

Combined Swiss LithoClast Master and Cholangioscopy-Assisted Laser Lithotripsy for Complex Biliary Calculi: A Pilot Exploration

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Research Article

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Abstract

Background: Complex biliary calculi (CBC) with a high stone burden remain difficult to treat. Conventional basket extraction is often inefficient for large or incarcerated stones, whereas laser lithotripsy can be prolonged when stone debris obscures the endoscopic field. This study evaluated the feasibility, safety, and short-term outcomes of a dual-modality strategy combining the Swiss LithoClast Master (EMS) ultrasonic system with cholangioscopy-assisted holmium:YAG laser lithotripsy.

Methods: We retrospectively analysed 13 patients with CBC treated at our centre between May 2021 and September 2025. A sequential "Debulk-and-Dust" technique was used. Large central stone burdens were first debulked with EMS ultrasonic lithotripsy under continuous active suction. Residual stones were then dusted using cholangioscopy-guided holmium:YAG laser lithotripsy. Procedures were performed through laparoscopic, percutaneous transhepatic cholangioscopic, or open approaches. Outcomes included final stone clearance, clearance efficiency, operative time, complications, and short-term follow-up.

Results: The median operative time was 233 minutes (IQR: 163.5-378 minutes). Single-session complete clearance was achieved in 46.2% of patients (6/13). Staged procedures were required in 53.8% (7/13) because of anatomical complexity. The final complete stone clearance rate was 61.5% (8/13), and 5 patients were discharged with residual stones. Postoperative complications occurred in 4 patients (30.8%), all classified as Clavien-Dindo grade I or II. No severe biliary sepsis or mortality occurred. During a median follow-up of 141 days (IQR: 106-448.5 days), recurrence occurred in 12.5% of stone-free patients (1/8).

Conclusions: Combined EMS ultrasonic lithotripsy and cholangioscopy-assisted laser lithotripsy is a feasible and safe option for selected patients with refractory CBC. This dual-modality strategy provided favourable short-term outcomes in a small retrospective cohort, but requires multidisciplinary planning for anatomically complex cases.

1. Introduction

Complex biliary calculi (CBC) remain difficult to manage in hepatobiliary surgery. They are often characterised by cast-like stones, biliary strictures, and wide anatomical distribution, all of which hinder complete clearance[1]. Treatment aims to remove stones and correct strictures to prevent cholangitis and secondary biliary cirrhosis. However, conventional surgical strategies are still associated with residual stones and recurrence[2, 3]. Although advances in endoscopic technology have promoted minimally invasive lithotripsy[4], the optimal strategy for large and refractory stone burdens remains uncertain.

Current lithotripsy techniques have physical limitations in complex cases. Basket-based mechanical lithotripsy is often ineffective for incarcerated or large stones and may cause basket impaction or wire fracture[5]. Electrohydraulic lithotripsy (EHL) is powerful, but its undirected shockwaves can damage the bile duct wall and generate large, irregular fragments that are difficult to extract[6, 7]. Holmium:YAG laser

lithotripsy has emerged as a precise alternative because it can vaporise stone surfaces[8]. In high-volume stone burdens, however, the laser mainly acts through a dusting mechanism[9]. This process is time-consuming and creates substantial fine particulate matter, producing the so-called "snowstorm effect"[10]. The resulting turbidity obscures the endoscopic field and often requires high-flow irrigation. Excessive irrigation may increase intrabiliary pressure and promote bacterial translocation into the hepatic venous circulation, potentially leading to bacteraemia or sepsis[11, 12].

To address these hydrodynamic and mechanical limitations, we introduced the Swiss LithoClast Master (EMS) system into biliary surgery. Originally developed for urological lithotripsy, this dual-modality system offers a distinct physical profile compared with single-energy platforms. Its ultrasonic mode uses piezoelectric vibration to grind fragments into fine powder[13]. The ultrasonic probe also contains an active suction channel. This design can continuously evacuate stone debris and irrigation fluid, thereby maintaining visibility and potentially reducing intrabiliary pressure, biliary absorption, and infectious risk.

The EMS probe is rigid, however, and cannot navigate the angulated anatomy of peripheral bile ducts[14]. A complementary strategy is therefore required. We proposed a "macro-micro" approach in which the rigid EMS system rapidly clears large stones in the main bile ducts, including the common bile duct and relatively straight intrahepatic ducts. Flexible cholangioscopy-guided holmium laser lithotripsy is then used for residual stones in tortuous peripheral ducts or anatomical "dead corners".

This retrospective pilot study evaluated the safety, efficacy, and potential hydrodynamic advantages of dual-modality ultrasonic lithotripsy with integrated suction combined with holmium laser lithotripsy in selected patients with CBC. We hypothesised that this rigid-flexible complementarity could improve clearance efficiency while limiting perioperative complications.

2. Materials and Methods

2.1 Study Design and Patient Population

We retrospectively analysed clinical data from patients diagnosed with CBC at the Department of Hepatobiliary-Pancreatic Surgery, The First Affiliated Hospital of Wenzhou Medical University, between May 2021 and September 2025. The study was approved by the Ethics Committee of The First Affiliated Hospital of Wenzhou Medical University (permit numbers: YLJS-2022002-01 and YLJS-2022003-01) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Thirteen patients (6 male and 7 female) were included. The median age was 65 years (IQR: 51.5-71.5 years). Nine patients (69.2%) had previously undergone biliary tract surgery.

The screening and enrolment process is shown in Fig. 1

2.2 Inclusion and Exclusion Criteria Patients were screened using strict criteria to define refractory disease:

Inclusion Criteria:

1. Diagnosis: radiological confirmation (CT/MRI) of complicated intrahepatic and/or extrahepatic biliary calculi.
2. Sufficient biliary dilation (typically >5 mm) to accommodate the 3.3-mm rigid ultrasonic probe without iatrogenic injury.
3. Stone characteristics: refractory stones, defined as cast-like calculi, multiple impacted stones, or hard stones expected to be difficult to extract using conventional basket or balloon techniques.
4. Patient status: adults (age ≥ 18 years) with preoperative liver function classified as Child-Pugh grade A or B.

Exclusion Criteria:

1. Absence of biliary duct dilation, which prevented safe insertion of the rigid EMS probe.
2. Concomitant cholangiocarcinoma or other biliary malignancy.
3. Severe coagulopathy (INR >1.5) or thrombocytopenia ($<50 \times 10^9/L$) that could not be corrected.
4. Incomplete clinical data or loss to follow-up.

2.3 Lithotripsy Equipment and Settings The dual-modality lithotripsy strategy integrated two distinct systems to address the complex stone burden: The Swiss LithoClast Master system (EMS Electro Medical Systems, Nyon, Switzerland) was used in ultrasonic-only mode for high-efficiency debulking. Precision dusting was performed using a Holmium:YAG laser system (VersaPulse® PowerSuite™ 60W, Lumenis Ltd., Yokneam, Israel) equipped with a 365- μm optical fiber (SlimLine™ EZ 365, Lumenis). Visualization and laser guidance were achieved using a high-definition flexible choledochoscope (Olympus Corp., Tokyo, Japan).

2.3.1 Ultrasonic Lithotripsy (Debulking Phase): A 3.3-mm rigid ultrasonic probe was used for central stone debulking. The ultrasonic drive uses a piezoelectric transducer to generate longitudinal vibrations, which disintegrate stones into fine powder. Ultrasonic energy was typically set at 80 J to achieve efficient fragmentation. The system was operated with continuous negative suction pressure of 0.2-0.4 bar through the probe's hollow channel. This enabled simultaneous aspiration of stone debris and purulent bile, while helping maintain a clear visual field and low intrabiliary pressure.

2.3.2 Laser Lithotripsy (Dusting Phase): A holmium:YAG laser was used with a 365-micrometre optical fibre. Laser lithotripsy was performed with pulse energy of 0.6-1.0 J and frequency of 10-25 Hz, adjusted

according to stone density and fragmentation response. Intraoperative visualisation was achieved using a high-definition choledochoscope.

2.4 Surgical Procedures All procedures were performed under general anaesthesia by a multidisciplinary team of hepatobiliary surgeons, urologists, and interventional radiologists. The surgical approach was individualised according to stone distribution and previous surgical history. Final surgical plans were implemented after written informed consent had been obtained from all patients.

2.4.1 Percutaneous Transhepatic Cholangioscopic Lithotripsy (PTCSL) For patients with CBC, or with a history of multiple abdominal surgeries that precluded safe open or laparoscopic access, a two-step strategy was used[15]. This approach aimed to reduce the risk of bile peritonitis and systemic sepsis by allowing controlled biliary decompression and sinus tract maturation:

Step 1 (Drainage and Tract Establishment): Ultrasound-guided percutaneous transhepatic cholangial drainage (PTCD) was performed using an 18-gauge needle to access the target bile duct. A drainage catheter was then placed.

Step 2 (Lithotripsy): Approximately 2-4 weeks after Step 1, after formation of a mature fibrous tract, the sinus tract was sequentially dilated over a guidewire. A 16-20 Fr peel-away sheath (Disposable Minimally Invasive Dilation and Drainage Kit, Shenzhen Kupo Technology Co., Ltd., Shenzhen, China) was inserted as a protected working channel. The EMS probe was introduced through the sheath for bulk stone removal. Residual stones in peripheral ducts were treated with the flexible cholangioscope and holmium laser.

2.4.2 Laparoscopic or Open Approaches Laparoscopic or open approaches were used for patients who required concurrent cholecystectomy or partial hepatectomy.

Access: A standard laparoscopic or open approach was used.

Probe Insertion: The insertion point for the rigid EMS probe was individualised. In patients with common bile duct (CBD) stones, access was obtained through a standard CBD incision. In patients requiring partial hepatectomy for lobar atrophy, the probe was introduced directly through the biliary orifice exposed on the liver resection surface. This approach facilitated clearance of residual stones in the central ducts.

2.4.3 Dual-Modality Lithotripsy Protocol

Macro-Fragmentation (EMS): Under direct endoscopic vision, the EMS ultrasonic mode was activated to pulverise fragments (energy = 80 J), while integrated vacuum suction (-0.2 to -0.4 bar) actively aspirated debris. Continuous irrigation with warm saline was maintained through the choledochoscope to preserve visualisation and prevent thermal injury. Stone debris was simultaneously removed through the EMS probe.

Micro-Clearance (Laser): For stones in angulated peripheral ducts or "dead corners" inaccessible to the rigid EMS probe, the flexible choledochoscope carrying a holmium laser fibre was advanced. Laser settings were 0.6-1.0 J at 10-25 Hz to dust residual calculi.

Clearance Verification: After lithotripsy and removal of larger fragments, a final thorough inspection was performed using the choledochoscope. This inspection verified stone clearance and excluded iatrogenic biliary injury before T-tube or drainage placement.

The intraoperative workflow for the ultrasonic-laser lithotripsy strategy and the advantage of active suction is shown in Fig. 2

2.5 Postoperative Management and Follow-up Patients were monitored for bile leakage, infection, bleeding, and other complications. Biliary drainage tubes were removed after a median of 78 days (IQR: 65-118 days), only after stone clearance had been confirmed by T-tube cholangiography, CT, or MRI. If residual stones were detected, secondary choledochoscopy was performed through the mature sinus tract.

2.6 Statistical Analysis Continuous variables are presented as medians with interquartile ranges (IQRs), and categorical variables are expressed as frequencies and percentages. All statistical analyses were performed using R software, version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1 Baseline Demographics and Stone Characteristics Thirteen patients with CBC were included in the final analysis. The cohort comprised 6 male and 7 female patients, with a median age of 65 years (IQR: 51.5-71.5). Case complexity was reflected by the high proportion of patients with previous hepatobiliary surgery (9/13, 69.2%), including previous cholecystectomy, choledochotomy, or partial hepatectomy. Baseline characteristics are summarised in Table 1. Detailed clinical data for all patients are provided in Supplementary Table S1.

Table 1: General Condition of The Patient (n=13)	
Age (years), median (IQR)	65 (51.5-71.5)
Sex, n (%)	
Male	6 (46.2)
Female	7 (53.8)
BMI (kg/m ²), median (IQR)	22.0 (19.5-24.6)
Previous biliary surgery, n (%)	9 (69.2)
Stone maximum size (mm), median (IQR)	15 (15-30)
Preoperative cholangitis, n (%)	11 (84.6)
Liver lobe atrophy, n (%)	7 (53.8)
Child-Pugh classification, n (%)	
A	10 (76.9)
B	3 (23.1)
Surgical method, n (%)	
Laparoscopic operation	7 (53.8)
Percutaneous transhepatic approach	5 (38.5)
Open surgery	1 (7.7)
Stone Location, n (%)	
Intrahepatic only	3 (23.1)
Combined intrahepatic and extrahepatic	10 (76.9)

Analysis of stone distribution showed that most patients (7/13, 53.8%) had diffuse bilateral intrahepatic stones, a particularly challenging pattern for clearance. The median maximum stone diameter was 15 mm (IQR: 15-30 mm). All cases involved complex stone burdens, presenting as multiple impacted or cast-like calculi. Representative preoperative magnetic resonance cholangiopancreatography (MRCP) images showing the complexity and stone burden of this cohort are presented in Fig. 3

3.2 Operative Outcomes and Stone Clearance Efficiency Aggregate operative outcomes are summarised in Table 2. The median operative time was 233 minutes (IQR: 163.5-378 minutes). Intraoperative blood loss was minimal (<50 mL) in laparoscopic and percutaneous cases, whereas the single open surgery case had an estimated blood loss of approximately 150 mL. Successful fragmentation and debulking of the primary target stones, defined as the main stone burden causing stricture or obstruction, were achieved in all 13 patients (100%) during the initial procedure. This initial debulking success should be distinguished from complete biliary clearance. Because of the anatomical complexity of the biliary tree

in this selected cohort, including sharp angulations, deep peripheral calculi, and diffuse intrahepatic distribution, the single-session complete clearance rate was 46.2% (6/13). In the remaining patients, attempting total clearance in one session was considered clinically unsafe because of prolonged anaesthesia and risk of intraoperative fluid overload. A deliberate safety-first staged approach was therefore adopted, and 53.8% (7/13) of patients underwent scheduled repeat lithotripsy sessions for further clearance.

Table 2. Operative Outcomes and Stone Clearance	
Operative time (min), median (IQR)	233 (163.5–378)
Estimated blood loss (mL)	
Laparoscopic / PTCSL	< 50
Open surgery	~150
Stone clearance, n (%)	
Successful target stone fragmentation	13 (100)
Single-session complete clearance	6 (46.2)
Final complete clearance, n (%)	8 (61.5)
Requirement for staged procedures, n (%)	7 (53.8)
Hospital stay (days), median (IQR)	14 (10–22.5)
Postoperative stay (days), median (IQR)	11 (5.5–15.5)
T-tube duration (days), median (IQR)	78 (65-118)

*Successful target stone fragmentation/debulking was defined as mechanical disruption and clearance of the primary, largest-burden calculi using the EMS system, even when peripheral residual stones remained because of anatomical limitations or operative time constraints.

Among the 7 patients requiring staged interventions, 6 underwent additional lithotripsy sessions through the established mature tract. The total number of procedures per patient varied (five sessions, n=1; four sessions, n=2; three sessions, n=2; two sessions, n=1). These staged procedures achieved complete clearance in 2 additional patients, increasing the final overall stone clearance rate to 61.5% (8/13). The remaining 5 patients (38.5%) did not achieve complete clearance because of substantial anatomical barriers. Four of these patients underwent multiple sessions without total clearance. In the remaining patient, stones were located beyond a severe biliary stricture. Because the patient declined the recommended partial hepatectomy, the targeted stone-bearing ducts remained inaccessible to the flexible laser fibre, precluding final clearance.

The median length of hospital stay was 14 days (IQR: 10-22.5 days), and the median postoperative stay was 11 days (IQR: 5.5-15.5 days). The median duration of T-tube retention was 78 days (IQR: 65-118 days). This prolonged duration reflected the need for biliary decompression, tract maturation, and staged clearance procedures in patients requiring T-tube placement. Detailed operative outcomes and postoperative complications for each patient are provided in Supplementary Table S2.

Representative radiological outcomes showing debulking and clearance of CBC are shown in Fig. 4

3.3 Safety and Complications Procedure-related postoperative complications occurred in 4 patients (30.8%). All adverse events were classified as Clavien-Dindo grade I or II and were managed conservatively.

Surgical Site Infections (Grade I, n=2): Superficial incisional infections occurred in two patients. Patient #11 was treated by open laparotomy. Patient #13 underwent a laparoscopic approach, but a mini-incision was created to allow direct insertion of the rigid EMS probe into the intrahepatic duct. This access site developed an incisional infection. Both cases were successfully managed with bedside wound care and dressing changes.

Bile Leakage (Grade II, n=1): Patient #2 experienced minor bile leakage. This was managed conservatively with a somatostatin analogue (Sandostatin) to decrease biliary secretion, together with drainage.

Infectious Complications (Grade II, n=1): Patient #12 developed postoperative bacteraemia. Blood cultures identified a polymicrobial infection involving *Escherichia coli* and *Klebsiella pneumoniae*. The patient responded to targeted intravenous antibiotic therapy and recovered uneventfully.

Table 3. Postoperative Complications (Clavien-Dindo Classification)				
Clavien-Dindo grade	Complication type	n (%)	Patient ID	Management strategy
Grade I	Incisional infection	2 (15.4)	#11, #13	Change dressing
Grade II	Bile leakage	1 (7.7)	#2	Somatostatin (Sandostatin) to decrease secretion; Drainage
	Bacteremia	1 (7.7)	#12	Targeted antibiotics (blood culture: E. coli, K. pneumoniae)
Grade III-V	-	0 (0)	-	-
Total		4 (30.8)		

3.4 Follow-up All 13 patients completed initial follow-up, with a minimum observation period of at least two months after surgery. Among the 8 patients who achieved complete stone clearance, recurrent choledocholithiasis occurred in one case (Patient #9, 12.5%). During the initial PTCSL procedure, this

patient was found to have a pre-existing biliary-duodenal fistula and non-absorbable vascular sutures from previous surgery, which likely acted as a nidus for recurrent stone formation. The patient developed cholangitis during follow-up and was successfully treated with endoscopic retrograde cholangiopancreatography (ERCP) to remove recurrent stones. No deaths occurred among the remaining patients during the surveillance period.

4. Discussion

Management of refractory CBC requires both speed and precision. Traditional single-modality approaches often fail to provide both. Mechanical baskets are inefficient for large impacted stones[16], whereas laser lithotripsy is precise but time-consuming in high-burden cases and prone to the "snowstorm effect"[17]. In this study, the "Debulk-and-Dust" dual-modality strategy addressed these limitations by integrating the strengths of two systems. The rigid EMS ultrasonic probe rapidly pulverised large stones in the central ducts, reducing the stone load before laser treatment. The flexible holmium laser then targeted residual stones in angulated peripheral ducts or "dead corners" inaccessible to the rigid probe. This complementary approach achieved a final complete clearance rate of 61.5% and provided symptom control in selected patients, despite marked anatomical complexity.

A key potential advantage of this dual-modality approach is its safety profile, particularly in relation to biliary sepsis. High intrabiliary pressure during lithotripsy is a recognised risk factor for bacteraemia and cholangitis[18]. Laser lithotripsy typically requires high-flow irrigation to clear stone dust, which may compromise safety[19]. By contrast, the EMS system's integrated active suction mechanism creates continuous negative pressure (-0.2 to -0.4 bar). During fragmentation, this mechanism aspirates stone debris, purulent bile, and irrigation fluid simultaneously. In this cohort, 84.6% of patients had preoperative cholangitis, indicating a high baseline infectious risk. Nevertheless, postoperative systemic infection occurred in only 1 patient (7.7%, bacteraemia), and no grade III-V complications, severe biliary sepsis, or liver abscess were observed. The overall procedure-related complication rate was 30.8%, with all events classified as grade I-II. These findings suggest that suction during fragmentation may help interrupt the cycle of high intrabiliary pressure, biliary reflux, and infection in selected high-risk patients.

Refractory CBC is not only a surgical problem but also a systems-level challenge requiring multidisciplinary care. Successful use of this technique depends on coordination among hepatobiliary surgeons, urologists, and interventional radiologists. Preoperative CT and MRCP mapping enabled selection of an individualised access route for each patient. For patients with altered anatomy or poor candidacy for surgery, interventional radiologists established precise PTCD tracts, while surgeons and urologists managed complex lithotripsy. Given the heterogeneity of CBC, we adopted an individualised staged-treatment approach in 53.8% of patients (7/13). In patients with acute cholangitis or severe biliary oedema, initial PTCD was used as a damage-control step to decompress the biliary system and control inflammation. Definitive lithotripsy was then performed after clinical stabilisation and sinus tract maturation, reducing the risk of bleeding, sepsis, and ductal perforation in inflamed tissues. In patients with massive stone volumes, including some laparoscopic cases, staging was also used to limit

operative duration and reduce the risk of fluid overload and physiological stress from prolonged irrigation. This safety-first multidisciplinary strategy prioritised systemic stability while pursuing stone clearance.

This study has several limitations. It was retrospective and included only 13 patients. The rigid EMS probe cannot navigate sharp biliary angles, so laser lithotripsy remains necessary for peripheral clearance. Larger prospective studies are needed to validate these findings and define the patients most likely to benefit from this approach.

5. Conclusion

In conclusion, combined EMS ultrasonic lithotripsy and cholangioscopy-assisted laser lithotripsy is a feasible and safe strategy for selected patients with CBC. In this small retrospective cohort, the technique enabled central stone debulking, staged peripheral clearance, and favourable short-term outcomes with only mild complications. It may therefore provide an additional treatment option for refractory biliary stone burdens when delivered by an experienced multidisciplinary team.

Abbreviations

CBC

complex biliary calculi

CBD

common bile duct

CLL

cholangioscopy-assisted laser lithotripsy

CT

computed tomography

EHL

electrohydraulic lithotripsy

EMS

Swiss LithoClast Master system (EMS Electro Medical Systems)

ERCP

endoscopic retrograde cholangiopancreatography

IQR

interquartile range

MDT

multidisciplinary team

MRCP

magnetic resonance cholangiopancreatography

PTCD

percutaneous transhepatic cholangial drainage

PTCSL
percutaneous transhepatic cholangioscopic lithotripsy
YAG
yttrium-aluminium-garnet

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of The First Affiliated Hospital of Wenzhou Medical University (permit numbers YLJS-2022002-01 and YLJS-2022003-01). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Consent for publication

Written informed consent was obtained from all patients for publication of the clinical data and accompanying images in anonymised form.

Data availability statement

The datasets generated and analysed during the current study are not publicly available because they contain patient-level clinical information. De-identified data may be made available from the corresponding author on reasonable request and subject to institutional ethics approval.

Declaration of interest statement

The authors report no conflicts of interest.

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Author contributions

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Resources: Jie Zhang, Cheng Li, Yong Guo.

Supervision: Yuepeng Jin.

Funding acquisition: Yuepeng Jin.

Writing – original draft: Zonghao Dai.

Writing – review & editing: Yuepeng Jin, Jie Zhang, Cheng Li, Yong Guo, Qinjian Lu.

All authors critically reviewed the manuscript, approved the final version, and agree to be accountable for all aspects of the work.

Reporting guideline

This surgical case series was prepared with reference to case-series reporting principles and the PROCESS framework where applicable. A completed checklist should be prepared as a supplementary file if requested by the journal.

Declaration of generative AI use.

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely for English language editing and improving readability. The AI tool was not used to generate scientific content, analyze data, interpret results, or draw conclusions. The authors critically reviewed and edited all AI-assisted text and take full responsibility for the final content of the manuscript.

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7. Disclosures

Zonghao Dai, Qinjian Lu, Zhehao Han, Huijie Xu, Puchuang Xu, Fudi Shi, Jie Zhang, Cheng Li, Yong Guo and Yuepeng Jin have no conflicts of interest or financial ties to disclose.

References

1. Behary J, Herba K, Craig PI (2017) Digital per-oral cholangioscopy with holmium laser lithotripsy to manage complex biliary calculi. VideoGIE 2:19-20

2. Park CY, Choi SH, Kwon CI, Cho JH, Jang SI, Lee TH, Han JH, Jeong S, Ko KH (2020) What is the better surgical treatment option for recurrent common bile duct stones? *Ann Surg Treat Res* 99:329-336
3. Cha SW (2018) [Management of Intrahepatic Duct Stone]. *Korean J Gastroenterol* 71:247-252
4. Fujita N, Yasuda I, Endo I, Isayama H, Iwashita T, Ueki T, Uemura K, Umezawa A, Katanuma A, Katayose Y, Suzuki Y, Shoda J, Tsuyuguchi T, Wakai T, Inui K, Unno M, Takeyama Y, Itoi T, Koike K, Mochida S (2023) Evidence-based clinical practice guidelines for cholelithiasis 2021. *J Gastroenterol* 58:801-833
5. Carbillet S, Brazier F, Fumery M, Yzet C (2024) Electrohydraulic lithotripsy: a safe and effective technique to retrieve an impacted Dormia basket. *Endoscopy* 56:E715
6. Sato T, Kogure H, Nakai Y, Isayama H, Koike K (2018) Electrohydraulic lithotripsy under double-balloon endoscope-assisted direct cholangioscopy for treatment of choledocholithiasis in a patient with Roux-en-Y gastrectomy. *VideoGIE* 3:113-114
7. Li X, Liu WH (2025) Small but mighty: cylindrical transparent cap-assisted cholangioscopic electrohydraulic lithotripsy and stone extraction for the treatment of difficult common bile duct stones. *Endoscopy* 57:E1290-e1291
8. Fried NM (2018) Recent advances in infrared laser lithotripsy [Invited]. *Biomed Opt Express* 9:4552-4568
9. Chen J, Ho DS, Xiang G, Sankin G, Preminger GM, Lipkin ME, Zhong P (2022) Cavitation Plays a Vital Role in Stone Dusting During Short Pulse Holmium:YAG Laser Lithotripsy. *J Endourol* 36:674-683
10. Gupta A, Ganpule AP, Puri A, Singh AG, Sabnis RB, Desai MR (2024) Comparative study of thulium fiber laser versus holmium:yttrium-aluminum-garnet laser for ureteric stone management with semi-rigid ureteroscopy: A prospective, single-center study. *Asian J Urol* 11:460-465
11. Ramchandani M, Pal P, Reddy DN (2017) Endoscopic management of acute cholangitis as a result of common bile duct stones. *Dig Endosc* 29 Suppl 2:78-87
12. Zhao J, Wang B, Zhao M, Pan X (2025) Clinical and biochemical factors for bacteria in bile among patients with acute cholangitis. *Eur J Gastroenterol Hepatol* 37:33-38
13. Axelsson TA, Cracco C, Desai M, Hasan MN, Knoll T, Montanari E, Pérez-Fentes D, Straub M, Thomas K, Williams JC, Jr., Brehmer M, Osther PJS (2021) Consultation on kidney stones, Copenhagen 2019: lithotripsy in percutaneous nephrolithotomy. *World J Urol* 39:1663-1670
14. Di Girolamo E, Belli A, Ottaiano A, Granata V, Borzillo V, Tarotto L, Tatangelo F, Palaia R, Civiletti C, Piccirillo M, D'Angelo V, Fiore F, Marone P, Nasti G, Izzo F, de Bellis M (2023) Impact of endobiliary radiofrequency ablation on survival of patients with unresectable cholangiocarcinoma: a narrative review. *Front Oncol* 13:1077794
15. Li L, Zeng Z, Li W, Lu J, Li L, Zhang J (2024) PTCd and choledochoscopy for recurrent choledocholithiasis after multiple abdominal surgeries: a case report. *Front Med (Lausanne)* 11:1466184

16. Libânio D, Giestas S, Martinez-Ares D, Canena J, Lopes L (2018) Cholangioscopy-guided holmium laser lithotripsy of a stone trapped in a mechanical lithotripter. VideoGIE 3:127-128
17. Wang T, Zhou J, Zhai X, Sun X, Wang Y, Ma C, Song D, Xu D, Chu C (2025) Tip-flexible suctioning ureteral access sheath combined with flexible ureteroscope: a single-institution experience including in vitro experiments. BMC Urol 25:232
18. Turan AS, Jenniskens S, Martens JM, Rutten M, Yo LSF, van Strijen MJL, Drenth JPH, Siersema PD, van Geenen EJM (2022) Complications of percutaneous transhepatic cholangiography and biliary drainage, a multicenter observational study. Abdom Radiol (NY) 47:3338-3344
19. Bai J, Shanguan T, Zou G, Liu L, Xue X, Lin J, Ye Y, Ruan X, Li Y, Yang S, Chi Y, Nian Y, Chen X, Liu R, Cai W, Zhu S, Chen J (2024) Efficacy and intrarenal pressure analysis of flexible and navigable suction ureteral access sheaths with flexible ureteroscopy in modified surgical positions for 2-6 cm upper urinary tract stones: a multicenter retrospective study. Front Med (Lausanne) 11:1501464

Figures

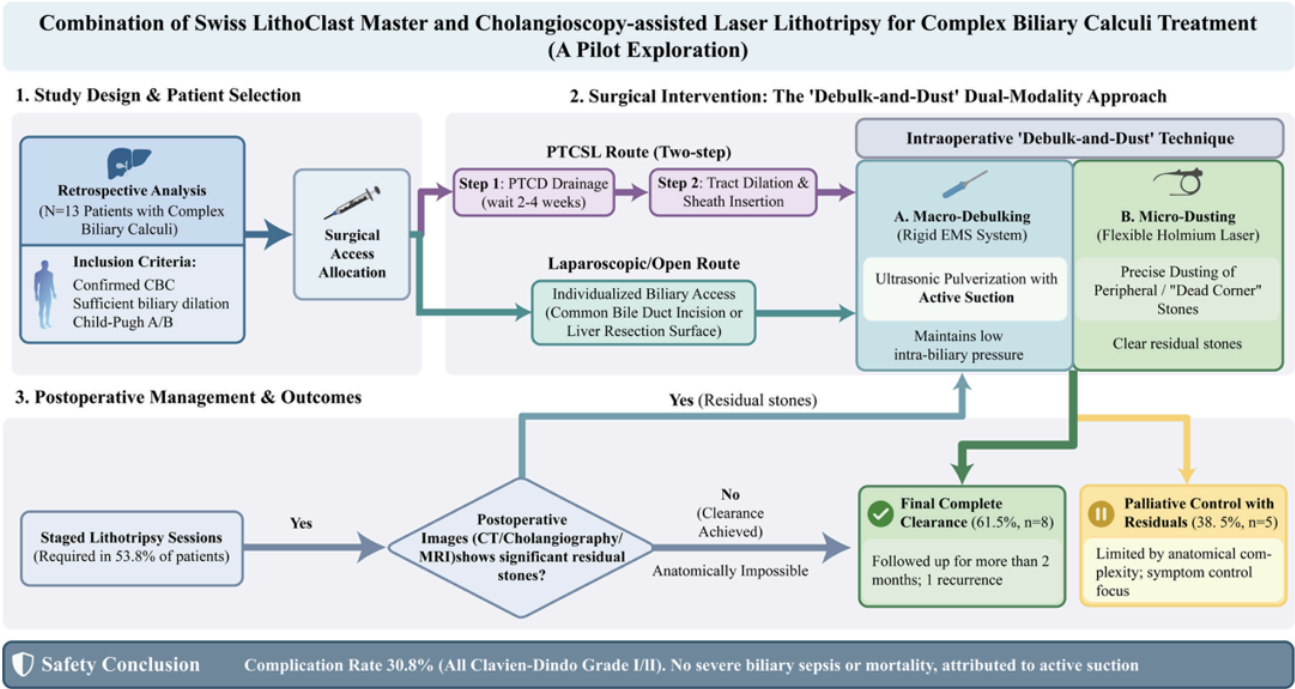


Figure 1

Flowchart of patient selection and study design.

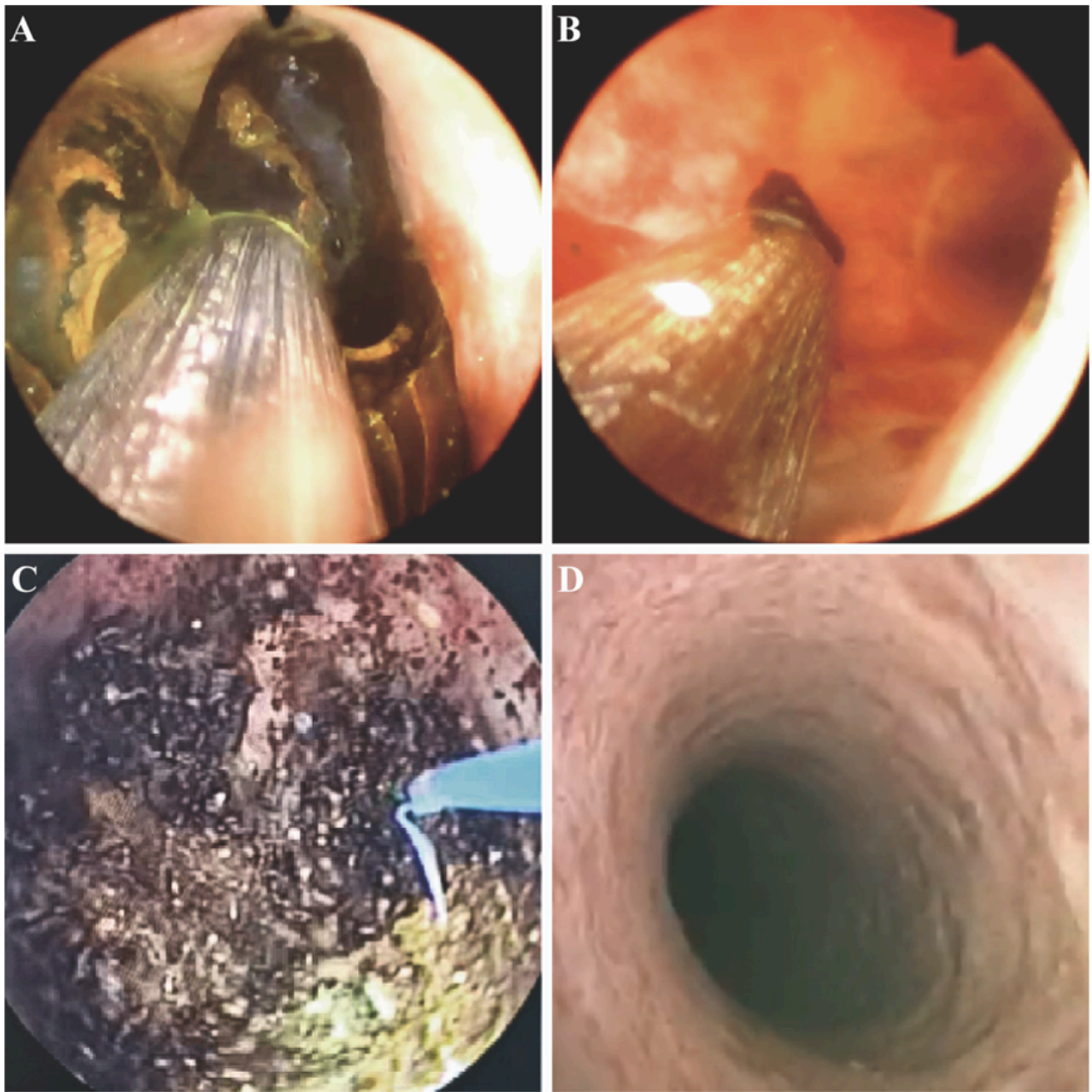


Figure 2

Intraoperative endoscopic views of the ultrasonic-laser dual-modality strategy for complex biliary calculi. (A) The rigid Swiss LithoClast Master probe debulks the central stone burden. (B) Active suction through the probe removes stone dust and turbid bile. (C) A holmium:YAG laser fibre dusts residual stones in peripheral ducts. (D) Final choledochoscopic inspection confirms stone clearance and preserved biliary mucosa.

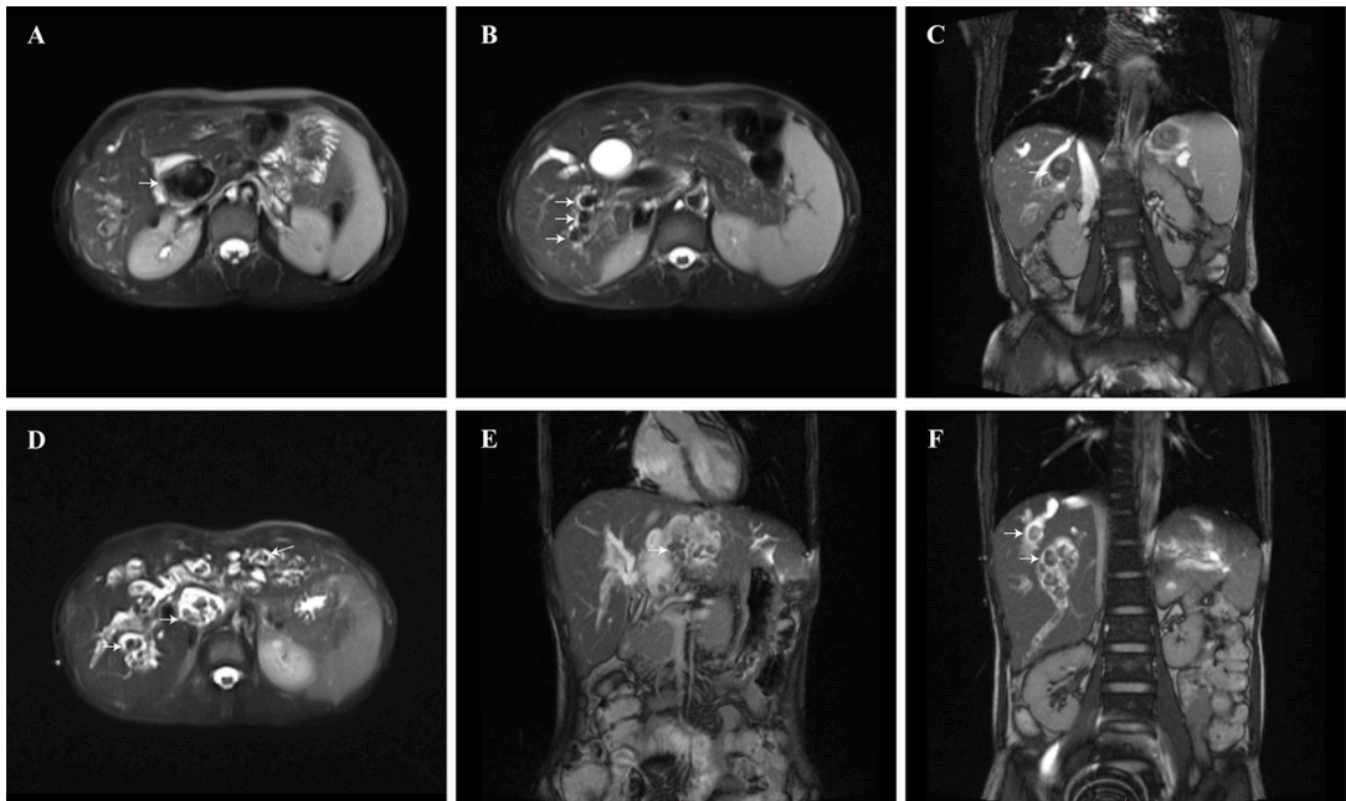


Figure 3

Preoperative magnetic resonance cholangiopancreatography images showing representative patterns of refractory stone burden. (A–C): Patient #1 had a giant common bile duct stone (stones, →, maximum diameter 40 mm) with multiple intrahepatic calculi and marked upstream biliary dilatation. (D–F): Patient #10 had diffuse pan-biliary lithiasis involving the bilateral intrahepatic and extrahepatic bile ducts (stones, →, maximum diameter 15 mm).

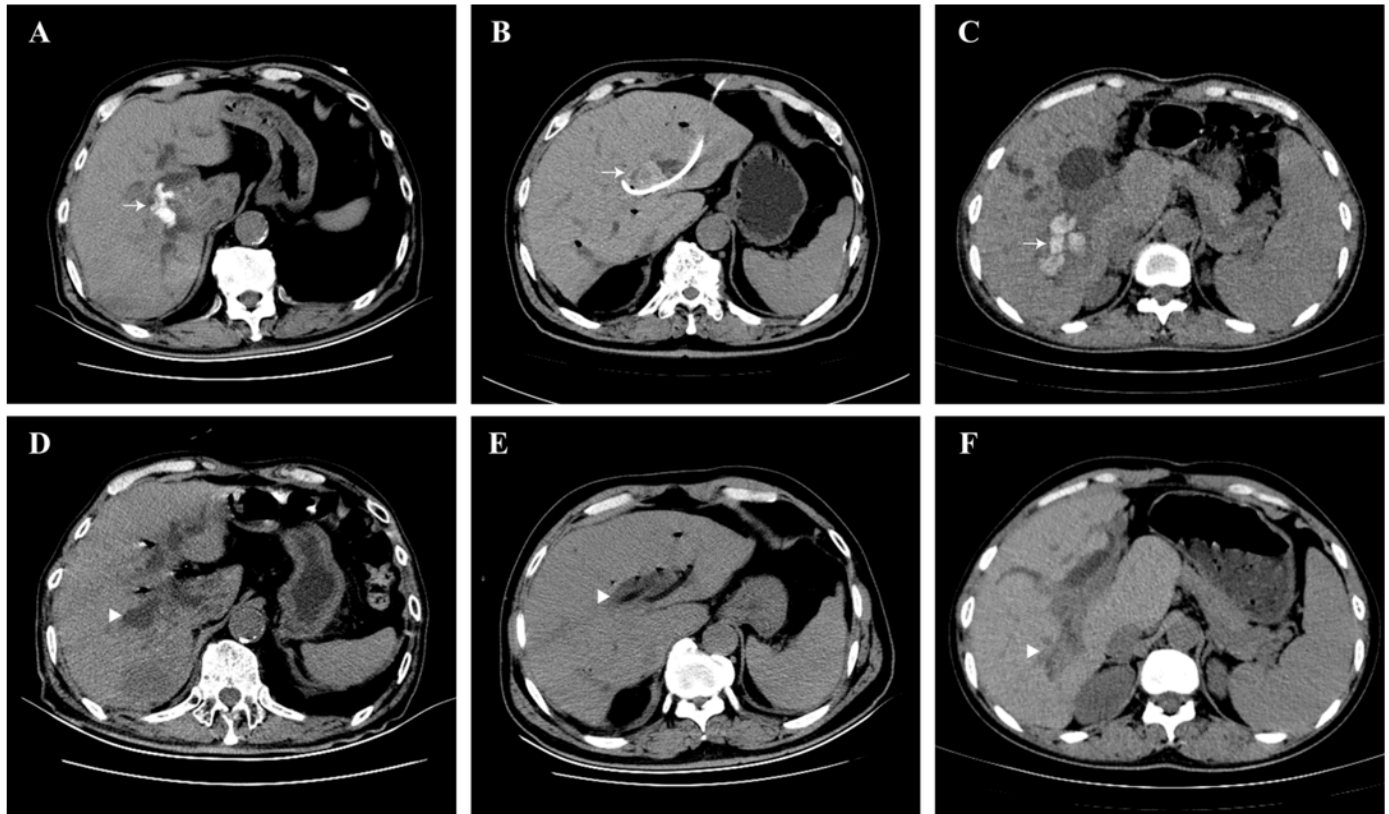


Figure 4

Representative computed tomography images before and after treatment. (A-C): Preoperative images show complex biliary calculi within dilated intrahepatic ducts (Stones, →). (D-F): Postoperative images at corresponding levels show clearance of the major stone burden, without visible high-density residual stones (Surgical area, △).