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Total robot-assisted choledochal cyst excision using da Vinci surgical system in pediatrics: Report of 10 cases☆,☆☆,★

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ABSTRACT

Background: The robotic surgery has been proposed as another adjunct for pediatric minimal surgery for choledochal cyst. However, the Roux-en-Y jejunal limb in most reports on robot-assist choledochal cyst resection is usually created extracorporeally in children. The pediatric surgery team of West China Hospital of Sichuan University had completed 10 cases of total robot-assisted choledochal cyst resection. The aim of this current study was to present our initial experience in total robot-assisted surgery and discuss the technical points.
Methods: Between January 2015 and February 2020, patients with choledochal cysts treated with total robot-assisted procedures were retrospectively analyzed. The data collected included demographic information of all patients, type and size of cyst, operative details and postoperative outcomes.
Results: A total of 10 episodes of patients were enrolled in the study. The median age of the patient was 69.50 months with a mean weight of 20.50 kg. The most common symptoms were abdominal pain, vomiting, and jaundice (60%, 30%, and 30%, respectively). The types of cyst included 2 Ia, 7 Ic and 1 IV. The mean operation time was 218.70 min and there were no red blood cell transfusion and conversion in the 10 patients. The mean time to taking water was 3.37 days and mean time to starting liquid diet was 3.77 days. And the average length of postoperative hospital stay was 7.92 days. All 10 patients were eventually discharged and made uneventful recoveries after the operation.
Conclusions: Total robot-assisted choledochal cyst excision comprising Roux-en-Y limb formation, excision of the cyst and hepaticojejunostomy appears to be safe and feasible in pediatrics. Our initial experience shows that it is recommended to perform total robot-assisted choledochal cyst excision for patients over 4 years while a Roux-en-Y jejunojejunal anastomosis is recommended to be performed extracorporeally by prolapsing the jejunum out of abdominal cavity for patients under 4 years old.
Level of evidence: Treatment Study.
Type of study: Retrospective Study.

A choledochal cyst (CCs) is a relatively rare occurrence characterized by congenital biliary tract dilatation and presents symptoms such as: abdominal pain, jaundice, and tumors. While it's incidence in European countries and in the United States is extremely low at 5–15 cases per million people [1–3], it is much more common in the Asian nations of China, Korea, and Japan, with an incidence of up to 1000 cases per million people [4–6]. Crucially, choledochal cysts have a high likelihood of progressing to severe hepatobiliary complications like cholangitis, pancreatitis, perforation of the cyst, and can even become cancerous [7]. Due to these factors, prompt treatment is essential.

Up to the present, the complete resection of the cyst with a Roux-en-Y hepaticojejunostomy, which traditionally has been performed as an open procedure, has been seen as the main treatment for choledochal cysts is [8]. It was in 1995 when Farello et al. performed the first laparoscopic choledochal cyst resection with a Roux-en-Y hepaticoenterostomy, performing it on a 6-year-old girl [9]. Then, with the advent of laparoscopy during the last decade, several authors have reported the feasibility and benefits of laparoscopic choledochal cyst excisions [10–13]. However, unfortunately in the eyes of the writers, laparoscopic approaches haven't yet gained widespread popularity, possibly due to the fact that they are technically demanding procedures. Meanwhile, some researchers have proposed that robotic surgery may be another adjunct for pediatric minimal surgery for hepatobiliary diseases, including operations on

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choledochal cysts [14]. A robotic laparoscope-assisted type I choledochocystectomy was first reported by Woo et al., with regards to the procedure performed on a 5-year-old child patient in 2006 [15]. Subsequent reports then followed [6,14,16]. However, the research shows that the Roux-en-Y jejunal limb in most reports on robot-assist choledochal cyst resection is usually created extracorporeally in children. Since the introduction of the da Vinci robotic surgery system in 2015, the pediatric surgery team of Sichuan University's West China Hospital has completed 84 cases of choledochal cyst resection in children up until February 2020. Interestingly, of these patients, 10 cases were performed under total robot-assisted procedures and this study has been done so as to present our initial experience in totally robot-assisted surgery and discuss technical specifics.

1. Methods

1.1. Study population

This is a retrospective cohort study which was approved by the ethics committees of Sichuan University's affiliated West China Hospital. Additionally, due to the retrospective nature of this study, our committee waived the need for patient consent, so it was not sought. Between the dates of January 2015 and February 2020, patients who had suffered from choledochal cysts and had undergone total robot-assisted procedures using the da Vinci surgical system were retrospectively analyzed. Whether the surgical approach using a Roux-en-Y jejunojejunal anastomosis was performed extracorporeally or not was decided between the surgeon and patient's parents according to their preferences. During the study phase, all children with clinical symptoms or abdominal ultrasonography which showed what were suspected to be choledochal cysts were diagnosed through the use of either magnetic resonance cholangiography or computed tomography.

1.2. Operation procedures

In this section, we will detail the operation procedures. Following the application of general anesthesia and endotracheal intubation, an arterial catheter and a peripheral intravenous catheter are subsequently put into use. Regarding the patient's situation, they are put in the supine position with their head elevated 15° and at an incline of 15° to the left and the operation bed is in the reverse Trendelenburg position (Fig. 1A). After their position is stable, a 12 mm trocar is inserted at the incision below umbilicus which is then used as a port for the 3D camera. The 8 mm operating port I is placed at left upper quadrant with 5–8 cm length from the first incision, thus being close to the left anterior axillary line. Then, we place the 8 mm operating port II 5-8 cm right of umbilicus and the 12 mm port for the assistant between Port I and this umbilical port (Fig. 1B). As for the jejunum's mesenteric vessels, at a location 15 cm from the duodenojejunal flexure, it is ligatured with a 5 mm synthetic clamp and a stapler (EC-45) is used to cut the jejunum transversely (Fig. 2A). Immediately following this, again using the stapler, a side-to-side jejunojejunostomy is created at a level 35 cm distal to the hepaticojejunostomy (EC-45) (Fig. 2B). The 3–0 absorbable suture is used for a full-thickness continuous suture of the intestinal wall, which is reinforced by another continuous suture technique (Fig. 2C) and subsequently the mesenteric hiatus of jejunum is closed. Then, at the base of the ligament teres and in the middle portion of gallbladder, traction sutures are performed for better exposure of the cyst and hilum (Fig. 3A). To free the adhesions between the outer serosal membrane of the choledochal cyst and the duodenum, an electric hook is used and the portal vein is separated accordingly. The common bile duct is dissected all the way to the point near the head of the pancreas and, after double ligation, the distal end of the cyst is transected (Fig. 3B). Following this, the openings of hepatic duct and cystic duct can be identified, and complete removal of the cyst can be achieved (Fig. 3C). The hepatic duct's opening site is in an oval-shape with a higher left side and lower right side. Through the avascular region of the transverse colon's right mesentery, a biliary loop is then lifted up. An End-to-side choledochojejunostomy is made 0.5 cm from the blind end using 4–0 Stratafix. We then proceed to make Singer-layer continuous sutures from the left to right and from the back to front (Fig.3D) and fix the mesentery defect and biliary loop. Finally the gallbladder is removed and whatever bile is spilled is then cleaned and following this a drainage catheter is placed around the liver portal.

1.3. Postoperative progress

Upon evidence of the return of bowel motility an oral diet commences, and this was usually found to be the third day after surgery in both groups. Water is given first, followed by a liquid and a then soft diet. After all diets are able to be consumed by the patient without any discomfort, abdominal pain, or other complications, only then is discharge considered.

1.4. Data collection

A wide range of data was collected including: demographic information of all patients, type and size of cyst, operative details and outcomes such as operation time, volume of blood loss, intra-operative blood transfusion, postoperative feeding of solids, post-operative hospital stay, and post-operative complications. The docking time is defined as being the time from creation of the portal incisions to the end of the docking phase and the console time was the actual time the surgeon spent at the robotic console during the procedure, which directly corresponded to the robotic portion of the procedure.

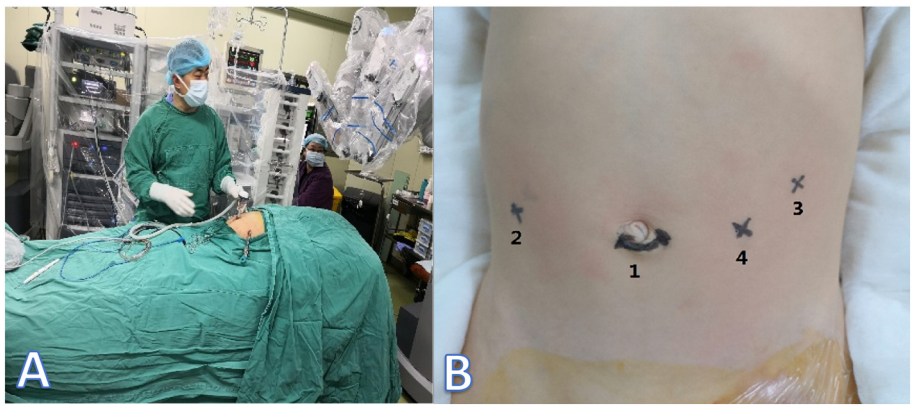

Fig. 1. The position and port placement of robot-assist operation. A, The position of robot-assist operation. B, Port placement: 1. Camera port. 2. Port I. 3. Port II. 4. Assistant port.

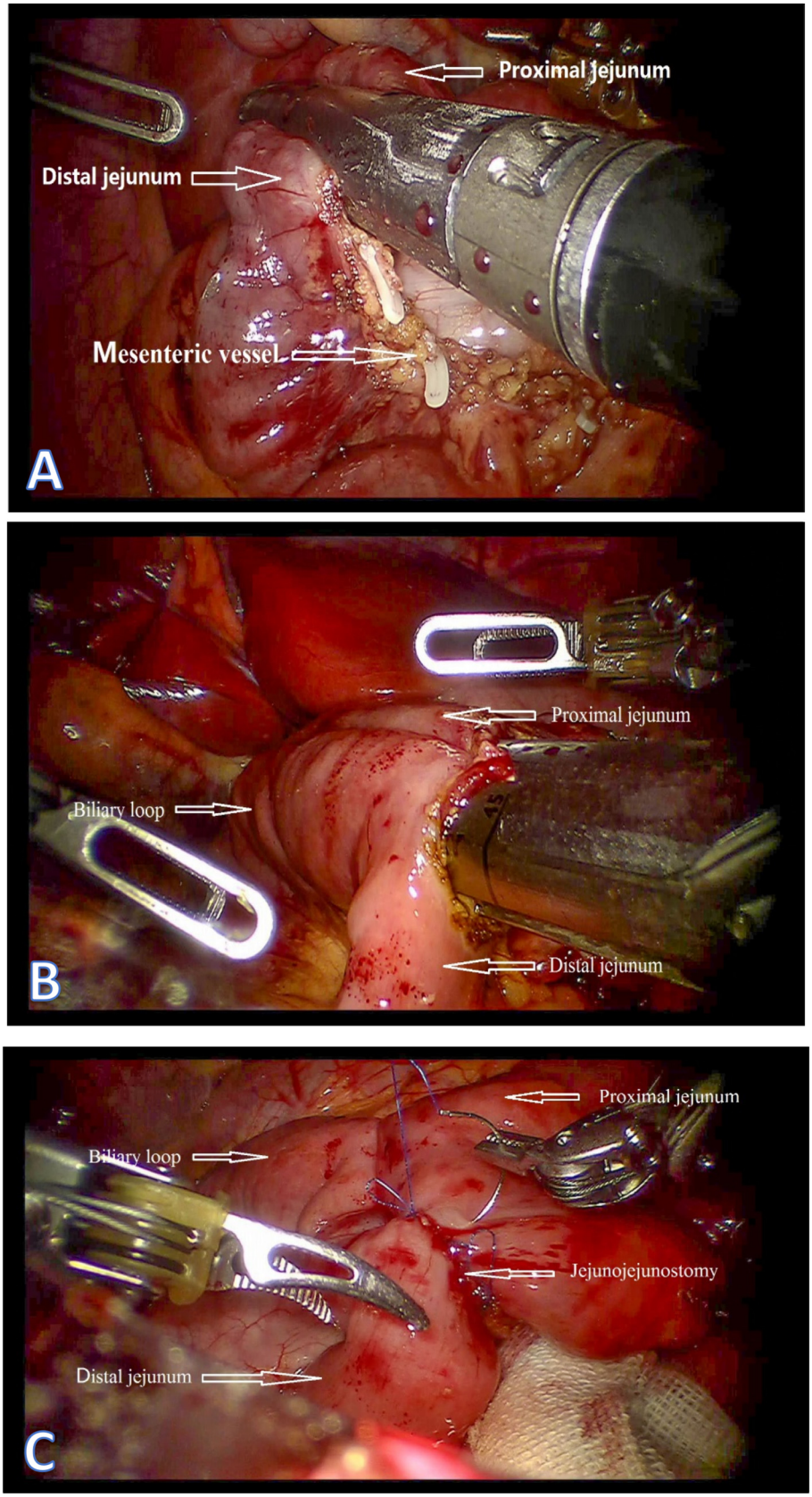

Fig. 2. Operation procedures of jejunojejunostomy. A, Transection of jejunum with a stapler. B, Jejunojejunostomy with a stapler. C, Full-thickness continuous suture of the intestinal wall.

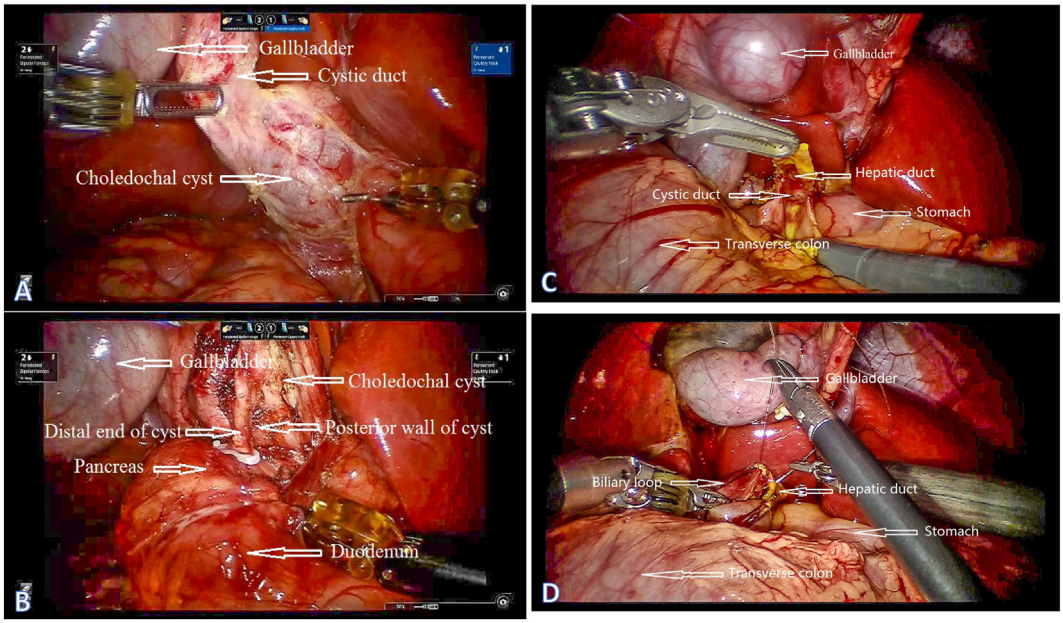

Fig. 3. Operation procedures of choledochal cyst resection and hepaticojejunostomy. A, Free the cyst. B, Ligation of the distal end of the cyst. C, Transection of the proximal end of the cyst. D, Hepaticojejunostomy.

1.5. Statistical analyses

The data was entered into the database by one author and subsequently reviewed by one of the other authors. Statistical analysis was performed using SPSS version 23.0. The categorical descriptive data was reported in counts (N) and as a percentage (%). Likewise, the numerical descriptive data was reported as both a mean and standard deviation.

2. Results

In total, 12 patients suffering from choledochal cysts and thus requiring excisions were accepted to undergo total robot-assisted procedures at our institution. While 2 patients under 4 years old lacked the body size and therefore space necessary for robot-assisted procedures, and so required Roux-en-Y jejunojejunal anastomosis be performed extracorporeally by prolapsing the jejunum out of abdominal cavity, the remaining 10 patients suffering from choledochal cysts and needing excisions were treated with fully robot-assisted procedures. The median follow-up time was 12 months. Specific details and characteristics of the study population are described for the reader in Table 1. The male to female ratio was 4:1. The median age of the patient was 69.50 months with a mean weight of 20.50 kg. The most common symptoms were abdominal pain, vomiting, and jaundice (60%, 30%, and 30%, respectively). It is also interesting to note a palpable abdominal mass and abdominal distension were observed in 10% of the patients. The types of cyst included 2 Ia, 7 I and 1 IV. The mean diameter of cyst was 2.49 cm.

Intraoperative data, postoperative outcomes and complications are summarized in Table 2 for the reader to review. The mean operation time was 218.70 min, while the mean docking time was 16.30 min and the mean console time was 187.10 min. The average total amounts of intraoperative fluid input was 435.00 ml and the mean volume of

Table 1
Characteristics of the patients.

N = 10	n (%)
Sex	
Male	2 (20%)
Female	8 (80%)
Age (month) [a]	69.50 (62.25–84.50)
Weight (kg) [b]	20.50 (5.28)
Abdominal pain	6 (60%)
Vomiting	3 (30%)
Distension	1 (10%)
Jaundice	3 (30%)
Palpable mass	1 (10%)
White blood cell count (/mm^3) [b]	9.98 (3.90)
Neutrophils (%) [b]	35.40 (12.72)
Alanine transferase, ALT (IU/L)[b]	60.39 (61.66)
Aspartic aminotransferase, AST (IU/L)[b]	61.60 (44.50)
Total bilirubin, TBIL (μmol/l)[b]	48.59 (49.37)
Direct bilirubin, DBIL (μmol/l)[b]	34.44 (44.16)
Indirect bilirubin, IBIL (μmol/l)[b]	13.15 (14.52)
Cyst type	
Ia	2 (20%)
Ic	7 (70%)
IV	1 (10%)
Diameter of cyst (cm)[b]	2.49 (1.39)

Notes: [a]Median, interquartile range; [b]mean, standard deviation.

Table 2
Intraoperative and postoperative outcomes and complications.

N = 10	n, (%)
Operation time (min)[b]	218.70 (11.85)
Docking time	16.30 (1.89)
Console time	187.10 (12.14)
Anesthesia time (min)[b]	246.30 (10.52)
Total fluid input (ml)[b]	435.00 (70.08)
Total Urine output (mL)[b]	120.50 (10.29)
Intraoperative bleeding (mL)[b]	17.50 (5.40)
Transfusion rate, n (%)	0 (0.00%)
Conversion to open surgery, n (%)	0 (0.00%)
Time to taking water (days)[b]	3.37 (0.28)
Time to starting solids diet (days)[b]	3.77 (0.16)
Total complication	0 (0.00%)
Bleeding at hepaticojejunostomy	0 (0.00%)
Bile leakage, n (%)	0 (0.00%)
Wound infection	0 (0.00%)
Respiratory tract infection	0 (0.00%)
Residual cyst	0 (0.00%)
Biliary stones	0 (0.00%)
Pancreatitis	0 (0.00%)
Intestinal obstruction, n (%)	0 (0.00%)
Stricture of hepaticojejunostomy, n (%)	0 (0.00%)
Reoperation, n (%)	0 (0.00%)
Hospital stay (days)[b]	7.92 (1.14)

Notes: [a]Median, interquartile range; [b]mean, standard deviation.

intraoperative bleeding was 17.50 ml. Red blood cell transfusion and conversion in the 10 patients was not needed. The mean time to taking water was 3.37 days and mean time to starting liquid diet was 3.77 days. In addition to this, the average length of the postoperative hospital stay was 7.92 days. All 10 patients were eventually discharged and made uneventful recoveries after the operation.

3. Discussion

At the moment in the medical field, open procedures, laparoscopic procedures and robotic-assisted procedures using da Vinci surgical system are the main surgical methods for dealing with choledochal cyst excisions with a Roux-en-Y hepaticojejunostomy. For the sake of comparison, the laparoscopic approaches and robotic-assisted approaches both have the advantage of being minimally invasive, providing a better vision of the deep anatomic structures, and resulting in a cosmetically enhanced recovery compared with the open approaches [10].

However, due to the technically demanding nature of the laparoscopic approaches, they have not as of yet gained widespread popularity. Indeed, a laparoscopic hepaticojejunostomy is especially demanding technically for a variety of factors including: rigid instruments used within a narrow working space, limited freedom of movement, an unstable camera platform with two-dimensional imaging, and poor instrument ergonomics. To make matters worse, there is also a steep learning curve in the initial stages. However, as one develops their surgical skills and experience, the risk of conversion and postoperative complications decreases significantly. Meanwhile, robotic surgery provides undoubted technical advantages over conventional laparoscopy [17]. It's equipped with 3D imaging, a tremor filter, and articulated instruments [18]. With this aforementioned advanced equipment, along with the significant improvements in visibility and manipulation afforded by it, robotic surgery is superior to conventional laparoscopic surgery [19,20]. In fact, Markar et al. in a systematic review demonstrated that there was a significantly reduced incidence of anastomotic stricture in the robotic Roux-en-Y gastric bypass compared with laparoscopic group [21]. Although, it is certainly true that robot-assisted procedures also have their limitations of course. The cost of robot-assisted procedures is much higher and a definite impediment to their widespread use because an extra 30–40 thousand RMB is needed. Additionally, newcomers to robot-assisted procedures who make knots and engage in tissue pulling are sometimes prone to use excessive force, thereby leading to adverse consequences. Due to these issues mentioned the tactile feedback surely needs to be improved.

In this following section we will detail our preliminary experiences with regards to our past enterostomy, choledochocystectomy, and choledochojejunostomy surgical procedures and share some tips discovered from them.① The No. 1 arm was equipped with gripping pliers and No. 2 arm was equipped with an electric hook to free the mesentery at a distance of 15 cm from the duodenojejunal flexure, and additionally the mesenteric vessels were clipped with 5 cm clip through the assistant port. Some experts have used a second light source through the accessory port to trans-illuminate the mesenteric vessels, which has proven to be a very useful technique in identifying the mesenteric vessels [22]. ② The use of a stapler has also shown to be useful, effectively reducing the difficulty and time of the operation. The jejunum would be cut off using the first stapler (EC-45). During this procedure, a 0.5 cm hole was made in the posterior wall of the proximal jejunum and a 0.5 cm hole in the anterior wall of the distal jejunum with a 35 cm biliary loop. The holes were made on the upper part of intestinal wall as a precaution to prevent the stapler from damaging the mesenteric vessels. The second stapler (EC-45) was inserted into the abdominal cavity through the assistant port while keeping the two arms open and steady. The proximal jejunum and distal jejunum were then placed on the two arms of the stapler (EC-45) and adjusted to the appropriate position with the no. 1 and 2 arms then equipped with gripping pliers. A side-to-side jejunojejunostomy was then created at a level 35 cm distal to the hepaticojejunostomy using the second stapler (EC-45). But, the stapler required sufficient space and this was why the patients in our study were older than the published reports [14.16]. We believe that this was the result of our strategy of not recommending total robot-assisted procedures in small patients with choledochal cysts, because insufficient space would limit the application of a stapler in very young patients thus posing risks. In our study the Roux-en-Y jejunojejunal anastomosis was performed extracorporeally by prolapsing the jejunum out of abdominal cavity for sake of the well-being of two young patients (3.9 year old girl and a 3.5 year old boy), both being deemed too small for the safe operation of robot-assisted procedures. Our initial experience is that it is recommended to perform total robot-assisted choledochal cyst excision only for patients four years and older. ③ The 3–0 absorbable suture was used for full-thickness continuous suture of the intestinal wall, which was also reinforced with another continuous suture (Fig. 2C). The mesenteric hiatus of jejunum was then subsequently closed. The gripper lifted the 3–0 absorbable suture through the assistant port for more suspension and support and the no. 1 arm was equipped with gripping pliers and no. 2 arm was equipped with a needle holder to be used for suture purposes.④ And then, the jejunum's mesenteric hiatus was closed with a 3/4–0 absorbable suture to prevent internal hernia formation. ⑤ We have witnessed that sufficient exposure is conducive to the smooth and rapid completion of the operation. In our study traction sutures were performed at the base of the ligament teres and in the middle portion of the gallbladder for better exposure of the cyst and hilum. ⑥ It is suggested that the cyst be free as a whole without any transect, and the anatomical direction from the distal part should be closed from the proximal part of pancreaticobiliary junction to the hepatic duct. It's very easy to separate the space between the cyst and the portal vein.⑦ The anastomosis sequence in robot-assist procedures is recommended to be done from left to right and then from the posterior to anterior wall. In our procedures, the size of the anastomotic opening of the intestinal loop was determined by the size of the end-to-end anastomotic opening of the hepatic duct. ⑧ The gallbladder was removed finally, mainly because it is difficult to remove the gallbladder from the abdominal cavity when making contact with the machine and the suspension position was in the middle of the gallbladder.

According to most reports on robot-assist choledochal cyst resection, the Roux-en-Y jejunal limb is usually created extracorporeally in children while all the 10 patients in our study received fully robot-assisted choledochal cyst excisions. The Jejunojejunostomy performed in the abdominal cavity can significantly reduce the time of intestinal exposure, providing several advantages including: reducing the occurrence of postoperative intestinal obstruction, restoring intestinal function and leading to starting a diet earlier compared with those performed outside of the abdominal cavity [10]. Equally important, a total robot-assisted choledochal cyst excision can avoid the entrapment of the extracorporeal intestine and mesenteric vessels by the subumbilical incision which could also end up affecting the recovery of intestinal function.

However, several limitations exist in our study. Firstly, the sample of total robot-assisted choledochal cyst excisions in our study was unfortunately quite small. Secondly, the study is a retrospective study in a single center and so, in order to validate our findings and to investigate further the true detailed benefits of total robotic-assisted surgery for the treatment of choledochal cysts, we believe these findings warrant a prospective larger, multi-center clinical trial. Thirdly, short follow-up time was an additional shortcoming and therefore a long term follow-up is deemed necessary to validate the probable advantages of this technique. However, all things considered, the authors conclude that total robot-assisted choledochal cyst excisions including Roux-en-Y limb formation, excisions of the cyst and hepaticojejunostomy appeared to be safe and feasible in pediatrics.

4. Conclusion

Total robot-assisted choledochal cyst excision comprising Roux-en-Y limb formation, excisions of the cyst and hepaticojejunostomy by all

accounts appear to be safe and quite feasible in pediatrics. Our initial experience shows that it is recommended to perform total robot-assisted choledochal cyst excision for patients over 4 years, while for patients under 4 years a Roux-en-Y jejunojejunal anastomosis is recommended to be performed extracorporeally by prolapsing the jejunum out of abdominal cavity.

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