ASTR

ORIGINAL ARTICLE
pISSN 2288-6575 • eISSN 2288-6796
https://doi.org/10.4174/astr.2024.106.6.322
Annals of Surgical Treatment and Research

Robotic surgeries in pediatric patients: an early experience in a single center

Ye-Chan Jeong[1], Ayoung Kang[1], Da-Young Ko[1], Joong-Kee Youn[1,2], Hyun-Young Kim[1,2]

[1]Division of Pediatric Surgery, Seoul National University Hospital, Seoul, Korea
[2]Department of Surgery, Seoul National University College of Medicine, Seoul, Korea

Purpose: Robotic surgery (RS) has the advantages of 3-dimensional view, optical magnification, motional scaling, and improved ergonomics and degree of freedom. Although RS has widely been performed on pediatric patients lately, there are still numerous restrictions and ambiguous indications. The purpose of this study was to report our early experience with RS on pediatric patients at a single center.
Methods: Electronic medical records of patients who underwent RS with the da Vinci Xi surgical platform (Intuitive Surgical, Inc.) in Seoul National University Children Hospital from November 2019 to August 2021 were reviewed retrospectively. The median follow-up was 21.0 months (range, 12.3–31.8 months). An online survey was conducted to investigate satisfaction with robotic surgical scars.
Results: Fifty-four patients underwent robotic surgeries (median age at operation, 11.1 years [range, 0.1–17.8 years]). In our hospital, patients had 20 different kinds of robotic surgeries, including choledochal cyst excision with hepaticojejunostomy, ovarian mass excision, and others. Median operation time and console time were 157.5 minutes (range, 45–505 minutes) and 40 minutes (range, 11–360 minutes), respectively. All cases were done without conversion into open or laparoscopic methods. Postoperative complications were found in 5 patients. According to an online survey, over half of patients (60.9%) answered that they felt satisfied with scars.
Conclusion: Our early experience demonstrated the safety and feasibility of RS in children with a range of diagnoses and complicated procedures. With more experience, RS could be an alternative to traditional open or laparoscopic operations in pediatric patients. Further studies are needed to clarify indications of pediatric RS.
[Ann Surg Treat Res 2024;106(6):322-329]

Key Words: Choledochal cyst, Minimally invasive surgical procedures; Pediatrics, Robotic surgical procedures

INTRODUCTION

Robotic surgery has the advantages of 3-dimensional view, optical magnification, motional scaling, and improved ergonomics and degree of freedom [1-9]. The first case of robot-assisted surgery in a pediatric patient using a da Vinci platform (Intuitive Surgical, Inc.) was reported in 2001 [10]. Since then, robot-assisted surgery has been widely adopted in multiple specialties such as general surgery, urology, cardiothoracic surgery and gynecology, and procedures for pediatric patients.

Previous studies have reported the safety and feasibility of robotic surgery in pediatric patients [9,11]. Pediatric patients with accompanying complex anatomy could benefit from robotic surgery due to its magnified and optimal robotic surgical view [2,4,9,10]. However, some studies have demonstrated no meaningful differences in surgical outcomes of robotic surgery in pediatric patients compared to a laparoscopic method [1,11]. Compared with a small-sized laparoscopic instrument,

Received January 2, 2024, **Revised** January 22, 2024,
Accepted March 6, 2024

Corresponding Author: Hyun-Young Kim
Department of Pediatric Surgery, Seoul National University College of Medicine, 101 Daehak-ro, Jongno-gu, Seoul 03080, Korea
Tel: +82-2-2072-2478, **Fax:** +82-2-747-5130
E-mail: spkhy02@snu.ac.kr
ORCID: https://orcid.org/0000-0003-0106-9969

relatively large instruments that have not been adjusted for use in young patients should be used in pediatric patients for robotic surgeries. In consequence, securing sufficient space between trocar sites is difficult. It can easily induce collision of robotic arms and limited visualized operative field [7,8,11,12]. Increased operative time, high financial cost, and absence of haptic feedback are also well-known drawbacks of robot-assisted surgery [4].

In alignment with laparoscopic or thoracoscopic methods, distinctive characteristics of pediatric patients should also be considered in robot-assisted surgery. With unique physiology different from their adult counterparts, several anesthetic considerations are also required in robotic surgery. For example, during CO_2 insufflation, the intraabdominal pressure (IAP) increases, which has important physiologic effects such as decreased aortic blood flow, decreased stroke volume, and increased systemic vascular resistance in pediatrics. As a result, the cardiovascular and respiratory systems could be affected by altered IAP during surgery. Thus, delicate managements are needed [1,12,13]. The aim of the present study was to report our early experience with robotic surgery in pediatric patients at a single center and discuss current issues.

METHODS

The study protocol was approved by the Institutional Review Board (IRB) of Seoul National University Hospital (No. 2210-169-1378). It was carried out according to the recommendations of the IRB Committee. Consent has been obtained from the legal guardians of all pediatric patients.

Electronic medical records of 54 pediatric patients who underwent robotic surgery with a da Vinci Xi platform in Seoul National University Children Hospital from November 2019 to August 2021 were reviewed retrospectively. The median follow-up was 21.0 months (range, 12.3–31.8 months). Considering the reliability of data, data of cases that underwent surgeries by 1 experienced surgeon were collected.

The following variables were analyzed with descriptive statistics: sex, age, height, weight and body mass index (BMI) at operation, comorbidity, diagnosis, length of hospital date, follow-up periods, kind of operation, operation time, console time, estimated blood loss (EBL), and postoperative complications. Medians, minimal, and maximal values were used for comparison with ratio scales.

To assess the utility of robotic surgery, robotic and laparoscopic surgeries were compared for 2 major diseases: choledochal cysts and ovarian masses. For this, laparoscopic surgery patients during the identical period were set as the comparison group. All analyses were completed using Microsoft Excel 2013 (Microsoft Corp.) and IBM SPSS Statistics ver. 25 (IBM Corp.).

An online survey was conducted to investigate patients' satisfaction with their surgical wounds. A modified and abbreviated 10-question version of "The Patient Scar Assessment Questionnaire from Research" by Wang et al. [14] was used in this study. Questions written in English in the original version were translated into Korean. Its online link address was given to all patients and their family members to respond to the online survey anonymously.

RESULTS

A total of 54 patients, comprising 14 boys and 40 girls, underwent robotic surgeries. Their median age at the time of operation was 11.1 years (range, 0.1–17.8 years), with a median body weight of 37.9 kg (range, 4.6–98.5 kg), a median height of 145.5 cm (range, 55.0–174.0 cm), and a median BMI of 17.2 kg/m^2 (range, 12.1–36.0 kg/m^2). Among the cohort, 20 different robotic surgeries were conducted. Procedures included predominantly choledochal cyst excision with hepaticojejunostomy and ovarian mass excision. The median length of hospital stay was 7 days (range, 1–30 days) and the follow-up was 21 months (range, 12.3–31.8 months) (Table 1).

The median operation time and console time were 157.5 minutes (range, 45–505 minutes) and 40 minutes (range, 11–360 minutes), respectively. There was no case of conversion to laparoscopic or open surgery. Postoperative complications such as postoperative fluid collection and ileus were found in 4 patients. All these symptoms resolved after conservative management without any invasive procedure. No other major complications of Clavien-Dindo classification grade III or higher, including mortality, were observed (Table 2).

With a comparison between 12 robotic and 11 laparoscopic cases of choledochal cyst, there was no significant statistical difference in sex, age, height or weight at operation, operation time, EBL, or complication. The length of hospital stay was shortened in the robot group (8.2 ± 1.3 days *vs.* 11.4 ± 3.0 days, P = 0.006) (Table 3). All cases with choledochal cyst excision were performed with a multiport robotic surgery. We categorized robotic surgeries for choledochal cysts into hybrid or total robotic surgery depending on whether the intracorporeal procedure with the robot confined to hepaticojejunostomy. Consequently, 9 cases were defined as hybrid robotic surgery which means laparoscopic choledochal cyst excision with robotic hepaticojejunostomy, and the others were defined as total robotic surgery. Total operation time between robotic and laparoscopic surgeries showed no statistically significant difference. However, when we compared the operation time between hybrid and total robotic surgeries, the operation time of the hybrid procedure was much shorter than that of the total robotic surgery (192 ± 65.4 minutes *vs.* 230.0 ± 56.8 minutes).

The ovarian mass group comprised 12 robotic and 20

Table 1. Patient demographics

Characteristic	Data
No. of patients	54
Male sex	14 (25.9)
Age at operation (yr)	11.1 (0.1–17.8)
Height at operation (cm)	145.5 (55.0–174.0)
Weight at operation (kg)	37.9 (4.6–98.5)
Body mass index at operation (kg/m^2)	17.2 (12.1–36.0)
Comorbidity	
Von Hippel-Lindau syndrome	3 (5.6)
Congenital heart disease	2 (3.7)
VACTERL syndrome	1 (1.9)
Congenital hypothyroidism	1 (1.9)
Chronic renal failure	1 (1.9)
Diagnosis	
Gastrointestinal tract	
Esophageal achalasia	2 (3.7)
Intestinal duplication	2 (3.7)
Familial adenomatous polyposis	1 (1.9)
Hirschsprung's disease	1 (1.9)
Intestinal malrotation	1 (1.9)
Imperforate anus	1 (1.9)
Meckel's diverticulum	1 (1.9)
Hepatobiliary, pancreas, and spleen	
Choledochal cyst	12 (22.2)
Pancreatic tumor[a]	4 (7.4)
Solid pseudopapillary tumor	3 (5.6)
Neuroendocrine tumor	1 (1.9)
Gallbladder polyp	3 (5.6)
Ectopic pancreas[b]	2 (3.7)
Gallbladder stone	1 (1.9)
Hereditary spherocytosis	1 (1.9)
Ovarian tumor	12 (22.2)
Mature teratoma	7 (13.0)
Cystadenoma	3 (5.6)
Yolk sac tumor	1 (1.9)
Paraovarian cyst	1 (1.9)
Other masses in the intraabdominal cavity	
Lymphatic malformation[c]	3 (5.6)
Pheochromocytoma	2 (3.7)
Paraganglioma	1 (1.9)
Ganglioneuroblastoma	1 (1.9)
Neurogenic tumor	1 (1.9)
Metastatic osteosarcoma	1 (1.9)
Unknown intraabdominal mass[d]	1 (1.9)
Length of hospital stay (day)	7 (1–30)
Follow-up (mo)	21.0 (12.3–31.8)

Values are presented as number only, median (range), or number (%).
[a]Location of pancreatic tumors: tail. [b]Location of ectopic pancreas: stomach antrum, 1 and jejunum, 1. [c]Location of lymphatic malformation: right adrenal gland, 1; retroperitoneum, 1, and jejunum, 1. [d]One patient complained about severe abdominal pain and a CT scan was taken. On CT scan, an intraabdominal mass with unknown origin at the right lower quadrant area was identified and operation was done for pathology confirmation. In the operational field, a mass located near the cecum was observed and excision was done. The mass proved as inflammatory tissue with reactive lymph node hyperplasia.

Table 2. Procedures and surgical outcomes (n = 54)

Variable	Data
Operation	
Hepatobiliary and pancreas	
Choledochal cyst excision with hepaticojejunostomy	12 (22.2)
Spleen-preserving distal pancreatectomy	4 (7.4)
Cholecystectomy	4 (7.4)
Genital organ	
Ovarian mass resection	12 (22.2)
Ovarian cystectomy	7 (13.0)
Oophorectomy	4 (7.4)
Salpingo-oophorectomy	1 (1.9)
Gastrointestinal tract	
Small bowel segmental resection	3 (5.6)
Esophagomyotomy	2 (3.7)
Stomach wedge resection	1 (1.9)
Ileocecectomy	1 (1.9)
Total proctocolectomy with ileal pouch-anal anastomosis	1 (1.9)
Pena's operation	1 (1.9)
Soave's operation	1 (1.9)
Ladd's operation	1 (1.9)
Endocrine	
Adrenalectomy	4 (7.4)
Others	
Retroperitoneal mass excision[a]	3 (5.6)
Lymph node excision[b]	1 (1.9)
Splenectomy	1 (1.9)
Mediastinal mass excision	1 (1.9)
Intraabdominal mass excision	1 (1.9)
Operation type	
Multiport	46 (85.2)
Single port	8 (14.8)
Cholecystectomy	4 (7.4)
Ovarian cystectomy	4 (7.4)
Operation time (min)	157.5 (45–505)
Console time (min)	40 (11–360)
Estimated blood loss (mL)	50 (0–1,600)
Postoperative complication[c]	4 (7.4)
Postoperative fluid collection	3 (5.6)
Ileus	1 (1.9)

Values are presented as number (%) or median (range).
[a]Location of retroperitoneal mass: left suprarenal area, 1; right pararenal area, 1; and perirectal area, 1. [b]Location of lymph node: left external iliac and inguinal area, 1. [c]All complication cases were suitable for Clavien-Dindo classification I or II.

laparoscopic cases. In contrast to the choledochal cyst group, statistically significant differences were found in operation time and console time between the 2 groups. The total operation time of robotic surgery was longer than that of the laparoscopic method (median [interquartile range]: 98.0 minutes [75.0–157.5 minutes] *vs.* 52.5 minutes [42.5–85.0 minutes], P = 0.013). On the other hand, the robotic console time itself was shorter than

Table 3. Comparison of outcomes between operative techniques for choledochal cysts

Variable	Robot surgery (n = 12)	Laparoscopy (n = 11)	P-value
Male sex	5 (41.7)	2 (18.2)	0.371
Age at operation (yr)	7.4 (0.1–17.3)	2.3 (0.0[a]–16.9)	0.190
Height at operation (cm)	120.1 ± 36.7	97.3 ± 39.7	0.167
Weight at operation (kg)	26.2 (4.6–67.8)	13.0 (2.8–55.8)	0.134
Hybrid procedure[b]	9 (75.0)	-	-
Operation time (min)	201.7 ± 63.2	200.9 ± 29.6	0.971
Hybrid procedure	192.2 ± 65.4	-	-
Total robot procedure	230.0 ± 56.8	-	-
Console time (min)	40.0 (20–160)	-	-
Complication[c]	0 (0)	1 (9.1)	0.478
Estimated blood loss (mL)	35.0 (0–910)	40.0 (0–170)	0.619
Length of hospital stay (day)	8.2 ± 1.3	11.4 ± 3.0	0.006
Follow-up (mo)	22.5 (17.2–34.5)	21.6 (17.0–37.2)	0.975

Values are presented as number (%) or median (range).
[a]One patient underwent laparoscopic choledochal cyst excision with hepaticojejunostomy at 16 days of age. [b]Definition of hybrid procedure is laparoscopic choledochal cyst excision with robotic hepaticojejunostomy. [c]Bile leakage was observed after the operation and hepaticojejunostomy revision by laparoscopy was done in 1 patient.

Table 4. Comparison of outcomes between operative techniques for ovarian tumors

Variable	Robot surgery (n = 12)	Laparoscopy (n = 20)	P-value
Age at operation (yr)	12.8 (11.0–14.5)	8.4 (0.4–13.8)	0.102
Height at operation (cm)	158.1 (147.6–162.8)	134.1 (65.8–159.8)	0.053
Weight at operation (kg)	51.3 ± 23.7	33.2 ± 25.0	0.052
Diagnosis			
Mature teratoma	7 (58.3)	9 (45.0)	-
Cystadenoma	3 (24.9)	1 (5.0)	-
Yolk sac tumor	1 (8.3)	0 (0)	-
Paraovarian cyst	1 (8.3)	9 (45.0)	-
Sex cord tumor	0 (0)	1 (5.0)	-
Operation			
Oophorectomy	7 (58.3)	8 (40.0)	-
Ovarian cystectomy	4 (33.3)	4 (20.0)	-
Salpingo-oophorectomy	1 (8.3)	5 (25.0)	-
Aspiration of ovarian cyst	0 (0)	3 (15.0)[a]	-
Mass size (cm)[b]	8.0 ± 4.8	5.3 ± 3.1	0.074
Operation time (min)	98.0 (75.0–157.5)	52.5 (42.5–85.0)	0.013
Operation time *vs.* console time (min)	32.5 (22.5–43.0)	52.5 (42.5–85.0)	0.019
Complication	0 (0)	0 (0)	-
Estimated blood loss (mL)	50.0 (5.0–125.0)	10.0 (0.0–40.0)	0.157
Length of hospital stay (day)	3.0 (2.0–4.5)	3.0 (3.0–4.5)	0.347
Follow-up (mo)	25.7 ± 5.4	27.7 ± 7.1	0.414

Values are presented as median (interquartile range) or number (%).
[a]Two patients in the laparoscopic group underwent ovarian cyst aspiration only on the surgeon's intention considering operational field. [b]The longest diameter was described according to the final pathology report.

the laparoscopic operation time (median [interquartile range]: 32.5 minutes [22.5–43.0 minutes] *vs.* 52.5 minutes [42.5–85.0 minutes], P = 0.019) (Table 4).

Regarding operative wounds in the robotic group, an online survey was conducted for satisfaction with operative scars. Among 54 candidates, 23 patients responded (response rate, 43%). One patient answered independently, while others participated in the survey through their mothers (Table 5). While a significant proportion of respondents perceived the length of the scar to be short (69.6%), a majority expressed that the scar somewhat (43.5%) or moderately (47.8%) bothered them. In terms of scar noticeability, half of respondents found it to

Table 5. Result of online survey about robotic surgical scars

Question	Response	n (%)
Respondents		23 (42.5)
Relationship with the patient	Self	1 (4.3)
	Mother	22 (95.7)
What type of robot surgery was performed?	Ovarian mass resection	6 (26.0)
	Cholecystectomy	5 (21.7)
	Adrenalectomy	3 (13.0)
	Colon resection	2 (8.7)
	Choledochal cyst excision	2 (8.7)
	Others	5 (21.7)
How much does the scar bother you?	Not at all	2 (8.7)
	Somewhat	10 (43.5)
	Moderately	11 (47.8)
	Very bothersome	0 (0)
In terms of length, the scar is?	Very short	5 (21.7)
	Short	16 (69.6)
	Long	2 (8.7)
	Very long	0 (0)
Does you or your child feel embarrassed by the scar?	No, never	10 (43.5)
	Yes, sometimes	12 (52.2)
	Yes, all the time	1 (4.3)
How noticeable is the scar?	Not at all noticeable	4 (17.4)
	Slightly noticeable	7 (30.4)
	Fairly noticeable	8 (34.8)
	Very noticeable	4 (17.4)
Overall, how pleased are you with the scar?	Very pleased	8 (34.8)
	Somewhat pleased	6 (26.1)
	Neutral	2 (8.7)
	Somewhat bothered	5 (21.7)
	Very bothered	2 (8.7)

be fairly (30.4%) or very noticeable (17.4%). Concerning overall satisfaction, more than half of respondents (60.9%) indicated a general sense of satisfaction with their surgical scars.

DISCUSSION

Robotic surgery as a form of minimally invasive surgery is likely to gain increasing popularity and demand over time. Known for its numerous advantages, including a magnified view, precise movement with articulation, and motion scaling, robotic surgery has made significant strides in recent years within the pediatric patient population. It is being utilized across various disease groups and subspecialties. After the first advent of robotic surgery in pediatric patients in 2001, overall surgical outcomes of robotic surgery for pediatrics have improved far more as proficiency has increased and many efforts are ongoing to find a dedicated surgical approach for children and reduce complications [4,5]. Likewise, the safety of robotic surgery in children is supported by previous studies. It can also help shorten the length of hospital stay and ease postoperative pain [3,5,11]. For pediatric patients, robot-assisted surgery can be considered in complex procedures that require delicate and elaborate surgical techniques such as intracorporeal anastomosis and sutures, especially in procedures usually performed in small or narrow spaces or encounter complicated anatomic structures and in procedures that are hard to acquire sufficient operative field with a conventional approach [1,3,4,5].

However, robotic surgery is limited in its application to children due to its high cost and the large size of the instrument. Also, one of the major challenges in applying robotic surgery to pediatric patients originates from the unique physiology of such patients. Their relatively small physique compared to adulthood makes it difficult to dock and adopt robot instruments. In addition, the lack of workspace can cause the robot arm to collide with other arms, consequently making it hard to perform an elaborate operation [7,11].

In our hospital, we found that the cost of robotic surgery was about 6 times more expensive than laparoscopic surgery in the choledochal cyst group and about 12 times more expensive in the ovarian cysts group. The main reason for this large cost difference between 2 surgical methods is that medical expenses of robotic surgery are not covered by the National Health Insurance, and it is also attributed to consumable robotic instruments which are quite high-priced compared to laparoscopic devices.

Considering medical expenses, it is questionable whether robotic surgery is necessary for procedures such as ovarian mass excision, cholecystectomy, and other surgeries generally regarded as simple procedures. Furthermore, it seems that more benefits could be gained from selectively performing robotic surgery in sophisticated procedures and combining it with other techniques such as a laparoscopic or hybrid method than only performing a robotic surgery in complex situations.

When a pediatric robotic surgery is performed with equipment originally designed for adulthood use, it poses many challenges for young patients. Limitation from the lack of dedicated instruments for pediatric patients makes it difficult to apply more robotic surgeries to children. The availability of robotic surgical devices specifically designed for pediatric use will be a major boost to the development of pediatric robotic surgery.

Overall results of our study suggest that robotic surgery is safe and feasible compared to a laparoscopic method judging by rare complications. However, there were no remarkable or statistically significant differences in results between robotic and laparoscopic surgeries. With similar results for each variable, it is difficult to determine the superiority or non-inferiority between the 2 surgical methods. More studies are needed and more applicants should be enrolled to achieve statistical importance.

According to surgical outcomes in our hospital, the length of hospital stays of the robot group was shorter than that of the laparoscopy group for those with choledochal cysts. It is thought that the shortened length of hospital stays does not indicate the superiority of robotic surgery itself. Because there were no clear factors that supported its strength. Other than that, patients who underwent robotic surgery were older than those who underwent laparoscopic surgery. Although the age difference at operation was not statistically significant, we believe that it might have had an impact. For instance, younger pediatric patients are more vulnerable to changes in physiology and external environment than older ones. In consequence, younger patients, especially neonates, may require more meticulous preoperative evaluation and postoperative management such as intensive care unit management for close monitoring to secure their safety in the perioperative period. On the other hand, no statistically significant differences were found in weight and age, but when looking at the distribution of each group, patients who underwent laparoscopic surgery were generally younger and lighter than those who underwent robotic surgery, which may be due to the small sample size.

Also, as stated earlier, the operation time of a hybrid procedure was significantly shorter than that of a total robot procedure. Thus, it will be better to perform a hybrid surgery for a choledochal cyst in a pediatric patient to shorten the operation time. A longer operation time of total robot procedure might be contributed to its own unique system, such as time-consuming robotic arm change, calibration, and docking and undocking steps.

In 2010, Dawrant et al. [15] reported that robotic choledochal cyst excision could be performed for children weighing under 10 kg as a safe and effective technique. We also had multiple cases of choledochal cysts of children weighing less than 10 kg at operation, with the lowest weight being 4.6 kg (Fig. 1). All surgeries for patients whose weights were under 10 kg were done successfully without intraoperative events or any following complications.

For the ovarian mass group, the total operation time of a robotic surgery was longer than that for the other group. The reason was the same as for the choledochal cyst group. It might be due to time delays caused by those additional steps required for a robotic system. Furthermore, the size of the tumor might have influenced the surgery time as patients who underwent a robotic surgery had larger tumor sizes than those in the laparoscopic group (8.0 ± 4.8 cm *vs.* 5.5 ± 3.1 cm, P = 0.074). In contrast to choledochal cysts, there was no difference in the length of hospital stays between the 2 groups. Ovarian mass resection was usually regarded as a simpler surgical approach with a shorter total operation time in our study. In addition, all patients in the ovarian mass group were discharged within 1

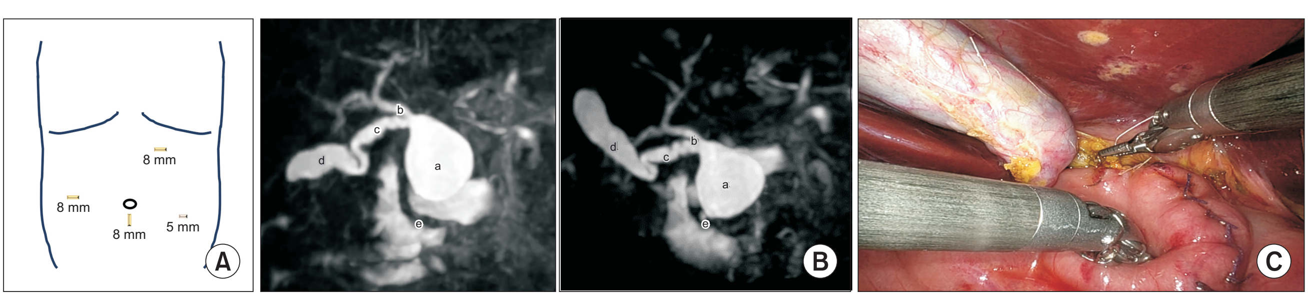

Fig. 1. Hybrid choledochal cyst excision with hepaticojejunostomy. (A) Four trocars, including a subumbilical camera port and additional 3 trocars, were placed. (B) A 1-month-old girl underwent magnetic resonance cholangiopancreatography for evaluation of the biliary tract before the operation, and a choledochal cyst (Todani type I) was identified. a, choledochal cyst; b, common hepatic duct; c, cystic duct; d, gallbladder; e, distal common bile duct. (C) Robot-assisted hepaticojejunostomy after choledochal cyst excision.

week without any complications.

In the last few decades, robotic surgery has gained attention due to its advantages. However, not all patients can benefit from it. Surgeons should consider many factors, such as the physique, comorbidities, availability of the procedure with a robot, and others, before performing a robotic surgery. We performed robot-assisted surgeries for a variety of diseases in this study. Ranging from benign to malignant masses, robotic surgery with trans-abdominal and trans-thoracic approaches can be applied to numerous diseases of pediatric patients. However, there is still no consensus on the absolute indication of robotic surgery for pediatric patients.

In our hospital, we figured that if pediatric patients could have laparoscopic surgery, they also could have robotic surgery. The medical staff explained the overall surgical procedure to the guardians, as well as the commonly known advantages and disadvantages of both methods and they could choose between laparoscopic and robotic surgery.

One of the main reasons that prevent robotic surgery from being applied to pediatric patients is the short distance between trocars. To prevent robot arms from colliding, it has been recommended that trocars should be placed at least 4–6 cm apart from each other [7]. However, it is difficult to apply this recommendation to all pediatric patients. There are no definite criteria for inter-trocar distance either. As a result, surgeons typically decide whether robotic surgery is available based on their own big data gained from experiences. As technology advances and the demand for more compact robotic platforms grows, the future of robotic surgery will move toward reducing the size of instruments and improving tactile feedback. Pediatric patients, especially newborns, will be at the forefront of this. Reconstructive surgeries which require delicate and zoomed-in access will benefit tremendously from these advances.

In conclusion, our early experience demonstrated the safety and feasibility of robotic surgery in children with a range of diagnoses and complicated procedures. With more experience, robotic surgery could be an alternative to traditional open or laparoscopic operations in pediatric patients. Further studies are needed to clarify the indications of pediatric robotic surgery.

ACKNOWLEDGEMENTS

Fund/Grant Support

None.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

ORCID iD

Ye-Chan Jeong: https://orcid.org/0009-0009-0729-9512
Ayoung Kang: https://orcid.org/0000-0002-5431-959X
Da-Young Ko: https://orcid.org/0000-0002-6090-1906
Joong-Kee Youn: https://orcid.org/0000-0002-6345-5745
Hyun-Young Kim: https://orcid.org/0000-0003-0106-9969

Author Contribution

Conceptualization, Project Administration: HYK
Formal Analysis, Methodology: DYK, JKY
Investigation: YCJ, AK
Writing – Original Draft: YCJ
Writing – Review & Editing: All authors

REFERENCES

1. Shen LT, Tou J. Application and prospects of robotic surgery in children: a scoping review. World J Pediatr Surg 2022;5:e000482.
2. Meehan JJ, Elliott S, Sandler A. The robotic approach to complex hepatobiliary anomalies in children: preliminary report. J Pediatr Surg 2007;42:2110-4.
3. Cave J, Clarke S. Paediatric robotic surgery. Ann R Coll Surg Engl 2018;100(Suppl 7):18-21.
4. Cundy TP, Shetty K, Clark J, Chang TP, Sriskandarajah K, Gattas NE, et al. The first decade of robotic surgery in children. J Pediatr Surg 2013;48:858-65.
5. Krebs TF, Schnorr I, Heye P, Häcker FM. Robotically assisted surgery in children: a perspective. Children (Basel) 2022;9:839.
6. Cundy TP, Marcus HJ, Hughes-Hallett A, Najmaldin AS, Yang GZ, Darzi A. International attitudes of early adopters to current and future robotic technologies in pediatric surgery. J Pediatr Surg 2014;49:1522-6.
7. van Haasteren G, Levine S, Hayes W. Pediatric robotic surgery: early assessment. Pediatrics 2009;124:1642-9.
8. O'Brien LP, Hannan E, Antao B, Peirce C. Paediatric robotic surgery: a narrative review. J Robot Surg 2023;17:1171-9.
9. Ihn K, Ho IG, Hong YJ, Jeon HJ, Lee D, Han SJ. Changes in outcomes and operative trends with pediatric robot-assisted resection of choledochal cyst. Surg Endosc 2022;36:2697-704.
10. Meininger DD, Byhahn C, Heller K, Gutt CN, Westphal K. Totally endoscopic Nissen fundoplication with a robotic system in a child. Surg Endosc

2001;15:1360.

11. Cundy TP, Marcus HJ, Hughes-Hallett A, Khurana S, Darzi A. Robotic surgery in children: adopt now, await, or dismiss? Pediatr Surg Int 2015;31:1119-25.
12. Wakimoto M, Michalsky M, Nafiu O, Tobias J. Anesthetic implications of robotic-assisted surgery in pediatric patients. Robot Surg 2021;8:9-19.
13. Meininger D, Byhahn C, Mierdl S, Lehnert M, Heller K, Zwissler B, et al. Hemodynamic and respiratory effects of robot-assisted laparoscopic fundoplication in children. World J Surg 2005;29:615-20.
14. Wang MK, Li Y, Selekman RE, Gaither T, Arnhym A, Baskin LS. Scar acceptance after pediatric urologic surgery. J Pediatr Urol 2018;14:175.
15. Dawrant MJ, Najmaldin AS, Alizai NK. Robot-assisted resection of choledochal cysts and hepaticojejunostomy in children less than 10 kg. J Pediatr Surg 2010;45:2364-8.