



# Minimally invasive strategy for type I choledochal cyst in adult: combination of laparoscopy and choledochoscopy

Haicheng Yuan<sup>1</sup> · Guoqiang Dong<sup>1</sup> · Nan Zhang<sup>2</sup> · Xiangyu Sun<sup>1</sup> · Hongzhi Zhao<sup>1</sup>

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## Abstract

**Background** Choledochal cyst (CC) is a rare disease entity, more commonly occurring in Asian populations. In case of no contraindication, CC is resected to avoid future malignancies and future complications.

**Objective** To determine the optimal technique for treatment of patients with type I choledochal cyst by comparisons of indicators, including the duration of surgery, loss of blood, rates of complication, duration of hospitalization, and outcomes of long-term follow-up.

**Methods** From January 2009 to September 2017, a combination of laparoscopy and choledochoscopy surgery was implemented for type I choledochal cyst in adult. Patients' demographics data and treatment outcomes were collected prospectively during the follow-up.

**Results** Fifty-eight patients with type I choledochal cyst were managed using this strategy. The combination of laparoscopic and intraoperative choledochoscopy was successfully performed in all patients without conversion or morbidity. When compared with a historical cohort of 71 patients who underwent a surgery for CC, this group of patients had significantly shorter duration of hospitalization ( $9.0 \pm 6.5$  days vs.  $13.0 \pm 8.0$  days,  $P < 0.05$ ). We also observed a lower blood loss ( $128.8 \pm 60.2$  mL vs.  $178.1 \pm 58.2$  mL,  $P < 0.05$ ), although the duration of the surgery ( $320.0 \pm 50.0$  min vs.  $190.0 \pm 24.5$  min,  $P < 0.05$ ) was longer. However, no significant difference was found in the rate of postoperative bleeding complication (3.45% vs. 4.23%,  $P = 0.82$ ) and bile leakage complication (6.90% vs. 4.23%,  $P = 0.51$ ). The two groups had similar rates of anastomotic stenosis (0.96% vs. 0.61%,  $P = 0.47$ ), jaundice (0.58% vs. 0.61%,  $P = 0.95$ ), cholangitis (0.38% vs. 0.30%,  $P = 0.81$ ), and reoperation (0.38% vs. 0.15%,  $P = 0.43$ ).

**Conclusion** The type I choledochal cyst in adult can be effectively managed by laparoscopic surgery combined with inoperative choledochoscopy, which is feasible and minimally invasive. With the development of laparoscopic techniques and instruments, laparoscopic surgery may become the first-choice treatment for type I choledochal cyst treatment.

**Keywords** Choledochal cyst · Choledochoscope · Laparoscopy · Minimally invasive

Choledochal cysts represent cystic dilation of the extrahepatic or intrahepatic ducts, or of both, that may result in significant morbidity and mortality, unless identified early and managed appropriately. Choledochal cysts are usually

diagnosed in childhood, although their diagnosis in adults is also common [1, 2]. Presentation is usually non-specific and vague, especially in adults. The complications include pancreatitis, cholangitis, secondary biliary cirrhosis, spontaneous rupture of cyst, and cholangiocarcinoma. Improved imaging modalities have facilitated the diagnosis at any time from antenatal to adult life. Surgical management has evolved from cystenterostomy, which was associated with the recurrence of symptoms and malignancy to primary cyst excision with roux-en-Y bilioenteric drainage, either open or laparoscopic. Laparoscopic excision of CC is safe and feasible [3–5]. Surgery should be performed early as outcomes are better in pediatric age as compared to those in adults [6]. CC is characterized by an increased risk of

✉ Haicheng Yuan  
ironyh2002@163.com

Hongzhi Zhao  
tjzhzh@126.com

<sup>1</sup> Department of Minimally Invasive Surgery, Tianjin Nankai Hospital, Nankai District, No. 122, San Wei Road, Tianjin 300100, China

<sup>2</sup> Department of Gastrointestinal Surgery, Tianjin Nankai Hospital, Tianjin, China

degeneration. Radiological examinations can reveal the diagnosis in younger and asymptomatic patients to ensure well-conducted and timely surgical treatment has been performed [7]. This paper presents a review of the literature on cancer in patients with choledochal cyst before and after excision. A postoperative follow-up concept that consists of annual controls of CA19-9 and abdominal ultrasound was introduced [8].

Type I cysts typically appear as anechoic cystic lesions which communicate with the biliary tract. A type I cyst can be associated with mild enlargement of the intrahepatic bile ducts secondary to biliary stasis [1]. The incidence of type I choledochal cyst is higher in adult.

The objective of this study was to determine the best technique for treatment the patients with type I choledochal cyst by comparing indicators, including the duration of surgery, loss of blood, rates of complication, duration of hospitalization, and the outcomes of long-term follow-up.

## Materials and methods

The first laparoscopic surgery combined with intraoperative choledochoscopy for the management of Type I cysts was implemented in our institution in the early 2007. Fifty-eight patients with type I cysts, usually presented with jaundice or pancreatitis, were included from January 2009 to September 2017. In addition to ultrasound (US), which is the preliminary routine investigation for biliary disease, computed tomography (CT) and magnetic resonance cholangiopancreatography (MRCP) were performed in patients with suspected Type I cysts. CT and MRCP were also helpful to exclude gall bladder cancer or cholangiocarcinoma, which might give rise to a similar clinical picture and US findings. Surgery could be performed once the liver function has returned to its normal level and pancreatitis has been subsided. MRCP imaging combined with intraoperative choledochoscopy can confirm type I cysts. The criteria for surgery: patients with type I cysts presented with jaundice or pancreatitis were indicated for surgery.

## Ethics statement

The study protocol was approved by the Tianjin Nankai Hospital Research Ethics Committee, and the informed consent was obtained from all the patients.

## Surgical approach

The patients were anesthetized in the supine position. Five operating holes were needed for the inspection of the pelvic cavity and abdominal organ surfaces,

including the liver, and the subsequent procedures. Cystic dilatation of the bile duct was observed next to the gallbladder. Then, the gallbladder triangle was dissected, the gallbladder duct and artery were cut off after proximal clamping, and the gallbladder was removed from the bed. The choledochal cyst was dissected as close to the wall as possible using an ultrasound knife with bipolar electrocoagulation. The separation of the left and posterior wall of the cyst from the hepatic artery and portal vein was meticulously and progressively performed until a dissector could penetrate through the space between the posterior wall of the cyst and the portal vein. To avoid pancreatic duct injury, we based our surgical approach on our experience and opened the anterior wall of the choledochal cyst, followed by intraoperative choledochoscopy confirmation.

Intraoperative choledochoscopy confirmed the absence of stones in the proximal and distal bile ducts, as well as the opening of the pancreatic duct in the distal bile duct, and the location of resection. The dilatation of the bile duct was resected, and the distal narrow end was closed by with polymeric Hem-o-lok clips or an endo-GIA stapler. The upper part of the cyst was completely transected by using the scissors at approximately 5 mm from the confluence of the right and left hepatic ducts at the proximal end. Next, the proximal end was retained for anastomosis.

After identifying the ligament of Treitz, approximately 20 cm-sized proximal jejunum from Treiz ligament was divided with an endo-GIA stapler (Ethicon Endo-Surgery, Cincinnati, OH, USA) and the mesenteric vessels were ligated by a harmonic scalpel. A 50-cm Roux limb was made by side-to-side anastomosis using an endo-GIA stapler. The Roux limb was brought to the hepatic duct in the retrocolic position through the transverse mesocolon. In this position, the limb easily reached the hepatic duct bifurcation without tension. The Roux limb was secured to the transverse mesocolon. Further, the hepatic duct was anastomosed laparoscopically to the jejunal limb of the Roux loop with a continuous, single-layer full-thickness 4-0 PDS II suture. A suction drain was positioned near the biliary anastomosis through the right port site. The specimen was placed in an endobag and removed immediately. It was removed earlier, if no evidence of bile leakage was noted. Patients were discharged from the hospital once they were fully mobilized and had an adequate oral intake.

Patients who underwent open surgery for the Type I cysts before the introduction of the combination of laparoscopy and choledochoscopy were identified from the database. We compared the demographic data, operative outcomes, rates of postoperative complication, mean days of hospitalization, and follow-up outcome between these two groups of patients.

## Statistical analysis

Quantitative data are expressed as means  $\pm$  standard deviation. Categorical and binary variables were tested using the  $\chi^2$  test and Fisher's exact test. Statistical significance was assumed at  $P < 0.05$ .

## Results

From January 2009 to September 2017, 58 patients (13 male and 45 female) with type I choledochal cyst were managed using the combined laparoscopic and inoperative choledochoscopy approach. Of these, 41 patients presented with jaundice and 17 with acute pancreatitis. Ultrasonography was the initial radiological investigation. CT plus MRCP and magnetic resonance imaging (MRI) were performed in all patients. The diameter of the Choledochal Cyst was  $5.5 \pm 1.2$  cm (Table 1).

The combined laparoscopic with inoperative choledochoscopy approach was successfully applied in all patients. There was no need for pancreatoduodenectomy, and no conversion was established. The duration of the surgery was  $320.0 \pm 50.0$  min, and the blood loss was  $128.8 \pm 60.2$  mL. No patient required transfusion. The postoperative bile leakage complication rate was 6.90% (4/58). Four cases of biliary leak were diagnosed by their drainage solution, which contained bile without abdominal pain and fever. The median time of disappearance of the biliary leak without treatment was 35 h (range 20–48 h). In four patients, the time of the disappearance was delayed to remove the drains after postoperative cholangiography. The drains were removed within the period from day 2 to 5. The mean number of the days of hospitalization was  $9.0 \pm 6.5$  days. The pathology of the resected specimens revealed choledochal cysts, but

no biliary carcinoma was detected. The result of the 72-h postoperative ultrasound (US) showed no bleeding or bile leakage, and thus the drainage tube was removed. Of all patients, 52 were followed up. The rate of anastomotic stenosis was 0.96%, of jaundice 0.58%, of cholangitis 0.38%, and of reoperation 0.38%.

A historical cohort of 71 adult patients who underwent surgery for type I choledochal cyst between 2000 and 2008 was identified. All patients underwent open surgery by the same surgeon team in the same hospital. The data of this group of patients were compared with those of the 58 patients in whom the combined laparoscopic with inoperative choledochoscope approach was implemented (Table 1). The two groups were comparable in terms of age, sex, and diameter of the choledochal cyst. The blood loss during the surgery in the combined approach group was significantly lower than that in the open group. The duration of the surgery through the combined approach significantly was longer than that in the open surgery group. No differences in the rates of complication were noted. The four bile leak complications in the combined approach and the three cases in the historical cohort were managed successfully through percutaneous drainage. The bleeding complication cases in the two groups were managed successfully by non-operative treatment. The duration of the hospitalization of the patients treated with the combined approach was significantly shorter than that of the historical cohort (Tables 2, 3). The median long-term follow-up duration after the original surgery in the two groups ( $28.8 \pm 1.5$  vs.  $30.4 \pm 10.4$ ) was similar. In the combined approach group, 52 patients were subjected to a long-term follow-up, whereas in the historical cohort group, 66 patients underwent long-term follow-up. We observed no significant differences between the two groups in the rates of anastomotic stenosis (0.96% vs. 0.61%,  $P = 0.47$ ), jaundice (0.58% vs. 0.61%,  $P = 0.95$ ), cholangitis (0.38% vs. 0.30%,

**Table 1** Baseline variables for the two groups

Variable	Combined choledochoscope with laparoscopic approach ( $n = 58$ )	Historical cohort ( $n = 71$ )	<i>P</i>
Age (mean $\pm$ SD) (years)	$26 \pm 7$	$28 \pm 6$	$> 0.05$
Sex Men ( <i>n</i> %)	13/58	15/71	0.86
Diameter of the Choledochal Cyst (cm) (mean $\pm$ SD)	$5.5 \pm 1.2$	$5.9 \pm 2.1$	$> 0.05$

**Table 2** Comparison of the new treatment strategy and historical cohort for Type I Choledochal Cyst

	Combined choledochoscope with laparoscopic approach ( $n = 58$ )	Historical cohort ( $n = 71$ )	<i>P</i>
Duration of surgery (min)	$320.0 \pm 50.0$	$190.0 \pm 24.5$	$< 0.05$
Blood loss during surgery (mL)	$128.8 \pm 60.2$	$178.1 \pm 58.2$	$< 0.05$
Mortality	0	0	NA
Mean duration of hospitalization (days)	$9.0 \pm 6.5$	$13.0 \pm 8.0$	$< 0.05$

**Table 3** Rate of postoperative complication between the two groups

Complication	Combined choledochoscope with laparoscopic approach (n = 58)	Historical cohort (n = 71)	P
Bleeding	2 (3.45%)	3 (4.23%)	0.82
Bile leakage	4 (6.90%)	3 (4.23%)	0.51

$P=0.81$ ), and reoperation (0.38% vs. 0.15%,  $P=0.43$ ). No common bile duct carcinogenesis case was established in the two groups (Table 4).

## Discussion

Choledochal cyst (CC) is a rare condition, which increases the risk of infection and cancer. Interestingly, the presentation of CC was found to vary between children and adults, and the resection was associated with morbidity. Although concomitant cancer was uncommon, it occurred in 3.0% of the patients [9]. In contrast, the incidence of malignancy in adults was 11.4%. The median age for diagnosis of cancer was 42 years, and the incidence increased with each decade [10]. In this study, we found an obvious tendency of a decreased CC occurrence in younger patients. It is more common in females, with an incidence of 78.3% (101/129). The symptoms of choledochal cysts include abdominal pain, jaundice, and cholangitis. This disorder may eventually lead to malignant transformations, so an early diagnosis and proper surgical excision are extremely important for a beneficial outcome. For many years, open excision was a standard procedure, which has contributed considerably to the effective treatment of choledochal cysts. So far, many studies have published comparisons of the safety of laparoscopic excision versus that of an open operation in the treatment of choledochal cyst. Although no sufficient data were available of randomized controlled trials, the present meta-analysis still remains the best evidence for the treatment outcomes. Based on the present evidence summarized herein, laparoscopic excision is feasible and valid [11].

Many different approaches of managing CC have been previously described in the literature. However, there is a lack of defined guidelines on both the diagnostic and the therapeutic aspects of this management. For example, it is still debatable if hepaticoduodenostomy or Roux-en-Y hepaticojejunostomy is the best type of biliodigestive reconstruction after cyst excision. Hepaticoduodenostomy is preferred by some surgeons because the direct bile drainage into the duodenum minimizes the risk of duodenal ulcer and fat malabsorption, which may occur due to hepaticojejunostomy. Hepaticoduodenostomy is a procedure simpler than Roux-en-Y hepaticojejunostomy. Laparoscopic repair for choledochal cyst is a safe and effective procedure for choledochal cyst treatment. Nonetheless, further studies with a long-term follow-up are needed to determine whether hepaticoduodenostomy and hepaticojejunostomy are comparable in terms of their risks of cholangitis and bile reflux [12]. The total excision of cysts through Roux-en-Y hepaticojejunostomy is now a common procedure for choledochal cyst therapy in both adults and children [13]. Minimally invasive surgery has become the standard of care for many procedures because of its advantages, including decreased pain, reduced length of stay, and quicker recovery [14].

Open operation has been the optimal surgical treatment for Type I choledochal cyst in adult for many years. Some surgeons still consider CC as one of the contraindications for laparoscopic surgery due to their view that the laparoscopic management of CC with intense fibrotic and cholecystobiliary fistula is exceedingly difficult and unsafe. In recent studies, surgeons recommended laparoscopic CC management. Although the operative time was longer, the length of the postoperative hospital stay was smaller, the intraoperative blood loss was lower, and the time period to food intake was shorter. The rate of postoperative morbidity in a laparoscopic group and an open group was found to be similar [15]. Therefore, with the improvement of laparoscopic techniques and advances in surgical practice, laparoscopic surgery may become first-choice procedure for choledochal cyst therapy.

In our study, blood loss during surgery of the combined approach was fewer significantly than the open group. The duration of surgery of the combined approach was

**Table 4** Long-term follow-up outcome

Variable	Combined choledochoscope with laparoscopic approach (n = 52)	Historical cohort (n = 66)	P
Duration of follow-up (mon)	58.8 ± 11.5	60.4 ± 10.4	> 0.05
Anastomotic stenosis	5 (0.96%)	4 (0.61%)	0.47
Jaundice	3 (0.58%)	4 (0.61%)	0.95
Cholangitis	2 (0.38%)	2 (0.30%)	0.81
Reoperation	2 (0.38%)	1 (0.15%)	0.43
Subsequent biliary cancer	0	0	NA

longer significantly than the open group ( $320.0 \pm 50.0$  vs.  $190.0 \pm 24.5$  min). No difference in the rate of complication was noted. With the improvement of laparoscopic techniques and deftness of surgeons practice, the operative time, while be shorter and similar with open operation. Laparoscopic treatment of choledochal cysts involving total cyst resection and hepaticojejunal Roux-en-Y loop anastomosis has several advantages: excellent intraoperative visualization of tiny structures and great surgical accuracy, early resumption of peristalsis, no postoperative pain, no laparocoele, and prevention of adhesions [16, 17]. The main outcomes were comparable to those of the open surgery, laparoscopic excision of the cyst, and Roux-en-Y hepaticojejunostomy is a safe and effective approach [18]. With case accumulation and technical improvement, single-incision laparoscopic Roux-en-Y hepaticojejunostomy is safe and feasible for majority of giant CC children [19]. As the laparoscopic suture technique of the Roux-en-Y hepaticojejunostomy is proficient, the rate of conversion has become lower since 2007, and there was no conversion of the combined procedures for Type I choledochal cyst in adult since 2009 in our center. It is recommended to use a combination of laparoscopy and inoperative choledochoscopy for CC. However, laparoscopic primary suture of the Roux-en-Y hepaticojejunostomy is relatively difficult; hence we recommend that it should be performed by experienced surgeons.

CC is not easily diagnosed preoperatively; in approximately 20% of the cases it is detected in adults [17]. Its surgical treatment in infancy or childhood was problematic, but the advancement in modern imaging techniques has facilitated the diagnosis of choledochal cyst at any time point, from antenatal to adult life [20]. Approximately 20% of choledochal cysts (CC) are detected in adult patients and are commonly associated with a high risk of complications, including malignancy. Additionally, children undergoing internal drainage procedures for CCs can develop complications during adulthood despite the treatment [21]. Choledochal cysts are rare cystic dilatations of the intrahepatic and/or extrahepatic biliary tree and may be mistaken for other cystic lesions if their characteristic features are not well recognized. MRCP has replaced more invasive techniques and has become the “gold standard” for diagnosis. In addition, MRCP is helpful in detecting an abnormal pancreaticobiliary junction, which occurs in the majority of choledochal cysts. Reaching a correct diagnosis is essential, given the associated risk of complications, including cholangitis, biliary strictures, stones, and malignancy, and accurately assessing the location and length of involvement is vitally important for surgical planning and efficacy [22]. MRI is a reliable method for the detection of choledochal cysts with biliary malignant changes. MR features such as irregular thickening of the gallbladder wall or cyst wall, mass or papillary nodules are suggestive of biliary malignant changes

[23]. Endoscopic retrograde cholangiopancreatography (ERCP) is not a routinely used imaging diagnosis tool in our center. The etiology of bile duct cyst is related to the abnormal confluence of bile duct and pancreatic duct. The rate of post-ERCP pancreatitis was high in bile duct cyst patients. Ultrasound examinations facilitate the measurement of the diameter of bile duct cysts. No differences were found in the diameter of choledochal cyst between the two studied groups ( $5.5 \pm 1.2$  vs.  $5.9 \pm 2.1$  cm). CT scans did not provide any additional information to that obtained by the US but was essential in the differentiation of CC from a malignant biliary obstruction. MRCP is frequently used in clinical practice for evaluating biliary strictures. Similarly to US, it can reveal the typical features of CC. Based on our experience, MRCP should be undertaken in cases of suspected CC even without obvious jaundice but with dilated CHD and without stones. The diagnosis of adult choledochal cysts is frequently delayed due to their non-specific clinical symptoms. The delays in the diagnosis and treatment can often extend for years, increasing the risk of malignant degeneration. Moreover, biliary cancer is particularly difficult to differentiate from CC. Hence, preoperative imaging studies and the examinations of intraoperative frozen sections are important for the detection of any suspicious signs of biliary cancer. In this study, preoperative CT, MRCP, and MRI were performed in all patients.

Our strategy demands an expertise in both laparoscopic and inoperative choledochoscopy surgery. Conventional open surgery requires large abdominal incisions, which is more traumatic to the patient. In our minimally invasive strategy, this group of patients had significantly shorter duration of hospitalization ( $9.0 \pm 6.5$  days vs.  $13.0 \pm 8.0$  days,  $P < 0.05$ ). We also established a lower blood loss ( $128.8 \pm 60.2$  mL vs.  $178.1 \pm 58.2$  mL,  $P < 0.05$ ). The conversion rates of laparoscopic choledochal cyst excision in another study were almost zero [24]. The combined laparoscopic with inoperative choledochoscopy approach was successfully performed in all patients, with no conversion. An earlier meta-analysis revealed that the mean operation time of the minimally invasive strategy was longer than that of open strategy, because the laparoscopic approach required more instruments and was technically more demanding [11]. In this study, the duration of surgery was significant longer ( $320.0 \pm 50.0$  min vs.  $190.0 \pm 24.5$  min,  $P < 0.05$ ). However, the general trend was towards a decrease in the operation time with the increase in the number of cases. In recent studies, the operative complication rate of laparoscopic choledochal cyst was 12.9%. Generally, the overall results of our data demonstrate that the total laparoscopic surgery is a safe approach [14, 25]. In our study, there was no significant difference in the rates of postoperative bleeding complication (3.45% vs. 4.23%,  $P = 0.82$ ) and bile leakage (6.90% vs. 4.23%,  $P = 0.51$ ).



Intraoperative choledochoscopy was an important aspect of our minimally invasive strategy. To avoid pancreatic duct injury, based on our experience, we opened the anterior wall of the choledochal cyst and obtained intraoperative choledochoscopy confirmation. A choledochoscope can be used for an examination of the biliary tract, removal of common bile duct stones, and confirmation of biliopancreatic duct confluence. A choledochoscope was employed in our study to measure the diameter of the common hepatic duct and the confluence of the left and right hepatic ducts. The proximal and distal resection lines had to be confirmed by intraoperative choledochoscopy. This technique is important in the management of patients, especially where the choledochal cyst may represent a premalignant state. Inoperative choledochoscopy can be applied to detect dysplasia of the bile ducts, with direct visualization of the mucosa and a possibility of obtaining biopsy samples [26]. The ultrasound knife with bipolar electrocoagulation is more efficient and convenient for performing bloodless dissection of cysts, but the proximal resection is to be conducted by scissors. The malignancy rate after incomplete resection of a CC is relatively high. To improve outcomes, all attempts should be made for complete resection of the intrapancreatic portion of CCs at the time of the primary operation [27–29].

Our experience in the separation of bile duct cysts is as follows:

- (1) The choledochal cyst was dissected as close as possible to the wall using an ultrasound knife;
- (2) It is a relevant approach in cases with hemostasis with bipolar electrocoagulation application. The choledochal cyst was dissected using an ultrasound knife with bipolar electrocoagulation, which obviously reduced the bleeding during the operation and maintained a clear operating view;
- (3) The distal narrow segment of the cyst was located at the front right of the cyst but not at the bottom of the cyst. The posterior wall of the cyst was pendulous and needed to be fully dissociated and identified;
- (4) A choledochoscope was employed to confirm the biliopancreatic duct confluence and the resection lines. Hence, intraoperative choledochoscopy is an important method in the minimally invasive strategy for CC therapy.

Hepaticojejunostomy is considered to be a technical challenge and the most difficult and time-consuming step. One study [30] recommended that the Roux-en-Y jejunostomy should be carried out intracorporeally by hand suture. In our study, however, all patients underwent laparoscopic Roux-en-Y loop construction. Surgeons should ensure that the hepaticojejunostomy is tension-free, and a good blood supply has been provided. Hepaticojejunostomy was

performed with a continuous, single-layer full-thickness 4-0 PDS II absorbable suture. The key point of hepaticojejunostomy is to avoid an anastomotic leak and the development of an anastomotic stoma stricture. The rate of bile leakage in our study was 6.90%, similar to that of the open group. The rate of anastomotic stenosis (0.96% vs. 0.61%,  $P=0.47$ ) and the rate of reoperation (0.38% vs. 0.15%,  $P=0.43$ ) were also similar in the two groups. All cases of reoperation were intrahepatic bile duct stones secondary to anastomotic stenosis. To avoid anastomotic stenosis, an inoperative choledochoscope was used to measure the diameter of the common hepatic duct and the confluence of the left and right hepatic ducts. If the size of hepatic ducts was  $< 1.0$  cm in, the anastomosis could be successfully performed after ductoplasty to prevent the formation of an anastomotic stoma stricture [31]. The application of hilar ductoplasty with Roux-en-Y hepaticojejunostomy as the primary surgery for bile duct cyst excision significantly reduced the postoperative complication of biliary-enteric anastomotic stricture [32]. Meticulous probing and excision of the intrahepatic bile duct stenosis-causing membrane or septum are effective for preventing hepatolithiasis after choledochal cyst excisions [33]. Meanwhile, along with the wide use of laparoscopic excision in clinical surgery and the increase of surgeons' experience, the time for laparoscopic suture might be shortened. An earlier study showed that the robot-assisted resection of a choledochal cyst with Roux-en-Y hepaticojejunostomy is a safe and feasible approach with short operation time [34]. Hepaticojejunostomy performed with barbed sutures was relatively easy, but caution had to be taken to prevent overtightening of the suture [35]. The cost of the study group because the auto-suture device and laparoscopic instruments as well as intraoperative choledochoscopy had been used was higher than open operation group. Along with the increase of surgeons' laparoscopic suture experience, the cost might be decreased.

Our strategy in this study was safe and feasible. There was no conversion to open surgery and no operative morbidity. All patients were discharged with a significantly shorter duration of hospitalization ( $9.0 \pm 6.5$  days vs.  $13.0 \pm 8.0$  days,  $P < 0.05$ ). With the continuous accumulation of experience, we consider that the duration of hospitalization can be further shortened. In contrast, the historical cohort had a significantly longer duration of hospitalization. These patients also had postoperative complications, albeit not statistically significant. No significant differences were noted in the rates of postoperative long-term complications between the two groups. Nevertheless, cancer may develop up to 10 years after the choledochal cyst excision, indicating the need for lifelong follow-up in this patient population [36]. It is noteworthy that no subsequent biliary cancer case occurred in our study. The patients will be subjected to a lifelong follow-up in our center. Therefore, combined

laparoscopic and intraoperative choledochoscope procedures were minimally invasive and effective in the treatment of type I CC.

## Conclusion

Type I choledochal cyst in adult can be effectively managed with a laparoscopic surgery combined with intraoperative choledochoscopy. This strategy is feasible and minimally invasive. With the further, ongoing development of laparoscopic techniques and instruments, laparoscopic surgery may become the first choice for type I choledochal cyst treatment.

**Author contributions** HCY, NZ, XYS, HZZ, and GQD contributed to the conception and the design of this study. HCY and GQD collected, analyzed, and interpreted the data. HCY and GQD drafted the manuscript, and HCY and HZZ critically revised the manuscript. All authors agree to be fully accountable for having ensured the integrity and accuracy of the work, and have read and approved the final version of the manuscript.

## Compliance with ethical standards

**Disclosures** Haicheng Yuan, Guoqiang Dong, Nan Zhang, Xiangyu Sun, and Hongzhi Zhao have no conflicts of interest or financial ties to disclose.

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