

INTERVENTIONAL



Safety, efficacy, and feasibility of percutaneous transhepatic endoscopic holmium laser lithotripsy for bile duct stones

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Abstract

Objective To evaluate the safety and efficacy of percutaneous transhepatic endoscopic holmium laser lithotripsy (PTEHL) for patients with intrahepatic bile duct (IHBD) and common bile duct (CBD) stones.

Material and methods This retrospective study included 530 patients (mean age: 55.6 ± 8.5 ; 64.2% female) with IHBD and/or CBD stones at a single institution from January 2019 to December 2021. PTEHL was the chosen treatment for patients with large, complex stones, or those for whom Endoscopic Retrograde Cholangiopancreatography (ERCP) failed or presented difficulties. Patients showing signs of cholangitis required pre-PTEHL drainage. Stone clearance was confirmed by post-procedural cholangiography, and the technique was deemed successful when target stones were removed. Complications were recorded according to the Society of Interventional Radiology adverse event classification.

Results The mean stone size was 20.9 ± 11.9 mm, multiple stones observed in 460 patients (86.8%). A total of 225 patients (42.5%) had stones in both the IHBD and CBD; biliary-enteric anastomosis in 50 patients (9.4%). ERCP for stone removal proved unsuccessful in 18 patients (3.4%). Pre-IHBD drainage was performed in 271 patients (51.1%). The majority (488 patients, 92.1%) underwent a single PTEHL session. The technique was successful in 523 patients (98.7%), with 7 patients requiring surgery due to unsuccessful target stone removal. Complications were noted in 75 patients (14.2%), including 4.7% with severe complications and 9.4% with minor complications.

Conclusion PTEHL is a safe and effective method for the treatment of both intrahepatic and extrahepatic bile duct stones. This approach is a valuable option for complex stone cases, particularly when ERCP is unsuccessful or encounters significant challenges.

Clinical relevance statement Percutaneous Transhepatic Endoscopic Holmium Laser Lithotripsy is a safe and effective treatment method for intrahepatic and extrahepatic biliary stones, particularly in cases of complex stones.

Key Points

- Percutaneous transhepatic biliary stone removal is difficult for large or intraductal stones.
- Percutaneous Transhepatic Endoscopic Holmium Laser Lithotripsy (PTEHL) demonstrated a high success rate with few major complications.
- PTEHL can treat biliary stones, particularly stones that are difficult or have failed ERCP treatment.

Keywords Cholelithiasis, Transhepatic, Endoscopic biliary, Laser, Lithotripsy

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Introduction

Biliary stones are a relatively common disease, affecting about 20% of the population. This includes gallbladder (GB) stones, intrahepatic bile duct (IHBD) stones, and common bile duct (CBD) stones. In contrast to Western countries where gallbladder stones constitute the majority, in our country as well as in other tropical regions, biliary tract stones predominate—accounting for approximately 85% of cases. Although there have been changes in recent years, this ratio remains high, often associated with the clinical presentation of biliary ascariasis and dietary habits [1, 2]. Stones in the CBD and IHBD typically manifest with clinical symptoms related to obstruction and infection, requiring early and appropriate management to avert serious, potentially life-threatening, complications [3].

Historically, the treatment for CBD and IBHD stones involved open surgical removal stones and placement of a Kehr's T-tube, later evolving into laparoscopic surgery [3]. Nowadays, endoscopic retrograde cholangiopancreatography (ERCP), sphincterotomy, and the use of balloons or baskets for stone extraction are considered primary options for managing both intra- and extrahepatic bile duct stones [3, 4]. However, factors such as stone number, size greater than 15 mm, CBD stones coexisting with IBHD stones, anatomical variations, post-surgical alterations of the biliary tract can reduce the success rate of stone removal and increase the risk of complications [4]. Percutaneous transhepatic stone removal (PTSR), first described by Perez et al, and subsequent advancements like extraction via the gallbladder, using dilating balloons or baskets, have shown comparable success rates to ERCP, but with lower complication rates and reduced need for sphincterotomy [5–7]. Yet, for large stones and those in the IBHD, both techniques still carry poor prognostic factors for successful outcomes [6, 8, 9].

The use of Holmium laser, approved by the Food and Drug Administration (FDA) for treating GB and CBD stones, has been widely recognized for its outstanding results in urolithiasis treatment [10–12]. Percutaneous biliary endoscopy (PBE) has become an effective auxiliary tool for the diagnosis and treatment of numerous biliary duct diseases [13–15]. Percutaneous transhepatic laser lithotripsy (PTLL) has also been employed and can be considered an alternative treatment for challenging stones unmanageable with ERCP or PTSR, particularly for large stones and intrahepatic bile duct stones [13, 16–19]. This study aims to evaluate the safety and efficacy of percutaneous transhepatic endoscopic holmium laser lithotripsy (PTEHL) using rigid endoscopy in treating CBD and IBHD stones.

Material and methods

Patient selection

In this retrospective cohort study, we collated data from 530 patients presenting with IHBD and/or CBD stones who underwent percutaneous PTEHL at a single institution between January 2019 and December 2021. This investigation received approval from the Institutional Review Board at our institution. Owing to the design of this study, the requirement for patient consent was exempted.

Treatment approach for patients with biliary duct stones is determined through discussions by a multidisciplinary group comprising surgeons, endoscopists, and interventional radiologists. We selected patients for PTEHL based on the following criteria: (1) presence of IHBD; (2) CBD stones larger than 2 cm or accompanied by IHBD stones; (3) patients who experienced unsuccessful or impractical with ERCP; (4) patients who had undergone surgeries related to the biliary tract or gastroduodenal procedures; (5) patients with progressive cardiopulmonary diseases not suitable for ERCP or surgery. Patients contraindicated for PTEHL included: (1), those with coagulation disorders (INR > 1.5, platelets < 50,000); (2), patients with malignant hepatic and biliary pathologies; (3), patients with IHBD stone and corresponding hepatic parenchymal atrophy.

Demographic, clinical, and radiological data

The patient demographics included age and sex. Data on previous biliary stone surgeries, other related surgical histories, and instances of failed ERCP were collected. Cholangitis status was diagnosed based on clinical signs and laboratory tests.

Magnetic Resonance Cholangiopancreatography (MRCP) with gadolinium contrast agents was performed on all patients, with evaluators blinded to clinical information. The imaging was assessed independently by two experienced diagnostic radiologists with ten and five years of expertise in hepatobiliary imaging (P.N.H., P.S.N. respectively). Stone characteristics, including size (categorized as ≥ 15 mm and ≥ 30 mm), quantity (single or multiple), and location, were meticulously evaluated using MRI. In addition, the presence of hepatic abscesses was documented based on MRI findings.

Procedure

The procedure was performed by interventional radiologists, each with a minimum of ten years of experience. The selection of the biliary tract entry point and approach is based on the location of the stone as well as any anatomical variations of the biliary duct, adhering to the principle of contralateral access (when right hepatic duct

stones are present, the left hepatic duct is accessed and vice versa). This approach ensures the most direct path to the stone. In cases of complex stones, a dual-access approach may be considered.

In patients diagnosed with cholangitis or exhibiting a deteriorated systemic health status, including advanced cardiac and pulmonary diseases or being older than 80 years, biliary drainage placement is performed 5–7 days prior to PTEHL, biliary drainage placement is performed 5–7 days prior to PTEHL, and antibiotic treatment is continued until the infection resolves. A 16 or 20-gauge needle (BD Angiocath) is employed to access the pre-determined biliary tract site under ultrasound guidance after local analgesic. This allows for cholangiography to accurately ascertain the stone's location and the anatomy of the biliary tract. A 0.035-inch guide wire (Terumo) is threaded through the needle into the biliary tract, followed by the placement of an 8 F pigtail catheter (Bioteq) in the CBD for external drainage. For patients without cholangitis, lithotripsy is conducted in a single session.

PTEHL is conducted following local anesthesia and systemic intravenous analgesia, utilizing an approach similar to biliary drainage with a predetermined site. A 0.035-inch guide wire (Terumo) is introduced into the biliary tract via a 16-gauge needle (BD Angiocath) (or through a pre-existing drainage catheter in patients who have already undergone drainage). This is followed by the gradual dilation of the hepatic parenchyma tunnel to the biliary tract using a dilation set ranging from 6 F to 16 F (Seplou Medical). Subsequently, a 16 F lithotripsy sheath (Seplou Medical) is inserted into the dilated tunnel. In patients presenting with cholangitis, PTEHL is undertaken once an improvement in the inflammatory condition is demonstrated by clinical and laboratory assessments. Following the withdrawal of the drainage catheter, the process of tunnel dilation is initiated using a 10 F sheath, with subsequent steps mirroring those applied to patients who have not undergone drainage previously. We employ a 9.5 F Rigid Ureteroscope (Karl Storz) for endoscopic visualization of the biliary tract to locate the stone and perform continuous irrigation. A laser fiber (550 nm) is introduced through the endoscope for fragmentation of the stone, which is then flushed out with water. The Holmium laser (Accutech) used has a power setting of 80–100 W, frequency of 20 Hz, and energy of 2 J. During the procedure, all main biliary tracts are endoscopically examined from upper branches to lower, from anterior to posterior. Following the successful fragmentation of large stones into smaller pieces that could be extracted through a 16 F sheath, the laser fiber was withdrawn. Subsequently, a stone retrieval basket (Seplou Medical) was inserted through the endoscope to remove the smaller stone fragments. During the

lithotripsy process, as well as for flushing the biliary tract, we utilized a water flushing system (Xinxing) with an irrigation pressure ranging from 0 to 80 Kpa and a maximum flow rate of 500 mL/min. The flow rate and pressure were individually adjusted for each patient. If residual stones are observed with cholangiography or ultrasound and cannot be reached through the first access point, a second or third access point may be considered, or the procedure may be repeated after 2–3 days. The lithotripsy duration should not exceed 3 h. In patients without biliary strictures, a 10 F external drainage (Bioteq) was inserted into the CBD. In patients with biliary strictures, the narrowed segments are dilated using a balloon (Cook Medical), followed by the placement of internal-external drainage catheters (12–14 F) across the stricture for an extended period (1–2 months).

In patients who had small residual stones in the terminal portion of the CBD following lithotripsy, and where endoscopic access to the stones was challenging or the stones were identified in cholangiography findings post-lithotripsy, the technique of percutaneous transhepatic papillary balloon dilation (PTPBD) was employed. This procedure was used to dilate the sphincter of Oddi and facilitate the expulsion of the stones into the duodenum.

In cholangitis cases, immediate broad-spectrum intravenous antibiotics are initiated post-drainage. For patients without cholangitis and no prior drainage, broad-spectrum oral antibiotics are prescribed for two days pre-procedure and four days post-procedure. Evidence of infection prompts a switch to intravenous antibiotics.

After PTEHL, patients are closely monitored for early detection of complications such as bleeding and infection. Abdominal ultrasound is routinely performed every two days until discharge. Fourteen days post-procedure, based on cholangiography findings, if there is no evidence of biliary-peritoneal or biliary-pleural fistula, the drainage catheter was removed. The hospitalization duration for patients following PTEHL is calculated from the time the patient receives PTEHL until discharge. Follow-up assessments after 14 days and the potential removal of biliary drainage can be conducted during subsequent outpatient visits. Patients will be monitored quarterly with abdominal ultrasound or whenever any abnormal symptoms related to biliary stones arise. If there is suspicion of recurrent biliary stones, MRCP will be indicated.

Evaluation of outcomes

The efficacy of the PTEHL method was assessed based on the technical success rate and the level of stone clearance achieved. Technical success is defined as the removal of target stones and the restoration of biliary tract flow. The technique is considered a failure when access to the biliary tract is not achieved or when the target stones cannot be

removed, necessitating the selection of an alternative treatment methods. The level of stone clearance is categorized as: (1) stone free when all intrahepatic and extrahepatic bile duct stones are removed; (2) nearly stone free when stones are cleared from the CBD, right and left hepatic ducts, and segmental bile ducts, with remaining stones in branches of the lower segments that do not require further intervention; (3) incomplete when stones persist in the CBD or/and right or/and left hepatic ducts, or/and segmental bile ducts, requiring further management. These evaluations are based on cholangiography images taken fourteen days after PTEHL. Complications were categorized in accordance with the guidelines of the Society of Interventional Radiology Adverse Event Classification 2017 [20].

Statistical analysis

In our research, continuous variables are reported using means and standard deviations (SD), while categorical variables are presented as frequencies or percentages. All statistical analyses are performed using SPSS version 26 (IBM Corp).

Results

During the three-year interval from January 2019 to December 2021, our study enrolled 530 patients presenting with IHBD and/or CBD stones. The cohort’s mean age was 55.6 ± 8.5 years, with a female predominance of 64.2%. The majority of patients have a history associated with hepatic, biliary diseases, or surgeries. Notably, 218 patients (41.1%) had undergone at least one biliary stone extraction surgery. Additionally, cholecystectomy was performed on 110 patients (20.8%), biliary-enteric anastomosis in 50 patients (9.4%), and cystic duct excision in 22 patients (4.2%). ERCP for stone removal proved unsuccessful in 18 patients (3.4%). The common clinical presentations in patients were cholangitis (38.1%) with 26 of these cases (4.9%) progressing to hepatic abscesses, obstructive jaundice (30.9%), and abdominal pain (22.8%). The patients exhibited a mean stone diameter of 20.9 ± 11.9 mm. Specifically, 90 patients (17%) had stones exceeding 30 mm in size, while 368 patients (69.4%) presented with stones larger than 15 mm. The prevalence of multiple stone formations was observed in 460 patients (86.8%). Concerning the location of the stone, 108 patients (20.4%) exhibited isolated CBD stones. The rest had IHBD stone, either solely or concomitantly with CBD. Of these, 225 patients (42.5%) had stones in both intra- and extra-hepatic bile ducts (Table 1).

In our cohort, 271 patients (51.1%) underwent biliary drainage prior to PTEHL treatment. The mean duration from the placement of the drainage catheter to PTEHL was 4.5 ± 2.8 days. Most patients received a single PTEHL

Table 1 Patient characteristics in the study

Baseline characteristics	No. of patients (%) (n = 530)
Age (years)	55.6 ± 8.5
Gender	
Male	190 (35.8)
Female	340 (64.2)
History of hepatobiliary disease:	
Biliary stone removal surgery at least once	218 (41.1)
Biliary-enteric anastomosis surgery	50 (9.4)
Resection of choledochal cyst	22 (4.2)
Cholecystectomy	110 (20.8)
Other abdominal surgeries	8 (1.5)
Clinical presentation	
Cholangitis	202 (38.1)
Obstructive jaundice	164 (30.9)
Abdominal pain	121 (22.8)
Other	43 (3.4)
Failed ERCP	18 (3.4)
Biliary stone-related parameters	
Stone size (Mean, mm)	20.9 ± 11.9
≥ 30 mm	90 (17)
≥ 15 mm	368 (69.4)
Stone number	
One	70 (13.2)
Multiple	460 (86.8)
Stone location	
RHBD	58 (10.9)
LHBD	60 (11.3)
R & LHBD	79 (14.9)
Combine IHBD & CBD	225 (42.5)
CBD stones	108 (20.4)

ERCP endoscopic retrograde cholangiopancreatography, RHBD right hepatic bile duct, LHBD left hepatic bile duct, IHBD intra hepatic bile duct, CBD common bile duct

session, accounting for 488 individuals (92.1%). The number of patients undergoing two and three PTEHL sessions was 40 (7.5%) and 2 (0.4%), respectively. The predominant number of access routes for PTEHL was one, noted in 440 patients (83%). In addition, 53 patients (10%) underwent a combined procedure of PTEHL and papillary balloon dilation for complete stone removal. Technical success was achieved in 523 patients (98.7%), with complete stone clearance in 386 patients (72.8%) and near-complete clearance in 137 patients (25.8%), where all target stones were removed. However, 7 patients (1.4%) required surgical procedures due to unsuccessful target stone removal via PTEHL (Table 2). A total of 34 patients with biliary strictures were treated by balloon dilation at

Table 2 Parameters related to percutaneous transhepatic endoscopic holmium laser lithotripsy

Baseline characteristics	No. of patients (%) (n = 530)
Biliary drainage prior to PTEHL	
Yes	271 (51.1)
No	259 (48.9)
Mean time from biliary drainage to PTEHL (days)	4.5 ± 2.8 (days)
Number of PTEHL sessions	
1	488 (92.1)
2	40 (7.5)
3	2 (0.4)
Number of access routes for PTEHL	
1	440 (83)
2	87 (16.4)
3	3 (0.6)
Combination with PTPBD	
Yes	53 (10)
No	477 (90)
Evaluation of stone clearance	
Stone - free	386 (72.8)
Nearly stone - free	137 (25.8)
Residual stones needing alternative treatment	7 (1.4)
CBD stone - free	530 (100)
Duration of hospitalization after PTEHL	5.6 ± 3.8 (days)

PTEHL percutaneous transhepatic endoscopic holmium laser lithotripsy, PTPBD percutaneous transhepatic papillary balloon dilation

the narrowed segment and subsequent placement of an internal-external drainage catheter across the stricture.

Complications were observed in 75 patients (14.2%), encompassing both major and minor complications. Major complications occurred in 25 patients (4.7%). Of these, ten patients (1.9%) experienced hepatic arterial bleeding requiring transarterial embolization. There were nine cases (1.7%) of sepsis associated with PTEHL. Three patients developed biliopleural fistula with one case progressing to the development of a pleural abscess necessitating surgery. Three patients presented with perihepatic fluid collections, of whom, two required drainage and one underwent surgery. Minor complications were noted in 50 patients (9.4%), with the most common being abdominal pain (4.3%) and minor biliary bleeding not requiring intervention in 25 patients (4.7%). The mean hospitalization duration for patients following PTEHL is 5.6 ± 3.8 days (Table 3).

Discussion

Our study, involving 530 patients with an average stone size of 20.9 ± 11.9 mm, where 69.4% had stones larger

Table 3 Complications following percutaneous transhepatic endoscopic holmium laser lithotripsy

Complication	No. of patients (%) (n = 530)
Minor complication	50 (9.4)
Abdominal pain	23 (4.3)
Nausea/vomiting	5 (0.9)
Pneumonia	14 (2.6)
Minimal haemobilia	25 (4.7)
Perihepatic fluid collection (no treatment required)	6 (1.1)
Pancreatitis	5 (0.9)
Major complication	25 (4.7)
Bleeding necessitates TAE	10 (1.9)
Biliopleural fistula	3 (0.6)
Perihepatic fluid collection (treatment required)	3 (0.6)
Sepsis	9 (1.7)

TAE trans arterial embolization

than 15 mm and 17% had stones larger than 30 mm, and 86.8% had multiple stones, demonstrated a 98.7% technical success rate in targeted stone removal using PTEHL (Fig. 1). We achieved a total stone removal rate of 72.8%. PTSR is emerging as a viable alternative for cases where endoscopic ERCP is either unsuccessful or impractical, especially in patients with post-gastro-duodenal surgical anatomical alterations or the existence of duodenal diverticulum, as well as in elderly patients with advanced cardiac diseases rendering ERCP infeasible. However, this method faces challenges in situations involving large-sized or multiple stones. The use of balloons and baskets to facilitate stone passage into the duodenum can be problematic, often requiring repeated and extended procedural efforts. Most studies have identified stone size as a critical factor influencing the success of this technique. According to Shin’s research on 968 cases, the average number of procedures per patient was 2.9 (ranging from 1 to 9), with a technical success rate of 92.3% [21]. Kim’s study, which focused on stones with a median size of 7.0 mm (ranging from 5–10 mm), reported a technical success rate of 80.5%, with 22% of patients undergoing multiple stone removal sessions [7]. In Chiu’s patient group, with an average stone size of 12.8 ± 5.42 mm (ranging from 3–32 mm), the technique achieved an 83% success rate [6].

Recent advances in biliary endoscopy have positioned it as a valuable option for both diagnosis and treatment of biliary tract disorders [22, 23]. According to Guan et al, the overall success rate of this technique stands at 94.1% [14]. The utilization of laser lithotripsy under biliary endoscopic guidance has emerged as a promising

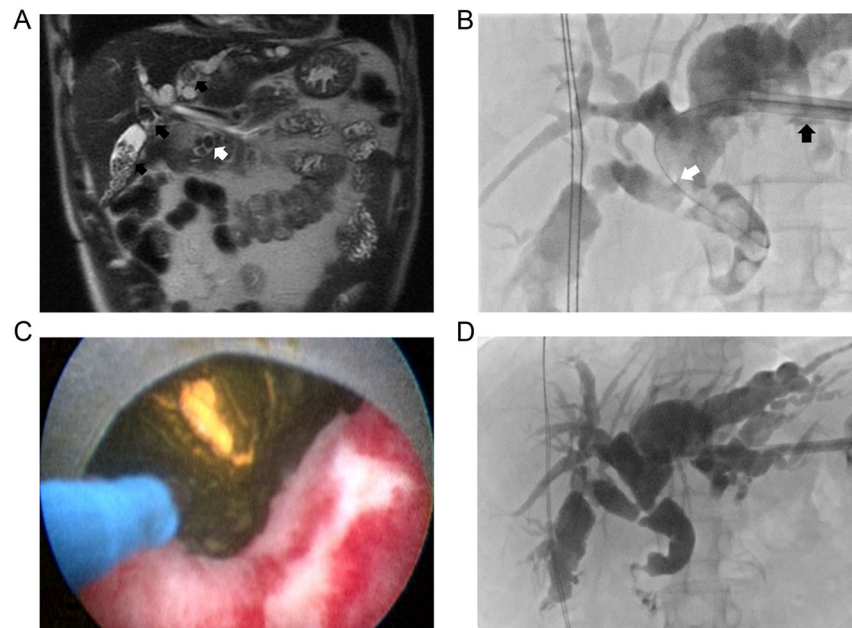


Fig. 1 A 45-year-old female patient with a history of cholecystectomy and common bile duct (CBD) stone removal performed 10 years ago. **A** MRI imaging: dilatation and multiple biliary stones within the intrahepatic bile ducts (IHBD) on both sides (black arrows), with the largest stone measuring 21 mm in diameter, and CBD stones (white arrow); **B** After accessing IHBD branch with a 16-gauge needle, a guide wire was inserted into CBD (white arrow), followed by the introduction of a dilation set ranging from 6 F to 16 F to widen the tract, and a 16 F lithotripsy sheath was placed at the left intrahepatic duct branch (black arrow); **C** Endoscopic examination through the 16 F lithotripsy sheath, employing Holmium Laser to fragment the stones and a retrieval basket for extraction; **D** Post-procedural percutaneous cholangiography: no abnormal radiolucent defects were observed within the biliary tract, indicating complete removal of the stones

treatment for challenging and complex biliary stones [11] (Fig. 2). Furthermore, the FDA's approval of Holmium laser for the fragmentation of gallbladder and biliary stones has paved the way for the wider adoption of this technique. Schatloff's application of Holmium laser under biliary endoscopic guidance achieved a success rate of 85.7% (12 out of 14 patients) [24]. Similarly, Lamana et al, reported successful stone clearance in all 12 patients treated with the Holmium YAG 2100 nM laser for IHBD stones, with 11 out of 12 patients achieving clearance in the first session [19]. Muglia's study involving 28 patients undergoing 43 PTEHL sessions (IHBD stones in 51%, CBD stones in 33%, and combined in 16%) reported a technical success rate of 82% (23 out of 28 patients), with 5 patients (18%) requiring surgical [16], (Table 4).

In our research, the overall incidence of complications was recorded at 14.1%, encompassing 4.7% major complications and 9.4% minor complications. Comparatively, Muglia's study observed major and minor complication rates were 3.6% and 14.3%, respectively; Lamana's research reported 8.3% and 25%; and Shim's study found rates of 4.1% and 17.1% [16, 19, 25]. Shin's investigation encountered no severe complications, noting minor complications in 8.9% of cases [21]. Among the severe complications, hepatic artery injury resulting in significant

haemobilia was observed in 10 patients (1.9%). All these cases were successfully managed with transarterial embolization, avoiding further complications. Sepsis associated with PTEHL occurred in 9 patients (1.7%), with no marked difference between those with pre-procedural drainage and those without. Schatloff et al, recommends administering oral antibiotics 7 to 10 days before the procedure to reduce the risk of infection [24]. Complications such as biliopleural fistula and perihepatic fluid collection require early diagnosis to facilitate minimally invasive treatment, thereby avoiding the necessity of surgical. Notably, our study did not record any instances of laser-induced biliary injury.

This study has several limitations. First, its retrospective design implies that data collection was passive, which might affect the robustness of the findings. However, the substantial patient population does provide a meaningful contribution to the existing literature on biliary stone treatment with PTEHL. Second, the lack of a control group limits comparative analysis with other treatment modalities, especially endoscopic surgery. Third, the study did not explore factors associated with stone recurrence. Future research is planned to investigate these factors and to establish appropriate preventive treatment strategies.

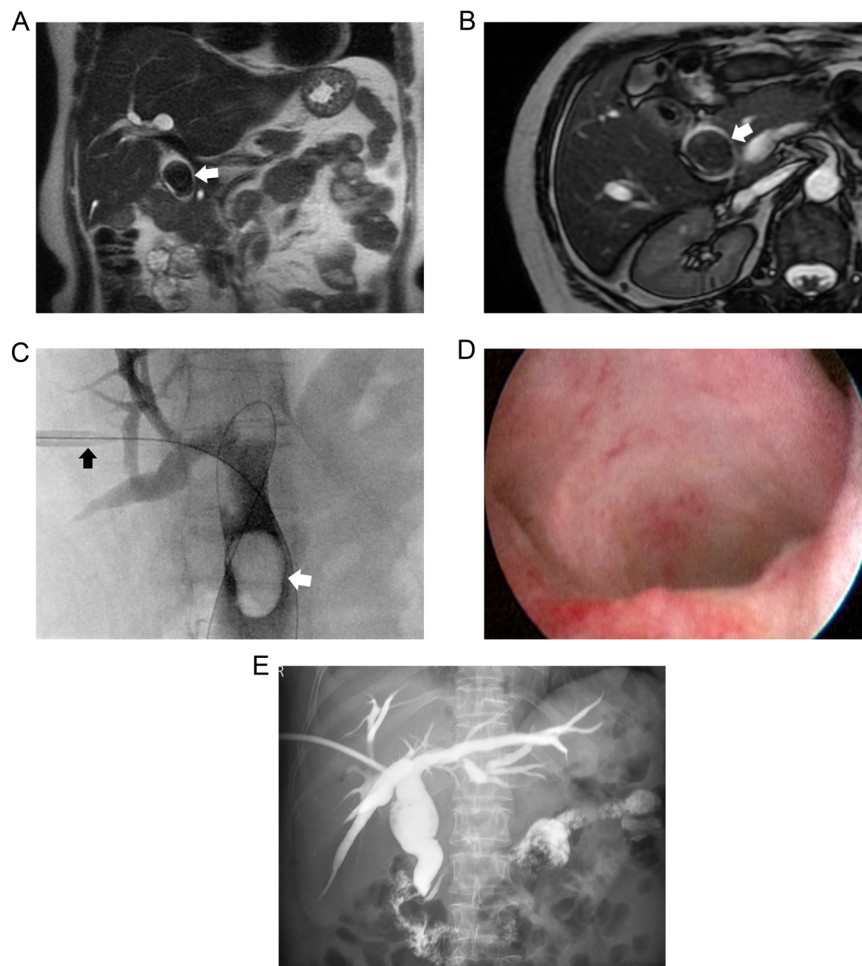


Fig. 2 A 78-year-old male patient with progressive cardiovascular disease. **A, B** MRI imaging: A large common bile duct (CBD) stone measuring 36 mm in diameter (white arrow), with mild dilatation of both intrahepatic and extrahepatic bile ducts. **C** After selecting the right hepatic bile duct (RHBD) for access with a 16-gauge needle, a guide wire was inserted into the CBD (white arrow), followed by the introduction of a dilation set ranging from 6 F to 16 F to widen the tract, and a 16 F lithotripsy sheath was positioned at the RHBD (black arrow); **(D)** Endoscopic examination CBD after lithotripsy; **(E)** Post-procedural percutaneous cholangiography after one week showed no abnormal radiolucent defects, indicating complete removal of the stones

Table 4 Comparison with other studies

Authors (years)	Method	Number patients	Number of procedures	Stone location	Stone size (mm)	Technique success (%)	Complication (%) (Major/Minor)
Muglia et al [16]	PTHLL	28	43	IHBD, CBD	Not available	82	3.6/14.3
Rimon et al [18]	PTHLL	21	24	IHBD, CBD	Not available	96	0/4.8
Lamana et al [19]	PTHLL	12	13	IHBD	Not available	100	8.3/25
Chiu et al [6]	PTSR	100	> 216	CBD	15.2	83	6/10
Kim et al [7]	PTSR, PTCSR	41	Not available	CBD	7	97.6	0/2.4
Shin et al [21]	PTSR	916	2807	IHBD, CBD	Not available	92.3	0/8.9
Shim et al [25]	PTSR, PTCSR	123	135	CBD	10	95.9	4.1/17.1
Jung et al [9]	PTCSR	114	Not available	CBD	9.9	84.2	0/7.9
Our study	PTHLL	530	574	IHBD, CBD	20.9	98.6	4.7/9.4

PTHLL Percutaneous transhepatic holmium laser lithotripsy, *IHBD* intra hepatic bile duct, *CBD* common bile duct, *PTSR* percutaneous transhepatic stone removal, *PTCSR* percutaneous transcholecystic stone removal

In conclusion, PTEHL is a safe and effective method for the treatment of bile duct stones, both intrahepatic and extrahepatic. This approach is a valuable option for complex stone cases, particularly when ERCP is unsuccessful or encounters significant challenges.

Abbreviations

CBD	Common bile duct
ERCP	Endoscopic retrograde cholangiopancreatography
GB	Gallbladder
IHBD	Intrahepatic bile duct
LHBD	Left hepatic bile duct
PBE	Percutaneous biliary endoscopy
PTEHL	Percutaneous transhepatic endoscopic holmium laser lithotripsy
PTHL	Percutaneous transhepatic holmium laser lithotripsy
PTPBD	Percutaneous transhepatic papillary balloon dilation
PTSR	Percutaneous transhepatic stone removal
RHBD	Right hepatic bile duct

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Compliance with ethical standards

Guarantor

The scientific guarantor of this publication is Phan Nhan Hien, Nguyen Thai Binh.

Conflict of interest

The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry

One of the authors has significant statistical expertise. No complex statistical methods were necessary for this paper.

Informed consent

Written informed consent was waived by the Institutional Review Board.

Ethical approval

This study protocol was reviewed and approved by the Institutional Review Boards of Hanoi Medical University (IRB No.9630/QD-DYHN).

Study subjects or cohorts overlap

None.

Methodology

- Retrospective
- Observational
- Performed at one institution

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