Retrospective Study

Outcomes of endoscopic sphincterotomy vs open choledochotomy for common bile duct stones

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Abstract

BACKGROUND
Endoscopic sphincterotomy (EST) for the management of common bile duct stones (CBDS) is used increasingly widely because it is a minimally invasive procedure. However, some clinical practitioners argued that EST may be complicated by post-endoscopic retrograde cholangiopancreatography (ERCP) pancreatitis (PEP) and accompanied by a higher recurrence of CBDS than open choledochotomy (OCT). Whether any differences in outcomes exist between these two approaches for treating CBDS has not been thoroughly elucidated to date.

AIM
To compare the outcomes of EST vs OCT for the management of CBDS and to clarify the risk factors associated with stone recurrence.

METHODS
Patients who underwent EST or OCT for CBDS between January 2010 and December 2012 were enrolled in this retrospective study. Follow-up data were obtained through telephone or by searching the medical records. Statistical analysis was carried out for 302 patients who had a follow-up period of at least 5 years or had a recurrence. Propensity score matching (1:1) was performed to adjust for clinical differences. A logistic regression model was used to identify potential risk factors for recurrence, and a receiver operating characteristic (ROC) curve was generated for qualifying independent risk factors.

RESULTS
In total, 302 patients undergoing successful EST ($n = 168$) or OCT ($n = 134$) were enrolled in the study and were followed for a median of 6.3 years. After propensity score matching, 176 patients remained, and all covariates were
Common bile duct stones (CBDS), a common condition of the biliary tree, cause serious medical conditions, such as obstructive jaundice, gallstone pancreatitis, and severe acute cholangitis[1]. CBDS typically requires surgical intervention, which primarily involves open choledochotomy (OCT), endoscopic sphincterotomy (EST), and laparoscopic CBD exploration[2-4]. Many studies show that the classical approach of OCT has a wide range of adverse events, with a reported incidence ranging from 14% to 36% and a high mortality rate of 1% to 2%[5,6]. OCT also has long recovery time and severe acute cholangitis[1]. Unfortunately, EST has also been associated with many long-term sequelae, including recurrent CBDS, post-endooscopic retrograde cholangiopancreatography (ERP) pancreatitis (PEP), acute cholangitis (AC), and malignant degeneration, and thus requires further intervention[8,9]. Furthermore, the assessment of the relative advantages of these approaches is hindered by the fact that complications and mortality after OCT have declined with time. Therefore, the superiority of EST in general clinical terms does not mean that EST has more superior treatment outcomes than OCT. EST is superior to OCT with regard to time to biliary obstruction relief, anesthetic duration, procedure time, and hospital stay and is not associated with an increased recurrence rate or mortality compared with OCT in the management of CBDS.

### Core tip
Therapeutic outcomes of endoscopic sphincterotomy (EST) and open choledochotomy (OCT) for the management of common bile duct stones (CBDS) have rarely been compared. The present study is the first to report on this issue and may represent the best evidence comparing these two interventions. The current results show that EST had more satisfactory short-term outcomes, including shorter time to biliary obstruction relief, anesthetic duration, procedure time, and hospital stay, than OCT. In addition, EST was not associated with a higher risk of subsequent recurrent CBDS or overall mortality.

### INTRODUCTION

Common bile duct stones (CBDS), a common condition of the biliary tree, cause serious medical conditions, such as obstructive jaundice, gallstone pancreatitis, and severe acute cholangitis[1]. CBDS typically requires surgical intervention, which primarily involves open choledochotomy (OCT), endoscopic sphincterotomy (EST), and laparoscopic CBD exploration[2-4]. Many studies show that the classical approach of OCT has a wide range of adverse events, with a reported incidence ranging from 14% to 36% and a high mortality rate of 1% to 2%[5,6]. OCT also has long recovery time and can cause low gastrointestinal quality of life[1]. However, the latter two approaches (EST and laparoscopic CBD exploration) are increasingly used due to their low invasiveness. Accumulating evidence has confirmed the safety and efficacy of EST in the treatment of CBDS[5-7]. Unfortunately, EST has also been associated with many long-term sequelae, including recurrent CBDS, post-endooscopic retrograde cholangiopancreatography (ERP) pancreatitis (PEP), acute cholangitis (AC), and malignant degeneration, and thus requires further intervention[8,9]. Furthermore, the assessment of the relative advantages of these approaches is hindered by the fact that complications and mortality after OCT have declined with time. Therefore, the superiority of EST in general clinical terms does not mean that EST has more satisfactory treatment outcomes than OCT. To date, there is a lack of well-designed studies of robust data comparing the short- and long-term outcomes of EST with OCT in the treatment of CBDS. Additionally, the risk factors associated with recurrence...
have not been firmly established to date and thus are a focus of our study.

MATERIALS AND METHODS

Patients
This study was approved by the institutional review board of the First Affiliated Hospital of Nanchang University. All patients gave written informed consent before the procedure. Inpatients undergoing successful EST or OCT between January 2010 and December 2012 for an initial diagnosis of CBDS with concomitant gallbladder stones or prior cholecystectomy were candidates for inclusion. The exclusion criteria were the presence of intrahepatic bile duct stones on computed tomography (CT) and/or magnetic resonance cholangiopancreatography (MRCP), previous EST, prior biliary surgery, biliary strictures, ampullary/pancreatic/biliary malignancies, hepatocirrhosis, severe cholangitis or active acute pancreatitis, and ≤ 18 years of age. Additionally, patients with gallbladder stones who did not undergo a cholecystectomy were also excluded from the study.

In total, 436 patients fulfilling the inclusion criteria were considered for the study. The following patients were excluded after confirmation by imaging and/or laboratory examinations: 50 patients with intrahepatic bile duct stones, 11 with hepatocirrhosis, 7 with benign biliary strictures, 3 with suspected malignancy, 6 with active acute pancreatitis, and 3 with severe cholangitis. Thus, 80 patients were excluded, and 356 patients were initially recruited. However, 13 patients with gallbladder stones refused to undergo a cholecystectomy, and in 6 patients, attempts to achieve complete stone clearance failed; additionally, 35 patients lost to follow-up were also excluded (Figure 1). Finally, 302 patients were enrolled for the analysis.

Methods and procedures
All procedures were performed by highly experienced (board-certified) endoscopists and general surgeons. Each patient’s medical records, including the chart, laboratory findings (complete blood count, coagulation function, and blood biochemistry), and imaging results (CT or MRCP), were reviewed to evaluate each patient’s general condition and to exclude contraindications prior to the procedure. All procedures were performed under intravenous sedation.

EST: EST was performed with a standard duodenoscope (TJF-240/TJF-260v; Olympus, Japan). Following deep cannulation with a sphincterotome, retrograde cholangiography, sphincterotomy, and CBDS extraction with either a basket or balloon were performed. Mechanical lithotripsy (ML) was used if necessary. A repeat cholangiogram was performed after stone removal to confirm complete clearance of the biliary tree. A temporary nasobiliary catheter was placed at the duct if gallbladder stones were present concurrently, and subsequent laparoscopic cholecystectomy (LC) was completed within several days post-ERCP.

OCT: OCT was achieved by open surgical exploration of the CBD. Stones were extracted by gently squeezing the CBD and/or by using a Dormia basket, followed by copious amounts of sodium chloride 0.9% for flushing to ensure patency. After ensuring CBD clearance with a choledochoscope, a T-tube was inserted into the CBD through the choledochotomy site, and a subhepatic drain was kept in all patients. The choledochotomy was closed using absorbable sutures followed by completion of the cholecystectomy and drain placement. T-tube cholangiography was performed 14-21 d postoperatively, and if no stone was discovered, the T-tube was clamped intermittently and removed after one month.

Data collection and long-term follow-up
All patients were assessed daily after the intervention during their hospital stay. Outpatient visits were scheduled one month after the initial procedure and every three to six months thereafter. During outpatient follow-up, liver function tests and abdominal ultrasounds were reexamined if indicated clinically. All patients with recurrence of biliary symptoms were required to be readmitted to the hospital.

Follow-up data were collected by telephone or personal interview of the patients until December 2017 or until their death. All patients were asked about recurrence of biliary symptoms and reintervention methods if any were needed. Reintervention procedure data were also studied. If the patient died before our interview, the clinical history and cause of death were traced by interviewing the relatives.

Definition and outcome measurements
Recurrence of biliary symptoms was defined as the combination of fever/chills,
jaundice, abdominal pain, abnormal liver function biochemical test results, and biliary dilatation and/or the existence of CBDS on imaging studies. Distal CBD angulation was defined as the first angulation from the ampullary orifice along the course of the CBD based on MRCP\(^{12}\) (Figure 2). Acute cholangitis and its severity grading were defined according to the 2018 Tokyo Guidelines\(^{13}\).

Short-term outcomes comprised time to biliary obstruction relief, procedure time, anesthetic duration, number of complete stone clearance sessions, complications, hospital stay, and hospitalization cost. Long-term outcomes were recurrent CBDS with or without AC, time to initial recurrence, times of recurrence, reintervention rate, reintervention method, and mortality.

### Statistical analysis

Propensity score matching (1:1) was designed to limit the influences of confounding factors when estimating treatment outcomes between the two groups. All statistical analyses were performed using SPSS version 19.0 (IBM, Armonk, NY, United States). Continuous data are expressed as the mean ± standard deviation (SD) or median and interquartile range (IQR). Groups were compared using Student's \(t\)-test for variables with a normal distribution. For variables with skewed distribution, intergroup comparisons were made using the Mann-Whitney \(U\) test. Categorical data are displayed as \(n\) (%) and were analyzed with the Pearson chi-square test or the Fisher exact test as appropriate. Recurrence of CBDS was calculated by the Kaplan-Meier method with the use of the log-rank test. Variables with a \(P < 0.20\) in the univariate analysis were introduced into a logistic regression model to analyze the findings of a multivariate analysis of CBDS recurrence. A receiver operating characteristic (ROC) curve was constructed to analyze the risk factors for CBDS recurrence and to determine the specific threshold value that would optimize its predictive value. Statistical significance was defined as \(P < 0.05\).

### RESULTS

#### Patient characteristics

In total, 302 patients were enrolled, and patient characteristics including baseline demographic data, clinical parameters, and follow-up outcomes are shown in Table 1. The information of these patients was gathered with a median follow-up period of 6.3 years (IQR: 5.4-7.3 years) and 6.2 years (IQR: 5.1-7.8 years) for the EST and OCT groups, respectively. There were 168 patients (73 males, 95 females; mean age, 57.1 ± 14.8 years) in the EST group and 134 patients (65 males, 69 females; mean age, 57.5 ± 13.5 years) in the OCT group. Cholecystectomy had been undertaken previously in 35
patients while 16 (5.3%) had undergone a prior gastrectomy (Billroth I: 7, Billroth II: 9). A gallbladder with stones in situ was observed in 267 patients (89.3% in the EST group vs 87.3% in the OCT group). The CBD diameter was significantly smaller in the EST group than in the OCT group (10.9 ± 4.4 mm vs 14.4 ± 5.8 mm, respectively; \( P < 0.001 \)). Additionally, the maximum stone size varied between the EST and OCT groups, and this difference was statistically significant at a size ≥ 20 mm (\( P < 0.001 \)). The two groups were similar in terms of the evaluated preoperative biochemical parameters aside from higher alanine aminotransferase (ALT) and alkaline phosphatase (ALP) concentrations in the EST group (\( P < 0.05 \)).

Comparison of outcomes between the EST and OCT groups

Short-term outcomes: To adjust for differences in baseline clinical characteristics between the EST and OCT groups, propensity score matching (1:1) was performed and shown in Table 1. All clinical variables that can affect the outcomes were adjusted and compared after propensity score matching. Time from admission to biliary obstruction relief, median anesthetic duration, and procedure time were significantly shorter with EST than with OCT (\( P < 0.001 \)). CBDS were completely cleared during the first procedure session in 77 patients in the EST group and in 86 patients in the OCT group, which was significantly different (\( P = 0.009 \)). The median length of hospital stay was also shorter in the EST group than in the OCT group at 6.5 (IQR: 5-9.5) d vs 9 (IQR: 8-12) d, respectively (\( P < 0.001 \)). However, there was no difference between groups for hospitalization cost. For procedure-related complications, a higher rate of bile leakage and port site infection was observed with OCT than with EST (2.3% vs 0% and 2.3% vs 0%, respectively). However, EST was associated with a significantly higher occurrence of PEP and hyperamylasemia than OCT (3.4% vs 0% and 4.5% vs 0%, respectively). However, the two groups did not differ, except for hyperamylasemia (\( P = 0.043 \)) (Table 2).

Long-term outcomes: The long-term follow-up results after propensity matching are summarized in Table 3. Recurrent CBDS occurred in a total of 33 (18.8%) patients. There was no significant difference in the recurrence rate between the EST (18/88, 20.5%) and OCT (15/88, 17.0%) groups (\( P = 0.418 \)) (Figure 3). The rate of AC was significantly higher in the OCT group than in the EST group (\( P = 0.009 \)). The median length of hospital stay was also shorter in the EST group than in the OCT group at 6.5 (IQR: 5-9.5) d vs 9 (IQR: 8-12) d, respectively (\( P < 0.001 \)). However, there was no difference between groups for hospitalization cost. For procedure-related complications, a higher rate of bile leakage and port site infection was observed with OCT than with EST (2.3% vs 0% and 2.3% vs 0%, respectively). However, EST was associated with a significantly higher occurrence of PEP and hyperamylasemia than OCT (3.4% vs 0% and 4.5% vs 0%, respectively). However, the two groups did not differ, except for hyperamylasemia (\( P = 0.043 \)) (Table 2).

Risk factors for recurrence of CBDS

The results of logistic regression analysis are summarized in Table 4. Compared with OCT, EST was not associated with an increased rate of recurrent CBDS (OR, 0.93; 95% CI, 0.47-1.86; \( P = 0.841 \)). Notably, univariate analysis revealed that CBD diameter, maximum stone size, CBD stone number, and distal CBD angle ≤ 145° were associated with a significant increase in recurrence (\( P < 0.05 \)). Multivariate analysis showed that
### Table 1 Baseline clinical characteristics of patients with common bile duct stones

| Characteristic                      | Before matching | After matching | P-value | Before matching | After matching | P-value |
|-------------------------------------|-----------------|----------------|---------|-----------------|----------------|---------|
|                                     | EST (n = 168)   | OCT (n = 134)  |         | EST (n = 88)    | OCT (n = 88)   |         |
| Age at enrollment, mean ± SD, yr    | 57.1 ± 14.8     | 57.5 ± 13.5    | 0.799   | 58.6 ± 14.7     | 58.4 ± 13.8    | 0.920   |
|                                     | Sex, male/female, n | 73/95          | 65/69   | 0.381           | 38/50          | 40/48   | 0.762   |
| Bile duct diameter, mean ± SD, mm   | 10.9 ± 4.4      | 14.4 ± 5.8     | < 0.001 | 12.4 ± 5.1      | 12.7 ± 4.2     | 0.663   |
|                                     | Stone number, multiple/single, n | 63/105 | 57/77 | 0.374           | 33/55          | 33/55   | 1.000   |
|                                     | Maximum stone size, n (%) | 1.0 ± 0.5 | 1.4 ± 0.7 | < 0.001 | 1.2 ± 0.5 | 1.2 ± 0.6 | 0.484   |
|                                     | Cholangitis on admission, n (%) | 42 (25.0) | 34 (25.4) | 0.941 | 23 (26.1) | 22 (25.0) | 0.863   |
|                                     | Mild            | 28 (16.6)      | 28 (20.9) | 0.133 | 13 (14.7) | 18 (20.5) | 0.139   |
|                                     | Moderate         | 7 (4.2)        | 5 (3.7)  | 0.663           | 5 (5.7)        | 3 (3.4)  |         |
|                                     | Severe           | 7 (4.2)        | 1 (0.8)  |                | 5 (5.7)        | 1 (1.1)  |         |
|                                     | Previous gastrectomy, n (%) | 0 | 0 | 0.006 | 0 | 0 |         |
|                                     | Billroth-I       | 7 (5.2)        | 9 (6.7)  | 0.005           | -              | -       |         |
|                                     | Billroth-II      | 0              | 9 (6.7)  | 0.005           | -              | -       |         |
|                                     | Hypertension, n (%) | 10 (11.3) | 15 (11.2) | 0.951 | 12 (13.6) | 11 (12.5) | 0.823   |
|                                     | Diabetes mellitus, n (%) | 11 (6.5) | 7 (5.2)  | 0.629           | 7 (7.9)        | 6 (6.8)  | 0.773   |
|                                     | Charlson comorbidity index, mean ± SD | 0.7 ± 0.9 | 0.8 ± 1.0 | 0.334 | 0.8 ± 1.0 | 0.8 ± 0.9 | 0.807   |
|                                     | Prior cholecystectomy, n (%) | 18 (10.7) | 17 (12.7) | 0.595 | 12 (13.6) | 9 (10.2) | 0.485   |
|                                     | Gallbladder with stones in situ, n (%) | 150 (89.3) | 117 (87.3) | 0.595 | 76 (86.4) | 79 (89.8) | 0.485   |
|                                      | Preoperative biochemical parameters, median (IQR) | | | | | |
| T-Bil, μmol/L                       | 18.9 (10.8-47.2) | 16.6 (9.5-39.1) | 0.164 | 16.9 (10.3-43.5) | 15.4 (9.1-40.3) | 0.432 |
| ALT, U/L                           | 81.5 (28.8-162.9) | 40.5 (18.0-96.3) | < 0.001 | 56.0 (22.3-101.8) | 36.5 (17.5-98.3) | 0.264 |
| AST, U/L                           | 47.0 (22.8-91.0) | 32.0 (20.0-62.2) | 0.053 | 37.0 (21.8-79.3) | 29.0 (19.0-60.0) | 0.259 |
| γ-GTP, U/L                         | 162.5 (82.0-266.3) | 147.0 (67.5-264.8) | 0.446 | 131.5 (74.8-296.0) | 133.0 (64.8-226.8) | 0.380 |
| ALP, U/L                           | 234.0 (76.0-475.5) | 126.5 (65.5-313.5) | 0.049 | 160.5 (66.3-351.5) | 121.0 (65.8-303.3) | 0.642 |
| Follow up period, median (IQR), yr  | 6.3 (5.4-7.3) | 6.2 (5.1-7.8) | 0.732 | 6.3 (5.2-7.3) | 6.9 (5.4-8.2) | 0.168 |

*P < 0.05.

**P < 0.01.

EST: Endoscopic sphincterotomy; OCT: Open choledochotomy; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; T-Bil: Total bilirubin; ALP: Alkaline phosphatase; γ-GTP: γ-glutamyl transferase; SD: Standard deviation; IQR: Interquartile range.

CBD diameter ≥ 15 mm (OR = 2.72; 95% CI: 1.26-5.87; P = 0.011), multiple CBDS (OR = 5.09; 95% CI: 2.58-10.07; P < 0.001), and distal CBD angle ≤ 145° (OR = 2.92; 95% CI: 1.54-5.55; P = 0.001) were independent risk factors associated with CBDS recurrence. The presence of multiple stones seemed to be a much stronger risk factor. Multivariate models were built to predict the incidence of recurrence. According to the ROC of the multivariate model, the area under the curve (AUC) was 0.81 (95% CI: 0.76-0.87) (Figure 4). However, age, sex, ML, bacterial cholangitis, previous gastrectomy, and concomitant diseases were not found to be related to recurrence at the P > 0.05 level (Table 4).

**DISCUSSION**

EST has been generally accepted as a primary treatment for CBDS in current practice and is especially popular for elderly and high-risk patients. Multiple long-term follow-up studies have validated the superiority of EST in terms of safety and efficacy[8,9]. Over the past decade, OCT has been used less frequently each year but is still being performed at a reasonable scale in many institutions. However, short- and long-term follow-up of patient outcomes for CBDS remains unevaluated in the current literature for either classical OCT or minimally invasive EST, which is a cause...
TABLE 2 Safety profile and procedure-related short-term outcomes of endoscopic sphincterotomy and open choledochotomy

| Short-term outcome measure | Before matching | After matching | P-value | P-value |
|----------------------------|-----------------|----------------|---------|---------|
| Time to biliary obstruction relief, mean ± SD, d | 2.8 ± 1.6 | 7.6 ± 4.3 | < 0.001<sup>a</sup> | 2.8 ± 1.6 | 7.1 ± 3.7 | < 0.001<sup>b</sup> |
| Anesthetic duration, median (IQR), min | 174 (150-215) | 222 (181.8-269.8) | < 0.001<sup>b</sup> | 175 (149-217.8) | 207 (170-252.5) | < 0.001<sup>b</sup> |
| Procedure time, median (IQR), min | 105 (84-141.2) | 150 (115.8-180) | < 0.001<sup>b</sup> | 110 (85-151.3) | 145 (112-180) | < 0.001<sup>b</sup> |
| No. of complete stone clearance sessions, n (%) | | | | | | |
| 1 | 19 (11.3) | 6 (4.5) | 11 (12.5) | 2 (2.3) | | |
| ≥ 2 | 149 (88.7) | 128 (95.5) | 77 (87.5) | 86 (97.7) | | |
| Methods of cholecystectomy, n (%) | | | | | | |
| OC | 7 (4.2) | 117 (87.3) | 1 (1.1) | 79 (89.8) | | |
| LC | 143 (85.1) | 0 | 75 (85.2) | 0 | | |
| Hospital stay, median (IQR), d | 17.9 (15.4-21.8) | 17.6 (13.7-21.2) | 0.083 | 18.0 (15.9-21.4) | 17.8 (14.3-21.5) | 0.115 |
| Complications, n (%) | 19 (11.3) | 19 (14.2) | 0.455 | 9 (10.2) | 9 (10.2) | 1.000 |
| Bleeding | 3 (1.8) | 7 (5.2) | 0.097 | 1 (1.1) | 4 (4.3) | 0.173 |
| PEP | 6 (3.6) | 0 | 0.022<sup>a</sup> | 3 (3.4) | 0 | 0.081 |
| Hyperamylasemia | 8 (4.8) | 0 | 0.010<sup>a</sup> | 4 (4.5) | 0 | 0.043<sup>a</sup> |
| Cholangitis | 2 (1.2) | 1 (0.7) | 0.699 | 1 (1.1) | 1 (1.1) | 1.000 |
| Bile leakage | 0 | 5 (3.7) | 0.012<sup>a</sup> | 0 | 2 (2.3) | 0.155 |
| Post port site infection | 0 | 6 (4.8) | 0.006<sup>b</sup> | 0 | 2 (2.3) | 0.155 |

<sup>a</sup>Procedure time in the open choledochotomy group was exclusively for common bile duct exploration.

<sup>b</sup>Retained stones were evacuated by endoscopic sphincterotomy (EST) or endoscopic papillary balloon dilation at a later date.

<sup>c</sup>Hospital stay for the EST group was defined as the duration of post-EST stay plus post-cholecystectomy stay.

<sup>P</sup>< 0.05.

<sup>b</sup>P < 0.01.

EST: Endoscopic sphincterotomy; OCT: Open choledochotomy; OC: Open cholecystectomy; LC: Laparoscopic cholecystectomy; PEP: Post-endoscopic retrograde cholangio pancreatography pancreatitis; SD: standard deviation; IQR: Interquartile range.

for concern, especially for younger patients. This study is the first to report on this issue and may represent the best evidence comparing these two interventions.

In this study, anesthetic duration and procedure time were obviously and significantly shorter in the EST group than in the OCT group. These benefits of EST may reduce the risk of anesthesia and the incidence of procedure-related complications, especially in the elderly with poor cardiopulmonary function. Bacterial infection secondary to prolonged partial or complete CBD obstruction may result in AC. This effect varies from mild disease that generally responds well to medical management alone to life-threatening disease with a mortality rate of approximately 5%-10% that requires urgent biliary decompression. In our study, the mean time from admission to biliary obstruction relief was longer for OCT (7.1 ± 3 d) than for EST (2.8 ± 1.6 d; P < 0.001). Theoretically, EST can relieve obstruction faster and may reduce the risk of anesthesia and the incidence of procedure-related complications, especially in the elderly with poor cardiopulmonary function.

Failure with the initial attempt to treat CBDS results in multiple procedures, incurring a significant increase in health and financial burden. Theoretically, EST is easier to perform than OCT and, thus, would be expected to lower hospitalization...
endoscopic therapy shortens the length of hospital stay, but this advantage is offset by a substantially higher rate of recurrent biliary symptoms, some of which demand readmission. Conversely, our results indicated that the OCT group had a higher rate of CBDS recurrence than the EST group, although this difference was not statistically significant (20.5% vs 17.0%, \( P = 0.418 \)). Presently, there are no relevant studies confirming our findings. Additionally, patients with recurrent CBDS complicated by AC were observed significantly more frequently after OCT, but there was no significant difference when compared with EST (\( P = 0.054 \)). It is possible that hyperplasia of fibrous scar tissue at the CBD incision site after OCT could cause CBD angulation or malformation. This effect may lead to chronic inflammation and thus cholangitic stenosis of the CBD, contributing to biliary tract bacterial infection by disturbing bile excretion and ultimately resulting in AC.

### Table 3  Procedure-related long-term outcomes of endoscopic sphincterotomy and open choledochotomy

| Long-term outcome measure | Before matching | After matching |
|---------------------------|-----------------|---------------|
|                          | EST (n = 168)   | OCT (n = 134) | \( P \)-value | EST (n = 88) | OCT (n = 88) | \( P \)-value |
| Recurrent bile duct stones, \( n \) (%) | 29 (17.3) | 32 (23.9) | 0.155 | 18 (20.5) | 15 (17.0) | 0.562 |
| With AC                   | 4 (2.4)    | 12 (8.9)    | 0.036* | 2 (2.4)    | 6 (8.9)    | 0.534 |
| Without AC                | 25 (14.9) | 20 (14.9) |         | 16 (14.9) | 9 (14.9)  |         |
| Time to initial recurrence, mean ± SD, yr | 2.8 ± 2.0 | 3.5 ± 2.2 | 0.183 | 3.0 ± 2.2 | 3.9 ± 2.7 | 0.321 |
| Times of recurrence ≥ 2, \( n \) (%) | 6 (3.6)    | 11 (8.2)   | 0.082 | 3 (3.4)    | 4 (4.5)    | 0.700 |
| Reintervention rate, \( n \) (%) | 24 (14.3) | 29 (21.6) | 0.095 | 15 (17.0) | 14 (15.9) | 0.839 |
| Reintervention method, \( n \) (%) |                       |             | 0.002b |                 |            |
| EST                       | 23 (13.7)  | 15 (11.2)  | 14 (15.9) | 7 (7.9)  |
| OCT                       | 1 (0.6)    | 13 (9.7)   | 1 (1.1)  | 6 (6.8)  |
| LCBDE                     | 0          | 1 (0.7)    | 0        | 1 (1.1)  |
| Mortality, \( n \) (%)    | 14 (8.3)   | 11 (8.2)   | 0.969 | 10 (11.4) | 9 (10.2) | 0.808 |
| Procedure-related         | 0          | 0          | -       | 0        | 0        | -       |
| Cholangiocarcinoma        | 0          | 2 (1.5)    | 0.112 | 0       | 1 (1.1)  | 0.316 |
| Cardiopulmonary complication | 8 (4.8) | 4 (3.0)    | 0.432 | 7 (7.9)  | 4 (4.5)  | 0.350 |
| Unknown etiology          | 6 (3.6)    | 5 (3.7)    | 0.941 | 3 (3.4)  | 4 (4.5)  | 0.700 |

1In the open choledochotomy group, 15 reinterventions for endoscopic sphincterotomy were required due to purely recurrent common bile duct stones (CBDS) (\( n = 8 \)), recurrent CBDS with acute cholangitis (\( n = 6 \)), or recurrent CBDS with cholangiocarcinoma (\( n = 1 \)).

\( aP < 0.05 \)

\( bP < 0.01 \)

EST: Endoscopic sphincterotomy; OCT: Open choledochotomy; AC: Acute cholangitis; LCBDE: Laparoscopic common bile duct exploration; SD: Standard deviation; IQR: Interquartile range.

The most frequent complications of EST were bleeding, cholangitis, hyperamylasemia, and PEP, with incidence rates of 1.8%, 1.2%, 4.8%, and 3.6%, respectively. These findings concurred with previous studies\(^{[13,14]}\). PEP, as the most frequent complication of ERCP, was probably due to sphincter of Oddi dysfunction. This likely resulted from postprocedural edema or sphincter spasm, which may worsen compression of the pancreatic orifice and thus increase the risk of PEP. Additionally, EST itself and the use of pancreatic duct indwelling guidewires were also two independent risk factors for PEP. The primary factors influencing the efficiency and safety of EST appeared to be the skill and experience of the endoscopists, regardless of patient age or general medical condition. OCT followed by T-tube drainage is a safe and effective method for postoperative biliary decompression to maximize healing of the CBD incision. However, it is not exempt from complications, which occur in up to 10% of patients\(^{[19]}\). The most frequent of these are biliary leakage and port site infection after removal, which occurred in 3.7% and 4.8% of cases in the current study, respectively. Keeping the T-tube in place for an appropriate period of time decreases the incidence of bile leakage into the peritoneal cavity. Therefore, dislodgement or fracture of the T-tube or its premature removal may increase the risk of biliary leakage and port site infection.

Many scholars believe that endoscopic therapy shortens the length of hospital stay, but this advantage is offset by a substantially higher rate of recurrent biliary symptoms, some of which demand readmission. Conversely, our results indicated that the OCT group had a higher rate of CBDS recurrence than the EST group, although this difference was not statistically significant (20.5% vs 17.0%, \( P = 0.418 \)). Presently, there are no relevant studies confirming our findings. Additionally, patients with recurrent CBDS complicated by AC were observed significantly more frequently after OCT, but there was no significant difference when compared with EST (\( P = 0.054 \)). It is possible that hyperplasia of fibrous scar tissue at the CBD incision site after OCT could cause CBD angulation or malformation. This effect may lead to chronic inflammation and thus cholangitic stenosis of the CBD, contributing to biliary tract bacterial infection by disturbing bile excretion and ultimately resulting in AC.
Figure 3 Kaplan-Meier analysis with the log-rank test for recurrence of common bile duct stones in the endoscopic sphincterotomy and open choledochotomy groups. A: Before matching; B: After matching. EST: Endoscopic sphincterotomy; OCT: Open choledochotomy.

With EST, there has been concern expressed that duodenobiliary reflux due to permanent loss of sphincter of Oddi function may lead to recurrence of stones or ascending cholangitis\cite{20,21}.

In the current study, we found a significant association between the two groups in terms of the length of time to initial recurrence of CBDS. Accumulating studies have reported that most recurrences occurred within the first 2 years after EST\cite{22}. Similarly, 39.3% of recurrences in our study occurred within 2 years of EST. These studies found that sphincter of Oddi basal pressure and amplitude decreased markedly after EST but could recover to some extent 2 years following this procedure\cite{23}. However, except for inflammatory stenosis, no studies have fully explained the underlying pathogenesis of stone recurrence after OCT. Thus, further study on this topic is needed.

Christos et al\cite{24} proposed that patients with recurrent CBDS were at an increased risk of a subsequent recurrence. In our study, 21.2% of patients with one recurrence had at least one further episode, while the first-time recurrence rate was 18.8%. However, there was no significant difference in the rates of a second recurrence between the EST and OCT groups in our study ($P = 0.700$). Furthermore, the rates of reintervention for an initial recurrence were similar in the EST and OCT groups (17.0% vs 15.9%, $P = 0.839$). However, EST was the approach chosen more frequently for reintervention for recurrent patients, with over 50.0% (7/14) of patients transferring from the OCT group to EST therapy. This could be due to EST being more favorable for postoperative recovery, with decreased pain and an increase in quality of life in the short term. Moreover, free external drainage from T-tubes may lead to slow wound healing, anorexia, and constipation, as well as increasing the risk of dehydration and electrolyte imbalance\cite{25}. Mortality was very low, and there was no significant difference in the postprocedure death rate between the two groups in our study. Our results concur with that of a retrospective study in which 1514 patients with CBDS were treated by OCT and the operative mortality was 2%. During our follow-up, we found that the primary causes of death were cardiopulmonary complications and unknown etiology rather than procedure-related adverse events.

The recurrence rate for CBDS quoted in the literature ranges from 4%-25%\cite{11}. However, the risk factors for stone recurrence remain unknown. Numerous studies have found that bile stagnation, duodenal-biliary reflux, bacterial colonization of the CBD, ML, and CBD angulation or deformity all contribute to recurrence\cite{26}. However, our study demonstrated that ML and CBD bacterial infection did not increase recurrence incidence. Although univariate analysis revealed that the stone recurrence rate was higher in patients with stones ≥ 20 mm, this was not statistically significant in multivariate analysis. Multivariate analysis revealed that CBD diameter, CBD angle ≤ 145°, and multiple CBDS were independent risk factors for CBDS recurrence. The underlying mechanism for CBD dilation, which predisposes to stone reformation, may be a decrease or loss of normal CBD functional movement or a decrease in the hydrostatic force of bile. Both of these events could slow down bile excretion, thus leading to CBDS formation. Additionally, cholesterol in the bile of patients with
Table 4 Risk factors for common bile duct stone recurrence

| Variable | Recurrence, n (%) | P-value | Multivariate analysis |
|----------|-------------------|---------|----------------------|
|          | No (n = 241)      | Yes (n = 61) | OR (95%CI) | P-value |
| Age, mean ± SD, yr | 57.2 ± 14.3 | 57.3 ± 14.1 | 0.974 | - | - |
| Sex (female) | 131 (54.4) | 33 (54.1) | 0.971 | - | - |
| Intervention method | | | 0.156 | 0.841 |
| OCT | 102 (42.3) | 32 (52.5) | | Reference |
| EST | 139 (57.7) | 29 (47.5) | 0.93 (0.47-1.86) | |
| Bile duct diameter, cm | | | < 0.001<sup>a</sup> | 0.011<sup>b</sup> |
| < 15 | 180 (74.7) | 25 (41.0) | | Reference |
| ≥ 15 | 61 (25.3) | 36 (59.0) | 2.72 (1.26-5.87) | |
| Distal CBD angle ≤ 145° | 78 (52.4) | 37 (60.6) | < 0.001<sup>a</sup> | 5.09 (2.58-10.07) |
| Stone number | | | < 0.001<sup>a</sup> | < 0.001<sup>b</sup> |
| Single | 167 (69.3) | 15 (24.6) | | Reference |
| Multiple | 74 (30.7) | 46 (75.4) | 5.09 (2.58-10.07) | |
| Maximum stone size, mm | | | 0.002<sup>c</sup> | 0.904 |
| < 20 | 216 (89.6) | 45 (73.8) | | Reference |
| ≥ 20 | 25 (10.4) | 16 (26.2) | 1.06 (0.43-2.63) | |
| Mechanical lithotripsy | 9 (3.7) | 3 (4.9) | 0.673 | - | - |
| Bacterial cholangitis | 63 (26.1) | 13 (21.3) | 0.438 | - | - |
| Previous gastrectomy | | | | | |
| Billroth-I | 6 (2.5) | 1 (1.6) | 0.696 | - | - |
| Billroth-II | 6 (2.5) | 3 (4.9) | 0.328 | - | - |
| Hypertension | 26 (10.8) | 8 (13.1) | 0.608 | - | - |
| Diabetes mellitus | 17 (7.1) | 1 (1.6) | 0.145 | 0.29 (0.03-2.51) | 0.261 |
| Charlson comorbidity index, mean ± SD | 0.7 ± 0.9 | 0.6 ± 0.9 | 0.499 | - | - |

<sup>a</sup>P < 0.05.  
<sup>b</sup>P < 0.01.  
<sup>c</sup>P < 0.1.  
EST: Endoscopic sphincterotomy; OCT: Open choledochotomy; CBD: Common bile duct; OR: Odds ratio; CI: Confidence interval; SD: Standard deviation; IQR: Interquartile range.

multiple stones might be prone to crystallizing and nucleating, causing a tendency toward stone formation. The comprehensive and long-term follow-up in our study provides novel insights into the different outcomes with EST and OCT, and the risk factors for subsequent stone recurrence. However, there are several limitations to our study. First, we could not rule out the possibility that recurrent CBDS might be asymptomatic and evade detection during follow-up. Second, due to its retrospective nature, a selection bias may have occurred with the two treatment groups. Last, we did not ascertain the composition of the stones at the initial intervention. Therefore, we could not examine whether differences in stone composition affected the risk of recurrent CBDS. In conclusion, EST currently remains the most commonly performed procedure for CBDS management. This may be because it is minimally invasive and has satisfactory short-term outcomes including shorter time to biliary obstruction relief, anesthetic duration, procedure time, and hospital stay. Furthermore, EST can be performed safely without posing a higher risk of subsequent recurrent CBDS or overall mortality than OCT. The recurrence rate appears to be associated with CBD diameter ≥ 15 mm, multiple CBDS, and distal CBD angle ≤ 145°.
Endoscopic sphincterotomy (EST) and open choledochotomy (OCT) are two common therapeutic modalities for the management of common bile duct stones (CBDS). Over time, EST as a minimally invasive approach has become safe, efficient, and cost-effective. However, it remains unclear whether there are any differences in outcomes between these two approaches for the treatment of CBDS.

Some clinical practitioners argued that EST may be complicated by post-endoscopic retrograde cholangiopancreatography (ERCP) pancreatitis (PEP) and are associated with a higher recurrence of CBDS than OCT. Additionally, the risk factors associated with recurrence have not yet been established firmly. We wanted to investigate these issues to help guide clinicians in efforts to manage CBDS better.

The retrospective study aimed to compare the clinical outcomes of EST vs OCT for the management of CBDS and to identify the risk factors associated with stone recurrence.

This study included 302 patients with CBDS who met the criteria. The short- and long-term clinical outcomes were compared between the EST and OCT groups. Propensity score matching was performed to adjust for the effects of confounding factors. Recurrence of CBDS was calculated by the Kaplan-Meier method with the use of the log-rank test. Risk factors for recurrence were identified using a logistic regression model.

EST was associated with shorter time to relieving the biliary obstruction, anesthetic duration, procedure time, and hospital stay than OCT. The overall incidence of complications and mortality did not differ significantly between the two groups. There was no significant difference in recurrence rate between the EST (18/88, 20.5%) and OCT (15/88, 17.0%) groups. The area under the receiver operating characteristic (ROC) curve for the logistic regression model incorporating CBD diameter ≥ 15 mm, multiple CBDS, and distal CBD angle ≤ 145° was 0.81 (95%CI: 0.76-0.87).

EST shows better results in short-term outcomes, including shorter time to relief of biliary obstruction, anesthetic duration, procedure time, and hospital stay, and was not associated with an increased recurrence rate or mortality compared with OCT in the management of CBDS. CBD dilatation, multiple CBDS, and distal CBD angle ≤ 145° are independent risk factors for CBDS recurrence, and these factors may help screen out high-risk patients who require follow-up more frequently.

EST can be performed safely without posing a higher risk of subsequent recurrent CBDS or overall mortality than OCT. Additional randomized controlled trials are needed to further validate these findings.
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