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Technical Note

Non-stapled, total laparoscopic Roux-en-Y anastomosis: A safe and effective procedure for radical pediatric choledochal cyst excision

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ABSTRACT

Background: Laparoscopic or robot-assisted surgery has become the main pediatric minimal invasive surgery for a choledochal cyst (CDC). However, the Roux-en-Y jejunal limb was created extracorporeally in most reports and intracorporeally in a few reports using an endoscopic stapler.
Objectives/methods: To investigate the safety and feasibility of non-stapled laparoscopic Roux-en-Y reconstruction in the radical treatment of congenital choledochal cysts (CDC). Between January 2019 and February 2023, 40 patients diagnosed with CDC underwent non-stapled laparoscopic Roux-en-Y reconstruction (non-stapled totally laparoscopic radical treatment, NTLR), 40 patients underwent conventional reconstruction (conventional laparoscopic radical treatment, CLR) included as control. Their clinical data such as intraoperative blood loss, proportion of transit laparotomy, length of operation, postoperative fasting times, postoperative drainage time, postoperative hospital stay, hospitalization cost, and postoperative complications were retrospectively analyzed.
Conclusion: non-stapled laparoscopic Roux-en-Y reconstruction is feasible and safe in total laparoscopic radical treatment of CDC. It may have the following advantages: rapid recovery of postoperative gastrointestinal function, short hospitalization, no age limit on the patient and no additional hospitalization costs, which is worthy of promotion and application.

Introduction

Congenital choledochal cyst (CDC) is a common congenital biliary anomaly in pediatric surgery characterized by congenital bile duct dilation. Currently, surgery is the only effective method to prevent severe complications of CDC such as perforation, liver fibrosis, or bile duct cancer [1,2]. The standard radical treatment for CDC involves excision of the choledochal cyst, cholecystectomy, and Roux-en-Y hepaticojejunostomy for biliary reconstruction. In recent years, with the development of minimally invasive techniques, laparoscopic and robot-assisted surgeries have become the main approaches for radical treatment of CDC [3–6]. In most reports of laparoscopic-assisted radical treatment of CDC, Roux-en-Y reconstruction is performed by temporarily exteriorizing the bowel through an enlarged umbilical incision and then reinserting it into the abdomen to complete the subsequent steps under laparoscopy. This procedure requires a 2–3 cm long umbilical incision and involves pulling the delicate intestines of pediatric patients out through the umbilical incision, exposing them to air for an extended period. Apart from damaging the umbilical structure, this process to some extent increases the trauma to the patients and the risk of complications such as intestinal wall congestion, edema, and adhesion obstruction.[7] Although recent studies have reported the use of laparoscopic staplers for laparoscopic Roux-en-Y reconstruction, achieving totally laparoscopic or robotic CDC treatment, which offers advantages such as smaller incisions, quicker intestinal motility recovery, and shorter postoperative hospital stay compared to conventional laparoscopic CDC procedures [7–9], remains limited due to the restricted abdominal space in pediatric patients, especially in the treatment of infantile CDC [8,9]. In this study, we completed 40 cases of totally laparoscopic radical treatment for CDC with non-stapled laparoscopic Roux-en-Y reconstruction, achieving favorable results. The operation procedures and outcomes are detailed in the following report.

Methods

Population

This study was approved by the Ethics Committee at the Second

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Affiliated Hospital of Xi'an Jiaotong University (NO. 2020–660), and informed consent was obtained from all patients and the guardians of children. 40 cases underwent non-stapled totally laparoscopic radical treatment for CDC, and 40 patients underwent conventional reconstruction (conventional laparoscopic radical treatment, CLR) as control in our hospital between January 2019 and February 2023. All patients underwent preoperative ultrasonography and magnetic resonance cholangiopancreatography (MRCP). There was no age restriction to patients.

Operation procedures

Patient positioning and trocar placement: routine bowel preparation was performed before surgery for all patients. Patients were placed in the supine position and underwent four-port surgery. A 5 mm trocar was inserted through the umbilicus or a transverse incision below the umbilicus to establish pneumoperitoneum for laparoscopic monitoring. A 3 mm or 5 mm trocar was placed at the right midclavicular line below the right rib margin and at the level of the right umbilicus along the outer edge of the rectus abdominis muscle (5 mm trocar for patients with larger abdominal space). A 3 mm trocar or 5 mm trocar was placed along the outer edge of the left upper rectus abdominis muscle as an assistant port (Fig. 1). The operator stood on the patient's right side, and the assistant was on the left side.

The operation procedures for conventional laparoscopic-assisted surgery for CDC have been adequately described in various reports. The procedures for non-anastomotic totally laparoscopic CDC treatment, including cyst excision, gallbladder removal, and hepaticojejunostomy, were similar to those reported previously [3,4]. Therefore, the following details will focus on the steps of non-stapled laparoscopic Roux-en-Y reconstruction.

①Jejunal "Y" anastomosis: first, identify the jejunal mesenteric vessels and preserve the vascular arcade under laparoscopy. Use LigaSure or electrocautery to coagulate and cut the mesenteric vessels, and moderately released the jejunal mesentery. Used LigaSure to vertically divide the jejunum at a distance of 10–15 cm from the distal end of the Treitz ligament (Fig. 2A, B). Closed the distal end of the jejunal bile duct with 5–0 absorbable sutures (Fig. 2C). The individualized length of the jejunal Roux loop was determined by the distance between the navel and the porta hepatis [10]. Approximately 20–25 cm from the distal end of the jejunal bile duct, created a side hole for end-to-side jejunojejunostomy using an electrocautery hook (Fig. 2D). Arranged the course of the proximal and distal jejunal limbs for anastomosis, gently separated the proximal jejunal stump (which appears adherent and "closed" after LigaSure division) (Fig. 2E), and completed the proximal jejunojejunostomy with 5–0 or 4–0 absorbable sutures. The sutures were directed from the mesenteric side to the anti-mesenteric side (Fig. 2F). The posterior wall was closed using a continuous locking suture with invagination (Fig. 2G), and the anterior wall closed with continuous seromuscular sutures (Fig. 2H). ②Hepaticojejunostomy: a tunnel was established through the avascular area of the right transverse colon mesentery to bring the blind end of the jejunal limb to hepatic hilar region. Created a side hole in the mesentery on the anti-mesenteric side, approximately 0.5 cm from the blind end, matching the diameter of the hepatic duct stump (Fig. 2J). Starting from the 9 o'clock position on the hepatic duct stump, completed the hepaticojejunostomy using 5–0 PDS sutures. The posterior wall was closed using continuous invagination locking sutures, and the anterior wall was closed with continuous seromuscular sutures (Fig. 2K). Finally, the proximal jejunal and jejunal bile duct mesenteric defects were closed with interrupted 5–0 absorbable sutures. Flushed the abdominal cavity, and removed the excised cyst and gallbladder through the umbilical incision without extending the incision.

Postoperative laboratory tests and abdominal ultrasound examinations were performed at 1, 6, and 12 months after operation. For the primary operative steps of non-stapled total laparoscopic radical treatment of CDC, please refer to the surgical video attachment. All participants consented to have these images and video published.

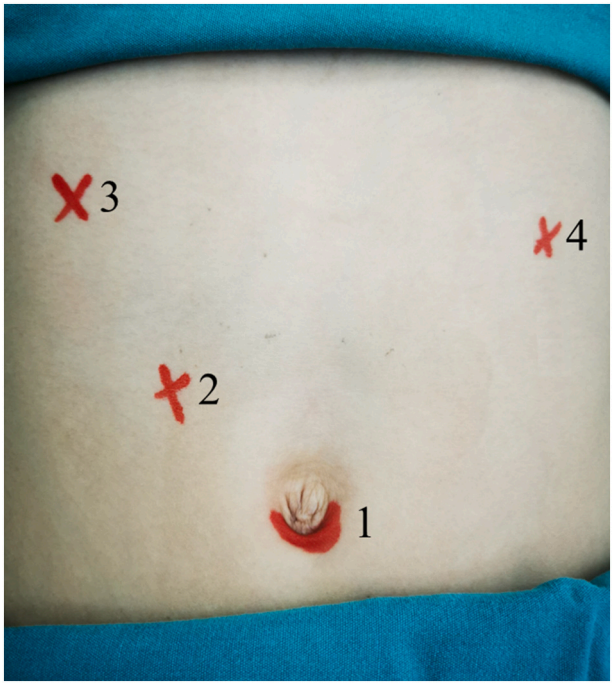

Fig. 1. The port placement of laparoscopy-assisted operation: 1. Camera port. 2. Port I. 3. Port II. 4. Assistant port.

Data collection and statistical analysis

The required statistical data for this study were obtained from electronic medical records, including the patients' basic clinical characteristics, cyst type and size, intraoperative blood loss, surgical duration, postoperative fasting times, postoperative hospital stay, hospitalization cost, postoperative complications, etc. Data were evaluated with SPSS 20.0 software (SPSS, Chicago, IL). The mean and standard deviation were calculated for numerical data.

Results

There were no statistically significant differences in preoperative clinical characteristics between the CLR group and the NTLR group (Table 1). Although the total duration of surgery did not differ significantly between the two groups, the duration for the non-stapled laparoscopic Roux-en-Y reconstruction gradually decreased and stabilized over cases (40 cases): the first 10 cases had a duration of 90 ± 10 min, the second 10 cases were 78 ± 9 min, the third 10 cases were 52 ± 8 min, and the fourth 10 cases were 40 ± 5 min. The surgical learning curve was shown in Fig. 3. In comparison to the CLR group, the NTLR group exhibited less intraoperative blood loss, quicker recovery of intestinal function, shorter fasting duration and hospital stay. There was no case of conversion to open surgery in either group. Postoperative follow-up was conducted for 1 to 48 months (median of 27 months). The incidence of postoperative complications did not exhibit a statistically significant difference between the two groups (Table 2).

Discussion

Although CDC is a benign condition, it has a higher likelihood of developing into serious complications such as cholangitis, pancreatitis, gallstones, cyst perforation, and malignant transformation. Surgery is currently the only effective treatment for this disease [1]. Especially for

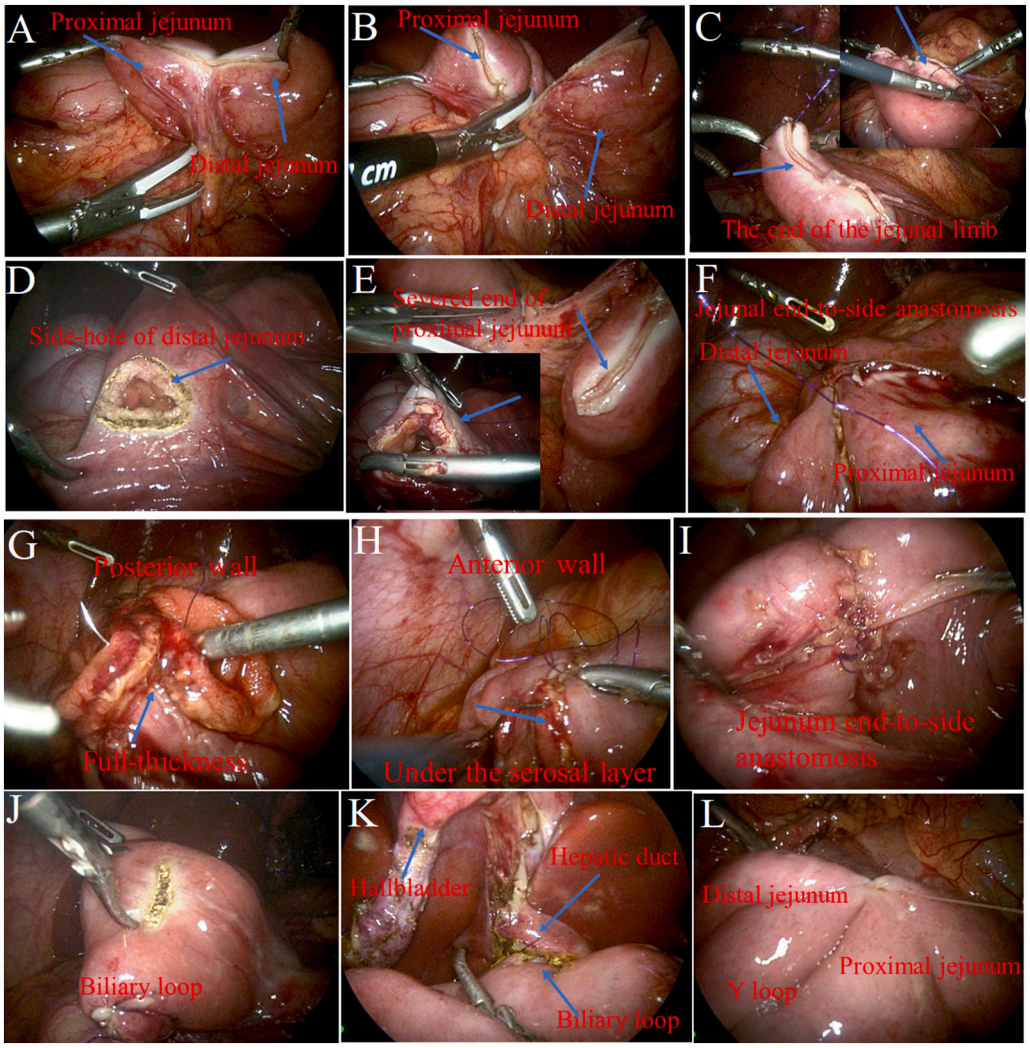

Fig. 2. Procedures of jejunal end-to-side anastomosis. A, Transecting jejunum with LigaSure. B Transecting mesojejunum with LigaSure. C, Full-thickness continuous suture of the end of the jejunal limb. D, Creating side-hole jejunostomy. E, Gently separating the end of the proximal jejunum transected by LigaSure. F, Hand sewing jejunal end-to-side anastomosis. G, Full-thickness continuous suture of the posterior wall of the jejunal end-to-side anastomosis. H, Continuous suture of the anterior wall under the Serosal layer. I, The anastomotic end to side jejunal anastomosis. J, Creating a side-hole jejunostomy on the antimesenteric border 0.5 cm from the blind end to match the diameter of the hepatic duct. K, Suturing the jejunal seromuscular layer in parallel for anti-reflux of intestinal contents. L, End-to-side hepaticojejunal anastomosis.

Table 1
Demographics of the NTLR group vs the CLJ group.

	NTLR group (n = 40)	CLR group (n = 40)	P
Male/Female	8/32	4/36	0.210
Age (months)	39.6 ± 51.7 (0.87–163.2 months)	35.9 ± 39.7 (1.00–60.50 months)	0.721
Clinical symptoms (with/not)	37/3	32/8	0.105
ALT mean ± SD (U/L)	125.53 ± 159.12	121.47 ± 175.58	0.914
AST mean ± SD (U/L)	139.75 ± 213.25	140.53 ± 232.17	0.988
TBIL mean ± SD L (μmol/L)	41.37 ± 59.14	41.51 ± 60.37	0.992
Serum amylase mean ± SD (U/L)	47.60 ± 28.1	52.30 ± 28.7	0.462
Diameter of cyst (cm)	2.80 ± 0.60	3.00 ± 0.78	0.203
Cyst type(Cystic /spindle)	24/16	25/15	0.819

prenatally diagnosed CDC, there is a higher tendency for it to progress to liver fibrosis after birth, highlighting the importance of early surgical intervention [2].

Laparoscopic-assisted radical treatment of CDC offers significant advantages over open surgery, including clearer visualization, precise operation, reduced trauma, better aesthetics, and faster postoperative recovery [3,11–13]. It has gradually become the preferred surgical approach for medical professionals all over the world. Robotic-assisted radical treatment of CDC is also being increasingly recognized as another minimally invasive treatment option for CDC [5,15,16]. Whether assisted by laparoscopy or robot, most studies reported that the Roux-en-Y reconstruction were performed externally. This requires making a 2–3 cm incision near the umbilicus to extract the small intestine. The size of the incision is closely related to the child's age and abdominal wall thickness. The older and more obese the child, the larger the incision needs to be. Although the umbilical incision is smaller than the incision used in open surgery for CDC and significantly reduces the difficulty of laparoscopic surgery, it still disrupts the normal structure of the umbilicus, leading to a certain degree of trauma. Some patients may also have noticeable scars at the umbilicus after surgery, affecting aesthetics. This approach also comes with several disadvantages, such as if an incision that is too large, which negating the benefits of minimally invasive surgery, or an incision that is too small, which can lead to artificial entanglement of the intestine and result in ischemia or edema.

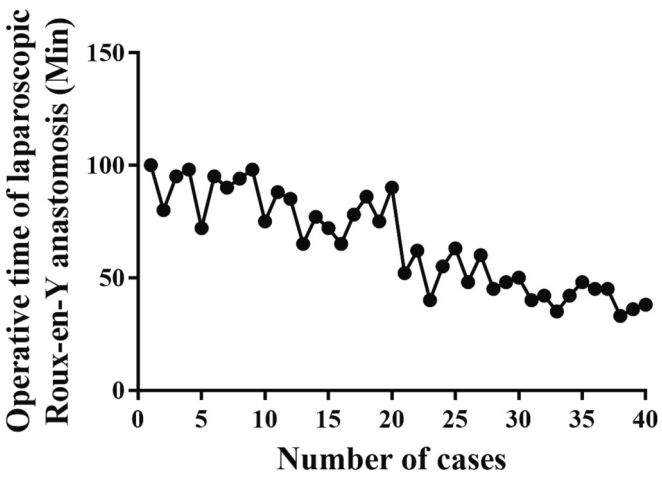

Fig. 3. The learning curve of non-stapled laparoscopic Roux-en-Y reconstruction. The average surgical duration of the first 10 patients was 90 ± 10 min. The 11th to 20th patients was 78 ± 9 min. The 21st to 30th patients was 52 ± 8 min. The 31st to 40th was 40 ± 5 min.

Table 2
Perioperative characteristics of the NTLR group vs the CLR group.

	NTLR group (n = 40)	CLR group (n = 40)	*P*
Operative time mean ± SD (min)	216.5 ± 25.2	219.30 ± 30.3	0.654
Intraoperative blood loss mean ± SD (mL)	7.0 ± 2.3	10 ± 3.5	<0.001
Conversion to open surgery	0	0	–
Time to recovery of bowel function mean ± SD (h)	10.6 ± 2.3	45.6 ± 18	*<0.001*
postoperative fasting times mean ± SD (h)	24.4 ± 8.0	72 ± 9.5	<0.001
postoperative drainage time mean ± SD (d)	2.6 ± 1.1	3 ± 1.5	*0.178*
Postoperative hospital stay mean ± SD (d)	5.3 ± 1.1	7.5 ± 1.5	*<0.001*
Postoperative complication			
Residual cyst	0	0	–
Bile leakage	1	1	–
Pancreatitis	0	0	–
Biliary stones	0	0	–
Hepaticojejunostomy strictures	0	0	–
Jejunojejunal anastomotic leak	0	0	–

What's more, it's challenging to determine the proximal and distal ends of the intestines after they are pulled out, closing the "Y"-shaped mesenteric hiatus is difficult and carries a risk of mesenteric hernia, and the prolonged exposure to air irritates the intestinal wall tissue, significantly prolonging the recovery time of intestinal function and increasing the likelihood of intestinal adhesions and obstruction [7–9]. Moreover, establishing pneumoperitoneum repeatedly can also disrupt the surgical process. Some research teams have achieved totally laparoscopic radical treatment of CDC using laparoscopic stapler. The Roux-en-Y reconstruction also being performed under laparoscopy or robot assistance, suggesting that this approach is safe and feasible [8,9]. However, the use of laparoscopic stapler requires the insertion of a 12 mm trocar in the upper left abdomen, and the incision in this region is not significantly smaller than the umbilical incision used in conventional laparoscopic CDC resection. Dramatically, there is a noticeable scar left in the upper left abdomen after surgery. It's worth to note that there is currently lack of laparoscopic linear cutting stapler specifically designed for pediatric use, which limited in their application in pediatric patients with limited abdominal space, and the procedure can be challenging. Furthermore, the use of laparoscopic stapler significantly increases the surgical-related costs compared to conventional laparoscopic CDC resection [8,9]. In most cases of this study, 3 mm instruments were used as operative instruments, which greatly reduced trauma, improved the convenience of surgery, and enhanced the postoperative aesthetics compared to the use of laparoscopic stapler.

With the maturation of laparoscopic techniques and the accumulation of experience, especially in challenging anastomosis procedures such as esophageal anastomosis for neonatal esophageal atresia and duodenal anastomosis for neonatal duodenal obstruction, this study applied laparoscopic intestinal anastomosis techniques to radical treatment of CDC. The handling of the small intestinal mesentery, closure of the intestinal ends, and end-to-side jejunojejunostomy were all performed manually under laparoscopic guidance. Ligasure was used during surgery to cut the intestine and mesentery. Due to Ligasure's strong sealing effect, it prevented bleeding from mesenteric vessels and spillage of intestinal contents. The procedure of non-stapled laparoscopic Roux-en-Y reconstruction was identical to the Roux-en-Y constructed by exteriorization. The posterior wall was sutured using a continuous full-thickness inverting technique, and the anterior wall was sutured with continuous seromuscular sutures, to ensure proper alignment of the intestinal wall edges for suturing. With the magnification provided by the laparoscope, the anastomotic site was treated with greater precision. Furthermore, there is no issue related to intestinal blood supply due to not exteriorizing the intestine through an incision. Therefore, with meticulous apposition and adequate blood supply ensured by the laparoscopic approach, none of the cases in NTLR group experienced anastomotic complications such as anastomotic fistula.

In this study, the NTLR group showed no statistically significant difference in surgical duration compared to the CLR group. However, the surgical duration of non-stapled laparoscopic Roux-en-Y reconstruction exhibited a gradually decreasing and stable trend, the average duration required decreased from an initial 90 min to an average of 40 min. This indicated that non-stapled laparoscopic radical treatment of CDC does not extend the surgical duration. Moreover, with the gradual maturation of experience and techniques, there was a tendency for the surgical duration of non-stapled total laparoscopic CDC radical resection to shorten compared to conventional laparoscopic procedures for CDC treatment. This also suggested that the technical challenges of non-stapled total laparoscopic radical treatment of CDC are not insurmountable hurdles.

Since non-stapled total laparoscopic radical treatment of CDC did not involve exteriorizing the intestine through an incision, which avoided issues related to intestinal blood supply such as ischemia or edema caused by artificial "entanglement." Moreover, it prevented disruption of intestinal peristalsis due to irritation from air, gauze, or gloves. All aspects of the procedure emphasize an "in-situ, precise, minimally invasive" approach. Therefore, the most significant advantage of non-stapled laparoscopic Roux-en-Y reconstruction is its minimal impact on intestinal function. As a result, the postoperative recovery time for intestinal function and fasting duration in the NTLR group were significantly shorter compared to the CLR group. Because the first 10 cases in the NTLR group, a routine gastric tube was placed postoperatively, but it was later found that there was minimal gastric content drainage due to the quick recovery of bowel function. As a result, the subsequent 30 cases did not require gastric tube placement, and they did not experience complications like abdominal distension or vomiting after surgery, which reduced the trauma for the patients to some extent. In the NTLR group, most patients began oral intake within 24 h postoperatively, significantly reduced the postoperative fluid input and shorten the length of hospital stay. This practice aligns with the concept of ERAS (enhanced recovery after surgery/rapid recovery programs) and also contributed to reduce hospitalization costs.

Additionally, laparoscopic intestinal anastomosis provides a clear view of the overall course and positioning of the intestine, reduced the likelihood of errors in determining the proximal and distal ends and inaccuracies in anastomotic placement. The laparoscopic approach

enabled the closure of the mesenteric hiatus of both the proximal small intestine and the bile duct-intestinal anastomosis, thereby minimized the occurrence of mesenteric hernias.

In summary, our results indicated that the non-stapled laparoscopic Roux-en-Y reconstruction has the following significant characteristics: ①It offers a more minimally invasive and aesthetically pleasing approach. ②It has a minimal impact on the intestine, resulting in rapid recovery of bowel peristalsis. ③It is safe, reliable, and associated with a low rate of complications. ④It accelerates patient recovery, reduces hospitalization costs, shortens postoperative hospital stay, and aligns with the concept of ERAS. ⑤It avoids inherent drawbacks associated with umbilical incisions, such as errors in intestinal anastomosis and the likelihood of mesenteric hernias. ⑥It does not require the use of the endoscopic linear cutting stapler or robotic instruments, and has no strict requirements for pediatric abdominal space. There's no need to consider whether the abdominal space and stapler match the diameter of the pediatric intestine. In this study, the youngest patient was 26 days old, while the oldest was 13.3 years old. ⑦It maintains a smooth surgical rhythm. There's no need to pause to enlarge the umbilical incision, to reinsert the trocar after externalizing the intestine for anastomosis, or to change trocars to accommodate the use of an anastomosis device. The entire procedure is seamlessly performed under laparoscopy, saving time that might otherwise be lost in intermediate steps [8,9,14].

Although the preliminary results of this study suggested that non-stapled laparoscopic Roux-en-Y reconstruction is safe and effective for radical treatment of CDC, with significant advantages over conventional laparoscopic treatment for CDC, there are also certain limitations to be acknowledged. This study is retrospective and conducted in a single center, with a relatively small sample size and short follow-up time. Dramatically, the surgeons in this study were experienced and highly skilled in suturing techniques, as laparoscopic intestinal anastomosis requires proficient laparoscopic suturing skills. Routine adoption of this technique might involve a learning curve. Therefore, future research should involve large-scale, multi-center, randomized controlled trials with surgeons of varying experience levels and longer follow-up times to confirm the potential advantages of non-stapled laparoscopic Roux-en-Y reconstruction as discovered in this study.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sopen.2023.12.012.

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Ethical approval

This retrospective study was conducted by the Helsinki Declaration and approved by the Ethics Committee at the Second Affiliated Hospital of Xi'an Jiaotong University (NO. 2020–660).

CRediT authorship contribution statement

Jiwen Cheng: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Qiang Yu:** Investigation, Resources. **JiaLu Fu:** Investigation, Resources. **Peng Li:** Funding acquisition, Supervision, Writing – review & editing, Conceptualization.

Declaration of competing interest

No authors have conflicts of interest or financial ties to disclose.

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