

Pharmacy Hospital between June 2023 and April 2025. The study was approved by the Institutional Review Board, and informed consent was obtained from all participants.

Patient selection

Patients were eligible for inclusion if they were diagnosed with choledocholithiasis and underwent open bile duct exploration combined with intraoperative cholangioscopy and laser lithotripsy using a flexible cholangioscope. Inclusion criteria were: (1) patients with intra- or extrahepatic bile duct stones confirmed by imaging studies, (2) suitability for open surgery with intraoperative cholangioscopy and laser lithotripsy, and (3) availability of complete medical records. Exclusion criteria included: (1) severe comorbid conditions or history of malignancy-related abdominal surgery, (2) sepsis or severe cholangitis requiring emergency interventions, and (3) incomplete clinical data.

Surgical technique

All procedures were performed under general anesthesia via open laparotomy. After bile duct exposure, a flexible cholangioscope was introduced for direct visualization. Stones were extracted using Dormia baskets and/or flushed with saline. If residual stones remained, holmium:YAG laser lithotripsy was employed under endoscopic guidance to fragment the stones, which were subsequently removed. Intraoperative bile duct clearance was confirmed visually.

Outcomes

Patient demographics, clinical presentation, laboratory findings, imaging characteristics, intraoperative findings, surgical duration, hospital stay, and postoperative complications were recorded. Stone clearance was assessed intraoperatively and confirmed with imaging studies when

indicated. Treatment outcomes were classified as:

Good: complete stone clearance without complications

Fair: incomplete stone clearance or minor complications

Poor: significant complications or failure of duct clearance

Statistical analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation (SD), and categorical variables were expressed as frequencies and percentages. Comparative analysis was performed using the chi-square test or paired t-test where appropriate. A p-value < 0.05 was considered statistically significant.

RESULTS

Patient characteristics

The patient population had a mean age of 52.3 ± 9.9 years, with a substantial proportion having a history of previous biliary surgery (64.3%) and cholecystectomy (35.7%). Comorbid conditions were present in 53.6% of patients. Clinically, all patients experienced right upper quadrant pain, while jaundice and fever were observed in 78.6% and 64.3% of cases, respectively; Charcot’s triad was documented in 35.7%. Laboratory investigations revealed leukocytosis in 67.9% of patients and elevated total bilirubin in 78.6%, with a mean level of 131.4 ± 180.8 µmol/L. AST and ALT were elevated in 82.1% and 78.6% of patients, respectively. Imaging showed that 78.6% had a common bile duct (CBD) diameter greater than 10 mm (mean: 15.3 ± 6.9 mm). The majority had multiple stones (82.1%) and 53.6% had cast-like stones. Regarding stone distribution, most cases (60.7%) had stones confined to the CBD. Other locations included the left hepatic duct with CBD (14.3%), the entire biliary tree including CBD, right, and left hepatic ducts (10.7%), left hepatic duct only (7.1%), right hepatic duct with CBD (3.6%), and both left and right hepatic ducts (3.6%) (Table 1).

Table 1. Patient characteristics

		%
Demographics	Mean age (years)	52.3 ± 9.9
	Previous biliary surgery	64.3%
	Previous cholecystectomy	35.7%
	Comorbidities	53.6%
Clinical signs	Right upper quadrant pain	100%
	Jaundice	78.6%
	Fever	64.3%
	Charcot’s triad	35.7%
Paraclinical signs	Leukocytosis	67.9%
	Elevated total bilirubin	78.6% (131.4 ± 180.8 µmol/L)
	Elevated AST	82.1%
	Elevated ALT	78.6%
	CBD diameter > 10 mm	78.6%
	Mean CBD diameter	15.3 ± 6.9 mm

	Stones in CBD alone	60.7%
	Multiple stones	82.1%
	Cast-like stones	53.6%
	Gallbladder stones	39.3%
Stone location	Common bile duct (CBD) only	60.7%
	Right hepatic duct + CBD	3.6%
	Left hepatic duct + CBD	14.3%
	Left hepatic duct only	7.1%
	Left and right hepatic ducts	3.6%
	CBD + right hepatic + left hepatic ducts	10.7%

Surgical outcomes

Intraoperatively, extensive abdominal adhesions were noted in the majority of cases (76.5%). Evaluation of stone location by intraoperative cholangioscopy revealed that most stones were confined to the common bile duct (CBD), accounting for 67.9%, compared to 60.7% identified by preoperative computed tomography (CT). Differences in stone localization between the two modalities were not statistically significant ($p = 0.95$). Complete stone clearance, assessed via cholangioscopy combined with laser lithotripsy, was achieved in 24 out of 28 patients (85.6%). Residual stones were detected in 4 patients (14.4%) and were predominantly located in intrahepatic bile ducts (left lobe segment IV, right lobe, or both lobes), where endoscopic access or laser lithotripsy was limited (Table 2).

Table 2. Intraoperative findings and stone clearance

	Location	Intraoperative Cholangioscopy (%)	Preoperative CT (%)
Stone Location	CBD only	67.9%	60.7%
	Left hepatic duct + CBD	3.6%	3.6%
	Right hepatic duct + CBD	10.7%	14.3%
	Left hepatic duct only	3.6%	7.1%
	Left + right hepatic ducts	3.6%	3.6%
	CBD + right + left hepatic ducts	10.7%	10.7%
	Stone clearance		
	Complete clearance	85.6%	
	Residual stones – Left lobe (segment IV)	3.6%	
	Residual stones – Right lobe	3.6%	
	Residual stones – Both lobes	7.2%	

The mean operative time was 98.2 ± 21.1 minutes (range: 59–152 minutes), and the mean hospital stay was 11.4 ± 4.8 days (range: 8–19 days). Postoperative complications occurred in 6 patients (21.4%), including bile leakage (7.1%), wound infection (7.1%), biliary tract bleeding (3.6%), and Kehr drain obstruction (3.6%). No complications were observed in 78.6% of patients.

Based on overall clinical and intraoperative assessments, treatment outcomes were rated as good in 22 patients (78.6%), fair in 2 patients (7.1%), and average in 4 patients (14.3%), primarily those with either residual stones or early postoperative complications (Table 3).

Table 3. Postoperative complications and treatment outcomes

		%
Postoperative complications	Biliary tract bleeding	3.6%
	Bile leakage	7.1%
	Kehr drain obstruction	3.6%
	Wound infection	7.1%
	No complications	78.6%
Overall	Good	78.6%
	Fair	7.1%
	Average	14.3%

DISCUSSION

The study showed surgical management of bile duct stones combined with intraoperative laser lithotripsy can be a safe and effective method that enables rapid stone fragmentation and removal. Clinically, all patients presented with right upper quadrant pain, and 35.7% fulfilled Charcot's triad. This is comparable to the study by Zheng et al., who analyzed 123 elderly patients (aged ≥ 70) with common bile duct stones and reported right upper quadrant pain in 95.9%, jaundice in 56.1%, fever in 19.5%, and cholangitis in 56.9% of cases [3]. The primary goal of combining biliary surgery with intraoperative laser lithotripsy is to achieve complete stone clearance and restore bile duct patency. Preoperative imaging plays a critical role in guiding treatment planning, yet conventional modalities such as ultrasound or CT have limitations, ultrasound is operator-dependent and less accurate in detecting intrahepatic stones, while CT requires contrast and may miss radiolucent calculi. Flexible cholangioscopy allows direct visualization of stone morphology, quantity, and location, enabling precise intraoperative intervention. In our study, patients with cast-like stones in the lower CBD were still considered suitable for flexible cholangioscopy and laser lithotripsy. The

distribution of intrahepatic stones was consistent with previous Vietnamese data; for instance, Vo Dai Dung reported bilateral intrahepatic stones in 54.3%, left-sided stones in 27.1%, and right-sided stones in 18.6% of cases [4].

Our intraoperative stone clearance rate was 85.7%, notably higher than Vo's reported rate of 39.5% [4]. In the 4 patients with retained stones, we intentionally left the stones in place due to ductal narrowing that prevented passage of the cholangioscope or laser probe. This underscores a key limitation: cholangioscopy alone cannot definitively confirm complete clearance, especially in cases with multiple or intrahepatic stones. A multimodal approach, including postoperative ultrasound and cholangiography, remains essential. Postoperative complications occurred in 21.4% of patients, consistent with published complication rates for cholangioscopy-based procedures, which range from 5% to 54% (average 20–22%). Bile leakage was the most common complication in our series (7.1%), similar to the 5.8% rate reported by Su Quoc Khoi [5]. Two of our patients experienced persistent bile drainage beyond postoperative day 5, which resolved by day 12–19. Liu D et al. defined bile leakage as drain output >100 ml/day for more than three days postoperatively [6]. Regarding

treatment outcomes, 78.6% of patients were assessed as having good results, while 14.3% had average outcomes due to residual stones and/or complications. These findings demonstrate that laser-assisted bile duct stone surgery is an effective approach with favorable outcomes in most cases.

The study had several limitations. First, the sample size was relatively small, which may limit the generalizability of the findings to broader populations. Second, the study design was a single-center, non-randomized study without a control group, which limits the ability to directly compare outcomes with other treatment modalities such as laparoscopic bile duct exploration or ERCP. Future randomized controlled trials are needed to validate the superiority or equivalence of this approach. Third, while intraoperative cholangioscopy was used to assess stone clearance, the accuracy of this method alone may be insufficient, especially in cases of intrahepatic stones or biliary strictures. Finally, the procedure requires advanced equipment and surgical expertise in laser lithotripsy and flexible cholangioscopy, which may not be widely available in lower-resource settings. This may limit the reproducibility and accessibility of the technique in general surgical practice.

CONCLUSION

Surgical management of bile duct stones combined with intraoperative laser lithotripsy can be a safe and effective method that enables rapid stone fragmentation and removal. The approach can be associated with a high stone clearance

rate, low complication rate, and favorable clinical outcomes.

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