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Original Article

Clinical value of laparoscopy combined with choledochoscopy in the treatment of intrahepatic and extrahepatic bile duct stones: a retrospective analysis

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Abstract: Objective: To compare the clinical efficacy, postoperative recovery, and safety of laparoscopy combined with choledochoscopy versus traditional laparotomy for intrahepatic and extrahepatic bile duct stones. Methods: Clinical data of 80 patients treated at Wenzhou People's Hospital from January 2022 to December 2024 were retrospectively analyzed. Patients were divided into an observation group (laparoscopy combined with choledochoscopy, n = 42) and a control group (traditional open bile duct exploration, n = 38). Operative parameters, stone clearance, postoperative recovery, complications, and follow-up outcomes were compared. Results: Operation time was longer in the observation group than in the control group (128.5 ± 32.6 min vs. 98.3 ± 25.4 min, P < 0.001), but intraoperative blood loss was significantly lower (35.4 ± 18.7 mL vs. 42.6 ± 17.3 mL, P < 0.05). No significant differences were found in stone clearance or residual stone rate between groups (both P > 0.05). The observation group showed significantly better outcomes in gastrointestinal function recovery, postoperative ambulation, analgesic use, and hospital stay (all P < 0.01). Total complication rate was lower in the observation group (7.1% vs. 21.1%, P < 0.001). No significant differences were observed in 6-month stone recurrence rate or 3-month liver function between groups (both P > 0.05). Conclusion: Laparoscopy combined with choledochoscopy has a slightly longer operation time but offers less intraoperative blood loss, reduced trauma, faster postoperative recovery, and comparable long-term efficacy compared with traditional laparotomy for intrahepatic and extrahepatic bile duct stones.

Keywords: Intrahepatic and extrahepatic bile duct stones, laparoscopy, choledochoscope, minimally invasive surgery, postoperative recovery

Introduction

Intrahepatic and extrahepatic bile duct stones are common benign diseases of the biliary system. The main manifestation is the deposition of stones in the bile duct, which can cause complications such as bile duct obstruction, biliary tract infection, and liver parenchymal injury. In severe cases, it can lead to biliary cirrhosis, liver abscess, and even cancer, which seriously threatens the health and life safety of patients [1, 2]. According to the latest research data, the global incidence of intrahepatic and extrahepatic bile duct stones is about 5%-10%, and the incidence is higher in South China and Southwest China. The course of the disease is prolonged and easy to relapse, which not only increases the pain of patients, but also increases the burden of clinical diagnosis and treatment [3, 4].

At present, surgical treatment is the main radical treatment for intrahepatic and extrahepatic bile duct stones. The core goal is to completely remove stones, relieve bile duct obstruction, restore biliary patency, and prevent recurrence of complications. As a classic operation, the traditional open bile duct exploration and lithotomy can remove stones to a certain extent, but it has the disadvantages of large surgical trauma, more intraoperative blood loss, slow postoperative recovery and high incidence of complications. Postoperative patients need to stay in bed for a long time, the recovery of gastrointestinal function is delayed, and the risk of complications such as incision infection and bile leakage is high, which seriously affects the postoperative rehabilitation and quality of life of patients [5, 6]. Therefore, it is of great clinical significance to explore a surgical method with less trauma, less blood loss, rapid recovery,

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and high safety to improve the diagnosis and treatment of patients with intrahepatic and extrahepatic bile duct stones.

With the rapid development of minimally invasive surgical techniques, laparoscopy combined with choledochoscopy has been gradually applied to the treatment of intrahepatic and extrahepatic bile duct stones. Laparoscopic surgery has the advantages of less trauma, clear vision and accurate operation, which can effectively reduce the damage of abdominal organs caused by surgery. Choledochoscopy can directly enter the bile duct, accurately locate the stone and complete the stone removal operation to improve the stone clearance rate [7, 8]. However, the current clinical comparative study of the two procedures is still controversial. Some studies believe that laparoscopy combined with choledochoscopy has complex operation and long operation time, and its clinical value has not been fully confirmed. In addition, there is still a lack of systematic comparative studies on the postoperative recovery, long-term efficacy and safety of the two procedures [9].

Based on this, this study retrospectively analyzed the clinical data of patients with intrahepatic and extrahepatic bile duct stones admitted to our hospital, compared the clinical efficacy, postoperative recovery and safety of laparoscopy combined with choledochoscopy and traditional laparotomy, and explored the clinical application value of laparoscopy combined with choledochoscopy, in order to provide a more scientific and reasonable basis for clinical treatment of intrahepatic and extrahepatic bile duct stones.

General information and methods

General information

The data of 80 patients with intrahepatic and extrahepatic bile duct stones admitted to the Department of Hepatobiliary Surgery of Wenzhou People's Hospital from January 2022 to December 2024 were retrospectively analyzed. According to the surgical methods, they were divided into control group and observation group. Among them, 38 cases were in the control group (traditional open bile duct exploration and lithotomy), and 42 cases were in the observation group (laparoscopy combined with choledochoscopy). This study was approved by the ethics committee of Wenzhou People's Hospital (ethics number: KYLL-2024-08-05).

Inclusion criteria

(1) Age 18-75 years; (2) Patients with intrahepatic and extrahepatic bile duct stones diagnosed by abdominal computed tomography (CT), magnetic resonance cholangiopancreatography (MRCP) and ultrasound; (3) No severe liver or kidney dysfunction, and no coagulation dysfunction; (4) Clear consciousness, with normal communication and cooperation; (5) Patients who received surgical treatment for intrahepatic and extrahepatic bile duct stones for the first time; (6) Patients with complete clinical data who can complete postoperative follow-up; (7) No surgical contraindications.

Exclusion criteria

(1) Previous severe liver disease (such as cirrhosis, liver cancer) or biliary tract malignant tumors; (2) Patients with severe cardiopulmonary insufficiency, diabetic ketoacidosis, or other serious underlying diseases that preclude tolerance to surgery; (3) Patients with a history of major abdominal surgery and severe abdominal adhesions; (4) Combined with biliary stricture, biliary malformations and other biliary diseases; (5) Pregnant or lactating women; (6) Incomplete data, unable to complete the observation index statistics and follow-up; (7) Patients allergic to surgical instruments or anesthetics.

Treatment methods

Preoperative preparation and surgical protocol: All patients in both groups received standardized preoperative assessments, including routine blood tests, liver and kidney function tests, coagulation function tests, and abdominal imaging (ultrasound, CT, or MRCP). Preoperative management included gastrointestinal decompression, anti-infection therapy, liver protection, and nutritional support as clinically indicated. Surgery was performed only after excluding contraindications to surgery.

Surgeon experience and standardization: All procedures were performed by the same surgical team consisting of three senior hepatobili-

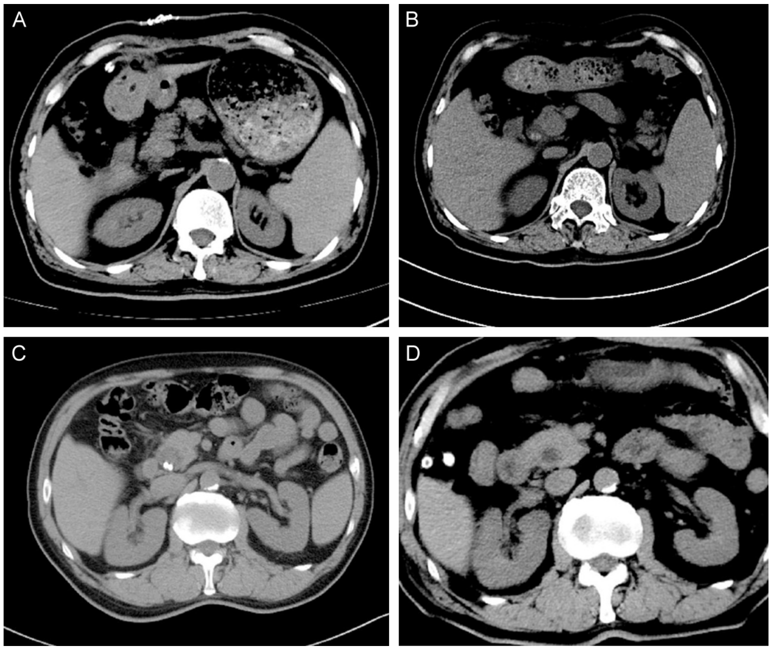

Figure 1. Comparison of axial abdominal CT findings in different groups (A-D). (A, B) Observation group; (C, D) Control group. CT, computed tomography.

ary surgeons, each with more than 10 years of experience in laparoscopic and open biliary surgery and each having performed more than 200 prior cases of bile duct exploration. A standardized surgical protocol was strictly followed for all patients in both groups. The perioperative management pathway, including anesthesia, intraoperative monitoring, and postoperative care, was identical between the two groups. Specific surgical procedures were as follows:

Observation group (laparoscopic combined with choledochoscopy): Under general anesthesia, the patient was placed in the supine position. Pneumoperitoneum was established with a pressure maintained at 12-14 mmHg. Three to four puncture sites were made at the umbilicus, subxiphoid region, and the right costal margin. Laparoscopic instruments were introduced, and the abdominal cavity was explored to inspect the liver, gallbladder, and bile duct. The location, size, and number of stones were determined. Calot's triangle was dissected, the gallbladder was removed if cholecystolithiasis was present, the anterior wall of the common bile duct was incised, and a choledochoscope was inserted. Intrahepatic and extrahepatic bile ducts were explored under direct visualization of the choledochoscope. Stones were removed using stone baskets, ultrasonic lithotripsy, or other appropriate instruments. The bile duct was repeatedly irrigated with saline. After confirming the absence of residual stones via choledochoscopy, a T-tube was placed for biliary drainage. The common bile duct and puncture sites were sutured, and the operation was completed (**Figure 1A**, **1B**).

Control group (traditional open bile duct exploration and stone removal): Under general anesthesia, the patient was placed in the supine position. A right upper abdominal incision (either a right subcostal oblique incision or a transrectus incision) was made, and the skin, subcutaneous tissue, and peritoneum were incised layer by layer to enter the abdominal cavity. The biliary tract was explored, the gallbladder (if cholecystolithiasis was present) was removed, the common bile duct was incised, and stones were explored and removed using biliary probes, stone baskets, and other instruments. After irrigation of the bile duct, a T-tube was placed, and the incision was closed layer by layer [10, 11] (**Figure 1C**, **1D**).

Quality control measures: To ensure intergroup comparability, the following measures were implemented: (1) Standardized operative procedure: All steps of the procedure (including pneumoperitoneum pressure, incision length, T-tube placement, and closure technique) were performed according to a written protocol. (2) Video recording and review: Selected operations (≥ 20% of cases in each group) were video-recorded and reviewed by an independent surgeon not involved in the operations to confirm adherence to the protocol. (3) Data collection: Preoperative, intraoperative, and postoperative data were collected prospectively using standardized case report forms. (4) Postoperative follow-up: All patients received the same postoperative care pathway, including analgesia protocol, antibiotic prophylaxis, and timing of T-tube removal.

Intergroup comparability: Baseline demographic and clinical characteristics (age, gender, body mass index [BMI], stone location and number, degree of biliary dilatation, presence of cholecystolithiasis, and preoperative laboratory values) were compared between the two groups; no significant differences were found (all P > 0.05). These data support the comparability of the two groups prior to surgical intervention.

Observation indicators

Main outcome measures: (1) Surgery-related indicators: The operation time and intraoperative blood loss of the two groups were recorded and compared between the two groups. (2) Stone clearance effect: The intraoperative stone clearance rate and postoperative residual stone rate (confirmed by abdominal CT and MRCP 1 week after operation) were counted in the two groups. (3) Postoperative recovery indices: The recovery time of gastrointestinal function (the first exhaust time), the time of getting out of bed after operation, the number of analgesics used after operation and the number of days of hospitalization after operation were recorded and compared between the two groups. (4) Postoperative complications: The incidence of postoperative complications (including incision infection, bile leakage, abdominal infection, and pulmonary infection) and the total complication rate in the two groups.

Secondary observation indicators: (1) Long-term follow-up: Patients were followed up for 6 months after operation, and the recurrence rate of stones in the two groups was counted. (2) Liver function indexes: Liver function-related indexes (alanine aminotransferase [ALT], aspartate aminotransferase [AST], total bilirubin [TBIL]) were measured in the two groups 3 months after operation, and the differences between the two groups were compared.

Data statistics

Data were analyzed using SPSS 26.0 (IBM Corp., Armonk, NY, USA). Normally distributed continuous data are presented as mean ± SD. Repeated measures of inflammatory factors (C-reactive protein [CRP], procalcitonin, interleukin-6 [IL-6], and tumor necrosis factor-alpha [TNF-α]) were analyzed using two-way repeated-measures analysis of variance with time as the within-subjects factor and group as the between-subjects factor. Mauchly's test of sphericity was performed, and the Greenhouse-Geisser correction was applied when necessary. Post-hoc comparisons were adjusted using Bonferroni correction. Multivariable linear regression models were used to adjust for potential confounders, including age, BMI, hypertension, diabetes, history of biliary surgery, and stone complexity. Categorical data were analyzed using the χ^2 test or Fisher's exact test. A two-sided P < 0.05 was considered statistically significant.

Results

Baseline patient data

No significant differences in baseline characteristics were observed between the two groups (P > 0.05), indicating they were comparable. In the observation group, there were 24 males and 18 females, compared to 21 males and 17 females in the control group. The mean age was 55.3 ± 12.4 years in the observation group and 56.1 ± 11.9 years in the control group. BMI was 23.8 ± 3.1 kg/m^2 and 24.1 ± 2.9 kg/m^2, respectively. Regarding stone distribution in the observation group: intrahepatic bile duct stones in 18 cases (42.9%), extrahepatic bile duct stones in 12 cases (28.6%), and combined intrahepatic and extrahepatic stones in 12 cases (28.6%). In the control group, the corresponding numbers were 16 (42.1%), 10 (26.3%), and 12 (31.6%). No significant differences were found in the prevalence of hypertension, diabetes, or coronary heart disease between the two groups (P > 0.05). Details are shown in **Table 1**.

Preoperative and postoperative inflammatory factors

As shown in **Table 2**, repeated-measures analysis of variance revealed significant main effects of group, time, and group-by-time interaction for IL-6, CRP, and TNF-α (all P < 0.001). Post-hoc comparisons with Bonferroni correction showed that at 1, 3, and 7 days post-surgery, levels of IL-6, CRP, and TNF-α in the observation group were significantly lower than those in the control group (all P < 0.001). No significant between-group differences were observed at baseline for any of the three in-

Table 1. Comparison of baseline data between the two groups of patients

Indicators	Observation group (n = 42)	Control group (n = 38)	Statistical value	*P* value
Gender (male/female, n)	24/18	21/17	$\chi^2 = 0.034$	0.854
Age (years, $\bar{x}\pm s$)	55.3 ± 12.4	56.1 ± 11.9	t = 0.299	0.766
Body mass index (kg/m^2, $\bar{x}\pm s$)	23.8 ± 3.1	24.1 ± 2.9	t = 0.454	0.651
Stone distribution (cases, %)			$\chi^2 = 0.196$	0.907
Intrahepatic bile duct stones	18 (42.9)	16 (42.1)		
Extrahepatic bile duct stones	12 (28.6)	10 (26.3)		
Intrahepatic and extrahepatic bile duct stones	12 (28.6)	12 (31.6)		
Previous history of abdominal surgery (cases, %)	9 (21.4)	8 (21.1)	$\chi^2 = 0.002$	0.969
Complications (cases, %)				
Hypertension	11 (26.2)	10 (26.3)	$\chi^2 = 0.000$	0.990
Diabetes	7 (16.7)	6 (15.8)	$\chi^2 = 0.012$	0.914
Coronary heart disease	4 (9.5)	3 (7.9)	$\chi^2 = 0.068$	0.795

Table 2. Comparison of inflammatory factors between the two groups at different time points

Index	Time point	Observation group (n = 42)	Control group (n = 38)	Adjusted difference (95% CI)	Adjusted *P* value*
IL-6 (pg/mL)	Preoperative	12.5 ± 3.2	12.8 ± 3.4	-0.3 (-1.8 to 1.2)	0.682
	1 day after operation	45.6 ± 10.2	68.3 ± 12.5	-22.7 (-27.6 to -17.8)	< 0.001
	3 days after operation	28.4 ± 7.6	45.2 ± 9.8	-16.8 (-20.9 to -12.7)	< 0.001
	7 days after operation	15.8 ± 4.3	24.6 ± 5.7	-8.8 (-11.2 to -6.4)	< 0.001
CRP (mg/L)	Preoperative	5.2 ± 1.8	5.4 ± 1.9	-0.2 (-1.0 to 0.6)	0.625
	1 day after operation	35.4 ± 8.5	52.6 ± 10.3	-17.2 (-21.6 to -12.8)	< 0.001
	3 days after operation	48.6 ± 11.2	78.3 ± 14.5	-29.7 (-35.8 to -23.6)	< 0.001
	7 days after operation	22.3 ± 6.4	38.5 ± 8.7	-16.2 (-19.9 to -12.5)	< 0.001
TNF-α (pg/mL)	Preoperative	8.6 ± 2.4	8.8 ± 2.5	-0.2 (-1.3 to 0.9)	0.714
	1 day after operation	18.5 ± 4.2	26.8 ± 5.6	-8.3 (-10.6 to -6.0)	< 0.001
	3 days after operation	14.2 ± 3.5	21.3 ± 4.8	-7.1 (-9.1 to -5.1)	< 0.001
	7 days after operation	10.1 ± 2.8	15.6 ± 3.9	-5.5 (-7.1 to -3.9)	< 0.001

Notes: Data are presented as $\bar{x}\pm s$. *Adjusted *P* values were calculated using multivariable linear regression models with age, BMI, hypertension, diabetes, history of biliary surgery, and stone complexity as covariates. Bonferroni correction was applied for multiple comparisons across time points. CI: confidence interval; IL-6: Interleukin-6; CRP: C-reactive protein; TNF-α: Tumor necrosis factor-alpha; CI: confidence interval.

flammatory markers (all $P > 0.05$). These results remained consistent after adjusting for age, BMI, and comorbidities. See **Table 2** for details.

Changes in liver and kidney function

No significant differences were observed between the two groups in preoperative liver function (ALT, AST, TBIL) or renal function (creatinine, blood urea nitrogen) ($P > 0.05$). After surgery, both groups showed improvements in liver and kidney function compared to preoperative levels, but no significant intergroup differences were found ($P > 0.05$), suggesting that the two surgical methods had comparable effects on liver and kidney function. Details are presented in **Table 3**.

Operation time and intraoperative blood loss

The mean operation time in the observation group was 128.5 ± 32.6 minutes, which was significantly longer than that in the control group 98.3 ± 25.4 minutes ($P < 0.001$). However, the mean intraoperative blood loss in the

Table 3. Comparison of liver and kidney function indexes between the two groups before and after treatment ($\bar{x} \pm s$)

Index	Time point	Observation group (n = 42)	Control group (n = 38)	t value	*P* value
ALT (U/L)	Preoperative	68.5 ± 22.3	70.2 ± 24.1	0.335	0.739
	Postoperative	45.6 ± 15.8	48.3 ± 17.2	0.735	0.465
AST (U/L)	Preoperative	62.4 ± 20.5	64.1 ± 21.8	0.359	0.720
	Postoperative	42.8 ± 14.6	44.5 ± 15.9	0.502	0.617
TBIL (μmol/L)	Preoperative	35.2 ± 12.4	36.8 ± 13.1	0.570	0.570
	Postoperative	18.5 ± 6.7	19.6 ± 7.2	0.710	0.480
Cr (μmol/L)	Preoperative	72.5 ± 15.6	74.2 ± 16.3	0.482	0.631
	Postoperative	70.8 ± 14.5	72.5 ± 15.1	0.518	0.606
BUN (mmol/L)	Preoperative	5.6 ± 1.4	5.8 ± 1.5	0.629	0.531
	Postoperative	5.3 ± 1.2	5.5 ± 1.3	0.727	0.470

ALT: alanine aminotransferase; AST: aspartate aminotransferase; TBIL: total bilirubin; Cr: creatinine; BUN: blood urea nitrogen.

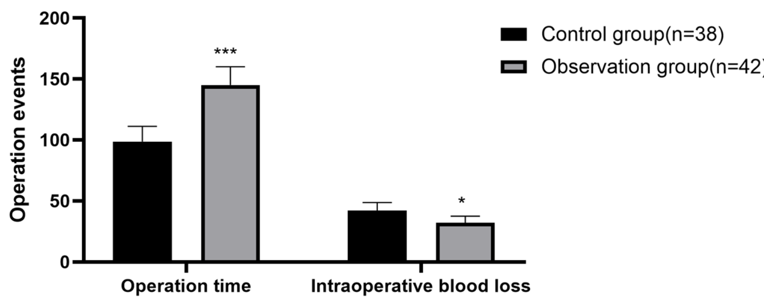

Figure 2. Comparison of intraoperative events between the two groups of patients. ***P < 0.001, *P < 0.05.

Table 4. Comparison of stone removal effect between the two groups [case (%)]

Groups	Number of samples	Intraoperative stone removal	Residual stones after operation
Observation group	42	38 (90.5)	4 (9.5)
Control group	38	35 (92.1)	3 (7.9)
χ^2 value		0.069	0.069
P value		0.793	0.793

observation group was 35.4 ± 18.7 mL, significantly less than that in the control group 42.6 ± 17.3 mL (P < 0.05). See **Figure 2**.

Stone removal outcomes

The stone clearance rate was 90.5% (38/42) in the observation group and 92.1% (35/38) in the control group. The postoperative residual stone rate was 9.5% (4/42) in the observation group and 7.9% (3/38) in the control group. No significant differences were found between the two groups (both P > 0.05), indicating that the two surgical methods were equivalent in stone removal efficacy. See **Table 4**.

Postoperative recovery indicators

Gastrointestinal function recovery time was significantly shorter in the observation group (32.5 ± 8.6 h) than in the control group (58.4 ± 12.3 h) (P < 0.01). The time to postoperative ambulation was also shorter in the observation group (18.6 ± 5.4 h vs. 32.5 ± 7.8 h, P < 0.01). The number of postoperative analgesic uses was significantly lower in the observation group (2.3 ± 0.8 times vs. 4.5 ± 1.2 times, P < 0.01). Postoperative hospital stay was shorter in the observation group (7.5 ± 2.1 days vs. 12.8 ± 3.4 days, P < 0.01). These findings indicate that laparoscopy combined with choledochoscopy offers significant advantages in postoperative recovery. See **Table 5**.

Incidence of adverse reactions

The overall incidence of postoperative complications was 7.1% (3/42) in the observation group, significantly lower than the 21.1% (8/38)

Table 5. Comparison of postoperative recovery indexes between the two groups ($\bar{x} \pm s$)

Indicators	Observation group (n = 42)	Control group (n = 38)	t value	*P* value
Gastrointestinal function recovery time (h)	32.5 ± 8.6	58.4 ± 12.3	10.856	< 0.01
Postoperative ambulation time (h)	18.6 ± 5.4	32.5 ± 7.8	9.234	< 0.01
Postoperative analgesic uses (times)	2.3 ± 0.8	4.5 ± 1.2	9.678	< 0.01
Postoperative hospital stay (d)	7.5 ± 2.1	12.8 ± 3.4	8.456	< 0.01

Table 6. Comparison of postoperative complications between the two groups [case (%)]

Types of complications	Observation group (n = 42)	Control group (n = 38)	χ^2 value	*P* value
Incision infection	1 (2.4)	3 (7.9)	1.306	0.253
Bile leakage	1 (2.4)	2 (5.3)	0.478	0.489
Abdominal infection	0 (0.0)	1 (2.6)	1.113	0.292
Pulmonary infection	1 (2.4)	2 (5.3)	0.478	0.489
Total	3 (7.1)	8 (21.1)	3.989	0.046

Table 7. Comparison of stone recurrence rate at 6 months after operation and liver function at 3 months after operation between the two groups

Indicators	Time point	Observation group (n = 42)	Control group (n = 38)	χ^2 value/t value	*P* value
Stone recurrence [case (%)]	6 months after operation	3 (7.1)	4 (10.5)	0.293	0.588
ALT (U/L)	3 months after operation	38.5 ± 12.6	40.2 ± 13.4	0.584	0.561
AST (U/L)	3 months after operation	35.8 ± 11.4	37.6 ± 12.1	0.691	0.492
TBIL (μmol/L)	3 months after operation	16.5 ± 5.8	17.2 ± 6.3	0.525	0.601

ALT: alanine aminotransferase; AST: aspartate aminotransferase; TBIL: total bilirubin.

in the control group (P = 0.046). In the observation group, there was 1 case of incision infection, 1 case of bile leakage, and 1 case of pulmonary infection. In the control group, there were 3 cases of incision infection, 2 cases of bile leakage, 1 case of abdominal infection, and 2 cases of pulmonary infection. No significant differences were observed between the two groups for any individual complication (all P > 0.05). See **Table 6**.

Postoperative follow-up outcomes

At 6 months post-surgery, the stone recurrence rate was 7.1% (3/42) in the observation group and 10.5% (4/38) in the control group, with no statistically significant difference (P = 0.588). At 3 months post-surgery, no significant differences were observed between the two groups in ALT, AST, or TBIL levels (all P > 0.05). These results suggest that the two surgical methods have comparable effects on long-term stone recurrence and recovery of liver function. See **Table 7**.

Discussion

Bile duct stones are benign diseases with a high incidence in hepatobiliary surgery. They mainly include intrahepatic, extrahepatic, and mixed intrahepatic and extrahepatic stones. The condition is complex and prone to recurrent attacks. Long-term obstruction can induce cholangitis, impair liver function, and even lead to malignant transformation. Surgery remains the main treatment modality [12, 13]. Traditional open bile duct lithotomy offers a wide surgical field, allows direct manipulation, and is effective for complex stone distribution. However, it has disadvantages such as large trauma, increased intraoperative bleeding, a strong postoperative stress response, and a high complication rate, which are not conducive to postoperative rehabilitation [14, 15]. With the rapid development of minimally invasive techniques, laparoscopy combined with choledochoscopy has gradually been applied in the clinical treatment of bile duct stones.

Leveraging the advantages of precise visualization and reduced trauma, this approach has become the mainstream alternative to traditional open surgery [16]. In this study, we compared the clinical efficacy, stress response, organ protection, and long-term prognosis of the two surgical methods, and explored the clinical application value and mechanisms of double-scope combined minimally invasive surgery, aiming to provide an evidence-based basis for optimizing the surgical strategy for bile duct stones.

Surgical trauma-induced inflammatory stress response is considered a core indicator for evaluating minimally invasive procedures. IL-6, CRP, and TNF-α, as classic clinical inflammatory markers, can accurately reflect the degree of tissue damage and the level of stress activation [17, 18]. Our results showed no significant difference in baseline inflammatory factor levels between the two groups before surgery. At 1, 3, and 7 days postoperatively, both groups exhibited a transient increase in inflammatory factors, confirming that any surgical procedure can activate the body's inflammatory-immune response pathway and induce stress-related inflammation [19]. However, the levels of IL-6, CRP, and TNF-α in the observation group were significantly lower than those in the control group at all postoperative time points, suggesting that laparoscopy combined with choledochoscopy induces less inflammatory stress. The mechanism may be that the double-scope procedure only requires small abdominal puncture incisions, avoiding extensive dissection of abdominal tissues, muscles, and ligaments, and causes minimal disturbance to abdominal organs. Meanwhile, choledochoscopy enables direct visualization of stone locations within the bile duct, allowing precise stone removal and avoiding additional damage to the bile duct mucosa from blind manipulation, thereby effectively reducing the release of inflammatory mediators. In contrast, traditional open surgery involves a large incision, extensive abdominal exposure, and severe tissue dissection, which can readily induce a strong stress response and promote the secretion of inflammatory factors. These findings are highly consistent with previous reports [20, 21].

Previous literature has confirmed that liver and kidney function are key measures for evaluating surgical safety and organ protection. Patients with bile duct stones often have varying degrees of liver dysfunction preoperatively due to bile duct obstruction. Therefore, minimizing intraoperative liver and kidney damage while ensuring organ function stability is particularly important [22]. Our data showed no differences between the two groups in preoperative liver function indexes (ALT, AST, TBIL) or renal function indexes (creatinine, blood urea nitrogen). Postoperatively, both groups showed significant improvements in liver and kidney function compared to preoperative levels, suggesting that both surgical methods effectively relieve bile duct obstruction, eliminate persistent stone-induced liver damage, promote normal bile excretion, and thereby restore impaired hepatocyte function. No significant intergroup differences were observed in postoperative liver and kidney function, indicating that laparoscopy combined with choledochoscopy and traditional open surgery have comparable effects on protecting liver and kidney organs. Minimally invasive surgery did not increase the risk of additional liver or kidney injury, and its safety was stable and reliable. The main reason is that both surgical methods aim for complete stone removal, relief of biliary obstruction, and restoration of bile drainage, both of which fundamentally alleviate liver function damage caused by cholestasis. Furthermore, intraoperative standardized fluid management and precise administration of anesthetic drugs effectively prevent renal function impairment and ensure perioperative organ function stability. Similar findings have been reported previously [23, 24].

Intraoperative clinical indicators are also important auxiliary measures for evaluating surgical methods. Our results showed that the operation time was longer in the observation group than in the control group, but intraoperative blood loss was significantly lower. The reasons may be as follows. The prolonged operation time is mainly due to the high technical demands of the double-scope procedure. During surgery, accurate coordination of laparoscopic and choledochoscopic views is required, along with careful exploration of different levels of bile ducts and precise removal of small stones. The procedure is more refined and complex, placing stringent demands on the surgeon's proficiency. The reduction in intraoperative blood loss is a significant advantage of minimally invasive surgery. The laparoscopic magnified view clearly identifies blood vessels, allows precise intraoperative hemostasis, reduces tissue dissection wounds, and lowers the risk of bleeding. These findings support previous research [25, 26].

Studies suggest that stone removal efficacy and long-term recurrence risk are the main criteria for evaluating the radical effect of surgery for bile duct stones. Our results showed no significant differences between the two groups in intraoperative stone clearance rate, postoperative residual stone rate, or stone recurrence rate at 6 months postoperatively, confirming that both procedures achieve ideal stone radical outcomes. These results also suggest that laparoscopy combined with choledochoscopy can reach different levels of intrahepatic bile ducts via choledochoscopy, identify hidden small stones under direct vision, and achieve complete removal. Meanwhile, traditional open surgery allows manual exploration of the bile duct and management of impacted large stones, also achieving stone clearance. Furthermore, long-term follow-up of liver function after surgery showed no significant differences in ALT, AST, and TBIL between the two groups at 3 months postoperatively, further indicating that both surgical methods lead to stable long-term recovery of liver function and ensure normal biliary physiological function. Similar conclusions have been reported previously [27].

Postoperative rehabilitation efficiency is an important reference index for reflecting the clinical advantages of minimally invasive surgery. Our results showed that recovery time of gastrointestinal function, time to ambulation, number of analgesic uses, and length of hospital stay were significantly better in the observation group than in the control group. The reasons are as follows. First, the double-scope combined minimally invasive procedure causes less trauma; the integrity of the abdominal wall is well preserved, and postoperative incisional pain is mild, which greatly reduces the need for analgesic drugs and facilitates early ambulation. Second, intraoperative disturbance to abdominal organs is minimal, the degree of gastrointestinal stress paralysis is mild, gastrointestinal motility recovers quickly, and normal oral intake can resume as early as possible. Finally, minimally invasive surgery does not require long-term indwelling drainage tubes, avoiding tube-related discomfort, accelerating the overall recovery process, and thereby shortening hospital stay. These findings are consistent with previous conclusions [28].

The incidence of postoperative complications has always been an important indicator of surgical safety. In this study, the total incidence of postoperative complications in the observation group was lower than that in the control group, preliminarily suggesting the safety advantages of the double-scope combined procedure. Further analysis showed that although no statistically significant differences were observed in individual complications such as incision infection, bile leakage, or pulmonary infection, the absolute number of each complication was lower in the observation group. The reasons are as follows. Minimally invasive small puncture incisions greatly reduce the probability of incision infection. Precise manipulation reduces bile duct mucosal tearing and lowers the risk of bile leakage. Moreover, early ambulation after surgery effectively promotes the discharge of pulmonary secretions and avoids bed-related complications such as pulmonary infection and abdominal infection. These findings are consistent with mainstream clinical reports [29].

In summary, laparoscopy combined with choledochoscopy for the treatment of bile duct stones has the limitation of a slightly longer operation time but significantly reduces inflammatory factor levels, decreases intraoperative bleeding, and lowers the risk of postoperative complications. At the same time, its stone removal efficacy and organ protection effects are comparable to those of open surgery, while postoperative rehabilitation and hospital stay are shortened. Therefore, this approach is worthy of clinical recommendation.

There are, however, still some deficiencies in this study: First, this study is only a single-center retrospective controlled study with a limited sample size of only 80 cases, which did not undergo a priori sample size calculation, potentially resulting in insufficient statistical power to detect small but clinically meaningful differences between groups. Second, the study excluded patients with biliary stricture or previous upper abdominal surgery, and did not include complex high-risk stone cases (e.g., complete staghorn calculi, stones with severe suppurative cholangitis, or cases with concomitant biliary tract anomalies), thereby limiting the generalizability of our findings to broader patient populations. Third, the long-term follow-up period is relatively short, with a mean follow-up of only 6 months, and extended follow-up data on stone recurrence and biliary stricture beyond 1 year postoperatively are lacking. Future prospective, multicenter studies with larger sample sizes (estimated at least 200-300 patients), adequate statistical power, and extended follow-up (at least 3-5 years) are needed to further validate the long-term clinical efficacy and safety of double-scope combined minimally invasive surgery.

Disclosure of conflict of interest

None.

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