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Comparative Effectiveness of Single-Stage Laparoscopic Common Bile Duct Exploration Plus Cholecystectomy Versus Staged ERCP/EST Plus Cholecystectomy for Cholecystocholedocholithiasis: A Propensity Score-Matched Retrospective Cohort Study

Ze Li
Hebei University
Quan Zhang
18486853480@qq.com
Hebei University
Jianfei Wu
Hebei University
Zhiyuan Hou
Hebei University
Cong Li
Hebei University
Qunjie Niu
Hebei University
Aonan Zhao
Hebei University
Shaohang Han
Hebei University

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Abstract

Background

The optimal strategy for patients with concomitant gallbladder and common bile duct stones remains debated. This study compared single-stage laparoscopic common bile duct exploration plus laparoscopic cholecystectomy (LCBDE + LC) with staged endoscopic retrograde cholangiopancreatography/endoscopic sphincterotomy plus LC (ERCP/EST + LC).

Methods

We conducted a retrospective cohort study including 598 analyzable patients (299 per group). Propensity scores were estimated from sex, age, body mass index, white blood cell count, total bilirubin, alanine aminotransferase, maximum stone diameter, and common bile duct diameter. One-to-one nearest-neighbor matching produced 206 matched pairs. Paired continuous outcomes were compared using the Wilcoxon signed-rank test, paired binary outcomes using the exact McNemar test, and odds ratios for binary outcomes using conditional logistic regression stratified by matched pair.

Results

After matching, most covariates were balanced, although mild residual imbalance remained in total bilirubin, common bile duct diameter, and maximum stone diameter. Median total procedural time was shorter with LCBDE + LC than with ERCP/EST + LC [150.0 (115.0-195.0) vs 177.0 (159.2–193.0) min; $P < 0.001$], and total hospitalization cost was lower [2.99 (2.55–3.63) vs 4.04 (3.36–4.70) $\times 10^4$ CNY; $P < 0.001$]. Median hospital stay was longer in the LCBDE + LC group [14.0 (12.0–17.0) vs 11.0 (8.0–13.0) days; $P < 0.001$]. No statistically significant differences were detected in conversion to open surgery, incomplete stone clearance, intra-abdominal infection, biliary bleeding, postoperative pancreatitis, postoperative cholangitis, or bile leakage. The median SSQ-8 score was higher with LCBDE + LC [86.0 (83.0–90.0) vs 82.0 (79.0–86.0); $P < 0.001$].

Conclusions

In this propensity score-matched cohort, LCBDE + LC was associated with shorter cumulative procedural time, lower hospitalization cost, and higher patient satisfaction, with similar observed rates of stone clearance and major complications compared with ERCP/EST + LC. The longer hospital stay and residual covariate imbalance warrant cautious interpretation and external validation.

1. Introduction

Choledocholithiasis accompanying gallbladder stones may cause biliary obstruction, acute cholangitis, and pancreatitis, and treatment generally aims to achieve complete bile duct stone clearance in patients suitable for intervention [1, 2]. Current guidelines recognize endoscopic and surgical pathways, with treatment selection influenced by stone characteristics, patient condition, local expertise, and procedural availability [3].A widely used two-stage strategy consists of ERCP with or without endoscopic sphincterotomy followed by laparoscopic cholecystectomy[3, 5]. This approach is familiar to many centers but exposes patients to separate procedures and

procedure-specific risks, including post-ERCP pancreatitis, bleeding, cholangitis, and failed cannulation [4]. In contrast, LCBDE + LC permits common bile duct clearance and cholecystectomy during one anesthetic episode while preserving an entirely laparoscopic pathway[5].

Randomized trials and meta-analyses have generally shown broadly comparable efficacy and safety between single-stage laparoscopic management and staged endoscopic-surgical management, although findings vary for stone clearance, bile leakage, pancreatitis, hospital stay, and cost [6]. Differences in institutional pathways and operator experience may explain part of this heterogeneity. Evidence from routine clinical practice remains valuable because treatment allocation is not random and may reflect disease complexity and local expertise. A 2025 meta-analysis of randomized trials also reported no significant differences in treatment success, residual stones, overall morbidity, mortality, or hospital stay between the two approaches [7].

We therefore conducted a retrospective cohort study using propensity score matching to compare LCBDE + LC with ERCP/EST + LC in patients with concomitant gallbladder and common bile duct stones. We assessed cumulative procedural time, conversion to open surgery, hospital stay, hospitalization cost, incomplete stone clearance, postoperative complications, and patient-reported surgical satisfaction.

2. Methods

2.1 Study design and reporting

We conducted a retrospective cohort study of consecutive patients treated in the Department of Hepatobiliary Surgery at the Affiliated Hospital of Hebei University between July 2023 and May 2025. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [8].This retrospective study was approved by the Institutional Ethics Committee of Hebei University Affiliated Hospital (Approval No. HDFYLL-KY-2026-187). The requirement for informed consent was obtained from all patients, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

2.2 Participants

Patients were eligible for inclusion if they met all of the following criteria: (1) age ≥ 18 years; (2) concomitant gallbladder stones and common bile duct stones (CBDS) confirmed by abdominal ultrasonography, computed tomography, magnetic resonance cholangiopancreatography, endoscopic retrograde cholangiopancreatography (ERCP), intraoperative cholangiography, or choledochoscopy; (3) completion of definitive treatment during the index hospitalization with either single-stage laparoscopic common bile duct exploration plus laparoscopic cholecystectomy (LCBDE + LC) or staged ERCP with endoscopic sphincterotomy followed by laparoscopic cholecystectomy (ERCP/EST + LC); and (4) availability of the baseline covariates required for propensity score estimation and the procedural and outcome data required for study analyses. Both elective patients and patients requiring urgent admission were eligible after appropriate clinical stabilization and assessment of suitability for the planned minimally invasive treatment.Patients were excluded if they met any of the following criteria: (1) isolated gallbladder stones or isolated CBDS; (2) previous cholecystectomy, common bile duct exploration, or biliary-enteric reconstruction; (3) therapeutic biliary intervention before the index treatment episode, including ERCP/EST, endoscopic papillary balloon dilation, or percutaneous transhepatic biliary drainage; (4) malignant biliary obstruction, benign common bile duct stricture, Mirizzi syndrome, intrahepatic bile duct stones, or biliary-enteric fistula; (5) severe acute cholangitis associated with sepsis or septic shock requiring emergency biliary decompression, severe acute pancreatitis requiring emergency biliary intervention or intensive care,

decompensated cirrhosis with portal hypertension, uncorrectable coagulopathy, or severe organ dysfunction precluding the planned intervention; (6) pregnancy; (7) concomitant major hepatobiliary surgery, including hemihepatectomy; (8) failure to complete either predefined treatment pathway, including ERCP alone without subsequent LC, refusal of definitive treatment, or transfer to another center before completion of treatment; or (9) missing data for variables required for propensity score matching or outcome assessment.

2.3 Treatment strategies

2.3.1 Single-stage LCBDE + LC

All procedures were performed under general anesthesia by hepatobiliary surgeons experienced in advanced laparoscopic biliary surgery.Patients were placed in the supine position and subsequently adjusted to a reverse Trendelenburg position with a slight left tilt. Carbon dioxide pneumoperitoneum was maintained at 13–15 mmHg, and a conventional four-port laparoscopic technique was used. After careful dissection of the hepatocystic triangle, the cystic artery was clipped and divided, while the cystic duct was temporarily preserved. The anterior wall of the common bile duct was exposed, and a longitudinal choledochotomy of approximately 8–10 mm was created.A flexible choledochoscope was introduced through the choledochotomy, and stones were extracted with a stone-retrieval basket under direct visualization. Saline irrigation was used as required. Complete ductal clearance was confirmed by systematic choledochoscopic examination of the proximal hepatic ducts and distal common bile duct.The choledochotomy was closed primarily with interrupted or continuous 4 − 0 or 5 − 0 absorbable sutures. T-tube drainage was selectively used according to intraoperative findings and surgeon judgment. Laparoscopic cholecystectomy was then completed. A closed-suction drain was placed in the subhepatic space and generally removed 3–5 days postoperatively, provided that there was no evidence of bile leakage, active bleeding, or bilious/hemorrhagic drainage.

2.3.2 Staged ERCP/EST + LC

Patients fasted overnight before the endoscopic procedure. Therapeutic endoscopic retrograde cholangiopancreatography with endoscopic sphincterotomy (ERCP/EST) was performed in the prone or left semiprone position under monitored anesthesia care with intravenous sedation and topical pharyngeal anesthesia, using a therapeutic side-viewing duodenoscope (TJF-260V; Olympus Medical Systems, Tokyo, Japan). All ERCP procedures were performed by one senior endoscopist experienced in therapeutic biliary endoscopy.After identification of the major duodenal papilla, selective biliary cannulation was achieved with a sphincterotome and hydrophilic guidewire. Contrast cholangiography was then performed to assess the number, size, and location of common bile duct stones, as well as biliary duct anatomy.

Endoscopic sphincterotomy was performed at the endoscopist’s discretion based on papillary anatomy and stone characteristics. Endoscopic papillary balloon dilation or large-balloon dilation was added as required to facilitate stone extraction. Stones were removed with a retrieval balloon and/or Dormia basket under fluoroscopic guidance, and mechanical lithotripsy was used for large, impacted, or difficult-to-extract stones as clinically indicated.Complete ductal clearance was confirmed by repeat cholangiography, with no residual filling defects and free passage of contrast into the duodenum. Endoscopic nasobiliary drainage (ENBD) was routinely placed per institutional protocol. For patients with incomplete stone clearance, inadequate biliary drainage, severe cholangitis, or marked papillary edema, a temporary plastic biliary stent was used instead of ENBD at the endoscopist’s discretion, and repeat ERCP was arranged as clinically indicated.Nasobiliary cholangiography was generally performed approximately 24 h after ERCP in patients with an ENBD catheter. After confirmation of no residual common bile duct stones, and in the absence of post-ERCP pancreatitis, active cholangitis, bleeding, perforation, or

other contraindications, laparoscopic cholecystectomy was performed during the same hospitalization under general anesthesia using a conventional three-port technique, generally within 24 h after successful ERCP/EST. The interval was extended when additional treatment or clinical stabilization was required.

2.4 Outcomes and definitions

2.4.1 Main comparative outcomes

The main comparative outcomes were total procedural time, length of hospital stay, and total hospitalization cost.

- **Total procedural time**: Duration data were extracted from official operative and endoscopic procedure records. For the LCBDE + LC group, total procedural time was defined as the duration of the single combined operation. For the ERCP/EST + LC group, total procedural time was calculated at the individual patient level as the sum of the ERCP/EST procedure duration and the subsequent LC operative duration; the interval between the two procedures was not included.
- **Length of hospital stay**: Defined as the number of days from index admission to discharge during the index hospitalization.
- **Total hospitalization cost**: Extracted from the hospital billing system, representing all medical expenses incurred during the index hospitalization. Costs were expressed in 10,000 Chinese yuan (×10^4 CNY).

2.4.2 Additional clinical outcomes

Additional clinical outcomes included conversion to open surgery, incomplete stone clearance, and perioperative complications (intra-abdominal infection, biliary bleeding, postoperative pancreatitis, postoperative cholangitis, and bile leakage). All outcomes were assessed during the index hospitalization.

- **Conversion to open surgery**: Defined as unplanned conversion from the intended laparoscopic approach to an open surgical procedure.
- **Incomplete stone clearance**: Defined as residual common bile duct stones confirmed by choledochoscopy, postoperative cholangiography, or nasobiliary cholangiography before discharge, after all intended stone extraction attempts during the index hospitalization.
- **Perioperative complications**: Intra-abdominal infection, biliary bleeding, postoperative pancreatitis, postoperative cholangitis, and bile leakage were ascertained based on clinical diagnoses documented in medical records, supported by corresponding laboratory, imaging, endoscopic, or intraoperative findings as clinically appropriate.

2.4.3 Patient-reported outcome

Patient satisfaction was evaluated approximately 1 month after hospital discharge using the Mandarin Chinese version of the Surgical Satisfaction Questionnaire-8 (SSQ-8)[9]. The questionnaire was administered by a trained investigator independent of the surgical team, either during an outpatient follow-up visit or via telephone interview.The SSQ-8 consists of 8 items covering satisfaction with postoperative pain control, return to daily activities, return to work and exercise, overall surgical results, and willingness to undergo or recommend the same procedure. Each item is rated on a 5-point Likert scale from 0 to 4, with higher scores indicating greater satisfaction. The standardized total score (range 0–100) was calculated by multiplying the mean score of completed items by 25.As the SSQ-8 was originally developed and validated in patients undergoing pelvic floor

surgery, and its Chinese version was applied for exploratory use in this hepatobiliary surgical cohort, this patient-reported outcome was considered exploratory.

2.5 Propensity score matching

To reduce baseline differences between the two treatment groups, propensity score matching was performed in the pre-matching cohort.Propensity scores, representing the probability of receiving LCBDE + LC, were estimated using a multivariable logistic regression model. The following baseline covariates were included in the model: sex, age, body mass index, white blood cell count, total bilirubin, alanine aminotransferase, maximum stone diameter, and common bile duct diameter. These covariates were selected based on their clinical relevance and potential associations with treatment allocation and outcomes.Patients were matched in a 1:1 ratio using greedy nearest-neighbor matching without replacement. A standardized caliper width of 0.20 standard deviations of the estimated propensity score was applied[10]. Matching was conducted in descending order of the estimated propensity score. No additional trimming based on a prespecified common-support restriction was performed. Patients without an eligible match within the specified caliper were left unmatched and excluded from the matched analysis. Propensity score estimation and matching were performed using the MatchIt package in R[12].Covariate balance before and after matching was assessed primarily using absolute standardized mean differences (SMDs) rather than hypothesis-testing P values. An absolute SMD < 0.10 was considered indicative of adequate balance, whereas an SMD ≥ 0.10 indicated residual imbalance [11]. Covariate balance was summarized in Table 1 and visually assessed using a Love plot (Fig. 1).

Table 1
Baseline Characteristics Before and After Propensity Score Matching

Variable	Before PSM				After PSM			
	LCBDE + LC (n = 299)	ERCP/EST + LC (n = 299)	Absolute SMD	P value	LCBDE + LC (n = 206)	ERCP/EST + LC (n = 206)	Absolute SMD	P value
Age (years)	71.0 (61.0-77.5)	67.0 (56.0–75.0)	0.302	< 0.001	69.0 (61.0–75.0)	69.0 (60.0–77.0)	0.032	0.977
Male sex, n (%)	142 (47.5)	153 (51.2)	0.074	0.368	103 (50.0)	100 (48.5)	0.029	0.841
Body mass index (kg/m²)	23.88 (21.64–25.82)	24.80 (22.62–27.21)	0.318	< 0.001	24.22 (21.66–26.41)	24.22 (22.11–26.41)	0.035	0.720
White blood cell count (×10⁹/L)	8.28 (5.46–12.15)	7.18 (5.05–10.16)	0.141	0.014	7.92 (5.43–11.63)	7.36 (5.20-10.85)	0.037	0.788
Total bilirubin (μmol/L)	45.63 (17.41–75.63)	25.83 (14.19–59.60)	0.297	< 0.001	36.74 (15.33–71.68)	31.05 (14.42–69.93)	0.105	0.320
Alanine aminotransferase (U/L)	125.0 (55.5–232.0)	93.0 (27.0-258.0)	0.026	0.069	123.5 (46.0-229.0)	113.0 (24.5-262.3)	0.020	0.787
Common bile duct diameter (mm)	13.0 (12.0–15.0)	11.0 (10.0–13.0)	0.549	< 0.001	13.0 (11.0–15.0)	12.0 (10.0–14.0)	0.122	0.008
Maximum stone diameter (mm)	8.0 (5.3–12.0)	6.0 (4.0–8.0)	0.385	< 0.001	7.5 (5.0–11.0)	6.0 (5.0–9.0)	0.128	< 0.001

Data are presented as median (interquartile range) or n (%). Before PSM, continuous variables were compared using the Mann-Whitney U test and categorical variables using the chi-square test. After PSM, paired continuous variables were compared using the Wilcoxon signed-rank test and paired categorical variables using the exact McNemar test. An absolute SMD < 0.10 was considered indicative of adequate covariate balance. Before-matching values are based on the supplied complete-case analytic dataset (n = 299 per group)., laparoscopic common bile duct exploration; LC, laparoscopic cholecystectomy; ERCP, endoscopic retrograde cholangiopancreatography; EST, endoscopic sphincterotomy; PSM, propensity score matching; SMD, standardized mean difference.

Absolute standardized mean differences are shown for each baseline covariate before and after 1:1 matching. The dashed vertical line indicates the prespecified balance threshold of 0.10. Most covariates achieved adequate balance after matching; mild residual imbalance remained in total bilirubin, common bile duct diameter, and maximum stone diameter. PSM, propensity score matching.

2.6 Statistical analysis

Continuous variables were summarized as medians with interquartile ranges (IQRs), and categorical variables were summarized as frequencies and percentages. In the unmatched cohort, continuous variables were compared using

the Mann–Whitney U test, whereas categorical variables were compared using Pearson's chi-square test or Fisher's exact test, as appropriate. In the propensity score-matched cohort, paired continuous variables were compared using the Wilcoxon signed-rank test, and paired categorical variables were compared using the exact McNemar test. The matched cohort served as the primary analytic cohort.For binary clinical outcomes in the matched cohort, odds ratios (ORs) and corresponding 95% confidence intervals (CIs) comparing LCBDE + LC with ERCP/EST + LC were estimated using conditional logistic regression, with the matched-pair identifier specified as the stratification variable[13]. The ERCP/EST + LC group was used as the reference category.All statistical tests were two-sided, and a P value < 0.05 was considered statistically significant. No adjustment for multiple comparisons was performed; therefore, findings for additional clinical outcomes were interpreted as exploratory. No imputation of missing data was performed, and analyses were based on complete cases. Descriptive statistics and group comparisons were performed using IBM SPSS Statistics for Windows, version 32.0.0 (IBM Corp., Armonk, NY, USA). Propensity score matching, covariate balance assessment, conditional logistic regression, and graphical analyses were performed using R version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria), with the MatchIt, cobalt, survival, and ggplot2 packages, as appropriate.

3. Results

3.1 Study cohort and covariate balance

A total of 623 patients were screened for eligibility. After application of the eligibility criteria, 25 patients were excluded: 12 had a history of prior cholecystectomy, 3 underwent ERCP alone without subsequent laparoscopic cholecystectomy, 6 underwent concomitant hemihepatectomy, and 4 declined definitive treatment or were transferred to another facility. The resulting pre-matching cohort comprised 598 patients, including 299 patients in the LCBDE + LC group and 299 in the ERCP/EST + LC group. After 1:1 propensity score matching, 206 patients from each group were retained, yielding 206 matched pairs for the primary matched analysis.Before matching, imbalance was observed in several baseline covariates. Covariate balance improved after matching, with most variables achieving absolute standardized mean differences (SMDs) < 0.10. Mild residual imbalance remained for total bilirubin (SMD, 0.105), common bile duct diameter (SMD, 0.122), and maximum stone diameter (SMD, 0.128), each slightly exceeding the balance threshold of 0.10. Baseline characteristics and covariate balance before and after matching are summarized in Table 1, and covariate balance is visualized using a Love plot (Fig. 1).

3.2 Procedural and hospitalization outcomes

The median total procedural time was shorter in the LCBDE + LC group than in the ERCP/EST + LC group [150.0 (115.0–195.0) vs 177.0 (159.2–193.0) min; P < 0.001]. The median length of hospital stay was longer in the LCBDE + LC group [14.0 (12.0–17.0) vs 11.0 (8.0–13.0) days; P < 0.001], whereas the median total hospitalization cost was lower [2.99 (2.55–3.63) vs 4.04 (3.36–4.70) × 10^4 CNY; P < 0.001]. These main comparative outcomes are summarized in Table 2 and visualized in Fig. 2A–C.Conversion to open surgery, a secondary clinical outcome, occurred in 4 of 206 patients (1.9%) in the LCBDE + LC group and 1 of 206 patients (0.5%) in the ERCP/EST + LC group, with no statistically significant between-group difference (P = 0.375). Given the low incidence of this event, the result was interpreted with caution. Data are presented in Table 2.

Table 2
Procedural and Hospitalization Outcomes After Propensity Score Matching

Variable	LCBDE + LC (n = 206)	ERCP/EST + LC (n = 206)	P value
LCBDE + LC operative time (min)	150.0 (115.0-195.0)	—	—
ERCP/EST procedure time (min)	—	30.0 (22.0–41.0)	—
LC operative time (min)	—	144.0 (131.2–154.0)	—
Total procedural time (min)	150.0 (115.0-195.0)	177.0 (159.2–193.0)	< 0.001
Conversion to open surgery	4 (1.9)	1 (0.5)	0.375
Length of hospital stay (days)	14.0 (12.0–17.0)	11.0 (8.0–13.0)	< 0.001
Total hospitalization cost (×10⁴ CNY)	2.99 (2.55–3.63)	4.04 (3.36–4.70)	< 0.001

Data are presented as median (interquartile range) or n (%). Continuous variables were compared using the Wilcoxon signed-rank test, and conversion to open surgery was compared using the exact McNemar test. P values were not calculated for procedure-specific time components because the corresponding procedure was not applicable to both groups. In the LCBDE + LC group, total procedural time was equivalent to the duration of the combined operation. In the ERCP/EST + LC group, total procedural time was calculated for each patient as the sum of ERCP/EST procedure time and LC operative time. CNY, Chinese yuan.

Box-and-jitter plots compare (A) total procedural time, (B) length of hospital stay, (C) total hospitalization cost, and (D) standardized SSQ-8 score assessed approximately 1 month after hospital discharge between the LCBDE + LC and ERCP/EST + LC groups. Points represent individual patients; center lines and boxes represent medians and interquartile ranges, respectively. Whiskers extend to 1.5 times the interquartile range. P values were calculated using the Wilcoxon signed-rank test for matched pairs. Higher SSQ-8 scores indicate greater early treatment satisfaction.

3.3 Stone clearance, postoperative complications, and satisfaction

Incomplete stone clearance occurred in 7 of 206 patients (3.4%) in the LCBDE + LC group and 9 of 206 patients (4.4%) in the ERCP/EST + LC group, with no statistically significant between-group difference (P = 0.774). No statistically significant between-group differences were observed in intra-abdominal infection, biliary bleeding, postoperative pancreatitis, postoperative cholangitis, or bile leakage (all P > 0.05) (Table 3).At approximately 1 month after hospital discharge, the median standardized SSQ-8 score was higher in the LCBDE + LC group than in the ERCP/EST + LC group [86.0 (83.0–90.0) vs 82.0 (79.0–86.0) points; P < 0.001] (Table 3 and Fig. 2D).Conditional logistic regression stratified by matched-pair identifier showed no statistically significant associations between treatment strategy and any of the binary clinical outcomes evaluated (Fig. 3). Confidence intervals were wide for uncommon outcomes, particularly conversion to open surgery and bile leakage, reflecting limited precision of the corresponding effect estimates.

Table 3
Postoperative Complications, Stone Clearance, and Patient Satisfaction After Propensity Score Matching

Variable	LCBDE + LC (n = 206)	ERCP/EST + LC (n = 206)	P value
Incomplete stone clearance	7 (3.4)	9 (4.4)	0.774
Intra-abdominal infection	3 (1.5)	2 (1.0)	1.000
Biliary bleeding	4 (1.9)	4 (1.9)	1.000
Postoperative pancreatitis	4 (1.9)	7 (3.4)	0.508
Postoperative cholangitis	5 (2.4)	6 (2.9)	1.000
Bile leakage	4 (1.9)	1 (0.5)	0.375
SSQ-8 score (points)	86.0 (83.0–90.0)	82.0 (79.0–86.0)	< 0.001

Data are presented as median (interquartile range) or n (%). Categorical outcomes were compared using the exact McNemar test, and the SSQ-8 score was compared using the Wilcoxon signed-rank test. SSQ-8, Surgical Satisfaction Questionnaire-8.

Odds ratios and 95% confidence intervals were estimated using conditional logistic regression stratified by matched pair, with ERCP/EST + LC as the reference group. An odds ratio below 1.0 indicates lower odds of the adverse outcome with LCBDE + LC, whereas an odds ratio above 1.0 indicates higher odds. CI, confidence interval; LCBDE, laparoscopic common bile duct exploration; LC, laparoscopic cholecystectomy; ERCP, endoscopic retrograde cholangiopancreatography; EST, endoscopic sphincterotomy.

4. Discussion

4.1 Principal findings

In this propensity score-matched retrospective cohort, single-stage LCBDE + LC was associated with a shorter total procedural time and lower total hospitalization cost, but a longer hospital stay, compared with staged ERCP/EST + LC. No statistically significant between-group differences were observed in conversion to open surgery, incomplete stone clearance, or any of the individual postoperative complications evaluated. In addition, the standardized SSQ-8 score assessed approximately 1 month after hospital discharge was higher in the LCBDE + LC group. Taken together, these findings suggest that the two treatment strategies may differ not only in procedural burden and resource utilization but also in early patient-reported experience. However, the mild residual covariate imbalance after matching and the limited precision of estimates for uncommon adverse events should be considered when interpreting these findings.

4.2 Comparison with previous evidence

Our findings regarding stone clearance and postoperative complications are broadly consistent with randomized trials and meta-analyses indicating that both single-stage laparoscopic and staged endoscopic-surgical strategies can achieve effective ductal clearance with acceptable perioperative outcomes in appropriately selected patients and experienced centers [5–7, 15]. Nevertheless, previous studies have reported heterogeneous findings for

outcomes including stone clearance, post-ERCP pancreatitis, bile leakage, length of hospital stay, and treatment-related costs. Such heterogeneity may reflect differences in patient selection, stone burden, procedural techniques, operator expertise, postoperative management, and institutional treatment pathways[1, 3, 5–7].The present study adds a contemporary real-world perspective to the existing randomized and pooled evidence. In routine clinical practice, treatment allocation may be influenced by disease complexity, patient characteristics, local expertise, and procedural availability. Although propensity score matching reduced measured baseline differences between the treatment groups, it cannot eliminate residual confounding arising from imperfectly balanced measured variables or unmeasured factors. Accordingly, the present findings should be considered complementary to existing randomized evidence rather than evidence of causal superiority of either treatment strategy [13–14].

4.3 Interpretation of procedural time, cost, and hospital stay

The shorter total procedural time observed with LCBDE + LC is clinically plausible because common bile duct exploration and cholecystectomy are completed during a single operative session, whereas the ERCP/EST + LC pathway requires separate endoscopic and laparoscopic procedures. Importantly, total procedural time in the present study was calculated from the actual durations of the procedures and did not include the interval between ERCP/EST and subsequent LC. It should therefore be interpreted primarily as a measure of procedural workload rather than the total elapsed duration of the treatment pathway.The lower total hospitalization cost observed with LCBDE + LC may partly reflect avoidance of a separate therapeutic endoscopic procedure and the associated procedural resources and peri-procedural care,A recent comparative cohort similarly reported lower hospitalization costs with LCBDE + LC than with ERCP/EST + LC[15]. However, hospitalization costs are strongly influenced by local billing systems, procedural charges, resource utilization, and institutional practice patterns. Therefore, the observed difference should not be interpreted as evidence of universal economic superiority or as the result of a formal cost-effectiveness analysis.In contrast, the longer hospital stay observed in the LCBDE + LC group (median, 14 vs 11 days) warrants particular consideration. A previous meta-analysis of randomized trials reported a shorter hospital stay with single-stage LCBDE + LC [6], and a recent retrospective comparative study also reported a modestly shorter stay following LCBDE + LC [15]. However, a 2025 meta-analysis of randomized controlled trials found no statistically significant difference in hospital stay between single-stage laparoscopic and staged endoscopic-surgical management [7]. Thus, the longer hospital stay observed in our cohort differs from some, but not all, previous evidence and may partly reflect institution-specific perioperative management. In the LCBDE + LC pathway, patients underwent choledochotomy closure followed by postoperative subhepatic drainage, with drains generally removed 3–5 days postoperatively when predefined clinical criteria were satisfied, which may have prolonged postoperative observation. In contrast, in the ERCP/EST + LC pathway, endoscopic nasobiliary drainage was routinely used, and LC was generally performed during the same hospitalization, usually within approximately 24 h after successful ERCP/EST. This relatively streamlined staged pathway may have contributed to the shorter observed hospital stay. Differences in discharge criteria and residual disease complexity may also have contributed. These explanations remain hypothesis-generating because the relative contributions of individual perioperative factors were not formally quantified.

4.4 Safety and patient-reported satisfaction

No statistically significant between-group difference was identified for any individual postoperative complication. However, the absolute number of adverse events was small, resulting in wide confidence intervals for several effect estimates. For example, the estimated ORs for conversion to open surgery and bile leakage were both 4.00, with corresponding 95% CIs of 0.45–35.79. Therefore, the absence of statistical significance should not be interpreted

as evidence of equivalence or comparable safety. Larger multicenter cohorts or pooled analyses are required to estimate differences in uncommon adverse events with greater precision.

The standardized SSQ-8 score was higher in the LCBDE + LC group approximately 1 month after hospital discharge. This finding suggests that patient-reported experience may provide information beyond conventional technical and perioperative outcomes. Potential explanations include differences in treatment burden, hospitalization cost, and recovery expectations; however, these factors were not directly measured in the present study. The SSQ-8 was originally developed and validated in patients undergoing surgery for pelvic organ prolapse and/or urinary incontinence rather than hepatobiliary surgery. Its exploratory application in the present study therefore provides an additional patient-centered perspective on this surgical comparison, but its measurement properties in biliary surgery remain uncertain. Furthermore, an established minimal clinically important difference for the SSQ-8 in this population is unavailable. Consequently, although the observed 4-point between-group difference was statistically significant, its clinical importance remains uncertain, and this patient-reported finding should be regarded as exploratory.

4.5 Clinical implications

For appropriately selected patients treated in centers with advanced laparoscopic biliary expertise and suitable equipment, LCBDE + LC may represent an efficient single-stage alternative to staged ERCP/EST + LC, particularly when reducing procedural burden and hospitalization cost is considered clinically relevant. However, the present findings do not establish the universal superiority of either strategy. Treatment selection should remain individualized according to patient fitness, biliary anatomy, stone burden, endoscopic and surgical expertise, and local procedural availability .The present findings should not be extrapolated to patients requiring emergency biliary decompression for severe acute cholangitis or to those who are poor candidates for laparoscopic surgery. In patients with acute cholangitis requiring biliary decompression, guidelines support endoscopic drainage as the preferred approach when feasible [16]. More broadly, the findings support a patient- and center-specific treatment strategy in which clinical characteristics and local expertise, rather than a single universally preferred pathway, guide treatment selection.

4.6 Limitations

Several limitations should be considered when interpreting these findings. From a methodological perspective, the retrospective observational design remains susceptible to residual and unmeasured confounding despite propensity score matching. In addition, total bilirubin, common bile duct diameter, and maximum stone diameter retained mild residual imbalance after matching (SMDs, 0.105, 0.122, and 0.128, respectively), which may have contributed to residual confounding and influenced the estimated between-group associations. Propensity score matching also excluded patients without suitable counterparts; consequently, the matched estimates primarily apply to the matched population rather than to the entire source cohort.External generalizability is limited by the single-center design. Treatment selection, operator expertise, postoperative drainage practices, discharge criteria, procedural scheduling, and local cost structures may differ across institutions and healthcare systems. In particular, the longer hospital stay observed with LCBDE + LC may partly reflect local perioperative management rather than an inherent characteristic of the surgical strategy.Outcome assessment also had limitations. Postoperative complications were ascertained retrospectively from routine clinical records during the index hospitalization, which may have introduced misclassification and may not have captured adverse events occurring after discharge. The small number of several adverse events resulted in wide confidence intervals and limited statistical power to detect clinically meaningful between-group differences. Furthermore, although the SSQ-8 provided an exploratory measure of patient-reported experience, it has not been specifically validated in a hepatobiliary surgical population, and the

clinical relevance of the observed score difference remains uncertain.Finally, long-term outcomes were not systematically evaluated. Recurrent common bile duct stones, late biliary complications, and the longer-term consequences of endoscopic sphincterotomy or choledochotomy may be important when comparing these two treatment pathways and should be evaluated in prospective multicenter studies with standardized follow-up.

5. Conclusions

Among propensity score-matched patients with concomitant gallbladder and common bile duct stones, LCBDE + LC was associated with a shorter total procedural time, lower total hospitalization cost, and higher standardized SSQ-8 scores, but a longer hospital stay, compared with staged ERCP/EST + LC. No statistically significant between-group differences were observed in conversion to open surgery, incomplete stone clearance, or any of the individual postoperative complications evaluated. These findings suggest that LCBDE + LC may represent a reasonable single-stage alternative for appropriately selected patients in centers with advanced laparoscopic biliary expertise. Given the residual covariate imbalance and single-center design, prospective multicenter studies with standardized long-term follow-up are warranted to confirm these findings.

Declarations

Author Contribution

ZL: Study conception and design, data acquisition, statistical analysis, manuscript drafting.QZ: Study supervision, critical manuscript revision, funding acquisition.JW: Clinical data verification, result interpretation.HZ: Patient data collection, data curation.CL: Statistical verification, result validation.NQ: Literature retrieval, table formatting.ZA: Reference management, literature screening.HS: Manuscript proofreading, figure preparation.All authors have read and approved the final manuscript.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to patient privacy protection and hospital data access restrictions, but are available from the corresponding author on reasonable request after approval by the Institutional Ethics Committee.

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Figures

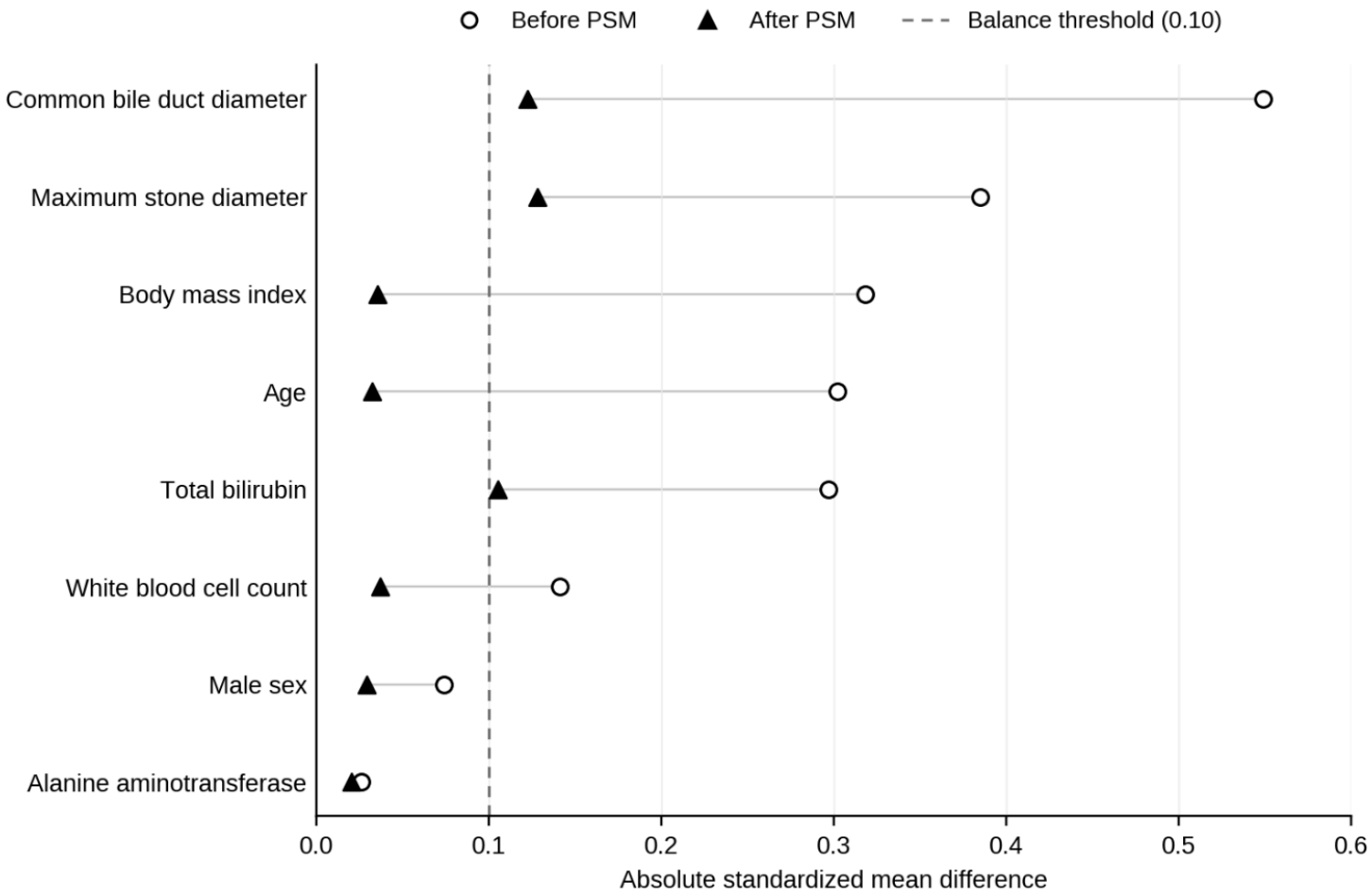


Figure 1

Covariate balance before and after propensity score matching.

Absolute standardized mean differences are shown for each baseline covariate before and after 1:1 matching. The dashed vertical line indicates the prespecified balance threshold of 0.10. Most covariates achieved adequate balance after matching; mild residual imbalance remained in total bilirubin, common bile duct diameter, and maximum stone diameter. PSM, propensity score matching.

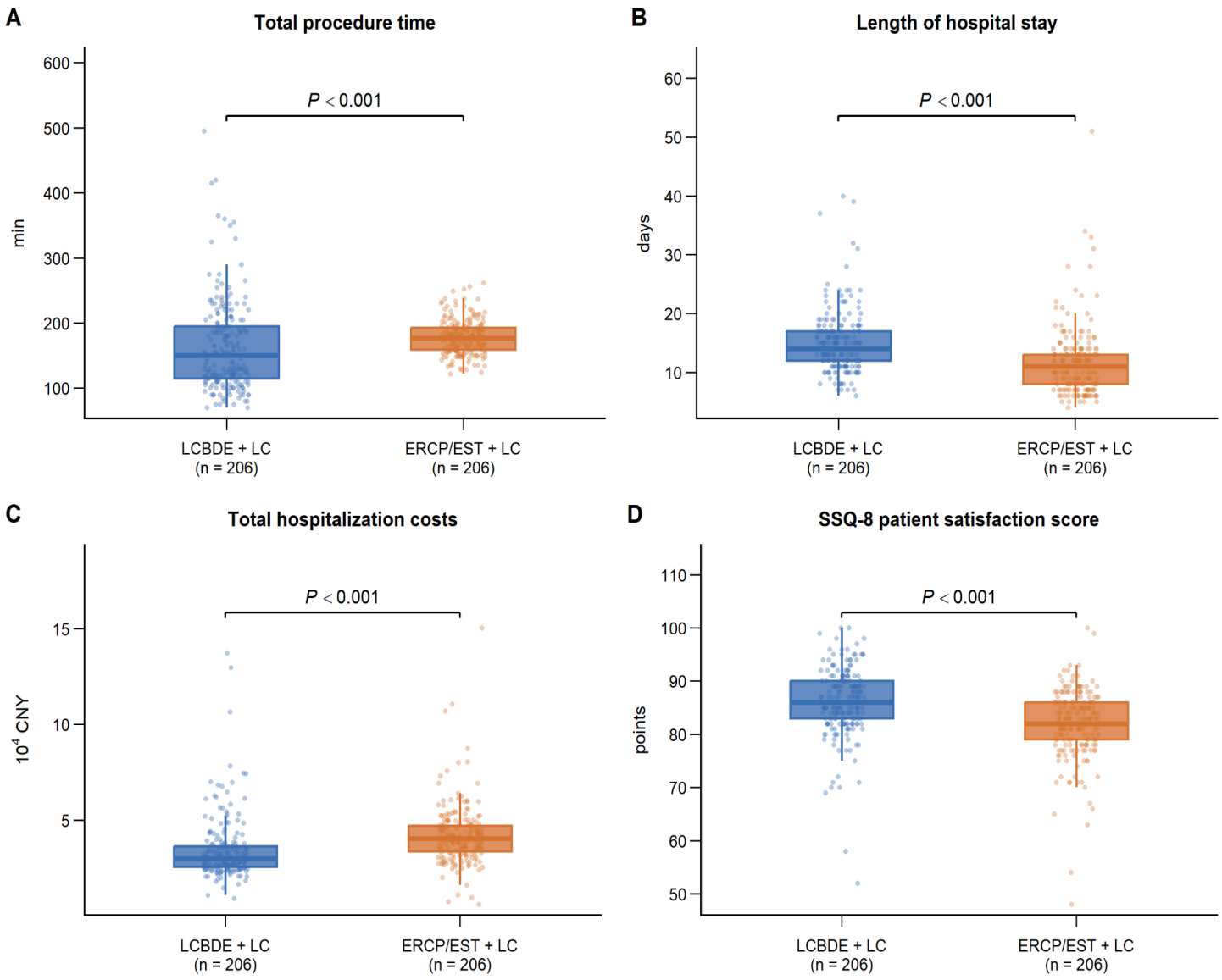


Figure 2

Continuous outcomes after propensity score matching.

Box-and-jitter plots compare (A) total procedural time, (B) length of hospital stay, (C) total hospitalization cost, and (D) standardized SSQ-8 score assessed approximately 1 month after hospital discharge between the LCBDE + LC and ERCP/EST + LC groups. Points represent individual patients; center lines and boxes represent medians and interquartile ranges, respectively. Whiskers extend to 1.5 times the interquartile range. P values were calculated using the Wilcoxon signed-rank test for matched pairs. Higher SSQ-8 scores indicate greater early treatment satisfaction.

Outcome	LCBDE + LC (n=206), n/N (%)	ERCP/EST + LC (n=206), n/N (%)	OR (95% CI)	P value
Incomplete stone clearance	7/206 (3.4%)	9/206 (4.4%)	0.71 (0.23–2.25)	0.566
Conversion to open surgery	4/206 (1.9%)	1/206 (0.5%)	4.00 (0.45–35.79)	0.215
Intra-abdominal infection	3/206 (1.5%)	2/206 (1.0%)	1.50 (0.25–8.98)	0.657
Biliary bleeding	4/206 (1.9%)	4/206 (1.9%)	1.00 (0.25–4.00)	1.000
Postoperative pancreatitis	4/206 (1.9%)	7/206 (3.4%)	0.50 (0.13–2.00)	0.327
Postoperative cholangitis	5/206 (2.4%)	6/206 (2.9%)	0.80 (0.21–2.98)	0.739
Bile leakage	4/206 (1.9%)	1/206 (0.5%)	4.00 (0.45–35.79)	0.215

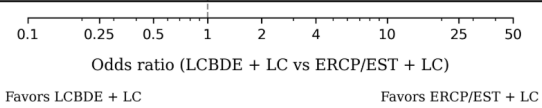


Figure 3

Associations between treatment strategy and binary clinical outcomes after propensity score matching.

Odds ratios and 95% confidence intervals were estimated using conditional logistic regression stratified by matched pair, with ERCP/EST + LC as the reference group. An odds ratio below 1.0 indicates lower odds of the adverse outcome with LCBDE + LC, whereas an odds ratio above 1.0 indicates higher odds. CI, confidence interval; LCBDE, laparoscopic common bile duct exploration; LC, laparoscopic cholecystectomy; ERCP, endoscopic retrograde cholangiopancreatography; EST, endoscopic sphincterotomy.