World Journal of Pediatric Surgery

Application and prospects of robotic surgery in children: a scoping review

Lei Ting Shen, Jinfa Tou

To cite: Shen LT, Tou J. Application and prospects of robotic surgery in children: a scoping review. *World Jnl Ped Surgery* 2022;**5**:e000482. doi:10.1136/wjps-2022-000482

Received 1 August 2022
Accepted 28 September 2022

Check for updates

Neonatal Surgery, The Children's Hospital, Zhejiang University School of Medicine, Hangzhou, China

Correspondence to
Dr Jinfa Tou; toujinfa@zju.edu.cn

ABSTRACT
As an innovative minimally invasive surgical technology, robot-assisted surgery (RAS) has greatly improved the accuracy and safety of surgery through the advantages of three-dimensional magnification, tremor filtering, precision and flexibility, and has been carried out by an increasing number of surgeries. In recent years, robots have been gradually applied to children, bringing new ideas and challenges to pediatric surgeons. This review will describe the advantages and limitations of robotic surgery in children, summarize its application in pediatric surgery, and provide an outlook. It is believed that clinicians should actively carry out RAS under the premise of rigorously ensuring surgical indications and strive to improve the efficacy of surgical treatment for children.

INTRODUCTION
Minimally invasive surgery has gradually become the trend of surgery with the development of medicine. Since the 21st century, the application of robot-assisted surgery (RAS) has become an important symbol of the progress of minimally invasive technology. The most representative robotic system is the Da Vinci surgical system (DVSS) approved by the US Food and Drug Administration, which is also widely used around the world. With the increase in experience, the superiority of RAS in minimally invasive surgery has gradually been confirmed and promoted by the majority of surgeons.[1 2] In recent years, RASs have been gradually applied in pediatrics, including in children's urology, cardiothoracic, general surgery and other disciplines, but there are still few reports in neonates and infants.[3] The relevant literature from 2000 to 2022 was searched in PubMed and Web of Science with keywords of "child", "robot", "robotic surgery", "pediatric", "urology", "thoracic surgery", "cardiac surgery", "general surgery", and "oncology". We also consulted the Journal of Robotic Surgery and the Journal of Pediatric Surgery. After collecting and summarizing the relevant literature, we described the advantages and limitations of robotic surgery in children and summarized its application in pediatric surgery.

OVERVIEW
The composition of RAS
As the most widely used robotic surgical system, the DVSS is composed of three separate components: the surgeon console, patient cart, and vision cart. The surgeon sits at the console and remotely controls the robotic arms beside the bed, manipulating surgical instruments to perform complex surgical procedures in a minimally invasive way. The patient cart supports the instrument arms and the endoscopic arm to ensure stable imaging and operation. The assistant is next to the patient cart, responsible for the installation and replacement of surgical instruments, supervising the use of instruments, and ensuring the safety of patients. The vision cart contains the core processor and image processing equipment of the surgical robot, and the endoscope can form a magnified three-dimensional (3D) stereoscopic image, allowing the surgeon to accurately distinguish the internal anatomy and perform delicate operations. In addition, devices such as function confirmation, intelligent self-inspection, and audio-visual communication help to communicate with each other and ensure the safety of patients.

There are also some robotic systems less widely used than the DVSS but also have potential for future development: the Telelap ALF-X robot consists of an open console with eye tracking, hands with tactile feedback, and robotic arms beside the bed; the Avatera robot has a closed console with microscope-like oculars and four arms on the side cart connected to the 5 mm instruments with 6 df; and the ReVO-I robot consists of an open console and four robotic arms on a cart.[4 5] The Hugo robotic surgical system is the latest robotic surgical system, including a surgical tower, console, surgical arm, and cart with a compact and mobile platform design, which can be moved throughout the hospital, reducing the cost of purchasing a robotic system for each operating room.[6 7] The Hugo robotic surgical system also has an upgradable system, which can be upgraded in time with the development of technology without requiring the hospital to replace the entire system. At present, it is mainly used in adult urology and gynecology.[8 9]

Advantages of RAS in children

Aiming at the small and complex anatomy of children, binocular loupes are often used in open surgery to magnify the fine structures in the field of view. Although the traditional laparoscopic endoscope has a magnifying effect, the unique advantages of the robot's 3D magnification can establish the surgeon's stereoscopic visualization, increasing the depth perception of the operator.[10] The robot is also equipped with motion scaling and tremor-filtering functions, avoiding the tiny movements of the hand and making the operation stable and precise.[11] At the same time, compared with the traditional laparoscopic 4 df, robotic surgical instruments with 7 df further eliminate tool constraints, which simplifies sutures and ligations in small areas.[12] The robot also has advantages in the details: the tip of the instrument moves in the same direction as the operator's hand, which is easier to learn than traditional laparoscopy; a small space leads to slower replacement of instruments, while robotic instruments can reach their original positions quickly and accurately, improving a certain efficiency; and the ergonomic sitting position of the console allows the operator to get some rest.[13]

Due to the small body size of children, especially neonates and infants, conventional laparoscopy often presents problems such as small operating space, poor visualization effect and limited freedom when involving complex and difficult dissections. However, with the designs described above, robots can overcome these limitations and achieve a more complete and efficient solution. For diseases such as Hirschsprung's disease (HSCR) and anorectal malformation (ARM), the operative field of vision is limited, and the operation is difficult. However, the robot provides the surgeon with extensive visualization of the deep pelvis, 3D imaging and a high df, so that the surgeon can carry out resection and reconstruction surgery more accurate in a limited space.[14 15] With the application of robots in children, new opportunities will be provided for these complicated surgeries.

Restrictions of RAS in children

The shortcomings of RAS are as follows: (1) high cost[16]; (2) due to the lack of tactile feedback, the operator has to rely on previous visual judgment and experience in anatomy[10]; (3) the larger size of the instrument also affects the application of RAS in children. Ballouhey *et al*[17] found that robotic surgery presents greater technical limitations in children under 3.0 kg. Taking the DVSS as an example, there are currently two types of surgical instruments with diameters of 5 mm and 8 mm, both of which are larger than the traditional laparoscopy with a diameter of 3 mm. The lack of commercially available 3 mm instruments is a significant limitation for the robot, hindering its use in infants.[16] (4) The Da Vinci manufacturer recommends an 8 cm distance between each port, which is obviously difficult in children. However, Ballouhey *et al*[17] showed that a distance of 5–6 cm is acceptable because the distance between the ports increases after inflation. Navarrete Arellano and Garibay González[18] performed various operations on the young infants with a 3 cm interval between each trocar without any problems. (5) Anesthesia in minimally invasive endoscopic surgery cannot be ignored, especially for infants and neonates with poor cardiopulmonary tolerance and strong peritoneal absorption, which can easily absorb CO_2 and lead to hypercapnia, affecting cardiopulmonary and brain functions.[19 20] Therefore, it is necessary to accurately regulate airway inflation pressure and oxygen concentration, which is also a major challenge in pediatric surgery.

The learning curve of RAS

The robot's learning curve (LC) is also worth mentioning. The LC represents how the ability to solve problems changes over time and experience. Some researchers believe that because the intuitive symmetric motion of the robot system is consistent with the surgeon's hand, while traditional laparoscopy requires reverse motion, the LC of RAS is shorter, and the surgeons can reach the comfort level faster than laparoscopic surgery.[21 22] Pio *et al* conducted the first systematic review of robot's LC in pediatric surgery, involving urology, general surgery and otolaryngology.[23] The total operative time, including console time and docking time, was most commonly used to assess the LC. In addition, some reports included intraoperative and postoperative complications, and length of hospital stay as evaluation criteria. The overall analysis showed that the operation time decreased as the number of cases performed by the surgeon increased, eventually leveling off, and in some cases, even approaching the time of conventional laparotomy. Therefore, they believed that surgeons transitioning from open surgery to robotic surgery can achieve professional levels in established robotic surgery programs under the guidance of trained robotic teams. Surgeons with or without experience in laparoscopic or robotic surgery can perform robotic surgery independently, and experience in robotic or laparoscopic surgery can make LC steep. However, they also indicated that due to the differences in the backgrounds of surgeons, the characteristics of patients and the types of surgeries, as well as different study designs and statistical analysis methods, multiple parameters related to proficiency should be considered in the assessment of LC. However, there is no consensus on the assessment criteria of LC in the literature.

APPLICATION OF RAS IN PEDIATRIC SURGERY

Urology

Robot-assisted laparoscopic surgery is currently the most widely applied in urology.[24] Robot-assisted pyeloplasty is a major surgical procedure in the field of pediatric urology, and other robotic surgeries, such as partial or complete nephrectomy, ureterostomy, ureteral reimplantation, bladder reconstruction, etc, and has also been proven to be safe and effective.[25–27] Navarrete Arellano and Garibay González reported a prospective observational study including 186 children who underwent RAS from 2015 to 2018.[18] There were 91 cases in urology department. Pyeloplasty, nephrectomy and ureteral replantation were successfully completed, and the overall postoperative recovery was good. The study showed that robotic surgery is safe and effective for children and can perform a variety of complex surgeries. Ballouhey *et al* prospectively collected and retrospectively analyzed perioperative and intraoperative data of 117 children undergoing various robotic urology procedures. The results showed that only two cases were converted to open surgery due to equipment problems, proving that robotic surgery is safe and feasible in pediatric urology.[17] In that study, children were divided into two groups (<15 kg and >15 kg), and no significant difference in the average operation time, hospital stay, and the postoperative follow-up results were found between the two groups. Therefore, the authors believed that RAS can be carried out on younger children with the same safety and efficiency as older children, and the robotic LC is faster than traditional laparoscopy.[17]

Although the cost of robotic surgery is higher than that of open surgery, there are documented reports of higher postoperative satisfaction and quality of life in patients.[28] A large multinational and multicenter study comparing the efficacy of traditional laparoscopic and robot-assisted pyeloplasty showed that both minimally invasive methods are safe and effective for the treatment of obstruction at the ureteropelvic junction in children, but the length of hospital stay after robotic surgery was shorter and the incidence of postoperative complications was lower.[29] A meta-analysis comparing robotic surgery with open and laparoscopic approaches also found that robot-assisted pyeloplasty in pediatric patients resulted in shorter hospital stays, lower blood loss and analgesic need compared with traditional laparoscopic or open pyeloplasty.[30] However, higher quality evidence from prospective observational studies and clinical trials is needed for further cost-effectiveness analysis. Robots are the main development field of urology at present. The advantages of various surgical procedures in pediatric urology in terms of safety and prognosis are gradually recognized, allowing surgeons to constantly innovate, break through the inherent specific technology, and challenge the complex surgery that cannot be completed by traditional laparoscopy.

General surgery

At present, robot-assisted fundoplication for the treatment of hiatal hernia has been widely used and has been proven safe and effective by many institutions.[17 18 21 31] In addition, RAS has involved more complex traditional laparoscopic surgery in pediatric gastrointestinal surgery, such as laparoscopic megacolon radical resection and laparoscopic anoplasty. Due to the unique advantages of the robotic system, the development of such operations is smoother. Accurate pelvic anatomy is an important link between HSCR and ARM surgery, which can reduce damage to pelvic nerve as much as possible, and reduce the resulting rectal and anal dysfunction,. Due to overcoming the limitations of limited space and poor visualization in the depths of the pelvis, RAS can be applied to ideally identify and dissociate the colon and rectum in the pelvic cavity with the advantages of 3D visualization and flexible operation, to perform a more complete rectal anatomy and to reduce damage to the pelvic nerve, which is of great importance to reduce postoperative complications.[32 33] Moreover, RAS is suitable for different surgical procedures of HSCR, whether Soave surgery or Swenson surgery, which can be carried out safely and effectively. In 2011, Hebra *et al* first reported the robot-assisted Swenson procedure in 12 infants with HSCR.[34] In 2017, Mattioli *et al* reported three cases of robot-assisted Soave procedures for HSCR in children aged 5 years, 16 years and 20 months.[32] According to the postoperative follow-up data of different centers, the clinical results of RAS are satisfactory, with no postoperative incontinence, good defecation function, and a low incidence of postoperative enterocolitis.[32–35]

Prospective studies of small samples found that Soave surgery performed by RAS could be successfully completed without intraoperative complications, and the incidence of postoperative complications was significantly reduced.[36] Long-term follow-up results also showed that robot-assisted Soave procedure can be used for the treatment of infant HSCR, which is safe, efficient and has a good long-term prognosis.[37] It is superior to laparoscopy and laparotomy in avoiding sphincter injury and reducing complications but requires a skilled and excellent team to perform the operation.[37] At the same time, with the accumulation of operational experience and improvement of technical level, the age of children treated by robotic surgery for HSCR is getting younger and younger.[36 37] The developmental advantages and potential of robotic surgery in the treatment of HSCR still need to be further verified by more prospective studies.

The advantages of robotic pelvic floor anatomy are also conducive to the accurate dissection of fistulas in children with ARM complicated with rectourethral fistula. The robot provides good visualization of the depth of the pelvis while improving reconstruction techniques with excellent dexterity and precision of motion, minimizing nerve around rectum and sphincter trauma and reducing complications, which is important in the surgical treatment of ARMs.[38 39] In 2016, Ruiz *et al* reported a case of a child with anal atresia treated by RAS.[15] The operation was successfully completed without any complications, and the child was discharged from the hospital on the 6th day after the operation and had a good follow-up result. However, the overall number of reports is still small, and the experience is still limited at present, which needs to be confirmed in a larger research series.

RAS has also been applied in pediatric hepatobiliary diseases. Compared with laparoscopy, the robot improves the visualization and identification of the hilum hepatis, reduces the difficulty of anatomy, greatly helps the anatomy of the hepatobiliary region and the reconstruction of the biliary tract, and shortens the LC of doctors.[12 40] In 2006, Woo *et al* used a robot to treat a child with type I choledochal cyst and completed resection of the choledochal cyst and a Roux-en-Y hepaticojejunostomy, with good follow-up results.[40] Later, several centers reported the application of RAS in treating choledochal cysts, and the surgeries were successfully completed with a low incidence of postoperative complications and good follow-up results.[41–43] In Chang *et al*'s report on the robotic treatment of 14 children with choledochal cysts, the first 3 patients had serious technical problems and complications due to lack of experience, but the remaining 11 patients were successfully operated on without any complications after completing systematic training, which showed that the use of robots requires a good and skilled team.[44] Although the operation of RAS in the hepatobiliary area has advantages, retrospective analyses between the robot and laparoscopy showed no significant difference in the intraoperative blood loss and the incidence of postoperative complications, and the medical cost of the robot was higher than that of laparoscopy.[45 46] Whether robotic and laparoscopic treatment are different in terms of postoperative outcomes, complication rates and long-term prognoses needs to be further compared and evaluated.

Cardiothoracic surgery

In 2004, Bodner *et al* carried out a series of robotic operations in adult thoracic surgery with good intraoperative and postoperative clinical results, indicating that the robot is safe and effective with accurate dissection in hard-to-reach areas.[47] Later, the robot was gradually applied in children's thoracic surgery to complete precise tissue resection and repair, including resection of mediastinal mass, pulmonary segmentectomy, diaphragmatic plication, diaphragmatic repair, bronchogenic cyst resection and so on.[17 18 31 48] However, under the protection of the ribs, the operation space in the thoracic cavity is small, and many organs and complex anatomical structures lead to easy collision of the instruments. At the same time, the cardiopulmonary tolerance of children is worse than that of adults, which leads to the lack of robotic surgery in pediatric cardiothoracic surgery. Ballouhey *et al* prospectively collected perioperative and intraoperative data on 11 pediatric robotic thoracic surgeries at two pediatric centers and then performed a retrospective analysis comparing operation time, completion rate, length of hospitalization and postoperative complications with thoracoscopic results in the literature.[49] The results showed that robotics had similar advantages to thoracoscopy in the removal of mediastinal cysts in older children. They also stated that in neonates, it takes a lot of time to position and place the trocar, and the technology is limited. Currently, there is a lack of evidence that low-weight children, especially neonates, are good candidates for robotic use in thoracic surgery, which needs to be evaluated with more case data.

Robotic surgery in pediatric cardiac surgery is also relatively rare and mainly involves the treatment of congenital heart disease, such as atrial septal defect closure repair and valve replacement. Due to the narrow intercostal space, small thoracic cavity space and relatively large size of robotic devices, the reported pediatric patients are all older children. Thus, the application of robots in infants is still lacking. Onan *et al* performed robotic surgery on 30 children who were between 13 and 17 years old from 2013 to 2018, including atrial septal defect closure, partial anomalous pulmonary venous connection repair, tricuspid valve annuloplasty and mitral valve replacement.[50] All surgeries were successfully performed without conversion, and there were no reoperations or deaths during a mean follow-up of 1.7 years, which confirms that robot-assisted heart surgery is feasible and safe. Gao *et al* performed robotic surgery on 45 patients with atrial defects and 10 patients with left atrial myxoma.[51] The patients ranged in age from 12 to 61 years old, and all patients were successfully resected or repaired without open conversion surgery, death, stroke, or device-related complications, indicating that RAS has no restrictions on the safe resection of left atrial myxoma and repair of atrial defect and has good cosmetic results. Xiao *et al* reported 160 cases of patients with atrial septal defects treated by RAS, aged 11–66 years, with similar results, without translational thoracotomy or serious complications and good follow-up results.[52] Although the robot can complete the precise resection and repair of the thoracic cavity, its development in young children still needs further experience and exploration.

Oncology surgery

For tumor surgery, some tumors are not easily accessible, and intraoperative visual and operational limitations often hinder the progress of traditional minimally invasive surgery and increase the surgical risks.[53] Chen *et al* reported a case of a 3-year-old child with S5 hepatoblastoma undergoing RAS in 2019.[12] Intraoperative liver tumor resection was successfully completed, preserving the gall bladder, which preliminarily indicated that robot-assisted partial hepatectomy is feasible, but relevant experience is still limited.

Blanc *et al* prospectively studied 10 children with cancer aged 3–14 years who underwent robot-assisted nephrectomy between December 2016 and September 2018.[54] Three of them were converted to open surgery. All tumors were completely resected without rupture, and the children were stable after the operations. One female patient died of complications of central nervous system metastasis 1 year after surgery during long-term follow-up. There was no difference in age, tumor stage, or operation time between the robotic group and the open approach group, and the hospital stay of the robotic group was shorter than that of the open approach group. The authors suggested that RAS can maintain a clear view of the extent of the tumor, facilitate safe dissection of the injured organ and repair of the diaphragm, and reproduce all the procedures of open surgery. After careful consideration of the indications, a surgical procedure by a highly experienced surgeon may be considered. Then, Blanc *et al* published a 4-year prospective study on tumor resection of RAS in 2022 and 89 children with abdominal, thoracic, pelvic, and retroperitoneal tumors were enrolled in the study.[55] A total of 93 operations were performed to remove 100 tumors. The overall postoperative effect was good, and the complication rate was relatively low. The results showed that robotic surgery is a safe option, but the authors emphasized that indications should be actively discussed and cases should be strictly selected for robotic surgery.

Vatta *et al* conducted a retrospective analysis of 14 children who received robot-assisted tumor resection.[56] The tumors involved included mature teratoma, serous papillary cystadenofibromas of the fallopian tube, ovarian cystadenoma, type 3 sacrococcygeal tumor, neuroblastoma and intermixed ganglioneuroblastoma. All tumors were successfully resected without conversion to open surgery, and no recurrence or complications occurred during follow-up. The results showed that RAS is feasible in pediatric tumors, but they believed that the use of RAS should be limited to selected cases and operated on by trained oncological surgeons. Although robotic surgery has been promoted in adult tumors, there are still many limitations in pediatric tumors. Further innovations in robotic technology may make it more widely used in pediatric tumors.

SUMMARY AND PROSPECTS

Reviewing the advantages and limitations of RAS, we can find its application in pediatric surgery: first, when involving complex anatomy in a small space, the robot has advantages over laparoscopy and has great development potential, but its application in children is still less in its infancy, especially in pediatric oncology and neonatal surgery. At present, the relevant literature is extremely limited, and it is necessary to accumulate case data to provide a more reliable basis for clinical treatment. Second, studies have shown that in the treatment of some diseases, there is no significant difference in postoperative outcomes between RAS and traditional laparoscopy, and the former has a higher cost, so the choice between the two is controversial. More prospective studies and long-term follow-up are needed to evaluate the advantages of robots over laparoscopy. Third, one of the limitations of robotic surgery in children, especially infants and newborns, is the large size of the robotic devices. With the advent of new and smaller devices in the future, robots will be more widely used in younger children. Fourth, although RAS, which is consistent with the doctor's hand, is intuitive and symmetric and easy to learn compared with laparoscopy with reverse motion, there is no unified standard for the evaluation of the robot's LC, and more research and statistical analysis are needed to determine more reliable evaluation parameters. Fifth, few specialists have mastered robotic surgery, and the crucial part of remote surgery performed by specialists has yet to benefit children farther away. Sixth, in children, there is still a lack of consensus on the intraoperative distance between trocars, which requires more exploration and experience. Lastly, although there are a variety of new robotic surgical systems, there is still a lack of their application in children. The Da Vinci robot still occupies a dominant position in pediatric surgery. Whether there will be a variety of robot applications and comparisons in children in the future depends on the continuous development of technology and the exploration and practice of surgeons.

The birth of new equipment and technology is constantly overcoming the previous defects, which is a progressive process. The use of RAS in children will undoubtedly increase as surgeons and patients demand, market competition drives the emergence of smaller robotic instruments and endoscopes, improves the lack of tactile feedback, reduces high cost, and further enhances the existing advantages of robotics. With the rapid development of remote networks, the learning and application of RAS will be popularized in more places.

Contributors LTS collected literature materials and wrote the article. JT reviewed and proofread the article and put forward suggestions for revision.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

ORCID iD
Lei Ting Shen http://orcid.org/0000-0001-7617-7150

REFERENCES

1 Leal Ghezzi T, Campos Corleta O. 30 years of robotic surgery. *World J Surg* 2016;40:2550–7.
2 Koh DH, Jang WS, Park JW, *et al*. Efficacy and safety of robotic procedures performed using the dA Vinci robotic surgical system at a single Institute in Korea: experience with 10000 cases. *Yonsei Med J* 2018;59:975–81.
3 Denning N-L, Kallis MP, Prince JM. Pediatric robotic surgery. *Surg Clin North Am* 2020;100:431–43.
4 Rassweiler JJ, Autorino R, Klein J, *et al*. Future of robotic surgery in urology. *BJU Int* 2017;120:822–41.
5 Alip SL, Kim J, Rha KH, *et al*. Future platforms of robotic surgery. *Urol Clin North Am* 2022;49:23–38.
6 Gueli Alletti S, Chiantera V, Arcuri G, *et al*. Introducing the new surgical robot HUGO™ Ras: system description and docking settings for gynecological surgery. *Front Oncol* 2022;12:898060.

7 Bravi CA, Paciotti M, Sarchi L, *et al*. Robot-Assisted radical prostatectomy with the novel Hugo robotic system: initial experience and optimal surgical set-up at a tertiary referral robotic center. *Eur Urol* 2022;82:233–7.
8 Totaro A, Campetella M, Bientinesi R, *et al*. The new surgical robotic platform HUGO™ RAS: System description and docking settings for robot-assisted radical prostatectomy. *Urologia* 2022;28:3915603221107855.
9 Monterossi G, Pedone Anchora L, Gueli Alletti S, *et al*. The first European gynaecological procedure with the new surgical robot Hugo™ Ras. A total hysterectomy and salpingo-oophorectomy in a woman affected by BRCA-1 mutation. *Facts Views Vis Obgyn* 2022;14:91–4.
10 Dutta S, Woo R, Albanese CT. Minimal access portoenterostomy: advantages and disadvantages of standard laparoscopic and robotic techniques. *J Laparoendosc Adv Surg Tech A* 2007;17:258–64.
11 Cundy TP, Shetty K, Clark J, *et al*. The first decade of robotic surgery in children. *J Pediatr Surg* 2013;48:858–65.
12 Chen D-X, Wang S-J, Jiang Y-N, *et al*. Robot-Assisted gallbladder-preserving hepatectomy for treating S5 hepatoblastoma in a child: a case report and review of the literature. *World J Clin Cases* 2019;7:872–80.
13 Lorincz A, Langenburg S, Klein MD. Robotics and the pediatric surgeon. *Curr Opin Pediatr* 2003;15:262–6.
14 Spinoit A-F, Nguyen H, Subramaniam R. Role of robotics in children: a brave new world! *Eur Urol Focus* 2017;3:172–80.
15 Ruiz MR, Kalfa N, Allal H. Advantages of robot-assisted surgery in anorectal malformations: report of a case. *J Minim Access Surg* 2016;12:176–8.
16 Bruns NE, Soldes OS, Ponsky TA. Robotic Surgery may Not "Make the Cut" in Pediatrics. *Front Pediatr* 2015;3:10.
17 Ballouhey Q, Villemagne T, Cros J, *et al*. A comparison of robotic surgery in children weighing above and below 15.0 kg: size does not affect surgery success. *Surg Endosc* 2015;29:2643–50.
18 Navarrete Arellano M, Garibay González F. Robot-Assisted laparoscopic and thoracoscopic surgery: prospective series of 186 pediatric surgeries. *Front Pediatr* 2019;7:200.
19 Mariano ER, Furukawa L, Woo RK, *et al*. Anesthetic concerns for robot-assisted laparoscopy in an infant. *Anesth Analg* 2004;99:1665–7.
20 Sureka SK, Patidar N, Mittal V, *et al*. Safe and optimal pneumoperitoneal pressure for transperitoneal laparoscopic renal surgery in infant less than 10 kg, looked beyond intraoperative period: A prospective randomized study. *J Pediatr Urol* 2016;12:281. e1–281.e7.
21 Fernandez N, Farhat WA. A comprehensive analysis of robot-assisted surgery uptake in the pediatric surgical discipline. *Front Surg* 2019;6:9.
22 van Haasteren G, Levine S, Hayes W. Pediatric robotic surgery: early assessment. *Pediatrics* 2009;124:1642–9.
23 Pio L, Musleh L, Paraboschi I, *et al*. Learning curve for robotic surgery in children: a systematic review of outcomes and fellowship programs. *J Robot Surg* 2020;14:531–41.
24 Cave J, Clarke S. Paediatric robotic surgery. *Ann R Coll Surg Engl* 2018;100:18–21.
25 Mizuno K, Kojima Y, Nishio H, *et al*. Robotic surgery in pediatric urology: current status. *Asian J Endosc Surg* 2018;11:308–17.
26 Subramaniam R. Current use of and indications for robot-assisted surgery in paediatric urology. *Eur Urol Focus* 2018;4:662–4.
27 Fuchs ME, DaJusta DG. Robotics in pediatric urology. *Int Braz J Urol* 2020;46:322–7.
28 Freilich DA, Penna FJ, Nelson CP, *et al*. Parental satisfaction after open versus robot assisted laparoscopic pyeloplasty: results from modified Glasgow children's benefit inventory survey. *J Urol* 2010;183:704–8.
29 Silay MS, Spinoit AF, Undre S, *et al*. Global minimally invasive pyeloplasty study in children: results from the pediatric urology expert group of the European association of urology young academic Urologists Working Party. *J Pediatr Urol* 2016;12:229. e1–229.e7.
30 Cundy TP, Harling L, Hughes-Hallett A, *et al*. Meta-Analysis of robot-assisted vs conventional laparoscopic and open pyeloplasty in children. *BJU Int* 2014;114:582–94.
31 Meehan JJ, Sandler A. Pediatric robotic surgery: a single-institutional review of the first 100 consecutive cases. *Surg Endosc* 2008;22:177–82.
32 Mattioli G, Pio L, Leonelli L, *et al*. A provisional experience with robot-assisted Soave procedure for older children with Hirschsprung disease: back to the future? *J Laparoendosc Adv Surg Tech A* 2017;27:546–9.
33 Pini Prato A, Arnoldi R, Dusio MP, *et al*. Totally robotic Soave pull-through procedure for Hirschsprung's disease: lessons learned from 11 consecutive pediatric patients. *Pediatr Surg Int* 2020;36:209–18.
34 Hebra A, Smith VA, Lesher AP. Robotic Swenson pull-through for Hirschsprung's disease in infants. *Am Surg* 2011;77:937–41.
35 Pini Prato A, Arnoldi R, Faticato MG, *et al*. Minimally invasive Redo Pull-Throughs in Hirschsprung disease. *J Laparoendosc Adv Surg Tech A* 2020;30:1023–8.
36 Delgado-Miguel C, Camps JI. Robotic Soave pull-through procedure for Hirschsprung's disease in children under 12-months: long-term outcomes. *Pediatr Surg Int* 2022;38:51–7.
37 Quynh TA, Hien PD, Du LQ, *et al*. The follow-up of the robotic-assisted Soave procedure for Hirschsprung's disease in children. *J Robot Surg* 2022;16:301–5.
38 Chang X, Cao G, Pu J, *et al*. Robot-Assisted anorectal pull-through for anorectal malformations with rectourethral and rectovesical fistula: feasibility and short-term outcome. *Surg Endosc* 2022;36:1910–5.
39 Phillips MR, Linden AF, Vinocur CD, *et al*. Robot-Assisted repair of a urogenital sinus with an anorectal malformation in a patient with McKusick-Kaufman syndrome. *J Pediatr Urol* 2019;15:481–3.
40 Woo R, Le D, Albanese CT, *et al*. Robot-Assisted laparoscopic resection of a type I choledochal cyst in a child. *J Laparoendosc Adv Surg Tech A* 2006;16:179–83.
41 Kim NY, Chang EY, Hong YJ, *et al*. Retrospective assessment of the validity of robotic surgery in comparison to open surgery for pediatric choledochal cyst. *Yonsei Med J* 2015;56:737–43.
42 Wang X-Q, Xu S-J, Wang Z, *et al*. Robotic-Assisted surgery for pediatric choledochal cyst: case report and literature review. *World J Clin Cases* 2018;6:143–9.
43 Xie X, Wu Y, Li K, *et al*. Preliminary experiences with robot-assisted choledochal cyst excision using the dA Vinci surgical system in children below the age of one. *Front Pediatr* 2021;9:741098.
44 Chang EY, Hong YJ, Chang HK, *et al*. Lessons and tips from the experience of pediatric robotic choledochal cyst resection. *J Laparoendosc Adv Surg Tech A* 2012;22:609–14.
45 Xie X, Li K, Wang J, *et al*. Comparison of pediatric choledochal cyst excisions with open procedures, laparoscopic procedures and robot-assisted procedures: a retrospective study. *Surg Endosc* 2020;34:3223–31.
46 Yoon JH, Hwang HK, Lee WJ, *et al*. Minimally invasive surgery for choledochal cysts: laparoscopic versus robotic approaches. *Ann Hepatobiliary Pancreat Surg* 2021;25:71–7.
47 Bodner J, Wykypiel H, Wetscher G, *et al*. First experiences with the dA Vinci operating robot in thoracic surgery. *Eur J Cardiothorac Surg* 2004;25:844–51.
48 Mattioli G, Pini Prato A, Razore B, *et al*. Da Vinci robotic surgery in a pediatric hospital. *J Laparoendosc Adv Surg Tech A* 2017;27:539–45.
49 Ballouhey Q, Villemagne T, Cros J, *et al*. Assessment of paediatric thoracic robotic surgery. *Interact Cardiovasc Thorac Surg* 2015;20:300–3.
50 Onan B, Aydin U, Kadirogullari E, *et al*. Totally endoscopic robotic-assisted cardiac surgery in children. *Artif Organs* 2019;43:342–9.
51 Gao C, Yang M, Wang G, *et al*. Totally robotic resection of myxoma and atrial septal defect repair. *Interact Cardiovasc Thorac Surg* 2008;7:947–50.
52 Xiao C, Gao C, Yang M, *et al*. Totally robotic atrial septal defect closure: 7-year single-institution experience and follow-up. *Interact Cardiovasc Thorac Surg* 2014;19:933–7.
53 Cundy TP, Marcus HJ, Clark J, *et al*. Robot-Assisted minimally invasive surgery for pediatric solid tumors: a systematic review of feasibility and current status. *Eur J Pediatr Surg* 2014;24:127–35.
54 Blanc T, Pio L, Clermidi P, *et al*. Robotic-Assisted laparoscopic management of renal tumors in children: preliminary results. *Pediatr Blood Cancer* 2019;66 Suppl 3:e27867.
55 Blanc T, Meignan P, Vinit N, *et al*. Robotic surgery in pediatric oncology: lessons learned from the first 100 Tumors-A nationwide experience. *Ann Surg Oncol* 2022;29:1315–26.
56 Vatta F, Gazzaneo M, Bertozzi M, *et al*. Robotics-Assisted pediatric oncology Surgery—A preliminary single-center report and a systematic review of published studies. *Front Pediatr* 2021;9:780830.