Comparative Study of Dual-Modality Endoscopic Surgery in Elderly Patients With Emergency Common Bile Duct Stone Complicated With Gallbladder Stones—Clinical Application Analysis of ERCP Combined With LC Versus LCBDE+LC

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Xinyuan Wu[1,†], Zhiqiang Yu[1,†], Jun Shao[1], Jun Li[1], Zuofu Liao[1]

[1]Department of General Surgery, Tongren Hospital, Shanghai Jiao Tong University School of Medicine, 200000 Shanghai, China

AIM: To compare and analyze the clinical efficacy of two surgical approaches, endoscopic retrograde cholangiopancreatography (ERCP) combined with laparoscopic cholecystectomy (LC) and laparoscopic common bile duct exploration (LCBDE)+LC, in the treatment of emergency common bile duct stones, providing evidence-based support for individualized clinical surgical selection.

METHODS: A retrospective analysis was conducted on 103 patients with emergency common bile duct stones complicated by gallbladder stones admitted between December 2016 and January 2023. The patients were divided into an ERCP+LC group (n = 56) and an LCBDE+LC group (n = 47). Surgical indicators, postoperative recovery, complications (Clavien-Dindo grade), and mid-term recurrence rates (1 and 1.5 years postoperatively), were compared between the two groups. Age and American Society of Anesthesiologists (ASA) classification were included as covariates in the multivariate Cox regression model, and multivariate logistic regression was performed to adjust for preoperative pancreatitis and evaluate its effects on operative time, postoperative complications and recurrence rate.

RESULTS: The ERCP+LC group demonstrated significantly better intraoperative blood loss (15.00 (10.00–25.00) mL) and operative time (64.11 ± 26.64 min) compared to the LCBDE+LC group (30.00 (20.00–42.50) mL and 116.11 ± 29.69 min, respectively), but with higher hospitalization costs ($p < 0.001$). The LCBDE+LC group showed higher clearance rates for mid-common bile duct stones (n = 41, 87.23%) and sandy stones (n = 38, 80.85%) ($p = 0.008$; $p = 0.010$), and due to the preservation of the Oddi sphincter, the mid-term recurrence rates at 1 year and 1.5 years postoperatively were lower than those in the ERCP+LC group, although the differences were not statistically significant. High-risk patients (e.g., those with advanced age combined with severe comorbidities or ASA classification ≥ III) demonstrated comparable safety and perioperative recovery profiles between the two procedures (with identical complication rates of 9.1% and $p > 0.05$ for recovery time and hospital stay), while the ERCP+LC group exhibited a significantly shorter single-session operative time ($p < 0.001$).

CONCLUSIONS: Both approaches are effective treatments. ERCP+LC offers a shorter single-session operative time while maintaining a safety profile comparable to LCBDE+LC, making it a suitable option for high-risk patients sensitive to prolonged surgical stress, while LCBDE+LC offers more thorough stone clearance and better mid-term control of recurrence. Clinical decisions should consider stone characteristics, patient conditions, and hospital technical capabilities to develop individualized treatment strategies.

Keywords: choledocholithiasis; cholecystolithiasis; endoscopic retrograde cholangiopancreatography; laparoscopic common bile duct exploration; laparoscopy; sphincter of Oddi

Introduction

Gallstones are a common clinical digestive tract disease, and a considerable proportion of cases are complicated by common bile duct stones, posing significant challenges for clinical emergency management [1,2]. The clinical management of elderly patients with emergency biliary stones faces significant challenges in surgical selection, as biliary obstruction can rapidly lead to life-threatening complications such as acute cholangitis and biliary pancreatitis [3,4]. Without timely intervention, organ failure or even death may occur. Minimally invasive techniques, characterized by reduced trauma, faster postoperative recovery, and shorter hospital stays, have become the preferred therapeutic approach [5]. In clinical practice, endoscopic retrograde cholangiopancreatography (ERCP) combined with laparoscopic cholecystectomy (LC) and laparoscopic common bile duct exploration (LCBDE) combined with LC, are the two mainstream minimally invasive approaches. However, widespread academic debate persists regarding their indications, technical complexity, postoperative complication risks, and long-term efficacy [6,7,8]. Specific points of contention include the potential impact of ERCP on Oddi sphincter function and the differences in direct stone clearance achieved by LCBDE. Elderly patients are a high-risk

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Correspondence to: Jun Li, Department of General Surgery, Tongren Hospital, Shanghai Jiao Tong University School of Medicine, 200000 Shanghai, China (e-mail: Upinrm@163.com); Zuofu Liao, Department of General Surgery, Tongren Hospital, Shanghai Jiao Tong University School of Medicine, 200000 Shanghai, China (e-mail: 18602367056@163.com).
[†]*These authors contributed equally.*
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population of emergency biliary stone disease, with more comorbidities and poor surgical tolerance; however, the optimal treatment scheme for this population is still controversial, which was the main reason for selecting elderly patients as the study subject in this study. Given the significant disparities in technical proficiency, equipment availability, and resource accessibility across healthcare institutions, clarifying the specific technical features, target populations, and risk-benefit ratios of each approach is critical for developing individualized treatment strategies and optimizing patient outcomes.

Therefore, this study aims to compare the clinical efficacy, perioperative safety, and mid-term stone recurrence of ERCP combined with LC and LCBDE combined with LC in elderly patients undergoing emergency treatment for concomitant common bile duct and gallbladder stones, with the aim of providing evidence to inform individualized surgical decision-making in this population.

Methods

Study Methods

This study adopted a retrospective cohort design, enrolling 103 elderly patients with emergency common bile duct stones complicated by gallbladder stones admitted to Tongren Hospital between December 2016 and January 2023. All patients required urgent intervention due to acute episodes meeting the diagnostic criteria of acute cholangitis (Tokyo Guidelines 2018) or obstructive jaundice [9]. Based on the final surgical approach, patients were systematically divided into the ERCP+LC group (56 cases) and the LCBDE+LC group (47 cases). Surgical selection was determined through multidisciplinary clinical evaluation based on patient risk profile, anatomical factors, and stone characteristics. ERCP+LC was preferentially selected for patients presenting with severe acute cholangitis requiring rapid biliary decompression, high perioperative risk (ASA class ≥ III or severe cardiopulmonary comorbidities), small or distal CBD stones, or anticipated dense abdominal adhesions. Conversely, LCBDE+LC was primarily indicated for patients with good physiological reserve, dilated common bile duct (diameter ≥8 mm), multiple or large CBD stones, mid-CBD stones, or sandy stones where complete endoscopic extraction was anticipated to be challenging. Inclusion criteria were as follows: ① diagnosed as acute cholangitis or obstructive jaundice according to Tokyo Guidelines 2018; ② confirmed common bile duct (CBD) stones + gallbladder stones by magnetic resonance cholangiopancreatography (MRCP)/computed tomography (CT); ③ emergency surgery required. Exclusion criteria were as follows: ① extensive intrahepatic bile duct stones; ②biliary stricture; ③ coagulation disorder (international normalized ratio (INR) >1.5, Platelet (PLT) <100 × 10^9/L); ④ severe organ dysfunction (e.g., NYHA class III–IV heart failure, Child-Pugh C liver function, inability to tolerate anesthesia and surgical stress) [10]. Screening was conducted using the hospital electronic medical record system to ensure data completeness and consistency. Patients aged ≥80 years with significant underlying comorbidities (e.g., cardiopulmonary dysfunction) or an ASA classification of ≥III were defined as the high-risk elderly subgroup (n = 33). It should be noted that this high-risk subgroup selection required both advanced age (≥80 years) and high physiological risk (ASA ≥ III or severe comorbidities); therefore, elderly patients without severe comorbidities (ASA < III) were excluded from this specific subgroup analysis.

Surgical Techniques and Key Points

ERCP+LC Staged Procedure

First, ERCP was performed using an Olympus TJF-260V duodenoscope (manufacturer: Olympus Medical Systems Corporation) to precisely localize stones, followed by endoscopic sphincterotomy (EST) or balloon dilation (EPBD) for stone extraction using an Olympus stone extraction basket and balloon catheter, with subsequent placement of a nasobiliary drainage tube. LC was performed 24–48 hours later with Storz laparoscopic equipment. Key technical details and injury prevention measures included: (1) selective bile duct cannulation: hydrophilic guidewire-assisted cannulation was adopted to avoid pancreatic duct injury, and abandon cannulation if repeated attempts (≥3 times) fail; (2) EST incision size control: the incision length was strictly controlled at 0.8–1.2 cm to avoid excessive incision leading to Oddi sphincter dysfunction; (3) LC guided by ERCP imaging: the position of the cystic duct and common bile duct was clearly identified according to ERCP cholangiography images, and the Calot triangle was carefully dissected to avoid bile duct injury; (4) for elderly patients with cardiopulmonary insufficiency, the operative time was shortened as much as possible, and the staged operation was completed in two times to reduce the stress of a single anesthesia. The staged strategy significantly reduced procedural risks for elderly and cardiopulmonary-compromised patients.

LCBDE+LC Single-Stage Procedure

Laparoscopic sequential cholecystectomy and common bile duct exploration with Storz laparoscopic equipment and choledochoscope (CHS-100) (manufactured by Karl Storz SE & Co. KG (Tuttlingen, Germany), including the Karl Storz IMAGE1 S™ 3D Camera System (Ref: 22201011U; Batch No.: KS-202108-04), a 10 mm 30° HOPKINS® Straight Forward Telescope (Ref: 26003BA; Lot No.: LOT-894123), a Power LED 300 light source, and an ENDOFLATOR® 50 high-flow insufflator (Lot No.: LOT-783401)): gallbladder removal followed by longitudinal choledochotomy (1.0–1.5 cm) at the anterior wall of the common bile duct 1 cm below the cystic duct opening, stone extraction under choledochoscopic visualization with stone extraction forceps and balloon catheter, and T-tube place-

ment with 16F latex T-tube. Core technical elements and injury prevention measures: (1) precise choledochotomy positioning: avoid incising the hepatic duct or pancreatic duct by referring to the anatomical markers of the cystic duct and common bile duct; (2) stone extraction skills: a balloon catheter was used to flush and extract sandy stones to avoid residual; for large stones (>1.5 cm), mechanical lithotripsy under choledochoscopy was used first; (3) Oddi sphincter protection measures: to avoid excessive traction or injury to the Oddi sphincter during stone extraction, unnecessary sphincterotomy was not performed to ensure the integrity of the sphincter muscle; after stone extraction, the patency of the Oddi sphincter by choledochoscopy was checked to confirm the normal peristalsis function; (4) bile duct suture: 4-0 absorbable polydioxanone suture was used for interrupted suture with a spacing of ≤2 mm to avoid bile leakage. Preservation of Oddi sphincter function is the key to improving mid-term outcomes.

Stone Characteristics Analysis

The stone size distribution of the two groups was shown in Table 1. Mid-common bile duct stones were defined as stones located in the segment from the cystic duct insertion to the upper margin of the duodenal papilla, and sandy stones were defined as calculi with a maximum diameter of <0.5 cm and multiple scattered distributions. Stone clearance was routinely evaluated prior to patient discharge based on intraoperative choledochoscopy/cholangiography and postoperative MRCP or T-tube cholangiography. Complete clearance was defined as the total absence of residual filling defects or stone signals in the common bile duct. The clearance rates for mid-CBD stones and sandy stones were calculated using the total number of patients in each treatment group as the denominator.

Efficacy Evaluation Index System

A multidimensional evaluation system was established. Short-term indicators (within 3 months postoperatively) included operative time, intraoperative blood loss, hospital stays, and postoperative recovery time. Operative time reflected procedural complexity and surgeon proficiency; intraoperative blood loss was estimated via suction and gauze measurements, serving as an indicator of surgical trauma; hospital stays and postoperative recovery time reflected recovery speed. Postoperative recovery time was operationally defined as the number of days from the completion of the final surgical procedure (the second-stage LC in the ERCP+LC group or the single-stage procedure in the LCBDE+LC group) to the date when the patient satisfied standardized discharge criteria, including complete tolerance of regular diet, effective oral pain control, independent ambulation, and absence of active complications. Postoperative complications were systematically evaluated within a 30-day window following the definitive procedure (covering both the initial inpatient stay and 30-day post-discharge follow-up) and categorized using the Clavien–Dindo classification system. Short-term indicator (recurrence rate at 3 months postoperatively) and mid-term indicators (recurrence rates at 1 year and 1.5 years postoperatively) were assessed using MRCP, and the recurrence was defined as the re-detection of common bile duct stones on imaging after initial complete stone clearance. Postoperative bile reflux was evaluated systematically during routine follow-up visits (at 3 months, 1 year, and 1.5 years postoperatively) or upon presentation of digestive symptoms (e.g., epigastric pain, nausea, or bilious vomiting). Bile reflux was diagnosed based on endoscopic criteria (upper gastrointestinal endoscopy showing significant yellow-greenish bile pooling in the stomach/duodenum accompanied by mucosal hyperemia) or radiological evidence (pneumobilia or reflux signals on follow-up MRCP/CT). Postoperative bile reflux in this study specifically referred to duodenobiliary reflux (retrograde flow into the common bile duct due to sphincter of Oddi incompetence), distinct from duodenogastric reflux. It was evaluated during follow-up using standardized criteria: ①Reflux signals: Defined radiologically as the presence of scattering echogenic gas signals (pneumobilia) or fluid-gas interfaces within the common bile duct lumen on ultrasound or MRCP, independent of recent instrumentation. ②Bile pooling: Defined as the sonographic visualization of abnormal, concentrated turbid bile or micro-sludge stasis within a non-obstructed, dilated common bile duct lumen. Patients exhibiting persistent reflux-related imaging findings accompanied by relevant symptoms were classified as having suspected postoperative duodenobiliary reflux.

Study Endpoints and Outcome Hierarchy

To evaluate the clinical efficacy and safety of LCBDE+LC versus ERCP+LC in a structured and transparent manner, study outcomes were explicitly defined and categorized prior to statistical analysis:

Primary Outcomes: (1) Complete stone clearance rate (assessed postoperatively prior to discharge); (2) overall postoperative complication incidence (within 30 days postprocedure); and (3) cumulative mid-term stone recurrence rate (evaluated during the 18-month follow-up).

Secondary Outcomes: Included single-session operative duration, postoperative recovery time, total length of hospital stay, specific individual complication types (e.g., post-ERCP pancreatitis, hyperamylasemia, bile leak, bleeding), and the incidence of postoperative duodenobiliary reflux.

Statistical Methods

All clinical data were extracted using standardized case report forms. Statistical analysis plans were predefined based on the specific outcome variable type (continuous, binary, or time-to-event): continuous outcomes (e.g., Operative time, intraoperative blood loss, hospital stays, postoperative recovery time, and hospitalization expense): normal-

Table 1. Baseline data comparison between the two groups.

		LCBDE+LC group (n = 47)	ERCP+LC group (n = 56)	*p*-value
Age (years)	70–79	25	29	0.887
	80–85	22	27	
Gender	Male	25	35	0.340
	Female	22	21	
BMI (kg/m^2)	<18	3	0	0.094
	18–24	24	22	
	24–28	13	19	
	>28	7	15	
Hypertension	Yes	27	31	0.831
	No	20	25	
Diabetes mellitus	Yes	35	41	0.885
	No	12	15	
Coronary heart disease	Yes	32	37	0.829
	No	15	19	
ASA score	1	0	0	0.435
	2	17	21	
	3	28	29	
	4	2	6	
Accompanied by other diseases	Yes	33	39	0.950
	No	14	17	
History of abdominal surgery	Yes	1	7	0.068
	No	46	49	
Stone size (cm), median (IQR)	—	1.2 (0.8–1.8)	1.1 (0.7–1.7)	0.241

LCBDE, laparoscopic common bile duct exploration; LC, laparoscopic cholecystectomy; ERCP, endoscopic retrograde cholangiopancreatography; BMI, body mass index; ASA, American Society of Anesthesiologists; IQR, interquartile range.

ity of continuous variables was assessed using the Shapiro–Wilk test. Continuous data with normal distribution were expressed as mean ± standard deviation and compared between groups using the independent-samples *t*-test. Non-normally distributed data were expressed as median (interquartile range) [M (Q1–Q3)] and compared using the Mann–Whitney U test. To evaluate the independent effect of surgical modality on continuous outcomes while controlling for continuous and categorical covariates (e.g., age, ASA grade, and baseline stone burden), multivariable linear regression models were constructed, reporting unstandardized regression coefficients with 95% confidence intervals (CIs). Binary categorical outcomes (e.g., overall postoperative complication rate and stone clearance rate): categorical data were expressed as frequencies and percentages [n (%)] and compared using the Pearson chi-square test or Fisher's exact test (when expected cell frequencies were <5). To adjust for potential baseline confounders (e.g., age, ASA classification, and stone characteristics) and accurately evaluate surgical outcomes, different multivariable models were employed based on the nature of the endpoint. Specifically, Multiple Linear Regression was utilized for continuous outcomes (such as single-session operative time and postoperative recovery time). Multivariate Logistic Regression was applied for binary categorical outcomes (such as the incidence of overall postoperative complications). For time-to-event outcomes (specifically, cumulative stone recurrence-free survival), Kaplan-Meier survival curves were generated and compared using the log-rank test, followed by Multivariate Cox Proportional Hazards Regression analysis to estimate hazard ratios (HRs) and 95% confidence intervals (CIs). Statistical analysis was performed using SPSS 26.0 software (IBM Corp., Armonk, NY, USA), and a $p < 0.05$ was considered statistically significant.

Results

Baseline Data Evaluation

Table 1 presents the baseline demographic, clinical, and biliary characteristics of patients in the LCBDE+LC (n = 47) and ERCP+LC (n = 56) groups. In addition to general demographics, stone maximum size—were fully evaluated and incorporated into Table 1. Overall, baseline general demographics, underlying comorbidities, and main biliary anatomical parameters demonstrated good comparability between the two groups (all $p > 0.05$). Detailed numerical values, proportions, and test statistics for all baseline variables are summarized in Table 1. However, given the retrospective and non-randomized nature of this study, statistical comparisons of baseline parameters alone cannot entirely eliminate potential residual or unmeasured con-

Table 2. Comparison of perioperative indicators between the two groups.

	LCBDE+LC group (n = 47)	ERCP+LC group (n = 56)	*p*-value
Length of stays (days)	9.87 ± 3.66	10.50 ± 2.29	0.309
Postoperative recovery time (days)	6.54 ± 2.96	5.51 ± 1.96	0.046
Operative time (min)	116.11 ± 29.69	64.11 ± 26.64	<0.001
Intraoperative blood loss (mL)	30.00 (20.00–42.50)	15.00 (10.00–25.00)	<0.001
Hospitalization expense (yuan)	39,037.58 ± 10,921.33	47,586.68 ± 5578.00	<0.001
Overall complications, n (%)	4 (8.5)	2 (3.6)	0.408
Clavien–Dindo grade (I–II), n	4 (8.5)	2 (3.6)	0.408
Clearance rate of mid-CBD stones, n (%)	41 (87.23%)	36 (64.29%)	0.008
Clearance rate of sandy stones	38 (80.85%)	32 (57.14%)	0.010

CBD, common bile duct; 1 yuan = 0.15 dollar.

founding. Therefore, multivariable statistical models were subsequently employed to further adjust for potential confounders when evaluating key operative and postoperative outcomes.

Primary Outcomes

The primary clinical outcomes—initial complete stone clearance rate and overall 30-day postoperative complication rate—are summarized in Table 2. The ERCP+LC group showed significantly lower intraoperative blood loss (15.00 (10.00–25.00) mL vs. 30.00 (20.00–42.50) mL; $p < 0.001$) and shorter operative time (64.11 ± 26.64 min vs. 116.11 ± 29.69 min; $p < 0.001$) (Table 2). However, the LCBDE+LC group achieved higher clearance rates for mid-common bile duct stones (87.23% vs. 64.29%, $p = 0.008$) and sandy stones (80.85% vs. 57.14%, $p = 0.010$), with statistically significant differences between the two groups. The number of postoperative complications in the two groups was 2 cases (3.6%) in the ERCP+LC group and 4 cases (8.5%) in the LCBDE+LC group, with no statistically significant difference ($p > 0.05$); the Clavien-Dindo grade of complications was mainly grade I–II, with no grade III–IV severe complications observed in both groups.

Multivariable Regression Analysis

Multivariate Cox regression for stone recurrence showed that age >80 years (HR = 2.13, 95% CI: 1.02–4.45, $p = 0.044$) and ERCP+LC procedure (HR = 2.87, 95% CI: 1.16–7.07, $p = 0.023$) were independent risk factors for recurrence.

Multivariate logistic regression for postoperative complications showed that preoperative pancreatitis (OR = 3.82, 95% CI: 0.79–18.42, $p = 0.096$) and ASA class ≥3 (OR = 2.15, 95% CI: 0.68–6.79, $p = 0.188$) were not independent risk factors.

Secondary Outcomes

Fig. 1 shows the comparison of short-term (3 months) and mid-term (1- and 1.5-year) stone recurrence rates between the two groups at 3 months, 1 year and 1.5 years postoperatively, with the sample size of the ERCP+LC group (n = 56) and the LCBDE+LC group (n = 47). Follow-up analysis revealed lower short-term (3 months) and mid-term (1- and 1.5-year) recurrence rates in the LCBDE+LC group compared with the ERCP+LC group (at 3 months: 2.1% (1/47, 95% CI: 0.0%–6.2%) in the LCBDE+LC group vs. 7.1% (4/56, 95% CI: 0.4%–13.8%) in the ERCP+LC group ($p = 0.375$). At 1 year: 4.3% (2/47, 95% CI: 0.0%–10.1%) in the LCBDE+LC group vs. 14.3% (8/56, 95% CI: 5.1%–23.5%) in the ERCP+LC group ($p = 0.096$). At 1.5 years (18 months): 6.4% (3/47, 95% CI: 0.0%–13.4%) in the LCBDE+LC group vs. 17.9% (10/56, 95% CI: 7.8%–27.9%) in the ERCP+LC group ($p = 0.077$)). Kaplan–Meier survival analysis demonstrated a statistically significant difference in cumulative recurrence-free survival between the two treatment groups over the 1.5-year follow-up period (log-rank $p = 0.041$; Fig. 1). Multivariate Cox proportional hazards regression confirmed that the ERCP+LC approach was an independent risk factor for mid-term stone recurrence (HR = 2.87, 95% CI: 1.16–7.07, $p = 0.023$) after adjusting for age and ASA classification. ERCP-induced sphincterotomy (EST) may disrupt the structural and functional integrity of the Oddi sphincter, and the postoperative bile reflux rate in the ERCP+LC group was 14.3% (n = 8), which may lead to bacterial infection and further stone recurrence; LCBDE+LC preserved the structural and functional integrity of the sphincter, maintained the normal physiological state of the biliary tract, reduced the incidence of bile reflux, and thus reduced the infection-related recurrence.

For high-risk elderly patients (i.e., those aged ≥80 years with multiple comorbidities such as diabetes, cardiopulmonary dysfunction, or higher ASA grades). Table 3 shows the comparison of surgical outcomes in these high-risk patients between the two groups, with the sample size of the ERCP+LC group (n = 11) and the LCBDE+LC group (n = 22). Among the 33 defined high-risk elderly patients (32.0% of the cohort), the two surgical approaches demonstrated statistically equivalent safety and perioperative recovery indicators, with identical overall complication rates (9.1% [1/11] vs. 9.1% [2/22], $p = 1.000$) and non-significant differences in postoperative recovery time and

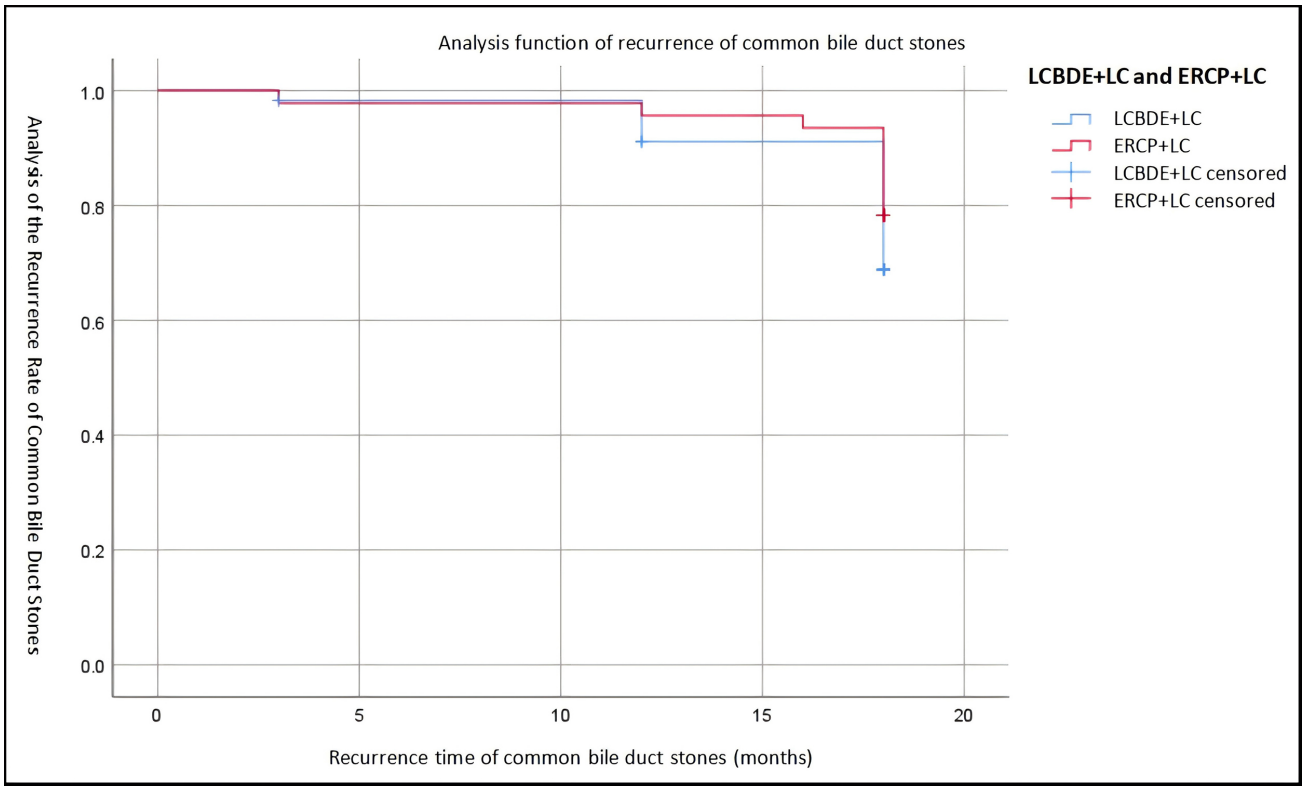

Fig. 1. Kaplan–Meier curves for cumulative common bile duct stone recurrence-free survival between the LCBDE+LC group (n = 47) and the ERCP+LC group (n = 56) over 1.5 years of follow-up. The LCBDE+LC group demonstrated significantly higher recurrence-free survival compared to the ERCP+LC group (log-rank $p = 0.041$). Point-wise cumulative recurrence rates at 3, 12, and 18 months were 2.1% vs. 7.1% ($p = 0.375$), 4.3% vs. 14.3% ($p = 0.096$), and 6.4% vs. 17.9% ($p = 0.077$), respectively. Multivariate Cox hazard ratio for ERCP+LC vs. LCBDE+LC was 2.87 (95% CI: 1.16–7.07, $p = 0.023$). Numbers at risk at baseline, 3, 6, 12, and 18 months are displayed below the x-axis. ERCP, endoscopic retrograde cholangiopancreatography; LCBDE, laparoscopic common bile duct exploration; LC, laparoscopic cholecystectomy.

length of stay. The primary quantitative distinction was a significantly shorter single-session operative time in the ERCP+LC group (55.55 ± 13.72 vs. 115.77 ± 28.34 min$p < 0.001$) (Table 3).

Discussion

This study demonstrated that ERCP+LC had the advantages of lower intraoperative blood loss and shorter operative time in the treatment of elderly patients with emergency common bile duct stones complicated with gallbladder stones, which is consistent with the results of a relevant comparative study on minimally invasive biliary surgery [11]. The reason may be that ERCP+LC is a staged minimally invasive operation, with a simpler single operation and less surgical trauma, which is more suitable for elderly patients with poor physical tolerance and limited ability to withstand long-term surgical stress. However, the hospitalization cost of ERCP+LC is significantly higher than that of LCBDE+LC, which is closely related to the need for two separate operations, the use of high-value endoscopic consumables and the corresponding anesthesia and nursing costs, a finding that is also consistent with the economic evaluation results of an existing biliary stone treatment study [12]. In contrast, LCBDE+LC is a one-stage surgical procedure that enables simultaneous complete cholecystectomy and common bile duct stone extraction. While total hospital stay was comparable between the two groups ($p = 0.309$), staged ERCP+LC was associated with a shorter postoperative recovery time ($p = 0.046$).

This study supplemented the quantitative statistical comparison of stone characteristics and clearance rates between the two groups, and found that LCBDE+LC had significantly higher clearance rates for mid-common bile duct stones and sandy stones, a key finding different from some previous single-center studies [13,14,15]. The main reason for this difference may be that LCBDE can directly explore the entire common bile duct under choledochoscopic visualization with a clear field of vision, which can effectively remove scattered sandy stones and stones in the middle segment of the common bile duct that are difficult to reach by duodenoscope; while ERCP is limited by the anatomical angle of the duodenal papilla and the operating range of the endoscope, which may lead to incomplete stones clearance when dealing with mid-common bile duct stones and sandy

Table 3. Comparison of surgical outcomes in high-risk patients (aged ≥80 years with severe comorbidities) between the two groups.

	LCBDE+LC group (n = 22)	ERCP+LC group (n = 11)	*p*-value
Complication rates, n (%)	2 (9.1)	1 (9.1)	1.000
Operative time (min)	115.77 ± 28.34	55.55 ± 13.72	<0.001
Length of stays (days)	10.34 ± 3.66	9.64 ± 2.07	0.559
Postoperative recovery time (days)	6.98 ± 2.66	5.86 ± 1.63	0.214

stones. This result further confirms that stone size, number and anatomical location are the key factors influencing the choice of surgical method for biliary stones, and clinical decision-making should be based on the specific stone characteristics evaluated by preoperative imaging.

The LCBDE+LC group had significantly lower mid-term stone recurrence rates than the ERCP+LC group at all follow-up time points. This is the most important advantage of LCBDE+LC in the treatment of elderly patients with emergency biliary stones and is closely related to its ability to completely preserve Oddi sphincter function. The Oddi sphincter is an important physiological barrier to the biliary tract, which can effectively prevent duodenal bile reflux and intestinal bacterial retrograde infection [16,17]. ERCP+LC requires endoscopic sphincterotomy or papillary balloon dilation, which may potentially affect the structural and functional integrity of the Oddi sphincter. In this study, the postoperative bile reflux rate in the ERCP+LC group was 14.3%, which may be associated with biliary infection and stone recurrence. Since direct functional assessment of the Oddi sphincter was not performed, this inference requires verification in the future.

High-risk patients, typically characterized by advanced age (≥80 years) combined with diabetes, cardiopulmonary insufficiency, or frailty, are a vulnerable population for emergency biliary stone surgery [4]. In the present study, evaluation of this subgroup (n = 33) revealed that staged ERCP+LC and single-stage LCBDE+LC achieved comparable perioperative safety and recovery outcomes, evidenced by identical overall complication rates (9.1% vs. 9.1%) and similar hospital stays and recovery times ($p > 0.05$). The main operational difference lay in single-session operative duration, where ERCP+LC significantly reduced procedural time per session ($p < 0.001$), thereby reducing single-stage anesthetic exposure. However, because primary safety and recovery indicators did not differ significantly between groups ($p > 0.05$), these data indicate equivalent safety rather than superior overall tolerance or procedural adaptability for ERCP+LC. Therefore, selection of ERCP+LC in high-risk patients should be viewed as a strategy to minimize single-session anesthetic duration rather than an approach with proven superior safety.

Based on the above research results, the clinical selection of surgical methods for elderly patients with emergency common bile duct stones complicated with gallbladder stones should follow the individualized treatment principle combined with three core factors: first, the characteristics of the stones (ERCP+LC for small, few and distal stones; LCBDE+LC for mid-common bile duct stones, sandy stones and multiple large stones); second, the patient's physical conditions (ERCP+LC as the first choice for high-risk patients aged ≥80 years with cardiopulmonary insufficiency; LCBDE+LC for elderly patients with good physical tolerance); third, the technical capacity of the hospital (ERCP+LC requires mature endoscopic operation technology, while LCBDE+LC requires proficient laparoscopic and choledochoscopic combined operation skills), and the surgical plan should be formulated comprehensively to maximize the safety and efficacy of the operation.

This study has several inherent limitations that need to be acknowledged. First, it is a single-center retrospective cohort study with a limited sample size (n = 103), which may lead to selection bias and restrict the generalizability of the results to a certain extent. Second, the follow-up duration is relatively short (≤18 months), which is insufficient to evaluate the long-term outcomes of Oddi sphincter dysfunction, such as recurrent cholangitis, intrahepatic bile duct stones and other secondary pathologies. Third, no direct functional assessment of the Oddi sphincter (e.g., manometry and cholangiography) was performed, and the mechanism underlying stone recurrence was inferred indirectly from bile reflux rate as an alternative indicator, lacking direct functional evidence. Fourth, several unmeasured key clinical indicators, such as long-term biliary tract physiological function, post-EST papillary stenosis and bile composition changes, were not systematically assessed, which may affect the in-depth analysis of the long-term efficacy of the two surgical methods. Fifth, this was a retrospective study, with patients grouped by actual surgical procedure, which may introduce selection bias. Sixth, some mechanistic inferences about stone recurrence and suitability for elderly patients were based on observational data rather than direct evidence.

In view of the limitations of this study, the following research directions are proposed to further improve the clinical evidence system of minimally invasive treatment for elderly patients with emergency biliary stones. First, multicenter prospective cohort studies with a large sample size and long-term follow-up should be carried out, which can effectively reduce selection bias and provide more reliable evidence for the long-term efficacy comparison between ERCP+LC and LCBDE+LC. Second, further comparative

studies on the "one-stop" same-session ERCP+LC surgical model are warranted to explore perioperative stress response and resource utilization efficiency of this model in elderly patients, thereby providing a new surgical option for clinical practice. Third, future research should focus on developing AI-assisted, individualized surgical decision-making systems by integrating preoperative imaging indicators (bile duct diameter, stone distribution), biochemical indicators (Alanine Aminotransferase (ALT), Alkaline Phosphatase (ALP), γ-Glutamyl Transferase (γ-GT)) and complication risk scores to realize accurate matching between surgical methods and patients, thereby improving the scientific rigor of clinical decision-making. Fourth, subsequent studies should incorporate comprehensive detection of Oddi sphincter function and explore the correlation between the degree of sphincter function damage and long-term stone recurrence, so as to provide a theoretical basis for the protection of sphincter function in minimally invasive biliary surgery.

Conclusions

Both ERCP+LC and LCBDE+LC are safe and effective for elderly patients with emergency choledocholithiasis complicated by cholecystolithiasis. ERCP+LC reduces single-session operative time while maintaining safety and short-term recovery profiles comparable to LCBDE+LC, rendering it a reasonable choice for high-risk patients who are particularly sensitive to prolonged single-stage surgical duration. LCBDE+LC provides superior stone clearance and lower mid-term recurrence, which may be associated with avoiding endoscopic sphincterotomy and preserving intact biliary anatomy. Treatment strategy selection should be individualized based on stone features, patient conditions, and institutional technical capabilities.

Availability of Data and Materials

The data analyzed are available from the corresponding authors upon reasonable request.

Author Contributions

ZL and JL conceived and designed the research and performed the experiments. XW and ZY collected and analyzed the data. XW drafted the manuscript. JS provided valuable clinical insights, designed the study, and revised the manuscript. All authors have been involved in revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study adhered to the principles outlined in the Declaration of Helsinki, and the study protocol was reviewed and approved by the Medical Ethics Committee of Tongren Hospital (Approval No.: K2025-103-01). All patients provided signed informed consent after understanding the research objectives.

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Conflict of Interest

The authors declare no conflict of interest.

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