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Preliminary experience with continuous submucosal-anastomosis in small diameters hepaticojejunostomy during single-port laparoscopic choledochal cyst surgery in children

yingming tang, jie zhang, miao luo, fei li, huang huang, zhou zhou, xia fan, zhijie qin, guoqing he, yize zhuang.

Affiliations below.

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Conflict of Interest: The authors declare that they have no conflict of interest.

Abstract:

Purpose:
Hepaticojejunostomy anastomosis (HJA) is the most challenging aspect in single-port laparoscopic choledochal cystectomy and Roux-en-Y hepaticojejunostomy (SPCH) in children, especially in small-diameter anastomoses (diameters less than 5 mm), which are more susceptible to anastomotic stricture. We developed the continuous submucosal technique for hepaticojejunostomy (CS-HJA) to lessen postoperative complications. The purpose of this study is to introduce our preliminary experiences with CS-HJA.

Methods:
We retrospectively analyzed all available clinical data of children who underwent SPCH surgery between March 2020 and October 2022. We operated with CS-HJA on 10 children who were diagnosed with small diameters hepaticojejunostomy (diameter is less than 5 mm). Data collection mainly included demographic information, imaging data, perioperative details, and postoperative outcomes. Ten patients were included in this study. The average patient age was 55.2 months and the age range was 3 months to 120 months and the average weight was 11.6 kg, male-female ratio was 1:9. The choledocho had fusiform dilatation in 5 cases and cystic dilatation in 5 cases, and there was no dilatation of the left and right hepatic ducts or intrahepatic bile ducts in all patients. All patients underwent a single-port laparoscopic bile-intestinal anastomosis using a sub-mucosal jejunal anastomosis technique. Analysis of the duration of the bile-intestinal anastomosis, the length of the child's stay in the hospital after surgery, the intraoperative complications, and the postoperative complications.

Results:
All the 10 patients underwent successful SPCH by CS-HJA technique. The average length of time for hepaticojejunostomy ranged from 22 to 40 minutes, and the postoperative hospital stay was 5.2 to 9.2 days. There were no instances of bile leakage following the operation. At 17 to 30 months of follow-up, there was no abdominal pain or jaundice, and the reexamination of transaminases, bilirubin and amylase were normal. Ultrasonography showed no bile duct stricture or dilated bile ducts, and the incision is elegant and the families of the patients were satisfied.

Conclusion:
In single-port laparoscopic choledochal cystectomy and Roux-en-Y hepaticojejunostomy (SPCH) in children, the CS-HJA technique is safe and feasible for small-diameter hepaticojejunostomy in SPCH surgery in children.

Corresponding Author:
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Introduction

Choledochal cysts (CDC) are the most common congenital malformation found in the biliary tract and are characterized by cystic or fusiform dilatation of the common bile duct. In particular, Asian populations have a high incidence of choledochal cysts\textsuperscript{1-2}. Patients with choledochal cysts may experience cyst perforation, recurrent pancreatitis, cancer, or even severe cholestasis without receiving effective treatment, which can then result in liver cirrhosis, portal hypertension, and ultimately liver failure\textsuperscript{3}. Surgery is the primary treatment option for choledochal cysts and typically involves choledochal cystectomy, cholecystectomy, and hepaticojejunostomy \textsuperscript{4}. Robotic surgery and laparoscopic surgery are two minimally invasive procedures commonly used to treat choledochal cysts. Currently, laparoscopic surgery is the most mainstream surgical approach in China and worldwide\textsuperscript{5}. Single-port laparoscopic CDC excision and Roux-en-Y hepaticoenterostomy (SPCH) have the advantages of being less traumatic and more cosmetic beneficial, Therefore, it is becoming more widely adopted\textsuperscript{6}. One of the most challenging aspects of this procedure is the hepaticojejunostomy, particularly when the anastomosis's diameter is less than 5 mm. In SPCH, it was very complicated for the surgeon to perform the procedure without an assistant, In the absence of an adequately exposed surgical field during the procedure. Anastomoses with a diameter
of less than 5 mm between the bile duct and jejunum are particularly challenging for the surgeon to complete. The unsuitable anastomosis was vulnerable to complications like stricture and biliary fistula. In our department, a retrospective analysis of 54 SPCH was performed in our department alone between March 2020 and October 2022. Among these cases, 10 children had a choledochal diameter of less than 5 mm, and all used the sub-mucosal jejunal anastomosis technique, and in this study, we present our experiences and discuss the relevant technical points.

**Materials**

**Study Population**

The study was conducted in accordance with the Declaration of Helsinki (revised in 2013) and was approved by the ethics committee of Guizhou Provincial People's Hospital with approval No. (2022) 083A01. As this was a retrospective analysis, individual consent was not obtained.

We retrospectively analyzed all available clinical data of children who underwent single hole laparoscopic choledochal cyst resection between March 2020 and October 2022. To be included in the study, patients needed to meet the following criteria: (1) The presence of choledochal cyst was confirmed through preoperative history, physical examination, B-ultrasound, CT, or MRCP. (2) The procedure was successfully completed under general anesthesia, and the choledocho diameter was determined to be less than 5 mm both before and during surgery. All patients underwent successful SPCH by CS-HJA technique. (3) The patient did not have any serious organ dysfunction, and their coagulation function was normal.
Exclusion criteria for the study included subsequent operations, cyst perforation, and malignant transformation of the choledochal cyst prior to the operation.

**Procedure of the continuous submucosal anastomosis in hepaticojejunostomy (CS-HJA)**

The patient was placed in the human font position with the laparoscopic monitor placed on the upper right side of the patient and the operator standing between the patient's legs. The umbilicus was incised longitudinally, the subcutaneous tissue was separated into the abdominal cavity, and a 5mm Trocar was inserted in the middle of the umbilical fossa and established pneumoperitoneum pressure of 8-12mmHg (1mmHg=0.133kPa). The subcutaneous tissues on both sides of the light source trocar were bluntly freed, and a 3mm Trocar was inserted at a distance of 1.0-1.5cm from both sides of the light source trocar(Figure 1).A 3/0 sliding suture is used to suspend the base of the gallbladder and the anterior wall of the common hepatic duct or the hepatic round ligament to expose the hilar region, respectively. The gallbladder is peeled from the base to the neck with an electrocoagulation hook. If the cyst was large, decompression was performed and the distal end of the CDC was suspended. An electric hook was used close to the cyst wall to dissect the anterior and posterior walls. After that, the distal end would be dissected to the proximal pancreaticobiliary junction and ligated with a 5-0 synthetic clip or dissociation directly. The CDC is completely removed by traction of the CDC from the bottom to the top freeing the posterior wall of the CDC to the choledochal. If there is a right hepatic artery riding across the choledochal, the ectopic anterior right hepatic artery is repositioned
posterior to the anastomosis (Figure 2). The jejunum was extracted through an umbilical incision 10~15 cm from the Treitz ligament. Roux-en-Y jejunoojejunostomy is constructed extracorporeally by use a 5/0 PDS suture. The pneumoperitoneum is reconstructed, Roux-en-Y loop jejunum was lifted up to the hepatic hilum through the right mesentery of transverse colon. The intestinal wall opposite to the mesentery of the biliary loop is opened according to the diameter of the common hepatic duct. The posterior wall was sutured preferentially with a double-needle 5/0 PDS suture. Through the submucosa at the right margin of the posterior lateral wall of the Roux-en-Y loop jejunum and exiting through serosal layer (Figure 3A); Then, the needle was injected from the outside to the inside at the 3 o'clock position of the hepatic duct. Repeated continuous submucosal anastomosis the wall of hepatic duct and the jejunum to the 9 o'clock position, To fully expose the visual field, the suture is not closed at this point. (Figure 3B). The suture of the anterior wall of the anastomosis in intestinal duct was entered from the serosal layer and exited from the submucosa (Figure 3C), while the bile duct was exited from the inside to the outside side. The anterior wall of the hepatic duct was continuously sutured to the 9 o'clock position, and the last two stitches were knotted to complete the hepaticojejunostomy (Figure 3D). The needle distance of Cs-HJA is controlled at 0.8~1.2mm, and the side distance is 1.2~2.5mm.

**Intraoperative and Postoperative Observations and Recording Indicators**

After the restoration of intestinal function, a liquid diet was initiated. Discharge would be authorized only when the patient was able to eat regularly without
experiencing abdominal pain or other issues. Demographic information, as well as clinical manifestation, cyst type, cyst diameter, surgery time, anaesthesia time, perioperative bleeding, transfusion, time to resume oral intake, length of hospital stay, and postoperative problems, were tracked and documented. The postoperative follow-up plan: monthly review within 6 months after surgery, then at an interval of 3 months, and once every 3-6 months after 1 year, including physical examination, abdominal ultrasound, laboratory tests, and abdominal CT or MRCP if necessary. The presence of postoperative complications will be evaluated based on the results of the examination.

Statistical Analyses

The statistical information was imported into Excel 2007 and evaluated with the SPSS 23.0 program. The standard deviation and the mean were used to express numerical variables, whereas counts (N) and percentages (%) were used to express categorical variables.

Results

The CS-HJA technique was successfully employed in all 10 children to perform SPCH surgery, without any intraoperative complications. The baseline data of the 10 children are shown in Table 1; Five of them were Todani type Ia, and five were Todani type Ic. The ectopic right hepatic artery was found to be riding across the common hepatic duct in two children, and the ectopic anterior right hepatic artery was repositioned behind the anastomosis. The mean duration of bile-intestinal anastomosis was 27.8 minutes, ranging from 20.4 to 34.3 minutes, and the average hospital stay...
was 7.04 days, ranging from 5.2 to 9.2 days.; no bile leakage occurred after surgery, and the preoperative direct bilirubin of 207.2 umol/L was reduced to 63.7 umol/L in one child at discharge, and the direct bilirubin returned to normal on reexamination 1 week after discharge. The remaining 9 children were discharged with normal bilirubin levels. During the 17 to 30-month follow-up period, the patients did not experience abdominal pain or jaundice. Reexamination of transaminases, bilirubin and amylase were normal. Ultrasound showed no bile duct stones and dilated intrahepatic bile ducts with anastomotic stenosis. Perioperative details and postoperative outcomes are presented in Table 2.

Discussion

Choledochal cysts are congenital biliary diseases characterized by the dilation of both intrahepatic and extrahepatic bile ducts. The most common type is type I, which involves the dilatation of the extrahepatic bile duct\(^7\), and the incidence of choledochal cysts is lower in Europe and North America\(^8\). They are more common in Asia, with a hospitalization rate of up to 1:1000. According to international literature, the male-to-female ratio of choledochal cysts is approximately 3-4:1, although this ratio varies in different regions\(^9\). Approximately 60% of choledochal cysts are diagnosed within the first year after birth. The main clinical manifestations include the triad of abdominal pain, abdominal mass, and jaundice. Surgical resection is the recommended treatment upon diagnosis\(^10\). Currently, the main surgical approaches for choledochal cysts include open surgery, laparoscopic surgery, and robotic surgery. Laparoscopic and robot-assisted surgeries have more advantages in terms of
cosmetics and faster recovery, and provide better vision in the narrow space for surgeries involving structures such as the bile duct, portal vein, and hepatic artery. However, Da Vinci robot surgery requires advanced hospital equipment and incurs higher costs, making it less commonly performed in China. Single-incision laparoscopic surgery, on the other hand, has been recognized as a "minimally invasive and scarless" surgical technique and has been developed the fastest in China. However, single-incision laparoscopic surgery is a difficult technique, and the learning curve is long. Surgeons need to fight against the narrow field of view and the poor "chopstick effect". Since the first report of laparoscopic choledochal cyst resection and hepaticojejunostomy by Diao M et al, for the treatment of pediatric choledochal cysts, our team has been performing this surgery for 10 years since January 2013, completing about 215 cases, accumulating valuable experience, and publishing relevant papers. The common complications after choledochal cyst excision are bile duct strictures. In a long-term follow-up study conducted by Stringer, M.D, which included 41 subjects, the incidence of anastomotic strictures was 10%. The anastomotic diameters in this study ranged from 6-25mm with a median width of 8mm. However, follow-up data for smaller anastomotic diameters are rarely reported. In clinical practice, we often encounter type I choledochal cysts in children, where the anastomosis required after cyst excision is usually the normal opening of the hepatic duct. Currently, there is no unified standard for the diameter of the hepatic and bile ducts in children. Zhang et al. measured the bile duct diameters of 343 children using ultrasound and found that the normal diameter of the bile duct in
children is positively correlated with age. Japanese scholars suggest that a bile duct diameter of 5mm should be used as the boundary for bile duct dilatation. For choledochoenterostomy with an anastomotic diameter less than 5mm under laparoscopy, the small anastomosis may make the anastomosis difficult to operate, and postoperative stricture is more likely to occur. Studies have demonstrated that the incidence of anastomotic stricture is highest when the diameter of the anastomosis is less than 5mm. This suggests that the incidence of stricture may be higher for anastomoses with a diameter less than 5mm. This may be directly related to the anastomotic technique. For smaller anastomoses, overly dense suturing can cause anastomotic stricture, while looser suturing can cause anastomotic fistula. Therefore, higher technical requirements are needed for such anastomoses. Currently, with advancements in laparoscopic techniques, some scholars propose a method for choledochoenterostomy with an anastomotic diameter less than 5mm. The proximal wall of the cyst should be retained to form a “trumpet mouth” to increase the diameter of the anastomosis to more than 1cm, in order to prevent anastomotic stricture. However, the remaining diseased extrahepatic bile duct may increase the risk of long-term cancer. Urushihara et al. recommend a surgical method of longitudinal splitting of the anterior wall of the hepatic duct, fixing the hepatic duct to the hepatic portal. This approach is employed when the diameter of the hepatic duct is small, followed by choledochoenterostomy. Chang XP et al. treated 47 patients with choledochal cysts by burying the jejunal loop into the hepatic portal, and no postoperative complications such as cholangitis, bile duct stones or anastomotic stricture occurred.
Zhang YB et al. longitudinally split the anterior wall of the small hepatic duct in the anterior direction, and intermittently performed anastomosis under the suspension of both ends. During a 3-year follow-up, ultrasound reexamination showed no signs of bile duct stenosis or dilation in 4 of the patients. These follow-up data indicate that the above methods are beneficial for bile drainage in patients with portal biliary dilation or a low convergence position of the left and right hepatic ducts, and can prevent postoperative bile duct stones and anastomotic strictures. However, in children without portal biliary dilation and with a high convergence position of the left and right hepatic ducts. After the resection of a cyst, the small cut ends of the liver ducts tend to sink deeply into the hepatic portal, resulting in increased difficulty when performing operations such as hepatic portal expansion or separation to reach the convergence of the left and right liver ducts. Moreover, animal experiments have shown that using simple end-to-end anastomosis in diameters greater than 8mm can lead to the formation of annular scars and bile duct stenosis. Therefore, we realize that solving the problem of anastomotic stenosis not only requires enlarging the diameter of the anastomosis but also changing the method of anastomosis.

Based on our nearly 10 years of experience in laparoscopic common bile duct cyst resection, we have developed a comprehensive anastomosis plan called the continuous submucosal jejunal hepatic duct anastomosis (CS-HJA) to address small anastomotic sites (diameter ≤5mm). According to our current follow-up results, the effect of this method is quite ideal, and it is especially suitable for single-incision laparoscopic operations without an assistant. This article aims to summarize and share
our preliminary experience in suturing techniques for small-diameter biliary anastomosis under single-incision laparoscopy.

1. Not suturing the mucosal layer of the intestinal wall

The technique of non-closure anastomosis involves suturing the submucosal layer directly to the serosal layer of the intestinal wall while excluding the mucosal layer of the small intestine (Figure 4). This type of suturing can protect the mucosa from damage, preserve the blood supply to the submucosa, and ensure a smooth and even mucosal apposition, which is beneficial for the healing of the anastomotic site and reduces scar formation. The apposition of the small intestinal serosal layer and the hepatic duct wall confines the fibrous scar tissue formed after healing to the space between the serosa of the small intestine and the outer wall of the hepatic duct, minimizing the risk of anastomotic stricture. The physical strength and stability of the anastomosis mainly depend on the submucosal muscular layer and the serosal layer of the intestine, therefore, excluding mucosal layer suturing does not compromise the strength of the anastomosis nor increase the risk of anastomotic fistula.

2. Order of Anastomosis

Performing hepaticojejunostomy without an assistant can be particularly challenging. To overcome this, we made modifications to a 5-0 PDS suture, adjusting it to a final length of approximately 20 cm for the anastomosis. The suturing process begins at the 3 o'clock position and proceeds clockwise to the 9 o'clock position to close the posterior wall. Similarly, the anterior wall is closed counterclockwise from 3 o'clock to 9 o'clock using another needle. Precise positioning of the anastomosis is crucial to facilitate the anastomosis process. A 20 cm suture line is used that does not
interfere with the procedure and knot-tying. PDS suture is smooth and easy to absorb, effectively reducing the inflammatory response. We use continuous suturing and complete one side of the bile duct before knotting. This allows for enough space to be retained during suturing, ensures clear vision, maintains neat stitch spacing, and ensures that the cutting force of each stitch on the anastomosis is the same after knotting, By avoiding discrepancies in tension between stitches, the risk of leakage is minimized.

3. Invaginating Anastomosis

During the suturing process, we ensure a margin that is approximately twice the distance between needles, meaning that the needle distance for biliary anastomosis is 0.8-1.2mm, and the margin is 1.2-2.5mm. The lateral wall of the common bile duct, which measures 1.5-2.5mm, is aligned with the serosal layer of the jejunum. After the suture is tightened, a portion of the bile duct is invaginated into the anastomotic site, promoting secure healing and reducing the occurrence of bile leakage and scarring. Because postoperative stricture of the anastomotic site is not only related to the diameter of the anastomotic site, but also to factors such as repeated postoperative cholangitis (Figure 5).

4. Handling of the right hepatic artery

During the operation of two patients in this group, it was observed that the right hepatic artery crossed in front of the hepatic duct. Addressing the ectopic anterior placement of the right hepatic artery is crucial as it has been reported that failure to do so can lead to biliary obstruction, it is recommended to fully mobilize the artery and
place it behind the anastomotic site.

However, our study has certain limitations. Firstly, the inclusion criteria for this study were limited to the use of single-port laparoscopic choledochal cyst excision. Secondly, the summary included children with an anastomotic diameter of less than 5mm, resulting in a relatively small sample size. Thirdly, our study was retrospective and had a short follow-up period, highlighting the need for further research with larger, multicenter studies and longer-term follow-up to validate the benefits of this anastomotic technique in children with choledochal cysts and a diameter of less than 5mm. Nevertheless, based on our collective experience thus far, the CS-HJA anastomotic technique appears to be a safe and feasible approach for these children's surgeries.

References


TABLE 1 | Characteristics of the patients.

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<th>Diameter of Anastomotic (mm)</th>
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N=10 3/7 55.2±43.6 11.6±4.1 8.62±2.33 5/4.1±1.2 38.4±3.23 124.26±11.98/9.98 141.3±111.79

DBIL, Direct bilirubin; r-GT, r-Glutamyl transpeptidase
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N = 218.5 ± 5

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TABLE 2 | Intraoperative and postoperative outcomes and complications.

*mean, standard deviation.