



Comparison of robotic versus laparoscopic hepaticojejunostomy for choledochal cyst in children: a first report

Hiroyuki Koga¹ · Hiroshi Murakami¹ · Takanori Ochi¹ · Go Miyano¹ · Geoffrey J. Lane¹ · Atsuyuki Yamataka¹

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Abstract

Aim We compared robotic hepaticojejunostomy anastomosis (RHJA) with laparoscopic hepaticojejunostomy anastomosis (LHJA) in children undergoing complete excision of choledochal cyst.

Methods Difficulty of suturing (DOS) during anastomosis was scored blindly, from intraoperative video recordings, using: 5 = impossible; 4 = difficult; 3 = tedious; 2 = slow; and 1 = easy. A panel of five independent surgeons was also asked to compare RHJA with matched LHJA and score + 1 if RHJA appeared superior to LHJA, 0 if RHJA appeared equivalent to LHJA, and – 1 if RHJA appeared inferior to LHJA.

Results RHJA ($n = 10$) was performed between 2017 and 2019; LHJA ($n = 27$) was performed between 2009 and 2018. LHJA cases were matched for age, weight, and anastomosis diameter to RHJA cases. Complete excision was performed laparoscopically in both groups. DOS was lower in RHJA with less variance. The panel all scored RHJA as + 1. Total anastomotic time (TAT) and TAT per suture were significantly shorter for RHJA. Times taken to ambulate and for return of bowel sounds postoperatively were significantly shorter for RHJA. There was one anastomotic leak with LHJA (3.7%) and no anastomotic complications with RHJA.

Conclusions RHJA is a more stable anastomosis that can be performed quicker, and thus, would appear to be superior to LHJA.

Keywords Choledochal cyst · Hepaticojejunostomy · Robotic surgery · Laparoscopic surgery · Da vinci

Introduction

Since the first report of laparoscopic repair for choledochal cyst (CC) was published in 1995 [1], laparoscopic repair has become the treatment of choice for CC at some centers with numerous reports of innovative techniques. Most authors agree about its safety and efficacy. However, despite reported advantages, laparoscopic repair is also not popular because some pediatric surgeons consider the hepaticojejunostomy anastomosis (HJA) to be very technically challenging, requiring considerable experience and diligence. We believe this is more the result of lack of confidence because CC is a relatively uncommon condition and there is a rather steep learning curve for laparoscopic repair of CC.

In recent years, robotic surgical systems (RSS) have been used to assist and overcome human physical limitations associated with surgery. During complete excision of CC, this is the HJA. RSS facilitate complex minimally invasive procedures outstandingly [2–6], but very little has been published about RSS for treating pediatric hepatobiliary conditions. The expectations, however, are very high.

After performing complete excision of CC with RSS assistance successfully in 10 cases, we were prompted to compare HJA performed with laparoscopy (LHJA) and HJA performed with RSS (RHJA). We present our initial experience.

Material and methods

Pediatric CC patients admitted to our institution specifically for RHJA between December 2017 and August 2019 ($n = 10$) were matched with LHJA performed between June 2009 and November 2017, for age, body weight at surgery,

✉ Hiroyuki Koga
h-koga@juntendo.ac.jp

¹ Department of Pediatric General and Urogenital Surgery, Juntendo University School of Medicine, Tokyo 113-8421, Japan

and HJA diameter. Both RHJA and LHJA were performed by the same surgical team.

Surgical procedure

Complete excision was performed laparoscopically in both groups according to a technique described previously, elsewhere [7, 8]. Briefly, a GelPOINT® mini Access Platform (Applied Medical, Rancho Santa Margarita, USA) inserted in a 2 cm umbilical incision is used to introduce a 30° 10 mm laparoscope into the abdomen. Two additional 5 mm trocars are inserted in the right upper quadrant and left upper quadrant, respectively. The CC is dissected free from surrounding structures, such as the portal vein and hepatic artery, then the distal one-third of the choledochal cyst is identified, and dissected free. At this stage, an opening is made in the distal one-third of the CC, and a fine pediatric ureteroscope (Karl Storz Int, Tuttlingen, Germany) equipped with a light source at its tip is inserted into the opened CC through an additional 3.9 mm trocar placed in the left epigastrium for intraoperative endoscopy (IE). Its tip is then inserted into the common channel and used to wash away any protein plugs under direct ureteroscopic view. IE is performed routinely in all CC patients unless the ureteroscope cannot be inserted into the intrapancreatic choledochus or common channel from the distal part of the cyst because they are too narrow. The exact level of transection of the distal common bile duct is determined by IE when the orifice of the pancreatic duct can be identified with the ureteroscope, and with intraoperative cholangiography (IC) if the orifice of the pancreatic duct cannot be identified. The proximal cyst is excised leaving 10 mm of common hepatic bile duct for the HJA. The Roux-en-Y jejunal loop is fashioned extra-corporeally. The Roux-en-Y limb returned to the abdominal cavity and the jejunal limb are passed through a retrocolic window to lie without tension at the porta hepatis. A scalpel should be used for the enterotomy in the jejunum to prevent thermal injury to the jejunal wall; we never use diathermy with coagulation mode for the enterotomy, since thermal injury can cause scarring.

Laparoscopic hepaticojejunostomy anastomosis (LHJA)

Additional two ports (3.9/5 mm) are required for LHJA: one lateral right subcostal port and one between the right subcostal and right upper quadrant ports to prevent the quality of the anastomosis from deteriorating. End-to-side hepaticojejunostomy is performed using interrupted 5/0 or 6/0 absorbable sutures with the right upper quadrant port as the needle holder in the right hand, the 5 mm port for the scope, and the 3 mm subcostal port as the needle receiver in the left hand. LHJA is performed with interrupted 5/0 or 6/0 absorbable sutures with knots tied extracorporeally using a knot pusher.

The right and left edge sutures are exteriorized and used as traction sutures during anastomosis of the anterior wall to facilitate accuracy.

Robotic hepaticojejunostomy anastomosis (RHJA)

The da Vinci Surgical system (Intuitive Surgical, Sunnyvale, CA) was used for RHJA. Although the da Vinci system we used had four robotic arms, we only used three. The Roux-en-Y limb is brought up to the hilum for HJA and laparoscopic trocars are replaced with da Vinci trocars (Fig. 1). A robotic platform is prepared and docked. RHJA is performed with interrupted sutures 5/0 or 6/0 absorbable sutures with all knots tied intracorporeally.

Difficulty of suturing during HJA (independent surgeon scores)

We developed a difficulty of suturing (DOS) scoring system that was used by a single board-certified specialist pediatric surgeon to score RHJA from intraoperative video recordings (IVR). Scoring was: 5 = impossible; 4 = difficult; 3 = tedious; 2 = slow; and 1 = easy. HJA were also compared by a panel of independent board-certified senior consultant level specialist pediatric surgeons ($n=5$) who viewed IVR from RHJA cases and matched LHJA cases and were asked to score +1 if RHJA appeared superior to LHJA, 0 if RHJA appeared equivalent to LHJA, and -1 if RHJA appeared inferior to LHJA.

RHJA and LHJA cases were compared for age and weight at surgery, body mass index (BMI), HJA diameter, number of sutures required, HJA diameter per suture, total anastomotic time (TAT), TAT per suture, coefficient of variation for TAT per suture, total operative time, blood loss, time taken to ambulate postoperatively, time taken for normal bowel sounds to return postoperatively, duration of drain insertion, and duration of hospitalization.

Data were expressed as mean \pm standard deviation. The Student's *t* test and the Chi squared test were used for statistical analysis. A *p* value > 0.05 was considered to be statistically significant. This study was approved by Institutional Review Boards and complies with the Helsinki Declaration of 1975 (revised 1983).

Results

All laparoscopic surgeries were completed successfully with no conversions to open repair. Subject demographic data are summarized in Table 1. There were no significant differences between the two groups for age at the time of surgery: 5.6 ± 3.4 years for RHJA versus 5.2 ± 3.8 years for LHJA ($p=0.76$); body weight at the time of surgery: 18.7 ± 8.2 kg

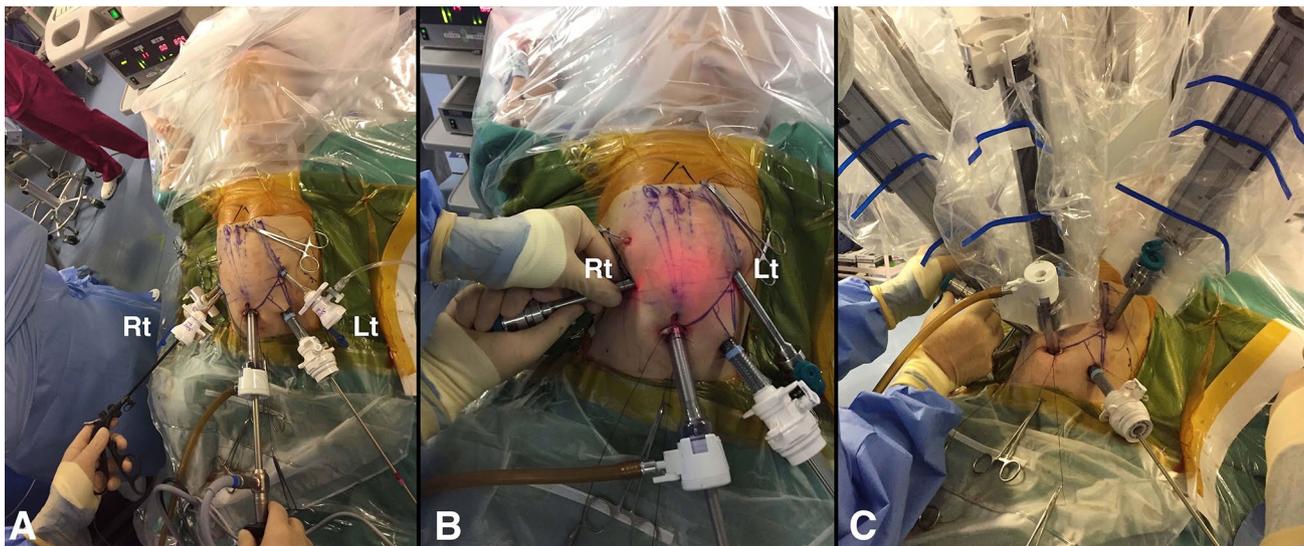


Fig. 1 Robotic hepaticojejunostomy. **a** Trocar positions for conventional laparoscopy. **b** Changing from laparoscopic to da Vinci trocars. The left trocar has been replaced and the right trocar is being replaced. **c** Docking of the da Vinci cart to the trocars

Table 1 Patient demographics

	RHJA (n=10)	LHJA (n=27)	p value
Age at surgery (years)	5.6±3.4 (range 1.8–11.2)	5.2±3.8 (range 0.7–13.8)	NS
Weight at surgery (kg)	18.7±8.2 (range 9.9–35.6)	18.5±11.6 (range 9.0–29.7)	NS
BMI (kg/m ²)	15.9±1.2	15.6±2.6	NS
HJA diameter (mm)	8.6 (range 4–10)	8.7 (range 5–13)	NS

RHJA robotic hepaticojejunostomy anastomosis, LHJA laparoscopic hepaticojejunostomy anastomosis, BMI body mass index, HJA hepaticojejunostomy anastomosis, NS not significant

for RHJA versus 18.5 ± 11.6 kg for LHJA (*p* = 0.97); BMI: 15.9 ± 1.2 kg/m² for RHJA versus 15.6 ± 2.6 kg/m² for LHJA (*p* = 0.71); mean HJA diameter: 8.6 mm (range 4–10 mm) for RHJA versus 8.7 mm (range 5–12 mm) for LHJA (*p* = 0.92). Time taken to perform HJA (TAT): 69.0 ± 12.7 min for RHJA versus 99.5 ± 36.5 min for LHJA (*p* < 0.05); mean number of sutures required: 10.1 ± 2.9 versus 10.1 ± 2.1 (*p* = 0.96); time taken for one suture during HJA (TAT divided by the number of sutures): 7.2 ± 2.2 for RHJA versus 10.3 ± 4.7 for LHJA (*p* = 0.05); HJA ratio (HJA diameter divided by the number of sutures): 0.8 ± 0.2 for RHJA versus 0.8 ± 0.2 for LHJA (*p* = 0.53); total operative time: (10.3 ± 1.6 h for RHJA versus 10.9 ± 2.5 h for LHJA (*p* = 0.50), and blood loss: 0.70 ± 0.32 mL/kg for RHJA versus 0.91 ± 0.51 mL/kg (*p* = 0.23) (Table 2). Interestingly, the coefficient of variation for the time taken to place one suture was smaller for RHJA than for LHJA (0.31 for RHJA versus 0.46 for LHJA).

RHJA was more favorable than LHJA for mean duration of drain tube insertion: 5.4 ± 1.4 days in RHJA versus 8.0 ± 2.3 days in LHJA (*p* < 0.01); mean time taken to ambulate postoperatively: 2.0 ± 0.8 days for RHJA versus

3.0 ± 0.7 days for LHJA (*p* < 0.01); mean time taken for bowel sounds to return postoperatively: 1.6 ± 0.7 days for RHJA versus 2.4 ± 0.5 days for LHJA (*p* < 0.01); and mean hospitalization: 7.4 ± 1.0 days for RHJA versus 11.0 ± 2.4 days for LHJA (*p* < 0.001) (Table 3).

DOS for RHJA was significantly easier than for LHJA (1.3 ± 0.6 versus 3.3 ± 0.4 (*p* < 0.01), and all 5 of the panel of surgeons gave RHJA a score of + 1. Anastomotic leakage complicated one LHJA case (3.7%); there were no anastomotic complications in RHJA cases.

Discussion

This is the first report comparing RHJA and LHJA performed in a series of pediatric CC cases matched for demographics and HJA diameter. By minimizing as many variables as possible, we believe any differences in data or outcome we identified must be the consequence of technique alone, which is a first for pediatric hepatobiliary surgery.

Laparoscopy provides magnified images, allowing dissection and surgical maneuvers to be performed more precisely

Table 2 Comparison of RHJA versus LHJA

	RHJA (n = 10)	LHJA (n = 27)	p value
Time taken to perform HJA (min)	69.0 ± 12.7	99.8 ± 36.5	< 0.05
Number of sutures	10.1 ± 2.9	10.1 ± 2.1	NS
Time taken for one suture during HJA (min)	7.2 ± 2.2	10.3 ± 4.7	NS
HJA ratio	0.8 ± 0.2	0.8 ± 0.2	NS
CV for time taken to place one suture	0.30	0.46	
Total operative time (h)	10.3 ± 1.6 ^a	10.9 ± 2.4	NS
Blood loss (ml/kg)	0.70 ± 0.32	0.91 ± 0.5	NS

HJA hepaticojejunostomy anastomosis, RHJA robotic hepaticojejunostomy anastomosis, LHJA laparoscopic hepaticojejunostomy anastomosis, HJA ratio HJA diameter divided by the number of sutures, CV coefficient of variation, NS not significant

^aIncludes robot docking time

Table 3 Postoperative outcomes

	RHJA (n = 10)	LHJA (n = 27)	p value
Duration of drain tube insertion (days)	5.4 ± 1.4	8.0 ± 2.3	< 0.01
Time taken to ambulate (days)	2.0 ± 0.8	3.0 ± 0.7	< 0.01
Time taken for bowel sounds to return (days)	1.6 ± 0.7	2.4 ± 0.5	< 0.01
Length of hospital stay (days)	7.4 ± 1.0	11.0 ± 2.4	< 0.001
Difficulty of suturing during HJA	1.3 ± 0.6	3.3 ± 0.4	< 0.01
Independent surgeon scores	+ 1 ^a	–	

RHJA robotic hepaticojejunostomy anastomosis, LHJA laparoscopic hepaticojejunostomy anastomosis, HJA hepaticojejunostomy anastomosis, NS not significant

^aScore was + 1 for RHJ for all 5 independent surgeons

with reduced tissue injury, and better cosmesis. However, rigid instruments with limited degrees of freedom, fulcrum effects, and two-dimensional vision lead to poor ergonomics for surgeons, thus hindering accurate and safe placement of sutures during LHJA.

The robotic platform overcomes many of the limitations encountered during laparoscopic surgery; instruments have an increased range of motion, and three-dimensional high-definition vision provides better depth perception. The functions of the robotic arms most related to precise meticulous surgery that RSS has a reputation for are tremor filtering and motion scaling, where large movements made by the operator are converted to minute movements of instruments, increasing the operator's dexterity immensely. In fact, suturing during an anastomosis and knot tying are much easier, because the operator sits comfortably at a console, with no ergonomic issues to hinder performance, and RSS stabilizes fine finger and wrist movements, eliminating tremor. Thus, HJA is far easier with RSS compared with conventional laparoscopic surgery. Indeed, we found the coefficient of variation for RHJA was lower, although there were no significant differences in HJA diameter or the number of sutures required. Lower coefficient of variation infers there is better precision and reproducibility while suturing as one would normally. Our DOS scores also indicated that RHJA is stable

and precise without stressing the operator, which we believe is an advantage that could contribute to reducing biliary tract complications such as leakage and constriction. As reported in many studies, robotic sutures are more precise and easier to handle, thereby providing secure sutures, compared with laparoscopic sutures [9].

A systematic literature review of robotic versus laparoscopic Roux-en-Y gastric bypass in morbidly obese patients showed there was a significantly reduced incidence of anastomotic stricture in the robotic group, though no significant difference between robotic and laparoscopic groups for anastomotic leak, post-operative complications, operative time, and length of hospital stay was found [10]. We also believe that postoperative recovery, including time taken to ambulate and time taken for return of bowel sounds might have been facilitated in our series because we did not need extra trocars to perform our RHJA; we just replaced the trocars used for laparoscopic cyst dissection with robotic ones.

To overcome the limitations of laparoscopic surgery for HJA, some surgeons have performed hepaticoduodenostomy instead of hepaticojejunostomy. However, hepaticoduodenostomy has been reported as a potential cause for "sump syndrome". Hepaticojejunostomy has a Roux-en-Y limb that can prevent the reflux of bowel contents to the biliary tract, so there is less possibility of causing sump

syndrome. We believe that the important principle of treatment for CC is the complete excision of the pathological cyst and safe reconstruction of the biliary tree (hepaticojejunostomy), and these principles must also be applied during minimally invasive surgery for CC.

To date, some 60 pediatric CC cases treated by robotic-assisted hepaticojejunostomy have been reported [2–6, 11, 12] with a mean operative time of 420 min (range 180–520 min), significantly longer than for conventional laparoscopic hepaticojejunostomy in general. We feel RSS is not suitable of dissecting tissue in children because of space constraints and a limited range of energy devices. Kim et al. reported on the technical limitations of robot-assisted CC resection in children. They excluded patients with severe inflamed friable pericholedochal tissue from robotic surgery because of difficulty with hemostasis, and also excluded patients with impacted protein plugs or calculi in the distal common channel because they would be difficult to remove using RSS. They converted to open surgery to remove impacted calculi in the distal common channel. We take a different approach as mentioned earlier and reported previously, elsewhere and perform IE to remove protein plugs and calculi from the distal common channel [8]. Thus, while robotic-assisted complete excision of CC could conceivably take longer compared with the conventional laparoscopic procedure, we found that TAT for RHJA were shorter than for LHJA and that differences in operative time were not statistically significant between the two groups, probably because we did not use RSS for the whole excision procedure.

Our hybrid of robotic and laparoscopic procedures for CC allows to be performed optimally using best available technique for each procedure. We chose to perform the cyst dissection using laparoscopy and the HJA using RSS for the following reasons. Laparoscopy allows more maneuverability; a larger range of movement with a variety of instruments, which contributes to smoother preparation of bowel for anastomosis. Furthermore, with laparoscopy, it is possible to change the positions of instruments and operators intraoperatively as required, which is limited with RSS once docking has been completed. We often swap instruments around during laparoscopic procedures to improve visibility, which helps to reduce operating times. Probably the most practical issue is related to conversion to open surgery should it be required because RSS is far more expensive than laparoscopic surgery. Currently, RSS use is not covered by the National Health Insurance System in Japan, so an average procedure can cost of the order of 1.5 million yen (approximately US\$15,000 using a rough exchange rate of 100 yen = US\$1). Hopefully, the national health insurance system in Japan will be revised in the near future, to decrease the financial burden of RSS surgery, but hybrid procedures, such as we used in this series may be a good compromise in the meantime.

In conclusion, although there are limitations to this study because of its retrospective nature and the small number of cases, we found that RHJA can be successfully performed without difficulty and that RHJA is superior to LHJA. In other words, using RSS for the HJA during the complete excision of CC in children is safe and feasible and can be considered as an emerging approach to reduce anastomosis-related complications compared with laparoscopic surgery alone. Coupled with operator comfort and rapid learning curves, achieving expertise with RSS will be a definite advantage.

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