Pediatric Surgery International (2019) 35:1211–1216
https://doi.org/10.1007/s00383-019-04518-w

ORIGINAL ARTICLE

Robotic-assisted surgery for choledochal cyst in children: early experience at Vietnam National Children's Hospital

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Accepted: 25 June 2019 / Published online: 3 July 2019

Abstract

Purpose We aimed to describe our robotic-assisted surgery (RAS) techniques and assess the early results of RAS for choledochal cysts in children.

Methods We conducted a retrospective chart review of children who underwent RAS for a congenital choledochal cyst at our institution between February 2013 and August 2016. We analyzed patient characteristics, operative data, and postoperative outcomes.

Results Thirty-nine patients underwent RAS for a choledochal cyst (female 30). The operation was performed with four robotic ports and one laparoscopic port for the assistant. The Roux loop was fashioned extracorporeally. Twenty patients (51.3%) had a Todani Type I cyst and the others had Type IV. The mean patient age and weight and choledochal cyst diameter at the time of the operation were 40.2 months (range 5–108 months), 13.4 kg (range 6.5–29 kg), and 27.2 mm (range 9–112 mm), respectively. The mean operating time was 192.7 min (range 150–330 min). There were no intraoperative complications; no conversions to laparoscopic or open surgery; and no postoperative complications, including cholangitis, cholelithiasis, or anastomotic stenosis.

Conclusion Pediatric RAS CC resection is safe and feasible. The robot-assisted technique overcame technical difficulties. However, in pediatric cases, a skilled robotic surgical team and procedural modifications are needed.

Keywords Robotic-assisted surgery · Choledochal cyst · Children · Minimally invasive surgery

Introduction

Choledochal cysts (CCs) are rare entities characterized by congenital biliary tract dilatation, and the incidence of CCs is higher in Asian countries. Although the pathological mechanism of CCs is still unclear, complete cyst excision with Roux-en-Y hepaticojejunostomy is the treatment of choice [1].

Rapid advancements in minimally invasive surgery, including laparoscopic and robotic surgery, have changed the approach to general abdominal surgery, particularly for hepatobiliary diseases. In 1995, Farello et al. performed the first laparoscopic CC resection with Roux-en-Y hepaticoenterostomy in a 6-year-old girl [2]. Over the last decade, with the advent of laparoscopy, several authors have reported the feasibility and benefits of laparoscopic CC excision [3–6]. However, it has not been widely used, because laparoscopic cyst resection and, especially, laparoscopic hepaticojejunostomy are quite technically demanding.

Laparoscopic choledochal cyst excision with hepaticojejunostomy has been the standard treatment for CCs at our institution since 2007, and we previously reported our experience [7, 8]. Although the laparoscopic approach to CCs in children is feasible and effective, there are technical difficulties, especially with the hepaticojejunostomy.

Recently, some surgeons have reported their experience with robotic-assisted surgery (RAS) for CCs in adult patients [9, 10], and it has been utilized to facilitate complex minimal access procedures in multiple surgical disciplines. RAS offers several advantages, including three-dimensional visualization through a stereo-endoscope controlled by the primary surgeon, intuitive instrument control, tremor reduction,

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and, most importantly, enhanced dexterity and 540 df provided by the wristed instruments that allow precise dissection and anastomosis. RAS could overcome many of the technical limitations of laparoscopic surgery, such as poor ergonomics, image instability, and a steep learning curve.

RAS has also been applied in the treatment of various pediatric conditions such as CCs, Hirschsprung disease, hydronephrosis, and intra-abdominal and intra-thoracic tumors [11–17]. However, the number of cases is still limited, and the safety, feasibility, and limitations of RAS in pediatric patients remain unclear.

We aimed to describe our surgical technique and assess our institution's early experience using RAS for the treatment of CCs in children.

Methods

Patient selection criteria

We performed a retrospective analysis of children under the age of 12 years who underwent RAS for a CC at our institution from February 2013 to August 2016. During the study period, all children with clinical symptoms or abdominal ultrasonography suspicious for a CC were diagnosed by magnetic resonance cholangiography. The surgical approach (robotic or laparoscopic procedure) was according to the surgeon's and patient's parent's preference. As this was an initial study of RAS in children with a CC, we established the following exclusion criteria: a giant choledochal cyst with a maximum transverse diameter over 120 mm, body weight below 6 kg, a history of abdominal surgery or panperitonitis due to CC rupture or other cause, and presence of other gastrointestinal anomalies.

Ethics approval

The Vietnam National Children's Hospital Institutional Review Board (IRB00009162) approved this study. All data were collected anonymously, and patient consent was not required.

Surgical technique

Placement of ports

All operations were performed with the patient under general anesthesia in the prone position by a single surgeon (H.P) and surgical team, including two pediatric surgeons (H.M, Y.O). Five ports were placed in total (Fig. 1). First, a 12-mm port was placed through the umbilicus using the standard open Hasson technique, and carbon dioxide pneumoperitoneum was established with a pressure of 8–12 mmHg. Then,

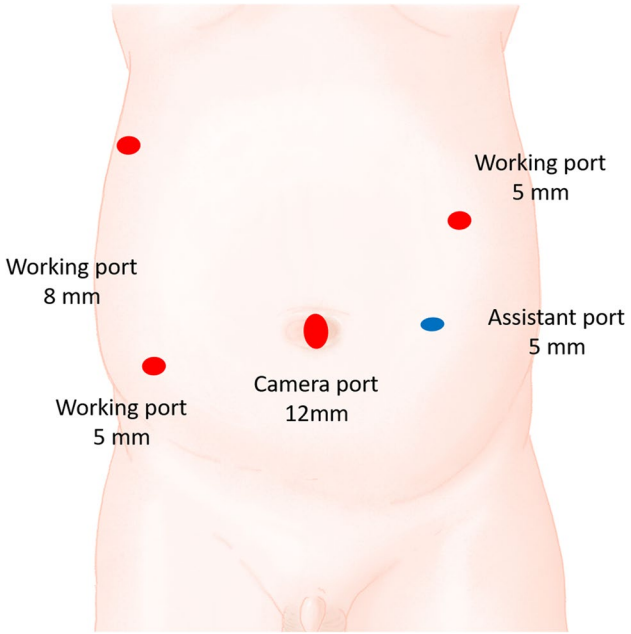

Fig. 1 Port placement in robot-assisted surgery for choledochal cysts: four robotic ports (red) and one conventional laparoscopic port for the assistant (blue)

a 5-mm robotic port was placed lateral to the midclavicular line on each side under laparoscopic vision, and an 8-mm robotic port was placed in the upper far-right lateral position, primarily for liver retraction. Finally, a 5-mm laparoscopic port was placed in the far-left position for the surgical assistant.

Pre-docking stage

The Roux loop was created extracorporeally after identifying and marking the jejunum 30 cm from the ligament of Treitz and bringing it out through the 12-mm umbilical camera port incision. The umbilical port wound was extended upward approximately 1.5 cm. The jejunojejunostomy was positioned 20 cm from the ligament of Treitz and 30 cm from the hepaticojejunostomy and fashioned using 5/0 absorbable monofilament extra-mucosal running sutures. The Roux loop was returned to the abdomen, and the umbilical wound was closed to fit a 12-mm port. We re-established pneumoperitoneum and made a small window in the transverse mesocolon to move the Roux loop to the retrocolic, transected hepatic duct.

Docking and console stage

The procedure continued with dissection of the gallbladder, and its distal portion was then grasped and retracted cephalad. The CC was dissected circumferentially using the

articulating robotic instruments, keeping close to the cyst wall and away from the portal vein and hepatic artery. The dissection continued down to the distal aspect of the CC to the point where it tapered, leaving a minimal amount of stump, taking care not to damage the pancreas or pancreatic duct. The distal end of the CC was clipped and divided. We then dissected upward along the cyst to free it from the portal vein. The dissection continued toward the hepatic ducts, and we divided the CC in the middle. In each case, at least 5 mm of the proximal common hepatic duct was retained to facilitate the construction of the hepaticojejunostomy.

The hepatic ducts were then inspected and irrigated (Fig. 2a). A tension-free hepaticojejunostomy was created with two single-armed 5/0 absorbable monofilament running sutures on the anterior and posterior sides of the duct if the diameter of the common hepatic duct was greater than 1 cm. If the diameter was less than 1 cm, simple interrupted sutures were utilized (Fig. 2b).

The gallbladder was then removed from the gallbladder fossa. A drain was placed near the anastomosis, the specimen was removed, and the ports sites were closed.

Postoperative care

The postoperative nutritional regimen was the same for all patients according to our institutional protocol for postoperative feeding. All patients started oral intake on the third postoperative day. Infants were discharged as soon as they tolerated full feeding. Patient follow-up consisted of medical examinations 1 month, 6 months, and 1 year after surgery.

Statistical analysis

Data are presented as the mean value and range. Mean values were compared for non-normal distributions with the Wilcoxon signed-rank sum test. Fisher's exact test was used to analyze categorical data.

All data analyses were performed with JMP 14.0 for Windows (SAS Institute, Cary, NC, US). Differences were considered statistically significant at $p < 0.05$.

Results

During the study period, 39 consecutive patients underwent robotic CC resection and hepaticojejunostomy using the da Vinci Si surgical system (Intuitive Surgical Inc., Sunnyvale, CA, US) at our institution. No case of CC was documented prenatally. Twenty patients (51.3%) had a Todani type I CC and 19 had a Todani type IV [18]. The male-to-female ratio was 1:3.3. The mean age and weight at operation were 40.2 months (range 5–108 months) and 13.4 kg (range 6.5–29 kg), respectively. The mean CC diameter was 27.2 mm (range 9–112 mm), and the mean diameter of the hepaticojejunostomy anastomosis was 12 mm (range 3–18 mm).

Operative data and postoperative outcomes

The operation times are summarized in Table 1. There was no conversion to laparoscopic surgery or laparotomy and no

Table 1 Operative time (minutes)

	Minimum	Maximum	Mean
Total operating time	150	330	192.7
Docking time	10	30	16.3
Robot (console) time	60	235	110.5
Jejunojejunostomy time	40	90	52.4
Hepaticojejunostomy time	20	80	40.4

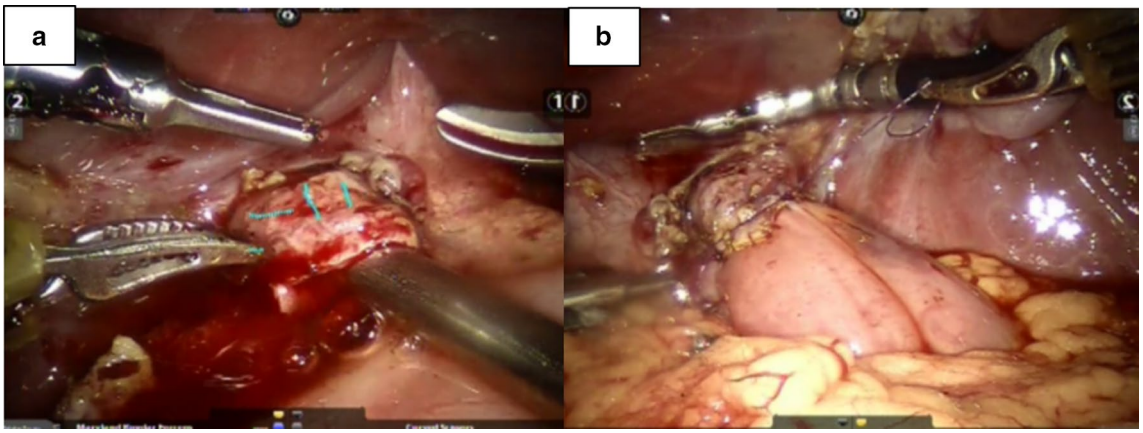

Fig. 2 Intraoperative photographs: **a** choledochal cyst dissected and resected at the level of common hepatic duct; **b** hepaticojejunostomy with robotic instruments

intraoperative complication, including injury of other organs and bleeding necessitating a blood transfusion. An intra-abdominal drain was inserted in three patients to provide information and removed on postoperative day four and five in one and two patients, respectively.

Although there was no significant correlation between age ($p = 0.614$), Type of CC ($p = 0.19$), maximum CC diameter ($p = 0.12$), anastomosis diameter ($p = 0.61$), and total operation time, the total operation time significantly decreased with each RAS procedure ($p < 0.001$, Fig. 3).

Oral intake was started on postoperative day 3 (mean) and was fully established by postoperative day 5 (mean). The mean hospital stay was 5 days (range 4–7). During the follow-up period, there were no complications, including death, bleeding, wound infection, cholangitis, cholelithiasis, anastomotic leakage, and anastomotic stricture. No infant required reintervention.

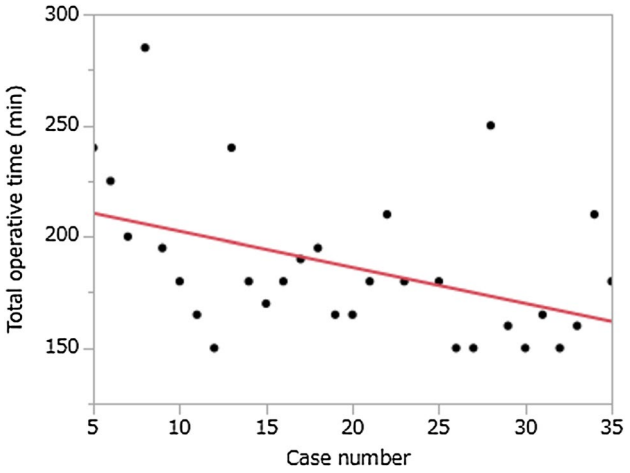

Fig. 3 Scatter diagram and regression line showing the correlation between each operation and total operation time

Discussion

In this study, we investigated our institution's preliminary experience with RAS for CCs in Vietnam, and 39 patients successfully underwent RAS for CC excision and hepaticojejunostomy with no major complication. To the best of our knowledge, this study is the largest series of RAS for CCs in small children. Our total operative time was shorter than that noted in two of the largest previously reported series (minimum time, 380 min; maximum time, 570 min; mean total operating time, 192 min; mean robotic console time, 110 min) [11, 12]. The mean total operative time in our series was also shorter than that of previous reports, especially in the robotic console component (Table 2). Two factors could account for this difference. First, in our department, we do not perform intraoperative endoscopic cholangiography due to lack of instruments. Therefore, we did not need additional time for this intraoperative evaluation, unlike other authors [19]. Second, we do not employ choledocoplasty to improve the passage of bile juice.

Compared with our previous laparoscopic CC cases [7, 8] (including unpublished data), the mean CC diameter was smaller in our RAS series (27 mm and 47 mm, respectively), although the mean patient age and weight were similar. Surprisingly, the mean RAS operation time was shorter than the laparoscopic surgery time that we previously reported (180 vs. 220 min), even though RAS requires additional docking time compared with laparoscopic surgery [7]. Although this finding might indicate that RAS is superior to laparoscopy due to the technical ease of CC dissection and, especially, anastomosis, selection bias may be implicated given that the mean maximum CC diameter in our RAS series was smaller than that in our laparoscopic cases (27 mm vs. 47 mm). This difference in CC diameter might have caused the shorter operation time in our RAS group [7, 8].

Table 2 Previous series of robotic-assisted hepaticojejunostomy for choledochal cyst in children

Study	Year	*n*	Age (years)	TO time (min)	Console time (min)	Conversion	Complications
Woo [17]	2006	1	5	440	390	0	None
Meehan [16]	2007	2	5.5	458	418	0	None
Dawrant [14]	2010	5	0.96	482	319	0	None
Chang [13]	2012	14	5.3	570	324	1	Anastomotic leakage, anastomotic stricture
Alizai [12]	2014	27	5.4	479	302	5	Anastomotic stricture[a]
Kim [11]	2015	36	4.8	520	300	0	Bile leakage 2 Anastomotic stricture 1 Intestinal obstruction 1
Present data	–	39	3.4	192	110	0	None

TO time total operating time

[a]Anastomotic stricture and omentum prolapse from port site and bile leak were occurred in a child

Interestingly, although there was no significant correlation between age, body weight, and type of choledochal cyst, the total operation time significantly decreased with each procedure. This finding implies that the technical advantages of RAS apply to any operation for CC regardless of patient age and body weight, CC maximum diameter and type, or anastomosis diameter.

The previous studies reported complications associated with RAS for CC in children. Kim et al. reported three complications including open conversion, anastomotic stricture, and leakage in their early cases, and Alizai et al. reported five cases of open conversion due to technical problems and one anastomotic stricture after RAS. In our study, no case required conversion to laparotomy, whereas other authors reported a higher conversion rate due to technical problems [11, 12]. We hypothesize that we avoided interoperative conversions, primarily because we benefitted from another institution's previous RAS experience. This information was shared by a visiting pediatric surgeon (Prof. Han) who taught us while participating in operations [11]. Alizai et al. had a relatively high open conversion rate, which may be due to their use of a Nathanson retractor to lift the liver and only three robotic arms. We believe that the Nathanson retractor could be too large for small children, and the fourth robotic arm facilitates flexible liver retraction. Thus, we recommend that pediatric surgeons use the fourth robotic arm as a liver retractor. The incidence of other complications, including anastomotic stricture and anastomotic leakage, was low after RAS, suggesting that these complications have no correlation with the RAS procedure [11, 12].

In this preliminary study of RAS for CCs, we tested the use of all four robotic arms to clarify their interactions with the patients' body structures. In our first four cases, we encountered substantial interaction between various elements, especially the right upper and lower robotic arms, right anterior superior iliac spine, and the operating table. Thus, we increased the distance between the two right-sided robotic arms and moved the patient's position to the right side of the operating table. We also re-positioned the right lower port to 1–2 cm above the right anterior superior iliac spine. After making these changes, we did not experience severe instrument interference in subsequent cases. Notably, a skilled RAS assistant played an important role in monitoring instrument interactions, allowing us to avoid complications secondary to the robotic arm itself in all cases. Furthermore, we performed over 100 RAS cases at our institution, including lung lobectomy, treatment of Hirschsprung disease, and pyeloplasty during the study period. This experience allowed us to establish a skilled robotic surgery team of individuals who are very familiar with robotic systems. We believe that developing a skilled robotic surgical team is important for the prevention of complications due to robotic instruments.

Currently, there is no surgical robot designed specifically for children. Therefore, we must modify surgical robots developed for use in adults to allow their use in small children. Decreasing the number of robotic arms is one of the easiest modifications for a small body. Furthermore, the robotic console does not have to be used to complete all procedures. For example, the robotic console may be used only for anastomosis, and it is expected to improve the quality and precision of this step.

RAS also has disadvantages, including the high purchase price of the robot, maintenance costs, and complete lack of haptic feedback. Although some surgeons have suggested that haptic feedback is important during surgery, we do not consider it necessary. We believe that, in the near future, technical refinements and further miniaturization of robotic instruments, as observed in the new robotic systems, will make it easier for pediatric surgeons to adapt RAS to any procedure in small children and even neonates.

Limitations

This study had limitations. First, we analyzed data derived from a single-center retrospective cohort study with a small sample size. Second, bias could have been introduced during the selection of patients using surgical judgment.

Conclusion

Our series demonstrated the feasibility and safety of robotic-assisted laparoscopic CC resection and hepaticojejunostomy. Compared to laparoscopy alone, the robot-assisted technique overcame technical difficulties, especially in the creation of the hepaticojejunostomy. However, compact, inexpensive instruments designed specifically for children could facilitate RAS in this population.

Acknowledgements We thank Professor Seok Joo Han (Yonsei University, Severance Children's Hospital, Seoul, Korea) for sharing his advice about robotic-assisted surgery for choledochal cysts in children.

Funding This research did not receive any specific grant.

Compliance with ethical standards

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

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was also approved by The Vietnam National Children's Hospital Institutional Review Board (IRB00009162).

Informed consent All data were collected anonymously, and patient consent was not required.

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