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RESEARCH

Clinical application of a self- dislodging biliary stent for one-stage suturing following choledochotomy

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Abstract

Background Choledochal exploration remains a reliable and effective therapeutic strategy for the management of choledocholithiasis. Nevertheless, the optimal approach to bile duct closure following exploration—specifically the choice between T-tube drainage and primary suture closure—remains controversial, with no clear consensus established in current surgical practice.

Objective This study aims to evaluate the safety and efficacy of self-detachable biliary stents in achieving primary closure following choledochotomy.Secondary research objective: Potential complications associated with the innovative surgical approach of using a self-dislodging biliary stent.

Methods From January 2021 to May 2023, a total of 112 patients diagnosed with choledocholithiasis were enrolled in this study. Among them, 60 patients were assigned to the TTD group, in which laparoscopic choledochotomy with T-tube drainage was performed, while 52 patients were included in the PDC group, receiving primary duct closure combined with placement of a self-detachable biliary stent. Postoperative outcomes were compared between the two groups, including operative time, time to first defecation, length of hospital stay, perioperative changes in hematological and liver function parameters, as well as the incidence of complications such as intra-abdominal hemorrhage, bile leakage, electrolyte disturbances, and wound infection.

Results There were no significant differences between the two groups with respect to operative time and intraoperative blood loss ($P>0.05$). However, the time to first defecation and length of hospital stay were significantly shorter in the PDC group compared with the TTD group ($P<0.05$). Postoperative WBC, TB, DB, and ALB levels did not differ significantly between the two groups ($P>0.05$), whereas postoperative ALT, AST, and TBA levels were significantly different ($P<0.05$). In addition, the overall incidence of postoperative complications was significantly lower in the PDC group than in the TTD group ($P<0.05$).

Conclusion Laparoscopic choledochal exploration followed by primary closure with a self-detachable biliary stent appears to be a safe, effective, and economically favorable strategy for the management of choledocholithiasis. This technique has the potential to serve as an alternative to conventional T-tube drainage, offering comparable safety while reducing postoperative complications and healthcare costs.

Keywords Choledocholithiasis · T-tube drainage · Primary common bile duct closure

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Introduction

Choledocholithiasis is a prevalent biliary disorder, affecting approximately 10–15% of the population [1]. Its incidence has been increasing in Western countries, a trend that is likely attributable to dietary habits and environmental factors [2]. Obstruction of the bile duct by stones can result in cholangitis and biliary stricture, and in severe cases may progress to acute suppurative cholangitis—a life-threatening condition that markedly impairs patients‘ quality of life [3].

The standard management of choledocholithiasis involves surgical stone removal, relief of biliary obstruction, and adequate drainage. Historically, conventional open choledochotomy and laparoscopic common bile duct exploration (LCBDE) have constituted the mainstay of treatment. In recent years, however, LCBDE has increasingly supplanted open surgery due to its minimally invasive nature and faster postoperative recovery [4]. Following choledochotomy, two primary techniques are employed for bile duct closure: (1) laparoscopic choledochotomy with stone extraction followed by T-tube drainage, and (2) laparoscopic choledochotomy with stone extraction combined with primary duct suturing. While T-tube drainage remains widely practiced, prolonged T-tube placement is associated with notable complications, including electrolyte disturbances, local pain, and incision-related infections [5]. Moreover, inadvertent T-tube dislodgement can precipitate severe consequences such as biliary peritonitis [6]. The requirement to maintain a T-tube for an extended period also imposes considerable inconvenience and adversely affects patient quality of life. In contrast, primary closure of the common bile duct has gained increasing support among surgeons, as it represents a more physiological approach. Primary suturing can reduce operative time, shorten hospital stay, and lower healthcare costs [7–9]. Nevertheless, this technique is not without risk, including potential bile leakage, elevated intraductal pressure, stricture formation, and recurrent cholangitis. Consequently, the choice between T-tube drainage and primary duct closure remains a subject of ongoing debate in contemporary biliary surgery.

To overcome the limitations associated with prolonged T-tube placement and the potential risks of primary bile duct suturing, we investigated the use of a self-detachable biliary stent, a concept adapted from endoscopic retrograde cholangiopancreatography (ERCP). This study reports on the clinical application of a self-detachable biliary stent in combination with primary closure of the common bile duct for the management of choledocholithiasis. The stent is designed to dislodge spontaneously postoperatively, thereby facilitating drainage while minimizing patient discomfort. We performed a retrospective analysis of clinical and follow-up data from patients who underwent choledochotomy with either T-tube drainage or primary suture closure between 2021 and 2023. Postoperative outcomes, including hematological parameters, liver function tests, and the incidence of complications, were compared between the two groups to assess the safety and efficacy of integrating a self-detachable biliary stent with primary bile duct suturing. At the same time, observe and evaluate what new complications may arise from this innovative surgical approach.

Methods

Study population and study design

A retrospective analysis was conducted on the clinical data of 122 patients with choledocholithiasis who underwent surgery at the Department of Hepatobiliary Surgery, First Affiliated Hospital of the University of Science and Technology of China, from January 2021 to May 2023. Patients were excluded if they had malignancies ($n=2$), incomplete clinical data ($n=7$), or if death occurred due to unrelated causes during follow-up ($n=1$), resulting in a final cohort of 112 patients with complete follow-up data. In this study, patients were randomly assigned to two groups (the TTD group and the PDC group) using a 1:1 parallel randomization method. The allocation process involved a random number table (generated by SPSS 26.0) combined with the sealed envelope method. The sealed envelopes were kept under the custody of a designated person and were opened at the start of treatment.Among these, 60 patients underwent choledochotomy with T-tube placement (TTD group), while 52 patients received one-stage primary closure combined with a self-detachable biliary stent (PDC group). The study was conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from all patients or their legal representatives. The study protocol was approved by the Ethics Committee of the First Affiliated Hospital of the University of Science and Technology of China (Approval No. XJS-2021-1-113WK).

Inclusion criteria and exclusion criteria

Inclusion criteria

- Presence of gallbladder stones with concomitant common bile duct stones, confirmed by imaging modalities such as ultrasound, computed tomography (CT) or magnetic resonance cholangiopancreatography (MRCP).

- Preoperative liver function classified as Child-Pugh grade A, or initially grade B with subsequent improvement to grade A.
- Preoperative total bilirubin level ≤ 10 times the upper limit of normal.
- Common bile duct diameter > 8 mm.

Exclusion criteria

- Presence of concomitant organ dysfunctions precluding surgical intervention.
- Diagnosis of malignant tumors.
- Incomplete clinical or follow-up data.
- Preoperative acute obstructive suppurative cholangitis or severe acute pancreatitis.
- Intraoperative findings of an excessively thin common bile duct, unexplained distal bile duct obstruction, or dysfunction of the duodenal papilla.
- Presence of intrahepatic bile duct stones or biliary strictures.
- For patients with common bile duct stones who are not candidates for common bile duct exploration and stone extraction, ERCP is evaluated as an interventional approach to address obstructive jaundice.

Preoperative evaluation

All patients underwent a comprehensive preoperative laboratory evaluation, including complete blood counts, serum biochemical analyses, coagulation profiles, immunological markers, and tumor markers. In addition, each patient underwent a minimum of two imaging modalities—such as ultrasonography, computed tomography (CT), or magnetic resonance cholangiopancreatography (MRCP)—to precisely delineate the location and number of bile duct stones, as well as to identify any biliary strictures or anatomical abnormalities.

Surgical procedure

All surgical procedures were performed by experienced hepatobiliary surgeons. The objectives of the surgery were to debride the lesion, remove bile duct stones, and ensure adequate biliary drainage. The surgical approach was determined according to the location, size, and number of stones, as well as the function of the sphincter of Oddi. Criteria for Sphincter of Oddi Function [10]: A normally functioning sphincter exhibits a dot-like or radial morphology and demonstrates the ability to open and close when manipulated by a choledochoscope, while still resisting passage of the scope. In contrast, if the sphincter fails to open or close under choledochoscopic examination, the duodenal mucosa is clearly visible, intestinal contents reflux occurs, and the choledochoscope passes freely into the duodenum without resistance, the sphincter is considered to be dysfunctional or non-functional. Based on the method of common bile duct management, patients were assigned to one of two groups: the one-stage primary duct closure combined with a self-detachable biliary stent (PDC group) or choledochotomy with T-tube drainage (TTD group). The surgical procedures were performed as follows:

(1) TTD group: Under general anesthesia with endotracheal intubation, pneumoperitoneum was established at a pressure of 12–14 mmHg, and a four-port laparoscopic approach was employed. Laparoscopic cholecystectomy was performed by retracting the gallbladder fundus to expose Calot's triangle. The cystic duct and cystic artery were dissected and isolated, and the cystic duct was clamped and transected. The gallbladder was then removed from the liver bed using electrocautery in a retrograde fashion. The hepatoduodenal ligament was exposed, and the anterior wall of the common bile duct was incised longitudinally by electrocautery for approximately 1.0–2.0 cm. A choledochoscope was inserted through the subxiphoid port to examine the distal common bile duct, common hepatic duct, left and right hepatic ducts, and secondary intrahepatic bile ducts. Stones were removed, and complete duct clearance was confirmed. The function of the sphincter of Oddi was also verified under choledochoscopic visualization. A T-tube was then inserted into the common bile duct via the anterior incision, and the duct was closed intermittently with 4−0 absorbable sutures (Ethicon, Vicryl). The T-tube was irrigated with 15–20 mL of saline, the surrounding area was inspected for any leakage, and a drainage tube was placed at the Winslow's foramen.

(2) PDC group: The procedure for cholecystectomy, choledochotomy for stone removal, and choledochoscopic exploration was performed as described for the TTD group. A matched biliary stent (Ireland, TTS0-8.5–11.5) with a diameter of 8.5 Fr and a length of 8 cm was used. A 4−0 absorbable Vicryl suture (Ethicon, 771D or 773D) was tied to the proposed proximal end of the bile duct, leaving a residual thread of approximately 15 cm for backup. Two to three lateral holes were created 6–8 mm distal to the stent.

Placement of the self-dislodging stent: A guidewire was inserted into the duodenum through the choledochoscope operating port. The choledochoscope was then withdrawn, and the biliary stent was advanced over the guidewire into the distal bile duct and duodenum. Once the distal end of the stent had entered the duodenum, the guidewire was removed. The proximal remnant of the stent was externalized through the choledochotomy, and the bile duct was closed in a single stage using interrupted absorbable sutures (Ethicon, 4−0 Vicryl). The stent was positioned with one end within the common bile duct (approximately 6 cm) and the distal end extending 1–2 cm into the duodenum. A drainage tube was placed in the Winslow's foramen. Following approximately 2–3 months, the absorbable suture underwent self-degradation, and the self-detachable biliary stent was expelled naturally via duodenal peristalsis. The preparation of the self-detachable biliary stent and a schematic illustration of its placement in the duodenum are shown in Figs. 1 and 2.

The principle of the release of the self-dislodging biliary stent: The distal end of the stent was positioned approximately 2 cm within the duodenum, while the proximal end was located about 6 cm within the common bile duct. The proximal end was secured to the lateral wall of the common bile duct using a 4−0 absorbable suture, which underwent self-degradation over 56–70 days postoperatively. As the suture degraded, the stent was naturally expelled through duodenal peristalsis, completing the self-detachment process.

Annotation instructions(①the anterior wall of the common bile duct was incised longitudinally by electrocautery for approximately 1.0–2.0 cm.The direction indicated by the arrow is the site of the common bile duct incision.②The choledochoscopy examination of the distal common bile duct, common hepatic duct, left hepatic duct, right hepatic duct, and secondary intrahepatic bile ducts confirmed complete stone extraction and verified that the biliary tract is fully patent。③Improved type of biliary stent, Improved type of biliary stent is in the direction indicated by the arrow。④Improved type of biliary stent was placed into the common bile duct。⑤Improved type of biliary stent was successfully placed into the common bile duct。The direction indicated by the arrow points to the end of the biliary stent that is equipped with absorbable suture。⑥The

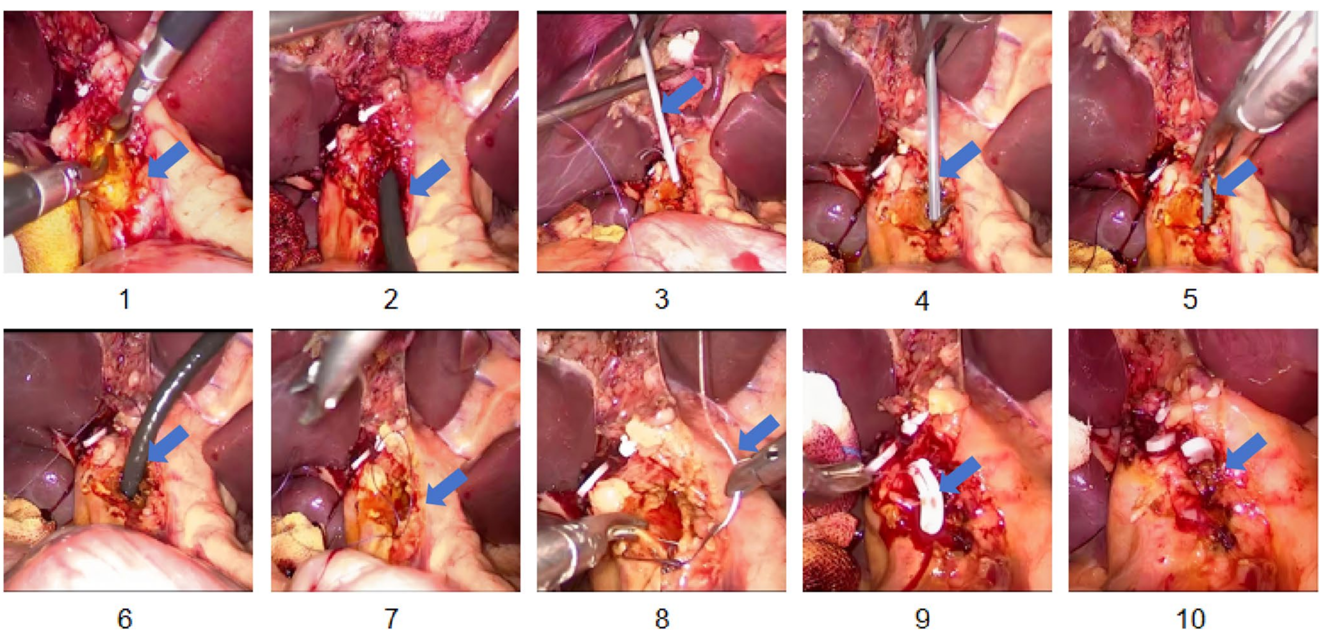

Fig. 1 Postoperative management

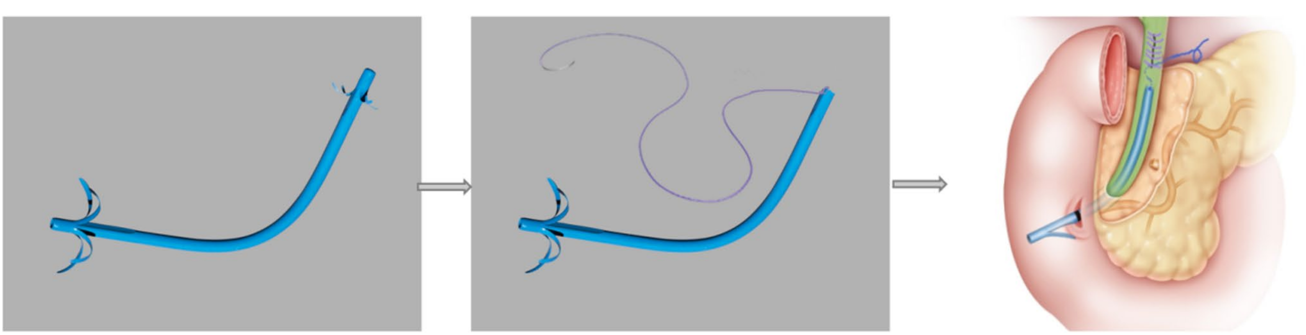

Fig. 2 Improved type of biliary stent

position of the modified biliary stent was re-examined with the choledochoscope。⑦The end of the biliary stent is equipped with an absorbable suture. This suture was then sutured and fixed to the lowermost part of the common bile duct incision site。The direction of the arrow indicates the remaining tail end of the absorbable suture after it was sewn and fixed to the common bile duct。⑧A new 4−0 absorbable suture (Ethicon, Vicryl) was selected to perform an interrupted suture of the bile duct。The direction indicated by the arrow points to the 4−0 absorbable suture (Ethicon, Vicryl).⑨After suturing the common bile duct, the sutures were secured with absorbable clips。⑩Following the placement of the modified biliary stent, the common bile duct was sutured.

Annotation instructions(The proximal end of the biliary stent was sutured with an absorbable suture.The stent was positioned with one end within the common bile duct (approximately 6 cm) and the distal end extending 1–2 cm into the duodenum.)

All patients received meticulous care during the early postoperative period, including continuous monitoring of vital signs, provision of caloric intake, and nutritional support. Proton pump inhibitors and prophylactic antibiotics were administered immediately after surgery, with antibiotic regimens adjusted based on bile culture sensitivity results. Hepatoprotective therapy was provided according to postoperative liver function assessments. Prior to discharge, all patients underwent abdominal CT scans to evaluate for residual stones. For patients with residual stones, choledochoscopy via the T-tube sinus tract was typically performed at 6–8 weeks postoperatively and repeated until complete stone clearance was achieved. In patients with initially cleared stones, T-tube cholangiography was performed at 6 weeks, and if stones were detected, choledochoscopic removal was carried out as described above.

Observation index and method

(1) Information on surgical methods, operative time, intraoperative blood loss, time to first defecation, and length of hospital stay was collected for both groups.
(2) Bile culture: Intraoperative bile samples were collected and initially inoculated onto Petri dishes, followed by culture on blood agar and China Blue agar plates. Bacterial growth and identification were performed using the BACT/ALERT 3D system and the VITEK 2 Compact automated microbial identification and susceptibility system (bioMérieux, France).
(3) Hematological Parameters: Venous blood samples (3 mL) were drawn at 7:00 a.m. on postoperative days 1, 7, and 14, as well as preoperatively. White blood cell (WBC) counts were measured using an automated hematology analyzer (XT-2000i).
(4) Liver function Tests: Venous blood samples (5 mL) were collected at 7:00 a.m. on postoperative days 1, 7, and 14. Samples were analyzed using the cyclic enzyme rate method on a fully automated biochemical analyzer (Hitachi 7600-020). The following parameters were recorded: alanine aminotransferase (ALT), aspartate aminotransferase (AST), albumin (ALB), total bilirubin (TBIL), direct bilirubin (DBIL), and total bile acid (TBA).
(5) Stent Detachment Assessment: Abdominal orthopantomograms were performed three months postoperatively to evaluate the rate of stent detachment.

Management of postoperative complications

(1) Abdominal bleeding: Postoperative bleeding is defined as a reduction in haemoglobin of more than 20 g/L compared with the preoperative level, as detected through postoperative monitoring of drainage tube colour, clinical manifestations, and confirmed by ultrasound or CT [11]. Close monitoring of the volume and characteristics of abdominal drainage, as well as vital signs, is essential. If the drainage of bloody fluid exceeds 50 mL/h or haemoglobin falls below 70 g/L accompanied by shock, and conservative internal medicine treatment proves ineffective, open surgical intervention is required. Intraoperative blood loss is estimated using the following formula [12]: Total volume in the suction reservoir + (weight of blood-soaked gauze – net weight of dry gauze – normal saline weight) – volume of irrigation fluid.
(2) Bile leakage: Bile leakage is defined and classified according to the criteria of the International Study Group of Liver Surgery (ISGLS) [13]. When the leakage is small and localized, the T-tube should be kept open for drainage. In cases of massive bile leakage or diffuse peritoneal contamination, re-exploration, debridement, and adequate drainage are required [14].
(3) Postoperative fever: Fever may result from intraoperative choledochoscopic exploration, stone extraction, or irrigation, which can lead to biliary tract or intra-abdominal infection. Some patients may develop severe cholangitis characterized by high fever and hypotension, requiring intensified anti-infective therapy. Antibiotic selection should be guided by the results of bile culture and sensitivity testing.
(4) Incisional infection: Incisional infection occurring within 30 days post-surgery is diagnosed when the

lesion involves only the incision or subincisional tissues and meets at least three of the following criteria: (1) presence of purulent discharge at the incision site; (2) positive pathogen culture from exudate or tissue samples; and (3) local signs of infection such as erythema, swelling, fever, pain, and tenderness [15] Management includes debridement, dressing changes, and other supportive measures.

(5) Pulmonary infection: Postoperative pulmonary infection is diagnosed according to the following criteria [16]: (1) aggravation of pre-existing respiratory symptoms, such as cough and expectoration, after surgery; (2) development of postoperative fever; (3) physical examination indicating signs of pulmonary consolidation, with rales audible on auscultation; (4) abnormal leukocyte count ($< 4 \times 10^9$/L or $>10 \times 10^9$/L) on laboratory testing; (5) chest X-ray showing patchy infiltrates or interstitial changes. After excluding other pulmonary diseases such as lung cancer, tuberculosis, or pulmonary embolism, a diagnosis can be established if any of criteria (1)–(4) are present in combination with criterion (5). Antibiotic therapy should be guided by sputum culture and drug sensitivity results.

(6) Acute pancreatitis: The diagnostic criteria include [17]: (1) persistent epigastric pain; (2) postoperative serum lipase (or amylase) activity at least threefold higher than the upper limit of normal; (3) imaging findings consistent with acute pancreatitis, such as pancreatic enlargement, peripancreatic exudation, or necrosis. The diagnosis is confirmed when at least two of the above three criteria are met. Management consists of comprehensive therapy, including fasting and water deprivation, antimicrobial treatment, suppression of pancreatic enzyme secretion, and nutritional support.

(7) Acute cholangitis: Diagnostic features include [18]: (A) Systemic inflammation: fever (temperature >38 °C), white blood cell count $< 4 \times 10^9$/L or $>10 \times 10^9$/L, or C-reactive protein (CRP) >1 g/L; (B) Cholestasis: jaundice (total bilirubin ≥ 34.2 µmol/L) or elevated ALP, ALT, AST, and GGT levels (≥ 1.5 times the upper limit of normal); (C) Imaging: evidence of bile duct dilatation, stenosis, or calculi. Treatment includes appropriate antimicrobial therapy, systemic supportive care, biliary drainage, and targeted etiological management.

(8) Electrolyte disorders: The normal ranges of serum electrolytes are as follows: K^+ 3.5–5.5 mmol/L (< 3.5 mmol/L: hypokalaemia; >5.5 mmol/L: hyperkalaemia) [19]; Na^+ 135–145 mmol/L (< 135 mmol/L: hyponatraemia; >145 mmol/L: hypernatraemia) [20]; Cl^- 96–110 mmol/L (< 96 mmol/L: hypochloraemia; >110 mmol/L: hyperchloraemia) [21]. Management strategies include fluid replacement, correction of electrolyte imbalances, and symptomatic treatment.

(9) Stone recurrence: Recurrence of choledocholithiasis is defined as the detection of stones ≥ 6 months after complete stone clearance [22]– [23]. Treatment strategies should be individualized based on the location and number of recurrent stones, as well as the patient's overall condition and comorbidities.

Follow-up

All patients were followed up for 1 year. Postoperative evaluations were performed every 3 months in the hepatobiliary surgery clinic, including routine blood tests, biochemical assays, and imaging examinations such as ultrasound, CT, and MRI.

Statistical analysis

SPSS 26.0 (SPSSInc, Chicago, IL, USA) and R (version 4.1.3) were used for statistical data analysis and graphing, and$\bar{x} \pm s$ ±*s* was used for measurement of normal data, and non-normal distribution was expressed as median [interquartile range (IQR)], and the two-group test was used as independent t-test or rank sum test (Mann-Whitney U). Count data expressed as number of cases (%) were used, and comparisons were made using the $\chi 2$ test.

Results

There were no statistically significant differences between the two groups in terms of age, sex, BMI, abdominal pain, fever, jaundice, preoperative leukocyte count, ALT, AST, TBA, DB, TB, or ALB ($P>0.05$), as shown in Table 1.

Comparison of intraoperative parameters and postoperative recovery between the two groups: all patients successfully underwent surgery without conversion to open surgery, and complete stone removal was achieved in both groups. There were no statistically significant differences in common bile duct diameter, maximum stone diameter, number of stones, intraoperative blood loss, or operative time ($P>0.05$). However, significant differences were observed in time to first defecation and length of hospital stay ($P<0.05$), as shown in Table 2.

Comparison of postoperative inflammatory markers and liver function recovery between the two groups: no significant difference was observed in postoperative white blood cell count between the two groups ($P>0.05$). On postoperative days 1 and 7, ALT, AST, and TBA levels recovered more rapidly in the PDC group than in the TTD group, with statistically

Table 1 Comparison of clinical characteristics between the one-stage suture group and the T-tube drainage group in patients undergoing LCBD

Characteristic	TTD group(n=60)	PDC group(n=52)	Z/t/χ^2	P值
Gender(male/female)	(28/32)	(27/25)	0.30	0.57
Age(years)	50.01±9.50	51.07±6.21	0.68	0.49
BMI	24.10±5.85	24.17±2.77	0.08	0.93
Abdominal pain[Y/N n(%)]	36(60.00)/24(40.00)	26(50.00)/26(50.00)	1.12	0.28
Fever[Y/N n(%)]	33(55.00)/27(45.00)	23(44.23)/29(55.77)	1.29	0.25
Jaundice[Y/N n(%)]	22(36.67)/38(63.33)	20(38.46)/32(61.54)	0.03	0.84
Preoperative comorbidities[n(%)]				
N	30(50.00)	28(53.84)	0.16	0.68
diabetes	18(30.00)	21(40.38)	1.15	0.28
hypertension	20(33.33)	14(26.92)	0.54	0.46
WBC	12.19±1.72	12.50±2.92	0.69	0.48
ALT	88.86±17.29	88.36±11.20	0.17	0.85
AST	86.88±17.00	85.65±11.14	0.44	0.65
TBIL	42.05±9.69	43.26±6.64	0.76	0.44
DBIL	29.40±7.78	29.01±6.35	0.28	0.77
ALB	42.03±4.25	42.21±6.29	0.17	0.86
TBA	16.78±8.07	17.05±2.80	0.23	0.81

Notes: *BMI* Body mass index, *WBC* White blood cell, *ALT* Alanine transaminase, *AST* Aspartate Transaminase, *TBIL* Total bilirubin, *DBIL* Direct bilirubin, *ALB* albumin, *TBA* total bile acid

Table 2 Comparison of intraoperative and postoperative recovery of patients in the two groups

Characteristic	TTD group(n=60)	PDC group(n=52)	Z/t/χ^2	*P* Value
Diameter of common bile duct (mm, ±*s*)	14.53±2.15	13.71±2.53	1.85	0.06
Maximum stone diameter (mm, ±*s*)	13.83±1.58	13.59±2.81	0.55	0.57
Number of stones[n(%)]				
≤2	10(33.33)	13(44.44)		
>2	50(63.33)	39(64.44)	1.18	0.27
Peroperative bleeding (ml, ±*s*)	50.50±9.71	53.36±10.91	1.47	0.14
Operation time (min, ±*s*)	126.16±9.15	123.76±19.03	0.86	0.38
First time defecation (h, ±*s*)	67.08±13.11	50.13±9.39	7.75	<0.01
Length of stay (day, ±*s*)	12.75±2.18	9.44±1.62	8.97	<0.01

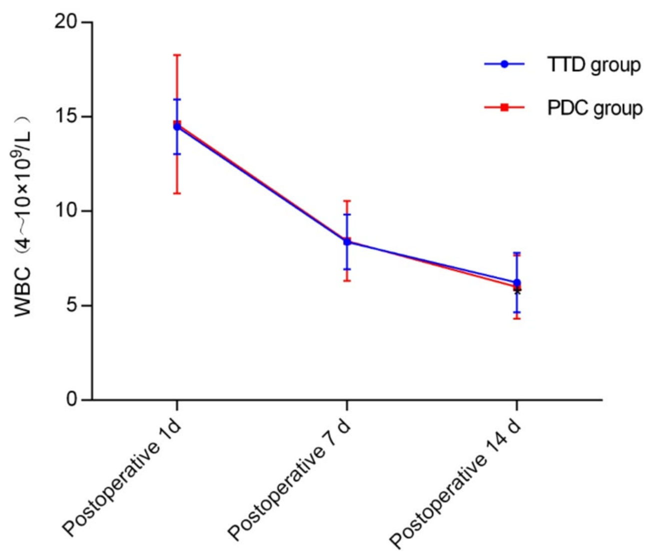

Fig. 3 Comparison of postoperative white blood cell counts between the two patient groups

significant differences (P<0.05). However, no significant differences were found between the two groups in terms of TB, DB, or ALB (P>0.05), as shown in Figs. 3 and 4.

Comparison of postoperative complications between the two groups: the incidences of bile leakage, electrolyte disorders, and incisional infection were significantly higher in the TTD group than in the PDC group (P<0.05). No significant differences were observed between the two groups in the incidences of abdominal haemorrhage, pulmonary infection, acute pancreatitis, or acute cholangitis (P>0.05). Only one patient experienced non-dislodgement of the biliary stent at 3 months; the stent was subsequently removed under ERCP at the patient's request, without any serious intraoperative or postoperative complications. Details are presented in Table 3.

Discussion

Gallbladder stones combined with common bile duct stones are frequently encountered in hepatobiliary surgery, and the primary therapeutic objectives are to relieve obstruction, clear calculi, and maintain unobstructed biliary drainage [24]. Laparoscopic common bile duct exploration (LCBDE) enables comprehensive assessment of the bile ducts under

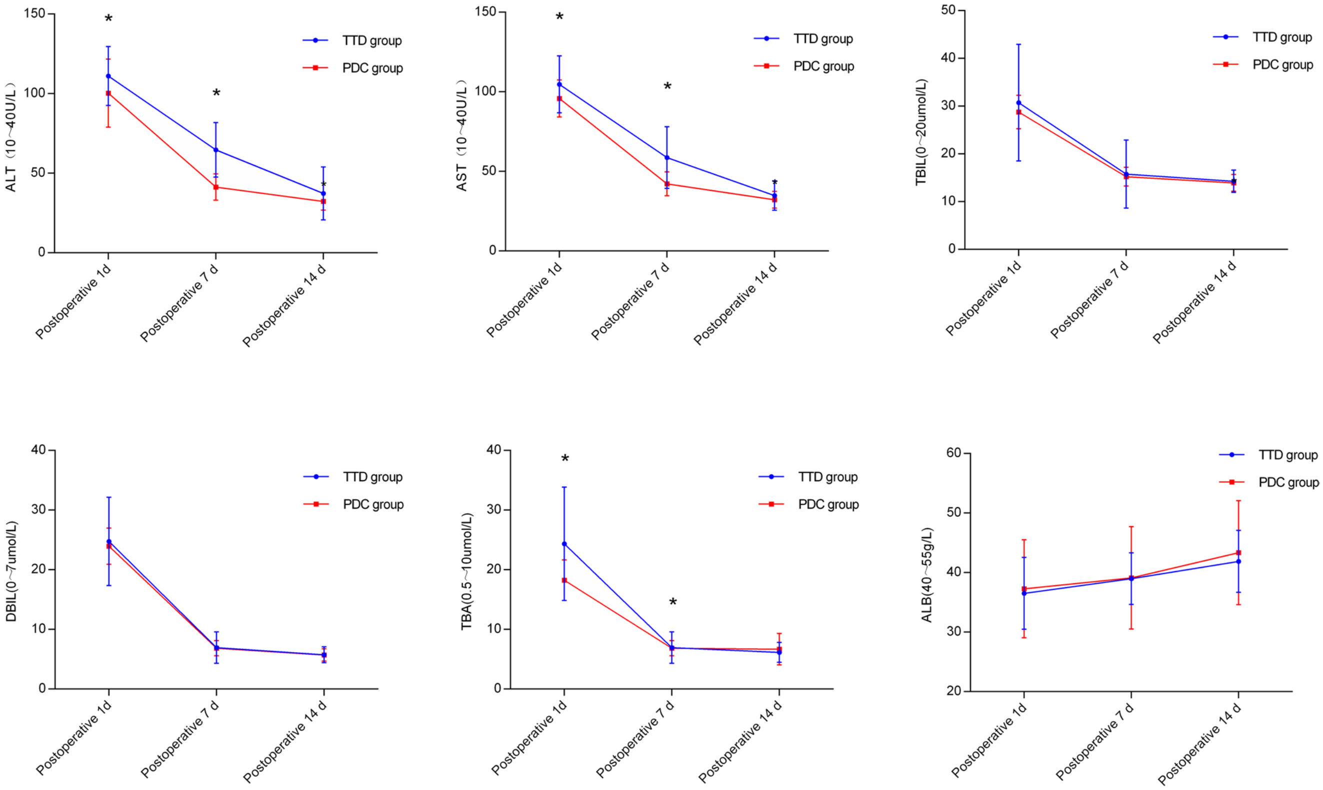

Fig. 4 Comparison of postoperative ALT, AST, TBA, TB, DB, and ALB levels between the two patient groups

Table 3 Comparison of postoperative complications between the two groups of patients

Complication [n(%)]	T-tube drainage group(n=60)	Primary suture group(n=52)	P
Intra-abdominal hemorrhage	1(1.6%)	1(1.9%)	0.36
Bile leakage	4(6.6%)	0	0.04
Infection of incisional wound	4(6.6%)	0	0.04
Pulmonary infection	1(1.6%)	1(1.9%)	0.36
Acute pancreatitis	1(1.6%)	1(1.9%)	0.36
Acute cholangitis	1(1.6%)	1(1.9%)	0.36
Electrolyte disturbance	3(5.0%)	0	0.04
Recurrence of calculus	1(1.6%)	1(1.9%)	0.36
Clavien-Dindo			
I	11(18.33%)	4(7.6%)	0.01
II	1(1.6%)	2(3.8%)	0.37

choledochoscopy, allowing detection of stones, strictures, and Oddi sphincter dysfunction, while facilitating simultaneous clearance of gallbladder and ductal stones in a single procedure [25–27]. Owing to its advantages—including lower complication rates, preservation of papillary function, and one-time resolution—LCBDE has become an established treatment modality in clinical practice. Despite these advances, the choice of biliary drainage method after LCBDE remains controversial. Traditionally, T-tube drainage has been widely employed to ensure decompression, prevent bile leakage, reduce distal duct edema, and improve postoperative liver function [28]. However, its limitations are well recognized, including substantial bile loss with fluid–electrolyte imbalance, accidental dislodgement causing biliary peritonitis, malposition-related leakage or stricture, chronic inflammation from foreign body reaction, and potential tract rupture during removal leading to peritonitis [29–31]. In recent years, primary ductal closure has gained popularity as it allows direct bile flow into the intestine, thereby reducing fluid and electrolyte loss, supporting enteral nutrition, and promoting faster postoperative recovery [32, 33]. Nevertheless, bile leakage remains the main concern, often attributed to sphincter edema or spasm, elevated intraductal pressure, excessive suture tension, or inappropriate closure technique.

To address the limitations of conventional T-tube drainage, we implemented a modified approach combining primary ductal closure with intraoperative placement of a self-dislodging biliary stent. This strategy ensures early postoperative biliary decompression while avoiding the long-term complications associated with T-tubes. During follow-up, the stent typically dislodged spontaneously within 20–40 days, maintaining effective drainage without the need for secondary intervention. Our findings indicate that this method is both safe and effective and may provide clinical advantages over traditional T-tube drainage, supporting its potential as a preferable option in the management of choledocholithiasis. In this study, patients in the primary ductal closure (PDC) group demonstrated significantly shorter time to first defecation, reduced postoperative hospital stay, and faster recovery of liver function markers (ALT, AST, and TBA) compared with the T-tube drainage (TTD) group. These benefits likely result from the laparoscopic one-stage suture technique, which avoids T-tube placement, reduces postoperative pain, allows earlier bile flow into the intestines, and promotes intestinal peristalsis. Consequently, bowel function recovers more rapidly, oral intake can be resumed sooner, and hospitalization is shortened. These findings are consistent with previously reported results [34, 35]. The improved liver function recovery in the PDC group may be attributed to unobstructed bile flow into the intestine, which restores enterohepatic circulation, promotes hepatocyte metabolism, and accelerates the reduction of transaminase levels. Notably, no significant differences were observed between the groups in inflammatory markers or total bilirubin (TB) levels. Although some studies have reported higher TBIL and DBIL levels in patients undergoing primary ductal closure compared to T-tube drainage—potentially due to postoperative edema of the duodenum and bile ducts following choledochoscopic manipulation [36]—our study did not observe such elevations. This discrepancy may be explained by the presence of the built-in biliary stent, which reduces intraductal pressure and alleviates obstruction, effectively serving a function similar to that of T-tube drainage in maintaining bile flow.

Postoperative complications, including abdominal hemorrhage, pulmonary infection, acute pancreatitis, and recurrence of acute cholangitis, did not differ significantly between the two groups. In the TTD group, four cases of bile leakage were observed; however, all resolved spontaneously with adequate drainage through abdominal tubes and did not result in serious complications. These bile leaks were likely caused by incomplete closure of needle holes or gaps around the T-tube during ductal suturing. Small biliary fistulas generally heal with sufficient drainage, and when drainage is inadequate or the tube becomes displaced, percutaneous drainage under ultrasound guidance is usually effective. The occurrence of bile leakage may also be related to bile duct congestion, edema of the Oddi sphincter, and elevated intraductal pressure. Previous studies have reported that the incidence of bile leakage after one-stage closure of the common bile duct ranges from 1.6% to 7% [37, 38]. Liu [39]et al. noted that the incidence decreases significantly as surgical experience increases, while Yin [36]et al. identified smaller bile duct diameter and elevated postoperative bilirubin levels as risk factors, particularly when the common bile duct diameter is less than 8 mm. Our study demonstrates that one-stage suturing combined with a biliary stent effectively reduces the incidence of bile leakage, likely due to alleviation of Oddi sphincter edema and decreased bile duct obstruction following stent placement.

Regarding incision infections, four cases occurred in the TTD group, corresponding to an infection rate of 6.6%, whereas no incision infections were observed in the PDC group. Previous studies report that the incidence of incision infection following T-tube drainage ranges from 1.7% to 10.2% [40]– [41]. In our study, all affected patients were successfully managed with dressing changes. One case in the TTD group was associated with bile leakage around the T-tube, and bacterial culture identified Escherichia coli, likely resulting from retrograde migration of bile-borne bacteria along the T-tube. The presence of a T-tube may increase the risk of surgical site infection during the perioperative period, as it can serve as a conduit for exogenous pathogens, promoting local infection and inflammation at the drainage site.

One patient in each group developed acute pancreatitis, both of whom recovered following comprehensive management, including antibiotics and pancreatic enzyme inhibitors. Clinically, factors such as prolonged stone presence, extended stone removal procedures, and repeated bile duct manipulation—which can cause edema of the duodenal papilla and impair bile and pancreatic fluid drainage—may increase the risk of postoperative pancreatitis [5]. Further follow-up is warranted to assess whether the placement of a biliary stent could also contribute to transient impairment of pancreatic fluid drainage.

In the TTD group, three cases of electrolyte disorders were observed, corresponding to an incidence of 5.0%, primarily manifesting as hyponatremia and hypokalemia, whereas no electrolyte imbalances were reported in the PDC group. One patient in the TTD group developed severe nausea and vomiting accompanied by hyponatremia and hypokalemia five days post-discharge, and fully recovered following symptomatic treatment. Analysis revealed that the patient had a postoperative T-tube drainage of 600–800 ml/day, which led to significant bile loss, impaired digestive function, and reduced gastrointestinal motility, resulting in inadequate nutritional intake. Continuous loss of electrolytes through bile drainage further contributed to the imbalance. Compared with the TTD group, the incidence of electrolyte disorders was markedly lower in the one-stage suture (PDC) group [5]. Additionally, prolonged postoperative fasting can reduce potassium intake, lowering serum potassium levels and increasing the risk of electrolyte disturbances. The earlier resumption of bowel function in the PDC group facilitated earlier oral intake, supporting adequate potassium replenishment and reducing the likelihood of postoperative electrolyte disorders.

A one-year follow-up revealed no significant difference in stone recurrence rates between the two groups. Chronic dilation of the common bile duct can impair ductal contractility, increase resistance to bile flow, and elevate intraductal pressure, potentially leading to biliary dysmotility, bile stasis, and obstruction. These conditions promote bile concentration, allowing precipitated mucus and fibrin to aggregate and form a nidus for stone formation [42]. Some studies have reported that stone recurrence is 2.82 times higher in patients with indwelling T-tubes compared to those without (OR, 2.82; 95% CI, 1.04–7.65; $p = 0.042$) [43]. T-tube drainage has thus been identified as an independent risk factor for stone recurrence, possibly due to multiple mechanisms. Following LC + LCBDE, compensatory dilation of the common bile duct can alter intraductal fluid dynamics, shifting from laminar to eddy flow, which facilitates bile pigment precipitation and stone formation. Additionally, prolonged T-tube placement may lead to displacement or external traction, distorting the bile duct wall or even angulating it, further predisposing to stone recurrence. Although no significant difference in recurrence was observed between the two groups in our study, this may be attributable to the limited sample size and relatively short follow-up duration. Extended follow-up is warranted to more accurately evaluate long-term recurrence rates.

Based on clinical experience at our center, one-stage choledochal suture can be safely performed in patients with a common bile duct diameter of ≥ 0.8 cm. However, T-tube drainage remains indicated in cases of LCBDE with abnormal biliopancreatic junctions. Previous reports have described instances of internal drainage tube migration into the liver or premature dislodgement shortly after surgery, resulting in inadequate biliary support and insufficient internal drainage. To address these limitations, we employed a self-dislodging biliary stent in this study. The stent was inserted into the common bile duct under direct choledochoscopic visualization using a guidewire, with the distal end positioned approximately 2 cm into the duodenum and the proximal end extending about 6 cm into the common bile duct. It was fixed to the lateral wall of the duct using a 4−0 absorbable suture, which gradually degraded over 56–70 days postoperatively. As the suture dissolved, the stent was naturally expelled through intestinal peristalsis. In one case, the stent did not self-discharge, but it was successfully removed endoscopically at the patient's request without adverse events. This modified technique effectively prevents stent displacement and premature dislodgement, ensuring sustained biliary support, smooth drainage, and reduced risk of bile duct stenosis.

Conclusion

In conclusion, combining one-stage choledochal suture with a self-dislodging biliary stent provides notable advantages over conventional T-tube drainage. This approach facilitates faster recovery of gastrointestinal and liver function, minimizes surgical trauma, and accelerates postoperative rehabilitation. Additionally, it effectively reduces the incidence of complications, including bile leakage, incision infections, and electrolyte disturbances. Overall, this technique represents a safe and highly effective treatment strategy for patients with gallbladder stones concomitant with common bile duct stones.

Research deficiencies

This study has several limitations. First, the small sample size and relatively short follow-up period may limit the reliability of the prognostic factor analysis. Future research should focus on large-sample, multicenter, prospective studies to more accurately identify and validate prognostic factors associated with surgical outcomes.

Author contributions Wang S T, the deputy chief physician, was the operator of the operation in the article, and carried out the writing of the article. Yu Q S gave help to the structure and methods of the article. Physicians Peng H, wanzong Z, and Jin L were responsible for the collection and statistics of patient information in the paper.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests To the best of our knowledge, the named authors have no conflict of interest, financial or otherwise.to the best ofall authors have completed the disclosure form and declare that: there are no other relationships or activities that could appear to have influenced the submitted work.

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