

Outcomes of Laparoscopic Versus Open Excision of Choledochal Cyst in Preschool-Aged Children: Analysis From a Nationally Representative Database

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Abstract

Background

Laparoscopic surgery for choledochal cysts (CC) in young children is a technically demanding procedure, and comparative outcomes with open surgery remain incompletely defined. This study aims to compare outcomes of laparoscopic surgery (LS) and open surgery (OS) in children ≤ 5 years.

Methods

A retrospective cohort study was conducted using the Pediatric Health Information System (PHIS) database to identify children with CC who underwent definitive surgical excision between 2015 and 2025. Patients were grouped by operative approach (LS vs OS). Demographic characteristics, operative techniques, and postoperative outcomes were compared.

Results

A total of 533 children were included (LS: 251, 47.1%; OS: 282, 52.9%). LS was more often performed during elective admissions ($p < 0.001$) and in older children ($p < 0.001$). Preoperative malnutrition ($p = 0.032$), cholangitis ($p = 0.029$), and the need for drainage procedures prior to definitive surgery ($p = 0.050$) were more common in OS. Hepaticoduodenostomy predominated in LS, while hepaticojejunostomy was more common with OS ($p < 0.001$). There were no differences in overall 90-day postoperative complications ($p = 0.618$). LS was associated with fewer blood transfusions ($p = 0.049$), total parenteral nutrition ($p = 0.005$), and mechanical ventilation ($p = 0.001$), decreased odds of intensive care unit admission ($p < 0.001$), and shorter length of stay ($p < 0.001$). At 90-day follow-up, biliary calculi were more common after LS (2.8% vs 0.4%, $p = 0.029$), while hepatic fibrosis was observed only after OS (3.5%, $p = 0.002$).

Conclusion

In preschool-aged children with choledochal cysts, laparoscopic and open approaches demonstrate similar short-term complication rates. Laparoscopy is associated with improved perioperative recovery and reduced resource utilization. When patient and disease factors permit, LS represents a reasonable primary operative approach, although careful patient selection remains essential.

1. Introduction

Choledochal cysts (CC) are rare malformations of the biliary tract, with an estimated incidence of about 1:100,000-150,000 live births in Western countries. [1, 2] The disease manifests with obstructive jaundice, cholangitis, and pancreatitis. If left untreated, recurrent infections and chronic inflammation

may lead to liver fibrosis and malignancy.[3] Therefore, complete cyst excision and reconstruction of the biliary system is the standard of care for the management of this malformation.[3–5] However, there is still considerable variability worldwide in the types of surgical approaches and biliary-enteric anastomoses for CC.[6] Multicenter studies revealed that about 28% of surgeons in the USA and 36.5% in Asia perform CC resections laparoscopically, whereas in Europe, it is less commonly used, with young age remaining the main limiting factor.[5, 7–9] The aim of the present study is to evaluate, at a national level, short- and mid-term outcomes in young children who underwent laparoscopic surgery for choledochal cysts.

2. Methods

2.1 Data source and study period

This study was a retrospective cohort analysis of a national database that included children aged 5 years or younger with CC who underwent cyst excision and bilioenteric reconstruction between October 2015 and May 2025. Data were extracted from the Pediatric Health Information System (PHIS) database, which is administered and maintained by the Children's Hospital Association (Lenexa, KS). The PHIS database includes inpatient, ambulatory, and emergency department clinical data and resource utilization from children's hospitals in the United States participating in the program. Data are de-identified and undergo reliability and validity checks before being incorporated into the database. Forty-six hospitals that treat CC were identified in the PHIS database. This study was exempt from Institutional Review Board review and approval as data were obtained from a de-identified database.

2.2 Cohort Construction

The International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) was used to identify children with a discharge diagnosis of choledochal cysts (ICD-10-CM code: Q44.4). The analysis included children aged 5 years or younger at the time of definitive hepatobiliary surgery. Principal and secondary operative procedures associated with the index hospitalization were extracted and reviewed to determine the surgical approach, laparoscopic or open, and the type of definitive hepatobiliary treatment, Roux-en-Y hepaticojejunostomy (RNYHJ) or hepaticoduodenostomy (HD) (Supplementary Table 1). Patient data were further reviewed to identify the presence of associated congenital malformations, symptoms, and secondary diagnoses indicating bile duct obstruction, preoperative cholangitis, pancreatitis, cyst perforations at the time of the index admission for surgery, or at any previous encounter prior to the index admission. Excluded from the analysis were encounters involving only diagnostic procedures, such as imaging or biopsy, or medical treatments (i.e. antibiotics or intravenous nutritional support) indicated by principal and/or secondary procedure codes. Because the number of patients who had robotic-assisted procedures in this cohort was small ($n = 17$), these cases were excluded to reduce confounding factors and maintain homogeneity in the study groups. Additionally, since there is no specific code for cystic biliary atresia, cases where the primary diagnosis (Q44.4: choledochal cyst) was paired with a secondary diagnostic code (Q44.2: biliary atresia) were also

excluded from the analysis to reduce selection bias. Details of the cohort construction, including inclusion and exclusion criteria, are shown in Fig. 1. The cohort was divided into two groups based on surgical approach: laparoscopic surgery (LS) and open surgery (OS). Preoperative characteristics and follow-up outcomes were compared between groups. Data from procedures converted from laparoscopic to open were analyzed within the original laparoscopic group, following the intention-to-treat principle.

2.3 Outcomes

Postoperative complications were identified by the presence of an extractable complication “Flag” during the index admission and associated diagnostic codes indicating cholangitis, adhesive small bowel obstruction, wound infection, bile leak, pancreatitis at any emergency department (ED) visit, or inpatient/observation unit/ambulatory surgery readmission following the index hospitalization. Diagnostic codes used to identify anastomotic stenosis were ICD-10 codes: K83.1 (obstruction of the bile duct), which covers acquired stenosis/stricture and occlusion, and K91.89 (other postprocedural complications and disorders of the digestive system). Given the rare occurrence of complications in children undergoing surgery for CC, our primary outcome of interest was the occurrence of any 90-day postoperative complication. Complications were classified according to the Clavien-Madadi classification.[10]

Secondary outcomes were blood transfusion, used as a proxy for intraoperative blood loss since this variable is not available in the PHIS database, total parenteral nutrition (TPN), intensive care unit (ICU) admission, and mechanical ventilation, identified by the extractable “Flags” based on predefined combinations of ICD-10 diagnostic codes and clinical transaction category (CTC) indicators of resource utilization. Additional secondary outcomes included postoperative length of stay (LOS) and inpatient readmissions within 90 days. Short-term follow-up was defined as outcomes within 90 days postoperatively. Mid-term follow-up was defined as the most recent follow-up available. To compare mid-term outcomes between the two groups, secondary outcomes also encompassed complications, any subsequent surgical procedures, overall readmissions, and inpatient readmissions at the latest follow-up.

2.4 Statistical analysis

Demographic information, clinical characteristics, and postoperative outcomes were compared between groups. Categorical variables were reported as numbers and percentages and analyzed using the Chi-square test and Fisher's exact test, as appropriate. Continuous variables were tested for normality with the Shapiro-Wilk test. Data with skewed distributions were reported as medians and interquartile range (IQR). The nonparametric Mann-Whitney U test was used to compare age at surgery, LOS, and postoperative follow-up duration between groups.

Unadjusted and adjusted logistic regression analyses and a generalized linear model were used to examine the effects of patient and surgical characteristics on 90-day overall complications, ICU

admission, inpatient hospital readmission, and hospital length of stay (LOS). The results of the regression analyses are presented as odds ratios (OR), β coefficients and 95% confidence intervals (CI). The regression models were built using forward stepwise methods for including covariates; variables significant at $p < 0.15$ in bivariate analysis were incorporated into the final models. Variables with wide confidence intervals, even if statistically significant, were excluded from the model because their true effect on the outcome could not be confidently explained due to the small number of events in this cohort. Despite meeting the significance threshold of $p < 0.15$ in the unadjusted regression analysis for binary outcomes, certain variables were omitted from the final model because their inclusion adversely affected calibration, as assessed by the Hosmer-Lemeshow goodness-of-fit test. For the continuous variables, following bivariate screening, we tested 3 models. The selected model was the one with the best fit to the data, based on the lowest absolute values of the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), which outperformed the models that included all significant covariates in the bivariate analysis. Additionally, age at surgery was selected a priori due to its clinical importance rather than statistical significance. IBM SPSS Statistics for Windows, version 29.0 (IBM Corp., Armonk, NY, USA), was used for all statistical analyses. The significance level was set at $p < 0.05$.

3. Results

3.1 Cohort characteristics

Of the 533 patients meeting inclusion criteria, 251 (47.1%) underwent LS, and 282 (52.9%) underwent OS. Preoperative characteristics are summarized in Table 1. Children in the LS group were older than those in the OS group (median age 26.8 vs 16.5 months, $p < 0.001$). Cholangitis was less common in children who underwent LS (6.8% vs 12.4%, $p = 0.029$), and those who underwent OS were more often malnourished or had failure to thrive (7.8% vs 13.1%, $p = 0.032$). Intestinal malrotation was present in 7 patients (2.5%) in the OS group and none in the LS group ($p = 0.016$). Preoperative percutaneous biliary or gallbladder drainage was less frequent in the LS group (1.2% vs 4.2%, $p = 0.050$), with no differences in preoperative interventional endoscopic retrograde cholangiopancreatography (ERCP) (Table 1).

Table 1
Preoperative Cohort Characteristics

Cohort Characteristics	LS Group N = 251	OS Group N = 282	P value
Demographics			
	Median (IQR)	Median (IQR)	
Age at Surgery, months	26.8 (10.2–48.9)	16.5 (4.7–38.7)	< 0.001
	N (%)	N (%)	
Preterm	46 (18.3)	53 (18.8)	0.912
Female	192 (76.5)	203 (72.0)	0.276
Race			0.146
White	126 (50.2)	120 (42.4)	
Black	34 (13.5)	45 (16)	
Asian	36 (14.3)	34 (12.1)	
Other	55 (21.9)	82 (29.2)	
Hispanic	64 (25.5)	74 (26.2)	0.921
Associated Comorbidities			
Total Comorbidities	69 (27.5)	95 (33.8)	0.132
Genetic syndromes/Congenital malformations	7 (2.8)	12 (4.3)	0.484
Annular pancreas/Other pancreatic malformations	10 (4.0)	15 (5.3)	0.541
Intestinal atresia	3 (1.2)	6 (2.1)	0.511
Intestinal malrotation	0 (0)	7 (2.5)	0.016
GERD	8 (3.2)	14 (5.0)	0.385
Cardiovascular	18 (7.2)	32 (11.3)	0.104
Hematologic/Immunologic	6 (2.4)	7 (2.5)	1.000
<i>*Technology-dependent refers to children with gastrostomy, tracheostomy, and/or ventriculoperitoneal shunt, or any other device. †Asymptomatic at presentation were medical records with no associated secondary diagnosis indicating symptoms or complications of choledochal cysts at any hospital encounter before surgery and/or at admission for definitive surgery. LS: laparoscopic surgery; OS: open surgery; GERD: gastroesophageal reflux disease; BD: biliary duct; ERCP: endoscopic retrograde cholangiopancreatography.</i>			

Cohort Characteristics	LS Group N = 251	OS Group N = 282	P value
Malignancy	2 (0.8)	2 (0.7)	1.000
Metabolic	12 (4.8)	23 (8.2)	0.160
Neurologic	6 (2.4)	3 (1.1)	0.318
Renal/Urologic	7 (2.8)	8 (2.8)	1.000
Respiratory	3 (1.2)	5 (1.8)	0.728
Technology dependent*	10 (4.0)	14 (5.0)	0.678
Symptoms			
Asymptomatic ^{‡*}	59 (23.5)	64 (22.7)	0.837
Jaundice	36 (14.3)	46 (16.3)	0.550
Acholic stools	5 (2.0)	11 (3.9)	0.216
Abdominal mass/distension	12 (4.8)	10 (3.5)	0.518
Abdominal pain	24 (9.6)	24 (8.5)	0.762
Vomiting	28 (11.2)	34 (12.1)	0.788
Dehydration/Electrolyte disturbance	25 (10.0)	36 (12.8)	0.342
Malnutrition/Failure to Thrive	18 (7.8)	37 (13.1)	0.032
Feeding difficulty	16 (6.4)	20 (7.1)	0.863
Sepsis	2 (0.8)	5 (1.8)	0.456
Cyst perforation	3 (1.2)	7 (2.5)	0.348
Ascites	10 (4.0)	15 (5.3)	0.541
Acute pancreatitis	79 (31.5)	72 (25.5)	0.149
Chronic pancreatitis	8 (3.2)	3 (1.1)	0.126
Cholecystitis	16 (6.4)	12 (4.3)	0.332
Cholangitis	17 (6.8)	35 (12.4)	0.029
<p>*Technology-dependent refers to children with gastrostomy, tracheostomy, and/or ventriculoperitoneal shunt, or any other device. [‡]Asymptomatic at presentation were medical records with no associated secondary diagnosis indicating symptoms or complications of choledochal cysts at any hospital encounter before surgery and/or at admission for definitive surgery. LS: laparoscopic surgery; OS: open surgery; GERD: gastroesophageal reflux disease; BD: biliary duct; ERCP: endoscopic retrograde cholangiopancreatography.</p>			

Cohort Characteristics	LS Group N = 251	OS Group N = 282	P value
BD obstruction	49 (19.5)	54 (19.1)	0.913
Calculus of BD	52 (20.7)	47 (16.7)	0.265
Disorders of bilirubin metabolism	9 (3.6)	21 (7.4)	0.061
Elevated liver enzymes	22 (8.8)	24 (8.5)	1.000
Procedure before definitive reconstruction			
ERCP Interventional	37 (14.7)	35 (12.4)	0.449
ERCP Diagnostic	11 (4.4)	12 (4.3)	1.000
Percutaneous drainage of BD/gallbladder	3 (1.2)	12 (4.2)	0.050
Peritoneal cavity drainage	1 (1.2)	5 (1.8)	0.728
<i>*Technology-dependent refers to children with gastrostomy, tracheostomy, and/or ventriculoperitoneal shunt, or any other device. †Asymptomatic at presentation were medical records with no associated secondary diagnosis indicating symptoms or complications of choledochal cysts at any hospital encounter before surgery and/or at admission for definitive surgery. LS: laparoscopic surgery; OS: open surgery; GERD: gastroesophageal reflux disease; BD: biliary duct; ERCP: endoscopic retrograde cholangiopancreatography.</i>			

LS procedures were more often performed as elective surgeries than OS (80.1% vs 64.2%, $p < 0.001$) (Table 2). The reconstruction technique varied considerably between groups, with HD performed more frequently in LS (72.9% vs 29.8%; $p < 0.001$). Twenty-six laparoscopic cases (10.4%) were converted to open. The conversion rate was noted to be higher in cases with preoperative inflammation, defined as those with cholecystitis, pancreatitis, or cyst perforation, compared to those without (LS: 11, 15% vs OS: 15, 8.4%); however, these differences did not reach statistical significance ($p = 0.115$). Liver biopsy and intraoperative cholangiogram were performed more frequently in OS cases (10.4% vs 19.5%, $p < 0.001$) (Table 2). Intraoperative liver biopsies demonstrated fibrosis in 26.8% of cases, and five patients (1.9%) had cirrhosis diagnosed prior to the index admission.

Table 2
Operative characteristics

	LS Group N = 251	OS Group N = 282	P value
	N (%)	N (%)	
Priority of admission			< 0.001
Elective	201 (80.1)	181 (64.2)	
Urgent/Emergency	50 (19.9)	101 (35.8)	
Reconstruction technique			< 0.001
HJ	68 (27.1)	198 (70.2)	
HD	183 (72.9)	84 (29.8)	
Level of anastomosis			0.449
CHD	197 (78.5)	229 (81.2)	
Above CHD bifurcation	54 (21.5)	53 (18.8)	
Liver Biopsy	16 (10.4)	55 (19.5)	< 0.001
<i>Inflammatory liver disease*</i>	9 (3.5)	5 (1.8)	
<i>Hepatic fibrosis/Cirrhosis</i>	5 (2.0)	14 (5.0)	
Cholangiogram	62 (25.6)	111 (40.8)	< 0.001
<i>LS: laparoscopic surgery; OS: open surgery; HJ: hepaticojejunostomy; HD: hepaticoduodenostomy; CHD: common hepatic duct. *Percentages are reported on the total number of cases in each group.</i>			

3.2 Primary and secondary outcomes

Overall, 75 patients experienced at least one postoperative complication, 33 (13.1%) in the LS group and 42 (14.9%) in the OS group, with no significant difference between groups ($p = 0.618$). Specifically, there were no differences in intraoperative vascular or organ injuries ($p = 0.763$), bile leak ($p = 0.613$), surgical site infection (SSI) ($p = 0.776$), postoperative cholangitis ($p = 0.307$), and biliary duct obstruction or anastomotic strictures ($p = 1.000$). Among postoperative complications, ileus was less common in the LS group (2.0% vs 6.4%, $p = 0.017$) (Table 3). According to the Clavien-Madadi classification, most postoperative complications were minor and more frequently observed in the OS group, whereas there was no significant difference in major complications requiring surgical intervention (Grade IIIA/IIIB) between groups (7.6% vs 8.2%, $p = 0.873$) (Table 3).

Table 3
Postoperative 90-day outcomes

Outcome Variable	LS Group	OS Group	P value
	n = 251	n = 282	
	N (%)	N (%)	
Clavien-Madadi Classification			
Grade IB	11 (4.4)	28 (9.9)	0.019
Grade II	11 (4.4)	33 (11.7)	0.003
Grade IIIA	3 (1.2)	10 (3.5)	0.095
Grade IIIB	16 (6.4)	13 (4.6)	0.445
Complications			
All Complications	33 (13.1)	42 (14.9)	0.618
Intraoperative vascular and organ injuries [‡]	6 (2.4)	5 (1.8)	0.763
Bile leak	9 (3.6)	7 (2.5)	0.613
Sepsis	1 (0.4)	3 (1.1)	0.626
Wound disruption	4 (1.6)	3 (1.1)	0.712
SSI	5 (2.0)	7 (2.4)	0.776
Ascites	0 (0)	4 (1.4)	0.126
Adhesive small bowel obstruction	4 (1.5)	3 (1.1)	1.000
Ileus	5 (2.0)	18 (6.4)	0.017
Incisional hernia without obstruction	3 (1.2)	1 (0.4)	0.347
Portal vein thrombosis	1 (0.4)	1 (0.4)	1.000
Acute pancreatitis	0 (0)	2 (0.7)	0.501
Hospital-acquired pneumonia	3 (1.2)	6 (2.1)	0.511

[‡]Portal vein and hepatic artery injuries, biliary duct lesions, accidental puncture and or laceration of small or large intestine requiring repair; duodenal hematoma. *Lysis of adhesion/repair of mesentery/reduction of intestinal intussusception. LS: laparoscopic surgery; OS: open surgery; SSI: surgical site infection; BD: bile duct; TPN: total parenteral nutrition; ICU: intensive care unit. All complications refer to the number of patients experiencing any complication. Some patients experienced more than one complication. Additionally, the Clavien-Madadi classification, which is based on interventions, overestimated the total number of complications because it includes additional minor complications(e.g. electrolyte imbalance, post-procedural pain), and interventions that may not be performed specifically for a complication but rather to address the worsening of a patient's overall condition, especially in those with poor preoperative health (i.e. blood transfusion, TPN).

Outcome Variable	LS Group	OS Group	P value
	n = 251	n = 282	
	N (%)	N (%)	
Cholangitis	5 (2.0)	10 (3.5)	0.307
Biliary duct obstruction/anastomotic stricture	3 (1.2)	4 (1.4)	1.000
Procedures/Interventions			
Central vein placement	8 (3.2)	26 (9.3)	0.004
Blood transfusions	10 (4.0)	23 (8.2)	0.049
Mechanical ventilation	2 (0.8)	16 (5.7)	0.001
TPN	37 (14.7)	70 (24.8)	0.005
ICU admission	24 (9.6)	65 (23.0)	< 0.001
Relaparotomy for small bowel obstruction*	5 (2.0)	5 (1.8)	1.000
Control bleeding	3 (1.2)	3 (1.1)	1.000
Bilioenteric anastomosis revision	5 (2.0)	3 (1.1)	0.485
Repair of abdominal wall	6 (2.4)	1 (0.4)	0.056
Endoscopic dilation of BD	3 (1.2)	4 (1.4)	1.000
90-day inpatient readmission	10 (4.0)	18 (6.4)	0.247
<p><i>‡Portal vein and hepatic artery injuries, biliary duct lesions, accidental puncture and or laceration of small or large intestine requiring repair; duodenal hematoma. *Lysis of adhesion/repair of mesentery/reduction of intestinal intussusception. LS: laparoscopic surgery; OS: open surgery; SSI: surgical site infection; BD: bile duct; TPN: total parenteral nutrition; ICU: intensive care unit. All complications refer to the number of patients experiencing any complication. Some patients experienced more than one complication. Additionally, the Clavien-Madadi classification, which is based on interventions, overestimated the total number of complications because it includes additional minor complications(e.g. electrolyte imbalance, post-procedural pain), and interventions that may not be performed specifically for a complication but rather to address the worsening of a patient's overall condition, especially in those with poor preoperative health (i.e. blood transfusion, TPN).</i></p>			

In adjusted logistic regression analysis, preoperative ascites was the only patient factor associated with increased odds of overall 90-day postoperative complications (OR: 2.671, 95% CI: 1.041–6.953; $p = 0.041$), whereas male sex was associated with decreased odds (OR: 0.467, 95% CI: 0.239–0.914; $p = 0.026$) (Fig. 2A, Supplementary Table 2). When analyzing the association between patient factors and each specific complication, preoperative cholangitis was associated with increased odds of postoperative bile leak, approaching statistical significance (OR: 3.184, 95% CI: 0.989–10.250; $p = 0.052$).

The OS group received more blood transfusions (4.0% vs 8.2%, $p = 0.049$), total parenteral nutrition (TPN) (14.7% vs 24.8%, $p = 0.005$), and ICU admission (9.6% vs 23%, $p < 0.001$). On multivariable analysis, LS

remained associated with decreased odds of ICU admission (OR: 0.417, 95% CI: 0.244–0.713; $p = 0.001$) (Fig. 2B; Supplementary Table 3). Median LOS was significantly shorter following LS; 5 days (IQR 3.5–7) vs 6 days (IQR 4–8), $p < 0.001$. Multivariable analysis identified feeding difficulties, metabolic “Flag”, and urgent/emergent admission as the strongest predictors of increased LOS ($p < 0.001$). Conversely, LS remained independently associated with reduced LOS even after adjustment for confounders ($\beta = -1.53$; 95% CI: -2.693 to -0.362; $p = 0.010$). Age, comorbidities, and the type of biliary reconstruction (HD vs HJ) were not significantly associated with LOS (Fig. 2C; Supplementary Table 4).

Children who underwent LS had a lower overall readmission rate (16.7% vs 24.5%, $p = 0.032$) and a lower inpatient readmission rate at the most recent follow-up (8.8% vs 14.5%, $p = 0.044$); however, there was no difference in inpatient readmissions within 90 days (4.0% vs 6.4%, $p = 0.247$). In the multivariable logistic regression model for inpatient readmission, cyst perforation emerged as the strongest predictor of readmission, with approximately 5-fold increased odds (OR: 4.989, 95% CI: 1.28–18.269, $p = 0.020$) (Fig. 2D; Supplementary Table 5). Cirrhosis or hepatic fibrosis documented by intraoperative biopsy (OR: 3.20, 95% CI: 1.102–9.292; $p = 0.032$) and the occurrence of a surgical complication during the hospital stay at the time of the index procedure (OR: 2.45, 95% CI: 1.219–4.907; $p = 0.012$) were also independently associated with increased odds of readmission. Age at surgery was inversely associated with readmission, suggesting that younger age is a risk factor for readmission (OR: 0.985, 95% CI 0.971–1.000; $p = 0.049$). After adjusting for confounders, surgical approach was not significantly associated with readmission (OR: 0.766, 95% CI: 0.428–1.371; $p = 0.369$) (Fig. 2D; Supplementary Table 5). Cholangitis accounted for 31.7% (20/63) of the principal diagnoses upon readmission.

At mid-term follow-up, at a median of 20.3 months (IQR 8.1–42.7), 61 patients (11.4%) presented with a combination of gastrointestinal dysfunction symptoms, including abdominal pain, vomiting, and constipation, with no difference between groups (LS: 12% vs OS: 11%; $p = 0.786$). Two patients in the OS group required relaparotomy for adhesive small bowel obstruction. Nine out of 11 esophagogastroduodenoscopies with gastric biopsies performed during follow-up showed signs of gastritis, in 7 cases (2.8%) in the LS group and in 2 (0.7%) in the OS group ($p = 0.091$). Based on the type of reconstruction, there was no difference in the rate of gastritis between HD (1.9%) and HJ (1.5%) (OR: 1.250, 95% CI 0.332–4.707; $p = 0.742$).

Overall, 18 patients (3.4%) exhibited symptoms of biliary duct obstruction. Higher rates of biliary duct calculi (LS: 7, 2.8% vs OS: 1, 0.4%; $p = 0.029$) and pancreatitis (LS: 12, 4.8% vs OS: 5, 1.8%; $p = 0.081$) were observed in the LS group compared with the OS group. Postoperative anastomotic stenosis (PAS) was confirmed in 9 (1.7%) patients, with 5 (2.0%) in the LS group and 4 (1.4%) in the OS group ($p = 0.741$). Treatment for PAS was surgical revision in 2 patients (0.7%) in the OS group, while 5 (2.0%) in the LS group and 2 (0.7%) in the OS group were treated endoscopically ($p = 0.263$). Newly diagnosed liver fibrosis was observed only in the OS group in 10 patients (3.5%). Five out of these 10 patients who developed liver fibrosis experienced recurrent cholangitis. However, there were no significant differences between groups in late cholangitis cases (LS: 2 cases, 0.8%; OS: 7 cases, 2.5%; $p = 0.183$). Four patients (0.8%) required sclerotherapy for esophageal varices (LS: 1 case vs OS: 3 cases); two of them had been

diagnosed at admission with cirrhosis, while the remaining two developed portal hypertension as a consequence of postoperative portal thrombosis. There were two deaths, both in the OS group, in patients with cirrhosis diagnosed at the time of the index procedure and associated genetic syndromes.

4. Discussion

The key finding of this study is that major complications after bilioenteric anastomosis for CC are uncommon in this group of patients, with LS and OS demonstrating comparable 90-day postoperative complication rates. Specifically, we found no differences in major complications requiring surgical intervention. However, laparoscopic surgery was associated with improved perioperative recovery and was independently associated with shorter length of stay and reduced need for ICU admission. The adjusted analysis confirmed that the surgical approach was not independently associated with complications or readmission. The only patient factor independently associated with increased odds of 90-day complications was preoperative ascites. In addition, male sex was associated with decreased odds of complications. By analyzing the relationship between patient and surgical factors and each complication, preoperative cholangitis was the only factor linked to a higher odds ratio of bile leakage, approaching statistical significance. These findings suggest that while laparoscopic surgery offers advantages in short-term recovery, overall outcomes are more strongly influenced by patient complexity than by operative approach.

Since the first report of laparoscopic surgery performed in a 6-year-old child in the late 1990s [11], with advancements in minimally invasive surgery, an increasing number of choledochal cysts in young children have been treated with this approach. However, due to its greater complexity and steeper learning curve, laparoscopic biliary reconstruction is less widely used in countries with a low incidence of CC.[12] Younger age is the main limiting factor for about 26% of surgeons when selecting the surgical approach, as they believe that limited operating space may increase the risk of injury to vital structures and impact the quality of the anastomosis.[9, 13] Studies analyzing the learning curve for mastering laparoscopic biliary anastomosis found that approximately 40 cases are needed to significantly improve outcomes, including reductions in operating time, the overall postoperative complication rate, and the length of hospital stay.[13–15] Longer operative times are associated with LS, which can be a concern when operating on neonates, as exposure to anesthetic medications during this critical phase of brain development should be minimized.[6, 8, 16]

Due to the small number of cases, a few studies subclassified the study population to evaluate the effect of age on LS outcomes in CC. [17, 18] A study from a high-volume center in Asia found no significant differences in operating time between LS and OS in a subgroup analysis of neonates. In addition, the authors reported less blood loss in the LS group and no cases of anastomotic stenosis, postoperative cholangitis, or intrahepatic stone formation.[17] The results are attributable to the magnified laparoscopic view of the hepatic hilum, portal vein, and hepatic arteries, which enables a meticulous dissection, cyst excision, hemostasis, ligation of the BD, and completion of the anastomosis.[17] Laparoscopy significantly reduces intestinal exposure and manipulation, thereby decreasing

postoperative ileus. In one of the largest pediatric series comparing LS versus OS, the authors found no adhesive small bowel obstruction (ASBO) in the LS group, whereas 4% were observed in the OS group. [17] In our study, there were no differences in the rate of ASBO; however, the LS group had a significantly lower rate of ileus (2.0% vs 6.4%).

Other factors limiting laparoscopic utilization are preoperative bile duct inflammation secondary to recent episodes of preoperative cholangitis or pancreatitis, and cyst perforation. In this scenario, adhesions, edema, cyst wall thickening, and small vessels forming on the cyst surface may increase the risk of excessive bleeding, injury to vascular structures, or injury to other abdominal organs during cyst excision, and may require conversion to an open procedure.[18–21] A conversion rate as high as 11.3% has been reported in a large series of laparoscopic surgeries for perforated CC.[21] Consistent with this data, we observed a higher rate of LS conversions to open surgery among patients with preoperative inflammatory conditions, including acute pancreatitis, cholangitis, and cyst perforations (15.3% vs 8.4%); however, these differences were not statistically significant. Two laparoscopic surgeries were converted to open due to intraoperative vascular and/or organ injuries, while in the other twenty-four cases, no specific reason for conversion was identified.

The rate of laparoscopic procedures converted to open in our study was higher than that reported in other large series.[15, 19, 20] One possible explanation is the absence of specific ICD-10 codes for extracorporeal bilioenteric anastomosis makes it difficult to determine whether the code for laparoscopic conversion to open was used to indicate a true conversion due to intraoperative difficulty or complications, or to denote an extracorporeal anastomosis. Therefore, the conversion rate reported in our study may be overestimated. Overall, there were no differences in blood vessel or organ injuries - including bile duct and intestinal perforations - during cyst excision between LS and OS, consistent with previously published large series. Patients in the OS group required more blood transfusions than those in the LS group, suggesting greater intraoperative blood loss. However, there was no difference in the rate of postoperative bleeding requiring relaparotomy between the two groups (LS: 0.4% vs OS: 0.7%).

Another notable finding from our study is that there were no differences in inpatient readmission rates within 90 days. When analyzing the cumulative inpatient readmissions over the most recent follow-up period, we observed that the OS group had a higher odds ratio of readmission. However, after adjusting for confounders, these differences were no longer statistically significant. Independent risk factors for inpatient readmissions identified in a multivariable logistic regression analysis were younger age, cyst perforation at presentation, an associated secondary discharge diagnosis of hepatic fibrosis, and any surgical complication occurring during the index hospitalization for cyst excision and biliary reconstruction, as indicated by the extractable “Flag”. The main diagnosis at readmission was postoperative cholangitis. Cholangitis is the most common long-term complication reported in 2.9–17% of cases in large series with at least 5-year follow-up.[5, 9, 22–24] However, the underlying causes of recurrent late cholangitis are not fully understood. An association between HJ stenosis and intrahepatic bile duct (IHBD) stone formation and cholangitis has been reported in one study.[22] Other risk factors for cholangitis were a laparoscopic approach in young children, type-IVA cyst, and anastomosis below

the hepatic hilum [9, 24], while others found no underlying causes.[5, 23] Recurrent cholangitis may be a sign of anastomotic stenosis or IHBD calculi and, in the long term, may lead to liver fibrosis. In our study, 1.7% of patients developed late cholangitis, where no specific underlying cause was found. However, two out of ten children who developed hepatic fibrosis had cholangitis, and among six of them, a biliary duct obstruction was documented.

The incidence of PAS in pediatric literature ranges from 1% to 9%. The overall PAS rate in our study, including cases with early postoperative manifestations that required surgical revision or endoscopic dilation within 90 days, was 3%, slightly higher than the 2.1% reported in a recent meta-analysis of 70 studies.[25] The exact cause of PAS is unknown, as risk predictors vary among studies.[8, 9, 18, 22, 26] Several studies have identified bile leakage, redo surgery, postoperative cholangitis, and IHBD stones as risk factors for PAS.[8, 22, 27–29] A risk prediction model built on data from 139 anastomotic stenoses requiring surgical revision identified choledochal cyst wall thickness proximal to the CHD and elevated C-reactive protein (CRP) levels on postoperative day 3 as independent predictors.[30] Others found that older age at definitive surgery was associated with an increased risk of PAS, with children aged 5 or younger having the lowest risk compared to other age groups.[18, 31, 32] Conversely, others consider young age at surgery a risk factor.[9] In addition, Todani classification type IV-A was found to be associated with an increased risk of PAS compared to type I [24, 33]. Therefore, the authors suggest performing a wide hilar anastomosis at the confluence of the hepatic duct to reduce the risk of this complication.[24] The type of surgical approach and type of reconstruction were not found to be associated with increased risk of PAS in the meta-analysis by Tanaka et al.[25, 34] Accordingly, we found no association between laparoscopy and HD with PAS. In the USA, HD reconstruction is more often chosen when CC are managed laparoscopically [6, 7], whereas in Asia, HJ remains the most common reconstruction due to concerns that HD is associated with an increased risk of duodenogastric reflux, which in the long term, may increase the risk of cholangiocarcinoma.[35–37] In a recent meta-analysis including 193 HJ and 253 HD, biliary reflux was documented in 15 patients in the latest group. [37] However, the true occurrence of gastritis is unknown as upper endoscopy is not routinely performed during follow-up. In one of the largest series of laparoscopic procedures for CC, gastritis owing to bilious reflux was reported in 3.8% of HD. [19] The overall rate of gastritis in our study was 1.7%, with no difference between HD (1.9%) and HJ (1.5%). Besides shorter operative time and restoration of relatively physiological bile drainage, the main advantage of HD is the endoscopic accessibility of the anastomosis, which may enable endoscopic treatment of PAS.[38, 39]

This study has several limitations inherent to the retrospective administrative dataset. First, it lacks laboratory data and imaging findings, which limits our ability to classify disease severity and choledochal malformation types according to the Todani classification. Although data underwent numerous reliability and validity checks before being added to the database, coding errors or misclassification can lead to over- or underestimation of complications. Additionally, due to the lack of a standardized scheduled follow-up for children who underwent biliodigestive reconstruction, postoperative complications might be underestimated if patients were readmitted to a different hospital from the original treating center. Lastly, given the low rate of postoperative complications and adverse events, a potential weakness of

this analysis is the insufficient power to control for patient preoperative characteristics, which may obscure true differences and limit the generalizability of these results. Despite these limitations, this study is one of the largest series of young children who underwent laparoscopic bilioenteric reconstruction for CC, confirming the safety and efficacy of this procedure in this patient group.

5. Conclusion

In conclusion, both laparoscopic and open surgery for congenital choledochal cysts in young children have similar 90-day complication rates. However, the laparoscopic approach appears to result in shorter length of stay, faster recovery, and reduced postoperative liver fibrosis.

Abbreviations

CC	choledochal cysts
LS	laparoscopic surgery
OS	open surgery
PHIS	Pediatric Health Information System
ICD-10-CM	International Classification of Diseases, 10th Revision, Clinical Modification
RNYHJ	Roux-en-Y hepaticojejunostomy
HD	hepaticoduodenostomy
ED	emergency department
TPN	total parenteral nutrition
ICU	intensive care unit
CTC	clinical transaction category
LOS	length of stay
IQR	interquartile range
OR	odds ratio

CI
confidence interval
ERCP
endoscopic retrograde cholangiopancreatography
PAS
postoperative anastomotic stenosis
ASBO
adhesive small bowel obstruction
IHBD
intrahepatic bile duct
GERD
gastroesophageal reflux disease
BD
bile duct
CHD
common hepatic duct
SSI
surgical site infection
FTT
failure to thrive

Declarations

Study approval

This study was exempt from our Institutional Review Board review and approval, as data were obtained from a de-identified database.

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Author Contribution

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by M.S.C and N.A., and J.N.M.. The first draft of the manuscript was written by M.S.C and N.A., and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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None

Data Availability

Anonymous data not included in this article can be made available upon request to qualified investigators after institutional review board approval in accordance with PHIS data accessibility requirements.

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40. Supplementary, Tables
41. Supplementary Table 1 ICD-10 Procedure Codes for Cyst Excision and Bilioenteric Reconstruction

Figures

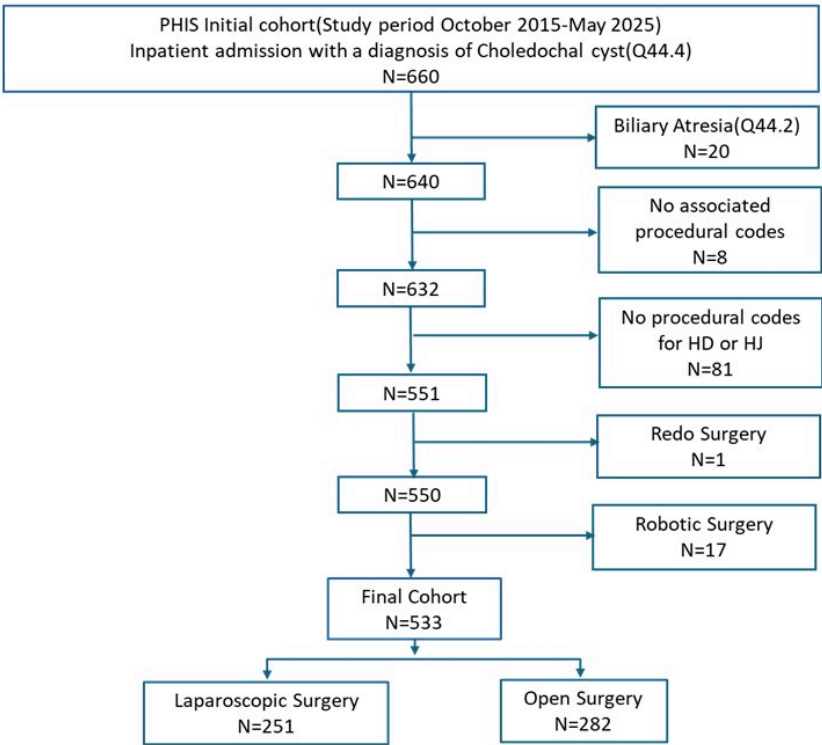


Figure 1

Cohort Builder Flowchart.

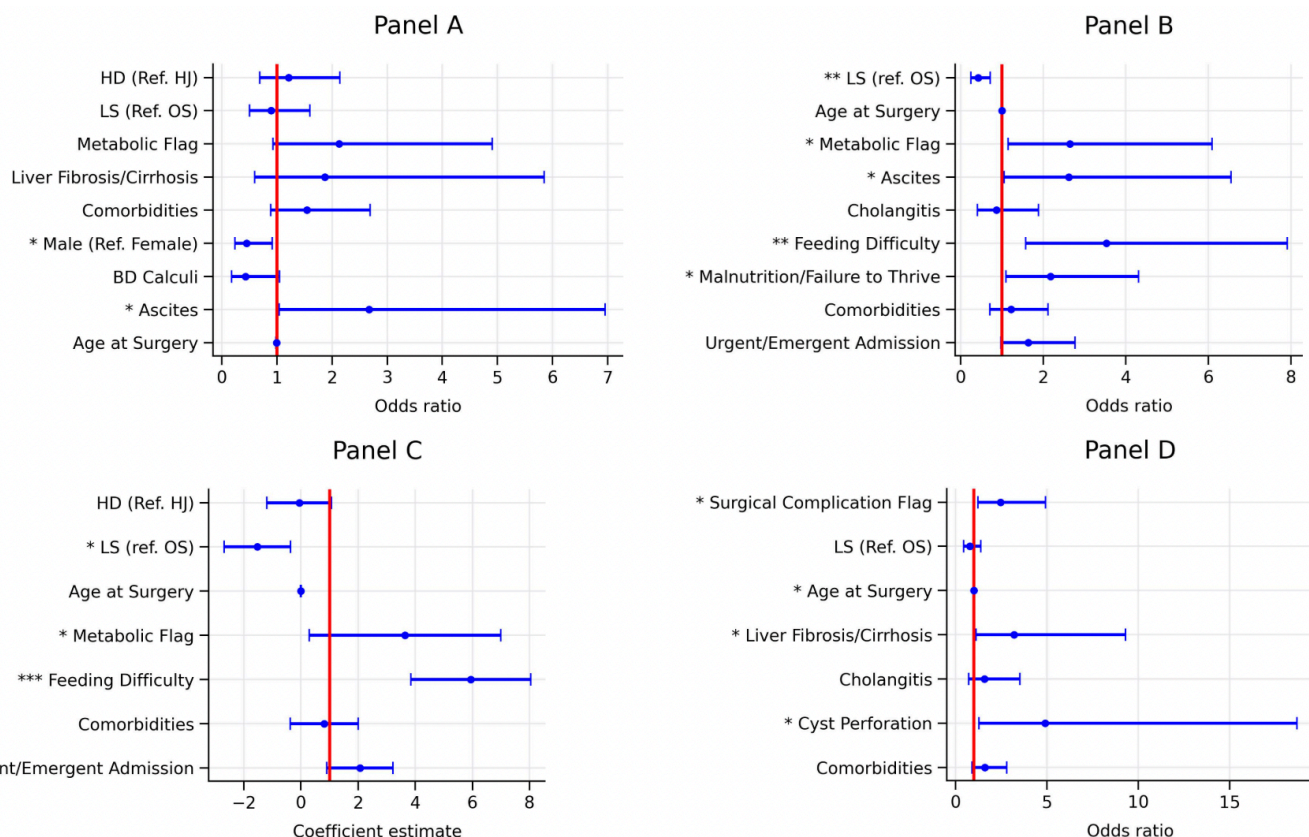


Figure 2

Forest plot from multivariable analysis (2A) Odds ratio (OR) with 95% Confidence Interval (CI) of having any 90-day postoperative complication; **(2B)** Odds ratio (OR) with 95% Confidence Interval (CI) for admission to the intensive care unit (ICU); **(2C)** Regression coefficient estimates for length of stay; **(2D)** Odds ratio (OR) with 95% Confidence Interval (CI) for readmission to the hospital in an inpatient setting.

Significant risk factors are indicated with an asterisk: $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***).

LS: Laparoscopic Surgery; OS: Open Surgery; FTT: failure to thrive; HD: hepaticoduodenostomy; HJ: hepaticojejunostomy.

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