

Recent Advances in the Treatment of Common Bile Duct Stones via Laparoscopic Common Bile Duct Incision and Stone Removal Following Failed ERCP

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Abstract: Endoscopic retrograde cholangiopancreatography (ERCP) is the first-line minimally invasive treatment for common bile duct stones; however, stone removal fails in 5% to 25% of patients due to difficulties with catheterization, massive impacted stones, anatomical variations, and other factors. For patients following ERCP failure, laparoscopic common bile duct exploration and stone extraction (LCBDE) has garnered increasing attention in recent years as a salvage treatment. This article systematically reviews the relevant research literature on LCBDE following ERCP failure, covering the causes of ERCP failure, as well as the indications, technical key points, clinical outcomes, and predictive factors for success of LCBDE, with the aim of providing a reference for clinical decision-making regarding common bile duct stones.

Keywords: Common Bile Duct Stones; Endoscopic Retrograde Cholangiopancreatography; Laparoscopic Common Bile Duct Exploration; Common Bile Duct Exploration and Stone Removal.

1. Introduction

Common bile duct stones are a common condition in biliary surgery, occurring in approximately 10%–20% of patients with gallbladder stones. If left untreated, they can lead to serious complications such as obstructive jaundice and acute cholangitis. ERCP combined with sphincterotomy and stone removal has become the first-line treatment for common bile duct stones due to its minimally invasive advantages, with a single-procedure stone clearance rate of 75%–90%. However, ERCP failure remains difficult to completely avoid in clinical practice. Causes of failure include difficulty in intubating the duodenal papilla, anatomical variations, large or impacted stones that are difficult to remove, and sedation failure. For patients with failed ERCP, selecting a follow-up treatment strategy poses a clinical challenge—repeat ERCP may increase the risk of complications such as pancreatitis, bleeding, and perforation, while traditional open exploration of the common bile duct is highly invasive. Against this backdrop, LCBDE—a minimally invasive technique capable of simultaneously treating gallbladder and common bile duct stones in a single procedure—has gradually emerged as an important salvage option following ERCP failure. However, LCBDE performed after ERCP failure faces several specific challenges: Previous ERCP procedures may cause local biliary tract edema and anatomical changes following papillary sphincterotomy; some patients may even have already developed ERCP-related complications. These factors may all increase the technical difficulty of subsequent LCBDE. This article provides a systematic review covering the causes of ERCP failure, the indications and technical key points of LCBDE in such cases, clinical outcomes and safety, predictive factors influencing success, and clinical decision-making pathways, with the aim of providing guidance for clinical practice.

2. Causes of ERCP Failure and Indications for LCBDE

2.1. Definition and Main Causes of ERCP Failure

There is currently no universally accepted definition of ERCP failure in the literature; most studies define it as the failure to achieve common bile duct cannulation or the failure to completely remove common bile duct stones. In a retrospective study involving 59 patients who underwent LCBDE, 31 had the procedure following ERCP failure. The causes of failure, in order of frequency, were: residual stones after ERCP (9 cases), failed cannulation (6 cases), failed sedation (6 cases), periampullary diverticula (5 cases), post-Bill II gastrectomy (3 cases), a giant stone (1 case), and an impacted stone (1 case) [1]. Another study analyzed 22 cases of LCBDE performed following ERCP failure and found that 8 cases were due to failed cannulation (abnormal papillary position or interference from diverticula), 9 cases were due to stones larger than 1 cm in diameter that were impacted and difficult to remove, 4 cases were complicated by Mirizzi syndrome, and 1 case involved too many stones to be removed in a single procedure [2]. Another study reported 42 patients with failed ERCP, with the primary causes of failure being intubation failure, large stones, impacted stones, and multiple stones [3]. Overall, the causes of ERCP failure can be categorized into three types: first, anatomical factors leading to intubation difficulties, such as periampullary diverticula or anatomical changes following prior gastrectomy; second, difficulty in stone extraction due to stone-related factors, such as stones with a diameter ≥ 15 mm, impacted stones, and multiple stones; and third, procedure-related factors, such as failed sedation and instrument malfunction. It is worth noting that some cases of ERCP failure are inherently high-complexity procedures; if such high-complexity cases can be accurately identified

preoperatively, it may be more appropriate to opt directly for LCBDE [1].

2.2. Indications and Timing for LCBDE Following ERCP Failure

Following ERCP failure, the indications for LCBDE are relatively broad, but a comprehensive assessment of the patient's condition is still required. The main indications include: ERCP-confirmed difficulty in stone removal or failure, large or multiple stones, concomitant gallbladder stones requiring simultaneous resection, and the patient's ability to tolerate general anesthesia. Relative contraindications include: common bile duct diameter <7 mm (increased risk of bile duct stricture), concurrent acute severe cholangitis or severe pancreatitis, and severe coagulation disorders. Studies have shown that in a prospective study involving 50 patients, 9 patients who had failed ERCP were included in the open or laparoscopic CBD exploration group; most of these cases involved multiple or giant stones, and all achieved satisfactory outcomes postoperatively [4].

Regarding the timing of surgery, most existing studies adopt an elective surgical strategy following ERCP failure, with intervals ranging from several days to several weeks. If the patient shows no signs of acute infection and is in stable general condition, waiting for local inflammation to subside before surgery can reduce technical difficulty; however, if acute cholangitis is present and drainage is inadequate, surgery should be performed as soon as possible to relieve the obstruction. A retrospective study analyzed 294 patients who underwent preoperative ERCP for suspected common bile duct stones and found that in 74.3% of cases, ERCP revealed only bile sludge, small stones (0–7 mm), or negative findings. These conditions can be fully managed through simple intraoperative lavage or exploration via the cystic duct, without the need for ERCP [5]. Based on this, the authors propose the “surgery-first” approach—for most patients with suspected common bile duct stones, directly opting for LCBDE may be more efficient, thereby avoiding unnecessary ERCP and its complications. This perspective challenges traditional treatment models but requires validation through further high-quality studies.

3. Technical Points of LCBDE Following ERCP Failure

3.1. Selection of Surgical Approach and Challenges

LCBDE approaches are categorized into the cystic duct approach and the common bile duct incision approach. The cystic duct approach utilizes a natural passageway, avoiding incision of the common bile duct, and theoretically reduces the risk of bile leakage and bile duct stricture; the common bile duct incision approach offers more ample operating space and is more effective for removing larger or multiple stones, but requires suturing of the common bile duct and is technically more demanding. A study reported a large dataset of 416 LCBDE cases, with 242 cases (58.2%) undergoing the common bile duct approach and 174 cases (41.8%) undergoing the cystic duct approach, with similar stone removal rates and conversion rates to open surgery between the two groups; however, the overall complication rate was significantly higher in the common bile duct group (bile leak 5.8% vs. 1.1%, pancreatitis 7.4% vs. 0.6%), and the postoperative hospital stay was also longer [6]. Therefore, the

cystic duct approach should be preferred when conditions permit. However, cases following ERCP failure often involve larger or impacted stones, limiting the applicability of the cystic duct approach. In a study by Kim et al., of the 31 patients in the ERCP failure group, 29 (93.5%) underwent the common bile duct approach, while only 2 underwent the cystic duct approach, reflecting the predominance of the common bile duct approach in this specific population [1]. Studies have confirmed that the upper limit for stone diameter that can be managed via the cystic duct approach is approximately 5 mm; for stones exceeding this limit, the common bile duct approach or conversion to open surgery should be considered [7].

3.2. The Clinical Value of Adjuvant Lithotripsy Techniques

For large or impacted stones—which are common in cases of ERCP failure—conventional basket or balloon stone retrieval is often ineffective, necessitating the use of adjunctive lithotripsy techniques. Holmium laser lithotripsy has become an increasingly widely used adjunctive method in recent years. In a retrospective analysis of 179 cases of LCBDE, 119 cases (66.5%) were successfully treated via the conventional cystic duct approach, 29 cases (16.2%) required holmium laser lithotripsy to achieve successful cystic duct stone removal, and 31 cases (17.3%) were ultimately converted to the common bile duct approach; The use of laser lithotripsy increased the success rate of the cystic duct approach from 66.5% to 82.7% [8]. Although the incidence of major complications was slightly higher in the laser lithotripsy group (5.6% vs. 0.7%), this was primarily related to the complexity of the cases, and no intraoperative laser-related complications occurred. A prospective randomized controlled study reported in China compared the efficacy of triple-endoscope-assisted holmium laser lithotripsy with primary suturing versus conventional LCBDE plus T-tube drainage. The results showed that although the triple-endoscope group had a longer operative time, it had a shorter hospital stay, with no significant differences in stone clearance rates or complication rates, demonstrating the feasibility of laser lithotripsy in a primary suturing strategy [9]. The use of a choledochoscope is key to ensuring complete stone removal. One study reported experience using a rigid ureteroscope as a substitute for a flexible choledochoscope: among 37 patients, 75.7% underwent LCBDE following failed ERCP, with a mean common bile duct diameter of 11.4 mm. Stone removal was successfully completed; 5 cases required conversion to open surgery, and the postoperative complication rate remained within an acceptable range [10].

3.3. Individualized Selection of Common Bile Duct Closure Methods

The choice of common bile duct closure for LCBDE following ERCP failure requires individualized decision-making. Although traditional T-tube drainage provides biliary decompression and a postoperative channel for stone removal, it is associated with disadvantages such as prolonged hospital stays, bile loss, T-tube dislodgement, and post-tube-removal bile leaks. In recent years, the use of primary suturing has become increasingly common. Studies have shown that primary suturing after LCBDE results in shorter operative times, shorter postoperative hospital stays, and faster recovery of gastrointestinal function compared to T-tube drainage, with no significant increase in the incidence of bile

leakage [11]. One study reported 56 cases of LCBDE with primary suturing following failed ERCP; all patients underwent the procedure successfully without conversion to open surgery. The average operative time was 106 minutes, the average postoperative hospital stay was 5 days, and no major complications occurred [12]. However, some scholars remain cautious. A study reported that among 121 cases of LCBDE following failed ERCP, 103 cases (85.1%) used T-tube drainage, while only 15 cases underwent primary suturing, reflecting that some centers apply stricter criteria for the indications of primary suturing [13]. Overall, primary suturing is well-suited for patients with marked dilation of the common bile duct, complete stone removal, unobstructed distal common bile duct, and no acute infection; for patients with a relatively narrow common bile duct, distal stenosis, or suspected residual stones, T-tube drainage provides a safety net and a channel for subsequent stone retrieval.

4. Clinical Outcomes of LCBDE Following ERCP Failure

4.1. Stone Clearance Rate and Complications

The stone clearance rate for LCBDE following ERCP failure is generally high, with most studies reporting rates between 88% and 100%. In a study by Kim et al., the stone clearance rate in the ERCP failure group reached 100%, comparable to the 96.4% rate in the single-stage LCBDE group [1]. Gupta et al. reported a clearance rate of 90.5% (38/42) in 42 cases; 4 patients required conversion to open surgery due to impacted stones [3]. Al-Ardah et al. reported a clearance rate of 88% in 22 cases [2]. These data indicate that even in more complex cases where ERCP has previously failed, LCBDE can still achieve a high stone clearance rate. Regarding complications, Di Mauro et al. compared the complication profiles of LCBDE following ERCP failure ($n = 18$) with those of primary LCBDE ($n = 36$). Both groups achieved stone clearance rates exceeding 90%, but the failure group had longer operative times (178.7 vs. 130.3 minutes) and longer hospital stays (5 vs. 2 days), with no significant difference in complication rates [14]. Zhu et al. published a systematic review and meta-analysis on this issue, incorporating 6 studies involving a total of 642 patients. The results showed that operative time was significantly longer in the ERCP-failure group ($P=0.02$), but there were no significant differences between the two groups in terms of overall complications, bile leaks, conversion to open surgery, or postoperative length of hospital stay [15]. This meta-analysis provides a high level of evidence-based support for the safety of LCBDE following ERCP failure. It is worth noting that relevant studies have indicated that repeated ERCP attempts may significantly increase the risk of subsequent surgery; therefore, patients should be promptly referred for surgical treatment following ERCP failure.

4.2. Length of Hospital Stay and Costs

In comparisons between LCBDE following ERCP failure and single-stage LCBDE, most studies show no significant difference in length of hospital stay between the two approaches. Reports indicate that the mean length of hospital stay was 7.0 days and 7.4 days, respectively ($P=0.591$) [1]. However, compared with the two-stage ERCP+LC strategy, the single-stage LCBDE strategy typically offers the advantages of a shorter hospital stay and lower costs. An economic analysis of 100 patients showed that the cost of the

single-stage laparoscopic strategy was \$3,636, significantly lower than the \$5,682 for the two-stage strategy [17]. A study comparing the efficacy of LCBDE with ERCP + EST found that although the LCBDE group had a longer drainage tube retention time and greater intraoperative blood loss, it achieved a higher single-stage stone clearance rate, shorter hospital stay, and lower hospitalization costs [18]. Regarding the cost of performing LCBDE following ERCP failure, although high-quality direct data are lacking, it can be logically inferred that—even though the ERCP failure has already incurred an additional cost—if the subsequent LCBDE resolves the problem in a single procedure, thereby avoiding repeat ERCPs or repeated hospitalizations, the overall cost may still be lower than the model involving multiple failed ERCP attempts followed by surgery.

4.3. Comparison of Efficacy with Primary LCBDE

Comparing the efficacy of LCBDE following ERCP failure with that of primary LCBDE is a key benchmark for assessing the clinical value of the former. Theoretically, cases following ERCP failure involve more complex stones and potentially more severe local inflammation, making the procedure more technically challenging. The results of multiple studies support this hypothesis: some studies have reported that operative time was significantly longer in the ERCP-failure group than in the primary LCBDE group, and hospital stays were longer [14,19]. However, there were no significant differences between the two groups in stone clearance rates, conversion to open surgery rates, or overall complication rates. A meta-analysis further corroborated these findings, suggesting that although LCBDE following ERCP failure presents increased technical challenges, experienced surgeons can still achieve therapeutic outcomes comparable to those of primary LCBDE [15]. Published literature reports treatment experiences involving 466 patients, of whom 92 underwent primary LCBDE + LC, 108 underwent LCBDE + LC following ERCP failure, and 266 underwent ERCP + LC; There were no significant differences in stone clearance rates (95.7% vs. 99.1% vs. 97.0%) or recurrence rates (5.4% vs. 13.0% vs. 7.9%) among the three groups; however, the single-stage LCBDE group required fewer treatment sessions, had a lower rate of postoperative complications (7.6% vs. 18.5% vs. 13.9%), and shorter hospital stays following the initial treatment (5.7 vs. 13.0 vs. 9.8 days) [20]. Notably, the recurrence rate in the ERCP failure group was numerically higher (13.0%); although this did not reach statistical significance, it suggests that these patients may have a higher risk of long-term recurrence and warrant close attention during follow-up.

5. Predictive Factors for Success and Decision-Making Strategies

5.1. Identification of Predictive Factors

Identifying predictive factors influencing the success of LCBDE following ERCP failure is of great significance for preoperative risk assessment and choice of procedure. A retrospective analysis of 374 LCBDE cases revealed that, in multivariate analysis, a small-diameter cystic duct ($OR = 0.45$) and a stone diameter >6 mm ($OR = 0.23$) were independent predictors of failure of the cystic duct approach; in univariate analysis, a stone-to-cystic-duct diameter ratio >1 and a stone count >3 were also associated with an increased risk of failure

[21]. In a large-case analysis of 952 cases of trans-cystic LCBDE, older age, higher ASA classification, a history of preoperative ERCP, and large stones confirmed preoperatively or intraoperatively were identified as risk factors for adverse outcomes; it is recommended that novice practitioners consider early “cutting their losses” when encountering these situations [22]. Other studies indicate that an analysis of 222 LCBDE cases found that male gender, anesthesia initiation after 4:00 p.m., pericholangitis, and a common bile duct diameter <4 mm were independent risk factors for LCBDE failure, suggesting that the timing of the procedure and operator fatigue may also affect the success rate [23]. Another study proposed the ABCdE score, specifically designed to predict the need for laser lithotripsy during trans-cystic LCBDE. It comprises four criteria—age ≤ 40 years, bilirubin > 2 times the upper limit of normal, CBD diameter ≥ 10 mm, and a history of failed ERCP stone removal—each assigned 1 point. A total score of ≥ 2 predicts the need for laser lithotripsy with a sensitivity of 71%, specificity of 81%, and accuracy of 79%, with a history of ERCP failure being the strongest predictor (HR = 10.06) [24].

5.2. Clinical Decision-Making Pathway Recommendations

Based on the current literature, the following decision pathway may be considered for patients with common bile duct stones following ERCP failure: First, comprehensively assess the cause of ERCP failure—if the failure was due to intubation difficulties and the stones are small and few in number, consider referral to a more experienced endoscopy center for a repeat ERCP attempt [25], or opt for laparoscopic exploration via the cystic duct; if extraction failure is due to large stones, impacted stones, or multiple stones, LCBDE is a more reasonable choice [26]. Second, assess the patient’s tolerance for surgery—for elderly patients, those with multiple comorbidities, or those at high anesthetic risk, the minimally invasive advantages of ERCP are more pronounced; even after an initial failure, a repeat ERCP attempt under optimized conditions may still be preferable to surgery; For patients in generally good condition who can tolerate general anesthesia, LCBDE may be the preferred option [27]. Furthermore, assess local anatomical conditions—the trans-cystic approach has a high success rate when the common bile duct diameter is ≥ 8 mm, the stone diameter is ≤ 15 mm, and the cystic duct is in good condition; for patients with a common bile duct diameter < 7 mm, common bile duct incision should be considered with caution, and priority should be given to repeat ERCP or the percutaneous transhepatic approach. Finally, medical resources and the operator’s experience must be considered—LCBDE places high demands on equipment (choledochoscope, laser lithotripter) and technical skills (laparoscopic suturing); centers lacking the necessary resources should refer patients or opt for open exploration.

6. Conclusion and Outlook

A systematic review of the existing literature leads to the following main conclusions: LCBDE is a safe and effective salvage treatment following ERCP failure, with a stone clearance rate ranging from 88% to 100%. The overall complication rate is comparable to that of single-stage LCBDE and is significantly lower than that of the approach involving surgery after repeated failed ERCP attempts. From

a technical perspective, cases of ERCP failure often require a common bile duct approach; adjunctive techniques such as laser lithotripsy can improve the success rate of the cystic duct approach, and primary suturing can be safely performed—provided indications are strictly adhered to—thereby shortening the length of hospital stay. However, existing studies still have significant limitations: the vast majority are single-center retrospective case series with generally small sample sizes (most fewer than 100 cases), resulting in limited evidence levels; there is a lack of high-quality randomized controlled trials specifically addressing LCBDE following ERCP failure, and head-to-head comparisons with other salvage strategies—such as repeat ERCP or percutaneous transhepatic stone extraction—remain absent; long-term follow-up data are scarce, and the assessment of long-term complications, such as stone recurrence and bile duct strictures, is insufficient; and there has been little discussion regarding the optimal timing for surgery following ERCP failure. Future research should focus on the following areas: conducting multicenter randomized controlled trials to compare the merits of LCBDE with strategies such as repeat ERCP and percutaneous transhepatic stone extraction following ERCP failure; establishing and refining risk prediction models for ERCP failure to help clinicians more accurately choose between ERCP and direct LCBDE when making initial treatment decisions; and conducting long-term prospective cohort studies to clarify the long-term prognosis of LCBDE following ERCP failure. With continuous advances in laparoscopic techniques and supporting equipment, the role of LCBDE in the treatment of common bile duct stones following ERCP failure is expected to grow further.

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