Chapter

Robotic-Assisted Minimally Invasive Surgery in Children

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Abstract

Currently, minimally invasive surgery (MIS) includes conventional laparo-thoracoscopic surgery and robot-assisted surgery (RAS) or robotic surgery. Robotic surgery is performed with robotic devices, for example the Da Vinci system from Intuitive Surgical, which has a miniaturized camera capable of image magnification, a three-dimensional image of the surgical field, and the instruments are articulated with 7 degrees of freedom of movement, and the surgeon operates in a sitting position at a surgical console near the patient. Robotic surgery has gained an enormous surge in use on adults, but it has been slowly accepted for children, although it offers important advantages in complex surgeries. The areas of application of robotic surgery in the pediatric population include urological, general surgery, thoracic, oncological, and otorhinolaryngology, the largest application has been in urological surgery. There is evidence that robotic surgery in children is safe and it is important to offer its benefits. Intraoperative complications are rare, and the frequency of postoperative complications ranges from 0–15%. Recommendations for the implementation of a pediatric robotic surgery program are included. The future will be fascinating with upcoming advancements in robotic surgical systems, the use of artificial intelligence, and digital surgery.

Keywords: robot-assisted surgery, minimally invasive surgery, laparoscopy, thoracoscopy, urological, gastrointestinal, hepatobiliary, thoracic, oncological, digital surgery, children

1. Introduction

Pediatric robotic surgery offers unique challenges within this rapidly advancing field. There has been a slow rate of uptake within most pediatric surgical centers around the world due to both finance, and difficulties associated with equipment primarily designed for adults. The ergonomics required for the da Vinci® master–slave-type platform currently challenge the small working space in very small children.

Currently, there are three options for surgical treatment for a wide variety of pathologies in the pediatric population, open surgery (traditional) and MIS, which include: conventional laparo-thoracoscopic surgery and RAS.

Minimally invasive techniques are applicable in more than 60% of abdominal and thoracic operations in children, and according to evidence-based data and ethical principles can be used properly [1].

In 1994, the first robotic system used in the urological practice known as AESOP was introduced. Later, the evolution of these devices would bring the Zeus system and finally the Da Vinci system while continuously increasing their precision and effectiveness [2].

Since these initial reports, robotic surgery has seen widespread application within the adult population, especially in urologic and gynecologic procedures. As is often the case for new devices, technology, and therapeutic options in surgery, the application of robotic surgery for children has occurred more slowly than in adults. This caution is due in part to technical limitations with developing appropriately sized instruments for the pediatric patient; however, in recent years broader implementation has been seen [3–6].

In April 2001, Meininger et al. [7] published the first cases of RAS in children. The first of these two Nissen fundoplication procedures was reported as occurring in July 2000 [7–10]. Shortly afterward, the first robotic urological procedure in a child was undertaken in March 2002 by Peters et al. (personal communication, July 2002) who performed a pyeloplasty using the da Vinci® [11, 12]. Since then to date, more than 70 different surgical techniques have been published [13, 14].

Currently, the only robotic system that is approved for pediatric use is the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA) [7]. The da Vinci robot is well suited for children of all ages, including infants and newborns, using careful preoperative planning, this allows the da Vinci to be used for numerous procedures in small children [14, 15].

The evolution of conventional laparoscopic surgery highlights the transitory stages that follow adoption and diffusion of surgical innovation [16–18]. RAS was introduced to the specialty of pediatric surgery following initial case reports in the early 21st century. Subsequently, this promising surgical technology has undergone a formative 10-year period of introduction, development, early dispersion, exploration and preliminary assessment [13].

Cundy et al. [13], performed a 2013 systematic literature search for all reported cases of RAS in children during an 11-year period. During this time, 2,393 procedures in 1,840 patients were reported and the most prevalent gastrointestinal, genitourinary, and thoracic procedures were fundoplication, pyeloplasty, and lobectomy, respectively.

Due to the limitations of conventional laparoscopic surgery in pediatric patients, expert pediatric surgeons should only perform the more complex or reconstructive laparoscopic techniques [19].

There have been few reports that have been published about robotic general pediatric surgery [20–29]. Thus, far, the largest number of procedures and publications have been produced about robotic urological pediatric surgery [11–13, 30–45]. Trends in the literature indicate that pediatric RAS is continuing to be globally utilized [11, 13, 30–35, 43–46].

The safety of RAS in children is reported to be similar to open procedures, and the outcomes are at least equivalent to conventional laparoscopy [47]. Robotic surgery on smaller children and infants require special considerations when discussing robotic surgery [48].

Numerous case reports, case series, and comparative studies have unequivocally demonstrated that robotic surgery in children is safe [13].

In systematic investigations of databases of pediatric RAS, the global surgical conversion rate was 4.7% [22], and a net overall surgical conversion rate of 2.5% was reported [13]. In published studies of pediatric RAS, transoperative complications are infrequent, and in the postoperative period, the frequency varies from 0 to 15% [22, 49–51].

2. Characteristics, advantages, benefits, limitations and applications of robotic surgery

2.1 Characteristics

In RAS robotic devices are used, such as the Da Vinci system from Intuitive Surgical, which has a miniaturized camera and the surgeon operates seated at a console close to the patient (telesurgery), with three-dimensional and magnified images of the operative field, and manipulates articulated instruments controlled by their hands and feet; It is supported by a second surgeon positioned next to the patient at the exposure of the operative field, with retraction, suction and exchange of instruments in the arms of the robot. There is greater precision than in open surgery and conventional laparo-thoracoscopic surgery [52].

2.2 Advantages

RAS enables more refined hand-eye coordination, superior suturing skills, better dexterity, and precise dissection. It is achieved by the characteristics of robotic surgical platforms that include motion scaling, greater optical magnification, 3D, and stereoscopic vision, increased articulated instrument tip dexterity, tremor filtration, operator-controlled camera movement, and elimination of the fulcrum effect [13], all of this translates into greater safety for patients and advantages for the surgeon.

Robotic instruments were specifically designed to mimic human wrist movements, allow 7 degrees of freedom of movement, and can be particularly advantageous for newborns, infants, and young children, as well as, certain hard-to-reach anatomical areas [29, 46]. By operating seated at the console, surgical fatigue and tremors are reduced [53].

2.3 Benefits

Robotic enhancements offer improvements in the technical capacity of human performance for surgery within spatially restricted workspaces in children [13]. Less time is required to acquire the right skills and confidence with RAS, "The learning curve is shorter" [46, 54–56]. Robotic assistance will allow more pediatric surgeons to perform a greater volume of minimally invasive procedures [57].

It also has a real benefit for the pediatric patient in terms of: minimizing operative trauma, minimal scarring, less postoperative pain, less need for opioids, less bleeding and transfusions, fewer complications, less risk of infection, shorter hospitalization, and quick return to daily activities, this also benefits parents [46, 47, 58].

2.4 Limitations

There are limitations in RAS, this includes, access to the patient by the anesthesiologist is limited after the robot is docked, changes to patient position or access to the patient requires detachment of the robot, and patients must remain entirely paralyzed when the robot is docked [59].

In addition, RAS frequently requires Trendelenburg or reverse Trendelenburg steeper positioning, which has hemodynamic consequences. This situation can typically be mitigated by adequate volume expansion [60].

Infants are typically more susceptible to the respiratory effects of pneumoperitoneum than older children or adults, abdominal insufflation decreases respiratory compliance and increases airway pressures, and the instilled CO_2 can cause hypercapnia and acidosis [61].

The primary disadvantage of robotic surgical technology in pediatric surgery is related to the size of the surgical robot and its associated instruments [4, 5, 46], the robotic instruments are only available in 2 sizes, 8 mm and 5 mm. Similarly, robotic endoscopes (lens) are currently only available as 12.0 mm and 8.5 mm.

The cost analysis for the use of the robot is not strictly measured by numerical cost in dollars, but should be considered as value equating to quality (as defined by positive outcomes/cost). Naturally, there is the initial cost of purchasing and maintaining the robot itself, as well as the increased costs from the disposable robotic equipment and the longer operative times [4]. It should be noted other factors associated with the robotic portion of a procedure, such as increased operating room or anesthesia time, staff training, and cost of marketing campaigns [62].

In contrast, patient and parent satisfaction, as well as emotional and professional benefits, should also be considered when evaluating cost/satisfaction of this type of investment [63]. One study found that it takes at least 3 to 5 cases per week in a program to demonstrate a net gain from robotic surgery [64].

Other cost analyses suggest that robotic surgeries are more expensive than those associated with laparoscopic or open surgery [65, 66]. However, RAS is associated with a 2% decrease in anastomotic leaks [67, 68]. This reduces hospitalization and costs of managing the resulting surgical morbidity, and benefits the earlier return of the patient to the workforce [66]. In addition, by preferably performing difficult and complex cases in which robotic surgery adds value to patient care; it should be a solution with the best profitability in hospitals that have a robotic system. In some countries such as in Latin America, costs represent a great inconvenience for the advancement of robotic surgery in children, especially in private hospitals.

A short hospital stay, prudent use of instruments, reduced operating room times, and competent robotic equipment reduce costs [69]. Therefore, future comparative analyses of outcomes in children should include financial factors such as loss of human capital, parents [70].

2.5 Applications

Robotic surgery has been used in almost all pediatric surgical subspecialties, including urology, general surgery (gastrointestinal-hepatopancreatobiliary), thoracic, oncology, and otorhinolaryngology. Among pediatric disciplines, robotic surgery is used most frequently in urology.

The best indications for robotic surgery are procedures that require a small surgical field, fine and precise dissection, and secure intracorporeal sutures [71]. The RAS have special application in complex and reconstructive surgery, for these procedures, from the open technique; surgeons often jump to RAS [14]. RAS in otorhinolaryngology with the application of the transoral approach is particularly useful in masses of the tongue base [72]. Furthermore, RAS has performed a wide spectrum of surgical procedures in children [13].

3. Urologic robotic surgery

To date, the application of MIS in pediatric urology has evolved over more than 30 years [73]. Urology has the highest acceptance of robotic surgery within pediatrics. The first use of robotics in children was a pyeloplasty for ureteropelvic junction (UPJ) obstruction, because the ureteropelvic anastomosis was a technical challenge using conventional laparoscopic surgery [11, 12].

In a systematic bibliographic search that was carried out of all the published cases of pediatric robot-assisted urological surgery between 2003 and 2016. A total of 151 publications that reported 3688 procedures in 3372 patients were identified. The most reported procedures were pyeloplasty (1923), ureteral reimplantation (1120), heminephrectomy (136), and nephrectomy or nephroureterectomy (117). There were 16 countries and 48 institutions represented in this literature [6].

We will approach the surgical urological pathology of the child based on the anatomy of the urinary tract as follows, i. Upper urinary tract, ii. Lower urinary tract and iii. Miscellaneous procedures.

3.1 RAS on the upper urinary tract

3.1.1 Nephrectomy

In pediatric patients, complete or partial nephrectomies are indicated more frequently for benign diseases and less frequently for malignant diseases. Indications for RAS nephrectomy for benign diseases are multicystic dysplastic kidney disease, kidney exclusion due to various pathologies, such as UPJ obstruction, reflux nephropathy, among others, indications of malignant tumors, particularly Wilms tumor are increasing legitimizing itself through corresponding treatment protocols, and surgery performed while adhering strictly to oncological surgical rules [74].

In nephrectomy, the initial step is the dissection and exposure of the renal pedicle, its ligation and cutting. The next step, the kidney is completely freed from its surrounding tissue. Subsequently, the dissection of the ureter is performed, in the case of radical nephroureterectomy it should be performed up to the bladder. The kidney is extracted through the umbilical access, in case of nephrectomy due to tumor, the use of a collection bag is mandatory, and it is removed through a Pfannenstiel incision, and finally lymph node sampling is crucial for surgical staging and guiding subsequent treatment.

3.1.2 Partial nephrectomy

Ureteral duplication is the most common congenital abnormality of the urinary tract. Partial nephrectomy for benign indication is performed for the resection of a deficient or non-functional fraction of a duplex system and can cause or be associated with obstruction and hydronephrosis, dysplasia, megaureter, ureterocele, and vesicoureteral reflux. Heminephroureterectomy is performed in cases with a reflux system [73]. It is recommended before surgery, to place a stent in the ureter to be preserved (for easy identification during dissection). If the ureter of the remaining fraction is to be reimplanted or if an ectopic ureter is to be followed in the deep pelvis, the robot is repositioned between the patient's legs and redocked [75].

3.1.3 Pyeloplasty

Robot-assisted pyeloplasty is the most common procedure performed robotically in pediatric patients, both within urology and overall [76]. The excellent experience with robot-assisted pyeloplasty has challenged other approaches as a new standard for the treatment of UPJ obstruction.

Dismembered pyeloplasty (Anderson-Hynes) includes resection of the UPJ and reduction of the renal pelvis. In the technique, the ureter is incised and spatulated laterally to provide sufficient ureteral wall length to achieve a wide side-to-side anastomosis. Once the anterior layer of the pelvic-ureteral anastomosis has been sutured, an antegrade transanastomotic double-J stent is passed. J-Vac transabdominal drainage was used in the surgical bed.

Patients undergoing robotic pyeloplasty have a shorter hospital stay, and less need for analgesics; however, there is no difference in the success rate of robotic pyeloplasty in comparison to the other two approaches [77–79].

In robotic pyeloplasty the learning curve is much shorter. This allows some surgeons to transition from the open pyeloplasty to the robotic approach without any prior laparoscopic experience with this technique [80].

Pyeloplasty in infants less than 10 kg has been performed successfully. A multi-institutional study of 60 infants less than 12 months old with a 91% success rate and an 11% complication rate, which is similar to other studies on larger children and adults [81]. The foregoing supports the personal experience of the author.

Also, the retroperitoneal robotic approach is indicated mainly for patients with previous abdominal surgery, when adhesion syndrome is suspected, and it has been validated for pyeloplasty and other techniques in this anatomical area [82].

3.1.4 Ureteroureterostomy

The procedures performed included pyeloureterostomy for incomplete duplication and lower pole UPJ obstruction and ipsilateral ureteroureterostomy along with distal ureterectomy for obstruction in a dysplastic upper pole with ureteral, ectopia, for the treatment of duplex anomalies and reconstruction of obstructed dilated ureteral segments [83]. This can also be applied to the lower ureter in duplex systems where it helps to avoid reimplantation of disparate ureters in the same tunnel. Also, transperitoneal robotic ureteroureterostomies have been reported for mid ureteric strictures and also for the correction of retrocaval ureters [84, 85]. Also with robotic assistance, the removal of a large ureteric stone at any level with the placement and closure of a stent is a relatively simple affair, using the Mikulicz procedure to close the ureterotomy or a spatulate anastomosis.

3.1.5 Ureterocalicostomy

Ureterocalicostomy is a potential, and technically feasible option in patients with UPJ obstruction and significant lower pole caliectasis which is often reserved for patients with a failed pyeloplasty and a minimal pelvis, or patients with an exaggerated intrarenal pelvis [86]. An ureterocalicostomy is a procedure in which the ureter is sutured to the lowermost calyx of the kidney. It is a salvage operation, which should be in the arsenal of every surgeon operating the UPJ [87]. The robotic approach is a good option.

3.2 RAS on the lower urinary tract

3.2.1 Extravesical ureteral reimplantation

The most performed procedure in the lower urinary tract in children is the antireflux ureteral reimplantation [13]. Indications for the surgical treatment of pediatric vesicoureteral reflux include severe urinary tract infections while taking continuous antibiotics prophylaxis, renal scarring, and worsening or non-resolution vesicoureteral reflux. Robotic ureteral reimplantation can be done by an extravesical or intravesical approach and, of these approaches, the extravesical is much more widely reported [88, 89]. The extravesical procedure is a ureteral reimplantation according to the well-established technique of Lich-Gregoir, for achieving an antireflux mechanism. This technique is an accepted alternative to endoscopic treatment and open reimplantation techniques in pediatric patients [73]. However, open surgery remains the gold standard for ureteral reimplantation [90].

The long-term results of the antireflux procedure are evaluated in terms of preservation of differential renal function, absence of urinary tract infections, and adequate urinary drainage, with a follow-up of more than one year [91]. In a prospective study of children undergoing robot extravesical ureteral reimplantation at eight academic centers from 2015 to 2017, 143 patients (199 ureters). The majority of ureters (73.4%) had grade III or higher vesicoureteral reflux preoperatively. Radiographic resolution was present in 93.8% of ureters. Robotic ureteral reimplantation should be considered as one of several viable options for management of vesicoureteral reflux in children [92].

3.2.2 Appendico-vesicostomy and continent catheterizable channels

3.2.2.1 Appendicovesicostomy (Mitrofanoff)

Complete bladder emptying in children with bladder emptying dysfunction (neuropathic bladder) is achieved with clean intermittent catheterization (CIC). In 1980, Mitrofanoff described his technique of a continent appendicovesicostomy for patients when transurethral CIC cannot be carried out for any reason. When medical therapy fails in the neuropathic bladder, the surgery aims to preserve upper tract function and social continence. A cystostomy with a continent opening easy to catheterize and associated with a closure of the vesical neck, was the objective. The tip of the appendix opened into the bladder at the end of an antireflux submucosal tunnel and the other end hemmed to the skin. The bladder neck is usually closed in the same operation. The continence of the vesicostomy is total and the comfort obtained is excellent [93].

The surgical technique is analogous to the Lich-Gregoir technique, to create an antireflux mechanism. The appendicocutaneostomy can be placed in the umbilicus or in the right lower abdominal quadrant [73]. Robotic continence procedures have been shown to be a safe and effective alternative [94]. An important point is to assess whether a simultaneous bladder augmentation is performed [95].

In patients with neurogenic bowel and bladder secondary to spinal dysraphism who tend to have multiple limb spasms and spinal scoliosis, RAS is a good option [96]. Complex lower urinary tract reconstruction defined as reconstruction of the bladder neck or catheterizable continent ducts, or both, as well as the creation of an antegrade Malone continence enema, for better management of constipation [97].

3.2.3 Augmentation cystoplasty

Augmentation cystoplasty often performed in the context of other reconstructive procedures such as appendicovesicostomy or bladder neck reconstruction. The procedure of bladder augmentation can be performed using a mega-ureter when nephrectomy is anticipated. At present day, the ileocystoplasty represents the currently accepted standard of care [73]. In robotic technique, a 20 cm segment of ileum is selected and isolated. Intestinal continuity is restored, and in the post-operative, the bladder is drained with a suprapubic tube, a urethral catheter and another catheter through the Mitrofanoff channel [98]. Another tissue option for bladder augmentation is the sigmoid colon, this technique significantly improved urodynamic parameters, such as bladder accommodation and filling pressure in children with myelomeningocele-associated neurogenic bladder [99].

3.3 Pediatric urology miscellaneous procedures

The miscellaneous pediatric urology procedures are some surgeries in the pelvic area, a narrow field that is ideal for the robotic approach. There are reports from

RAS of; symptomatic bladder diverticulum excision [36], symptomatic or malignant urachal cyst excision [100], posterior urethral diverticula excision, mainly after surgical reconstruction of imperforate anus [101], prostatic utricle removal, is a malformation due to incomplete regression of Müllerian ducts [102], and varicocele cure, a condition that has a significant association with infertility [103].

4. General surgery (gastrointestinal and hepatopancreatobiliary)

RAS in general surgery, and thoracic surgery have not yet reached the magnitude that it has in pediatric urology. Robotic procedures that have been reported include, fundoplication, cholecystectomy, choledochal cysts resection, hepatectomy, colectomies, proctectomy with ileal pouch-anorectal anastomosis [104]. Other techniques are, Thal fundoplication and salpingo-oophorectomy [8], Soave pull-through procedure for Hirschsprung's disease [105]. Others that are less common, RAS for the treatment of duodenal obstruction, such as the Ladd cure in intestinal malrotation, the duodenojejunostomy for superior mesenteric artery syndrome [106], the repair of congenital duodenal atresia [107], and gastroduodenal obstruction due to trichobezoar [14].

Hepatopancreatobiliary RAS in children inevitably involves high complexity, such as Kasai portoenterostomies and choledochal cyst resection [108–109]. Furthermore, liver resection, robot-assisted generally indicated for treatment of tumors [110].

4.1 Fundoplication

Fundoplication is the most widely performed and reported robotic-assisted surgery in pediatric general and thoracic surgery [3].

When comparing conventional laparoscopic primary fundoplication and RAS in children, there were no differences between the two groups in terms of operative time, length of hospital stay, conversions, and complications. The conclusion is that RAS is a safe alternative to conventional laparoscopic surgery [111]. Regarding the advantages of RAS, a systematic review of primary fundoplication showed that postoperative complications are reduced in the robotic group. Because in the RAS there is greater dexterity and precision in the subphrenic space, than with laparoscopy [112]. In addition, RAS plays an important role in difficult cases, such as obese patients, large hiatal hernias, and redo fundoplication [113, 114]. On the other hand, with conventional laparoscopy, only skilled pediatric surgeons resolve difficult cases [114].

4.2 Choledochal cyst resection

Choledochal cyst resection and reconstructive Roux-en-Y hepaticojejunostomy are technically complex and, only in Southeast Asian centers there is extensive experience in the laparoscopic technique. In the rest of the pediatric centers of the world, most of this surgeries are performed with the open technique [115].

In 2006, the first pediatric RAS choledochal cyst resection was reported [116]. Since that time and up to 2019, several authors have reported cohorts of 1 to 39 pediatric patients undergoing RAS choledochal cyst resection [109]. A recent publication informed 70 cases with RAS and 70 cases by conventional laparoscopy, and concluded that RAS choledochal cyst excision and hepaticojejunostomy were associated with better short-term intraoperative and postoperative outcomes, and proved the safety and feasibility of RAS in children with choledochal cysts [117].

The ideal treatment for children with choledochal cyst, nowadays, is MIS, laparoscopic, through expert pediatric surgeons or RAS, in institutions where technology is available. But, if one or another situation is not present, the author recommends continuing with the open approach to offer children the greatest safety and effectiveness [109].

4.3 Kasai procedure

The Kasai procedure can be ideal for RAS because it is a complex technique, it has an ideal instrumentation to dissect the hepatic portal and find the portal plate [118]. To date, there are very few reported cases of Kasai operation for RAS for biliary atresia. The experience is larger with conventional laparoscopy, especially in Southeast Asian countries, where the pathology is more frequent than in other latitudes of the world [115].

4.4 Pancreatic pathology

There are very few publications of pancreatic pathology in children treated with RAS, we find only case reports about: tumor enucleation, distal pancreatectomy, subtotal pancreatectomy, and pancreaticoduodenectomy. The traditional open surgeries have been largely replaced by MIS, including laparoscopic surgery and RAS.

RAS distal spleen-sparing pancreatectomy is safe and feasible in pediatric patients with insulinoma [119]. Also, robotic enucleation is indicated in small neuroendocrine tumors of the pancreas. This technique provides the dual benefits of minimal invasiveness and good preservation of the pancreatic parenchyma. The experience has demonstrated the feasibility and safety of the RAS enucleation, with an excellent curative effect for pediatric insulinoma [120, 121].

4.5 Soave pull-through

Hirschsprung's disease (HSCR) has also been shown to benefit from robotic surgery, the outcome of totally robotic soave pull-through for HSCR is promising. This technique is particularly suitable for older HSCR patients, even those requiring a redo surgery, and represents a valid alternative for HSCR patients. In cases of total colonic aganglionosis, for the hepatic angle or only recto sigmoid, RAS has been used and its versatility has been confirmed. The published results are promising, continence scored from excellent to good in all patients who could be evaluated in this regard [105]. In the first series of infants less than 6 kg who underwent the Swenson RAS, morbidity did not increase [122].

4.6 Treatment of duodenal obstruction

Superior mesenteric artery syndrome is a rare condition that results from intermittent functional obstruction of the third part of the duodenum. The diagnostic criteria are clinical, radiological and endoscopic. The classic approach has been open surgery [123]. There are case reports of robotic Roux-en-Y duodenojejunostomy as a surgical option for the treatment of this condition [106, 124].

Robotic repair of congenital duodenal atresia may help overcome the obstacles presented by the use of traditional rigid laparoscopic instruments, due to the difficulty in constructing a precise duodenal anastomosis, with robotic surgery the procedure is relatively straightforward [107]. About gastroduodenal obstruction due to trichobezoar in children and laparoscopy, we found several reports. We operated with RAS on a 12-year-old girl weighing 23 kg with pica and psychological disorder, with success and without postoperative morbidity [14].

4.7 Various procedures in general surgery

4.7.1 Cholecystectomy

Elective robot-assisted cholecystectomy *is* relatively prevalent in the literature [13]. Multiport robotic cholecystectomy and single-site robotic cholecystectomy are the approach options. Robotic cholecystectomy is safe and effective and serves as an excellent introductory procedure for pediatric surgeons considering the development of a pediatric robotic surgery program, useful for training [125].

4.7.2 Splenectomy

Splenectomy remains the mainstay of treatment for the sequelae of pediatric hereditary hematologic disorders. These conditions can lead to splenomegaly, medically refractory cytopenias, and dependence on transfusions. Laparoscopic splenectomy is the standard of surgical care. Robot-assisted splenectomy is an option and is associated with a shorter length of hospital stay compared to laparoscopic splenectomy [126].

4.7.3 Gynecological surgery

There are case reports and series documenting a variety of robotic gynecological surgeries in children with favorable results. Procedures consisted of ovarian cystectomies, oophorectomies for ovarian masses, and salpingo-oophorectomy for gonadal dysgenesis [127]. In addition, robotic resection of mature cystic teratoma and mucinous ovarian tumor. It is an easy and safe technique in selected patients and also for the treatment of complex gynecological diseases [128]. Surgeries in the pelvis have a reduced field of work and are ideal for the robotic approach.

4.7.4 Heller's cardiomyotomy for achalasia

Achalasia is rare in children. Surgical options include open, laparoscopic, and robotic approaches, and Heller's myotomy remains the treatment of choice. Concomitant partial posterior fundoplication is suggested for all patients. Heller's robotic myotomy for esophageal achalasia in children has been shown to be safe and effective. Both laparoscopic and robotic esophageal myotomy are comparable in their results. However, robotic surgery is superior in terms of avoiding mucosal perforation, this complication occurred in 16% of patients in the laparoscopic group [129–131].

4.7.5 Management for anorectal malformations

Anorectal pull-through for anorectal malformations, with the robotic technology assists the pediatric surgeon by increasing dexterity and precision of movement. This is important in anorectal malformations surgery, where the dissection of the fistula and the pull-through of the rectum into the muscular complex are crucial to achieve continence in future. RAS permits easier closure of the fistula, improves reconstruction technique, and minimizes trauma to important surrounding structures, providing better visualization of the muscular complex. Robotic anorectal pull-through makes use of fundamental concepts learned from decades of high-anorectal malformation open repair, and combines them with modern advances in surgical instrumentation and techniques [132].

5. Thoracic robotic surgery

The global experience in thoracoscopic surgery in children is more than 30 years compared to robot-assisted thoracic surgery (RATS). The learning curve of thoracoscopy is longer compared to RAS. Thoracic MIS reduces the risk of thoracic and spinal deformities after lung resection in children. Lobectomy is one of the robotic techniques most frequently performed in children [133].

Early publications on RATS in children reported having performed cardiovascular techniques such as patent ductus arteriosus (PDA) closure and vascular ring section [134, 135]. Le Bret, et al. [134] in 2000, 56 children operated on for PDA surgical closure, 28 cases with thoracoscopy and 28 cases with robotic approach. They used the ZEUS robotic surgical system (Computer Motion, Inc., Goleta, CA. USA). Their results were comparable in both approaches.

Cundy et al. [13], in a systematic search in the literature of reported cases of robotic surgery in children of 2393 procedures, thoracic procedures accounted for 3.2% (77 surgeries and 12 different techniques), and the conversion rate was 10% in thoracic procedures. In this report, the five most frequent RATS procedures are: lobectomy (18), thymectomy (14), benign mass excision (9), diaphragmatic plasty (8), and malignant tumor resection (5).

There are three series reported with a greater number of cases, each with 11 RATS in children (total 33), in order of frequency the procedures include: tumor masses resection (8), lobectomy (7), diaphragmatic plication (4), diaphragmatic plasty (3), esophageal atresia correction (3), bronchogenic cysts resection (3) and unique procedures of segmentectomy, esophageal duplication resection, pleural and lung biopsies, gastric tube/esophagoplasty and Heller myotomy. Overall, there were 6 (18%) conversions to open surgery in neonatal patients and (3) 9% postoperative complications. The neonatal thorax represents the greatest obstacle in the adaptation of the 5 or 8 mm robotic platform instruments [20, 133, 136]. In RATS, children weighing more than 4 kg are more easily treated [15].

5.1 Pulmonary lobectomy

The most common RATS in children is lobectomy. The first publication on robotic lobectomy, including pediatric cases, was by Park et al. [137], in 2006. Series with few cases of segmental lung resections and lobectomies have been published with excellent results with conversions mainly on the first attempt [14, 15, 133, 136]. Addressing the disadvantages of RATS lobectomy, a prolonged total operative time was reported, but without having a negative effect, since it did not increase the postoperative morbidity and mortality of patients [138].

5.2 Congenital diaphragmatic hernia repair

Congenital diaphragm abnormalities, including eventration and Morgagni and Bochdalek diaphragmatic hernias, have been successfully repaired through the use of conventional MIS. However, some reports have shown a high recurrence rate for some defects. Robotic surgery is the alternative to close diaphragmatic hernias more efficiently [139].

Some authors prefer the thoracic approach to repair Bochdalek's diaphragmatic hernia, but infants weighing less than 2.5 kg are better treated with the abdominal approach. The author performed one case of Morgagni's diaphragmatic hernia and another case of Bochdalek's diaphragmatic hernia via the abdominal route. Robotic assistance allows the surgeon to more easily reach this area to suture diaphragmatic defects [139].

Acquired anomalies, such as diaphragmatic paralysis, can also be resolved with RATS [14, 139].

5.3 Thymectomy

Radical thymectomy is the comprehensive treatment of myasthenia gravis. The feasibility and effectiveness of robotic thymectomy is evident in this cohort study [140]. In addition, performing the "early thymectomy" (performed within a year of diagnosis) resulted in higher remission rates compared to "late thymectomy" [141], including minimizing the adverse effects of immunosuppression in pediatric patients [142].

In recent studies including 49 children, thoracoscopic thymectomy was also safe for children with juvenile myasthenia gravis (JMG) [143, 144]. Two other studies with 9 and 18 children, reported the same results [145, 146]. Robotic thymectomy is a safe procedure, complications were low, and without mortality. Thymectomy should be offered as a part of multimodal therapy for treating children and adolescents with acetylcholine receptor antibody-Positive JMG [146].

5.4 Other robotic thoracic procedures

There are RATS publications of other specific procedures, such as tracheopexy for the treatment of severe tracheomalacia [147], and reports of pediatric cases of resection of a bronchogenic cyst [148, 149].

6. Oncologic robotic surgery

Presently, the use of MIS in patients with cancer is progressing. However, the role of MIS in children with solid neoplasms is less clear than it is in adults. Although the use of diagnostic MIS to obtain biopsy specimens for pathology is accepted in pediatric surgical oncology, there is limited evidence to support the use of MIS for the resection of malignancies (solid tumors) in the thorax and abdomen in children [150].

Open surgery remains the main technique for the resection of solid tumors in children. RAS offers technical and ergonomic advantages that can make MIS more achievable in this environment, allowing benefits for both the patient and the surgeon. Reduced postoperative recovery time and faster initiation of adjuvant therapy are the most important benefits for the patient [104].

A systematic search of multiple electronic databases, of 23 publications, reported 40 cancer cases in total. The indications for surgery were more than 20 different pathologies. One third of the tumors were malignant. Most of the procedures involved abdominal or retroperitoneal tumors in adolescent patients. Oncological adverse events were two isolated events, one tumor spillage and one residual disease. The evidence is limited to case reports and small case series only. Pediatric cancer surgery is an area of opportunity for robotic surgery. Its technical challenges create the opportunity to develop robotic approaches that meet the challenges of complex cancer procedures [151].

6.1 Thoracic tumors

As an anecdote, the robot appears to be well adapted to complex mediastinal dissection and has been used in excision of left ventricular myxoma [152], and in excision of complex massive leiomyoma of the esophagus [153]. The robot offered excellent visualization and ease of resection. The other case of complex massive retrocardiac esophageal leiomyoma was successfully removed using RAS. In the latter case, intraoperative esophagoscopy and transillumination were useful adjuncts to identify the esophagus and develop a safe extramucosal dissection plane.

There is a publication with five pediatric patients with a mean age of 9.8 years and weight of 41.5 kg, who underwent robotic resection of a mediastinal thoracic mass, including a ganglioneuroma, ganglioneuroblastoma, teratoma, germ cell tumor, and a large inflammatory mass of unclear etiology. The application of RATS in malignant solid tumors in children in selected cases is an option, but oncological surgical principles should be applied [154].

6.2 Abdominal tumors

There are mostly individual case reports for robot-assisted abdominal oncological surgery in children.

Neuroblastoma is the most common extracranial solid tumor in children and the most common malignancy in infants. Complete resection is curative in low-stage disease. Robotic surgery can skeletonize abdominal blood vessels in the tumor and cut the tumor into pieces, including stage IV retroperitoneal neuroblastoma [155, 156].

Juvenile cystic adenomyoma is the focal presence of ectopic endometrial glands and stroma within the uterine myometrium. Another case, a 15-year-old adolescent girl underwent RAS of a 4 cm cyst, and the uterus was closed in four layers, the postoperative period was uneventful [157].

Management of rhabdomyosarcoma. A 22-month-old, 8-kg boy with an embryo-rhabdomyosarcoma in the urinary bladder and prostate, the treatment was a robot-assisted radical cystoprostatectomy, and the postoperative course was uneventful [158]. Another application of RAS is in the dissection of retroperitoneal lymph nodes in selected pediatric and adolescent patients with paratesticular rhabdomyosarcoma or germ cell tumor of the testicle, a report of a case of each of these conditions, they were treated with good results. The robotic approach to extended lymph node dissection is suitable [159].

Robotic partial nephrectomy has been reported in appropriately selected children with renal cell carcinoma. However, there are limited reports of laparoscopic or robotic partial nephrectomy for cancer surgery in children. RAS allows for an oncologically sound resection of partial nephrectomy, as well as extended lymph node dissection [160].

Robotic adrenalectomy is an increasingly used procedure in patients with a variety of surgical adrenal lesions, including adenomas, aldosteronomas, pheochromocytomas, and adrenal gland metastases. Emerging literature also supports the role of RAS in partial adrenalectomy [161]. With robotic partial adrenalectomy, successful preservation of adrenocortical function is achieved [162].

RAS is an emerging technique for the treatment of pancreatic neoplasms. Robotic spleen-preserving distal pancreatectomy for a solid pseudopapillary tumor in pediatric patient, can be considered in younger patients presenting with a solid pseudopapillary tumor in the distal pancreas, and its use as an alternative to open pancreatectomy [163]. A report with 15 adolescents with pancreatic head tumor treated with MIS. Pancreaticoduodenectomy was performed, 10 cases with conventional laparoscopic surgery and 5 cases with RAS. The pathological diagnoses were solid pseudopapillary neoplasms (8), neuroendocrine neoplasms (3), intraductal papillary mucinous neoplasm (1), cystic fibroma (1), serous cystadenoma (1), Ewing's sarcoma (1). Six patients presented postoperative complications. The median follow-up was 37 months. The patient with Ewing's sarcoma was diagnosed with liver metastasis 41 months after surgery and died 63 months after surgery. All other patients survived without a tumor [164].

Robotic gynecological surgery in girls with ovarian disease, the ideal is to maintain the morphology of the ovary, which is beneficial for the recovery of postoperative ovarian function, especially in benign diseases. In centers where robotic surgery is available, ovarian tumors are a suitable entry procedure [128].

Robotic surgery can also be used in supportive care in pediatric oncology including placement of gastrostomy tubes and ovarian transposition [104].

The fundamental oncological principles of no tumor spillage and total resection of tumor margins can be adhered to by RAS; a specific concern being the lack of haptics having an impact on the surgeon's ability to differentiate cancerous from healthy tissue. However, it has been noted that the loss of tactile feedback is, very well compensated for by the excellent optical system [158]. Cancer patients are necessarily followed for recurrences, and only long-term prospective studies of robotic resections can guarantee adherence of the RAS to oncological principles.

Contraindications in children for MIS in tumors, including robotic surgery, are large or fragile tumors that carry a high risk of fracture and tumor spillage, significant adhesions from previous operations, and significant deterioration of respiratory or cardiovascular physiology [104].

7. Otorhinolaryngology

Pediatric robotic surgery has been used least frequently in otorhinolaryngology [72]. Until now, the majority of RAS applications in otorhinolaryngology is a transoral approach, particularly useful in masses of the base of the tongue. Open surgery can facilitate access to the oropharyngeal region, including the base of the tongue, but can lead to the morbidity of splitting the lip and jaw or require pharyngotomy. As a result, the robotic transoral approach is being used [165]. In the near future, we believe that transoral robotic surgery may become the gold standard.

In a publication of pediatric cases of robotic transoral surgery, with 41 patients, with age between 2 months and 19 years, the techniques were, lingual tonsillectomies (16), lingual and lingual based tonsillectomies (9), 2 malignant diseases in the oropharynx (high-grade undifferentiated sarcoma and biphasic synovial sarcoma), a thyroglossal duct cyst at the base of the tongue, laryngeal cleft cysts (11), a posterior glottic stenosis, and a surgery for congenital true vocal cord paralysis. A minor intraoperative complication occurred. No patient required postoperative tracheostomy. Conversion index was 9.8% [166].

8. Author's experience in robotic surgery

From March 2015 to January 2021, since the beginning the prospective registry of the casuistry has been carried out. We have performed 258 robot-assisted laparoscopic and thoracoscopic surgeries (RALTS) in 227 patients (224 children and 3 adults), in a public hospital and two private hospitals in Mexico City**.** The demographic data of the patients are, in relation to gender, 52.4% male and 47.6% female. The average and range of age, weight and height of the patients were, age 79.5 months (2 to 204), weight 26.8 kg (4.4 to 102) and height 114.5 cm (55 to 185), the smallest patient was 2 months old, 4.4 kg in weight and 57 cm in height, a left pyeloplasty was performed. The adult patients were 31, 63 and 64 years old.

We grouped our RALTS into gastrointestinal-hepatobiliary 123 (47.68%), urological 117 (45.35%), thoracic 10 (3.87% and oncological 8 (3.1%). We have performed 46 different techniques, globally our conversion rate is 3.1%, the hemotransfusion rate is 4.2%, the mean postoperative stay is 2.5 days, and the mean follow-up is 40 months.

From the group of gastrointestinal-hepatobiliary robotic surgery, in order of frequency, the techniques performed were: primary fundoplication 50 (41.67%), redo fundoplication 20 (15.83%), gastrostomy 17 (14.16%), cholecystectomy 14 (11.67%), biliodigestive 7 (5%), being 5 resections of choledochal cysts with hepaticojejunostomy, a Kasai operation and a hepaticojejunostomy to manage the lesion of the left hepatic duct. Splenectomy 6 (5%), Malone operation 2 (1.67%) and various techniques 7 (5%), of single cases, duodenoplasty and adhesiolysis, gastric trichobezoar extraction, drainage of recurrent retrohepatic abscess after appendectomy, gastric antrum membrane resection, gastrojejunostomy de-derivation, and Ladd's Cure. In this group of gastro-intestinal-hepatobiliary robotic surgery, the conversion rate was 3.25%, intraoperative complications 1.6%, and postoperative complications 4%. In this group of RAS 14 different techniques were performed.

From the robotic urological surgery group, in order of frequency, the techniques performed were: pyeloplasty 26 (22.2%), ureteral reimplantation 21 (17.94%), nephrectomy 20 (17.1%), Mitrofanoff operation 8 (6.8%), nephroureterectomy 7 (6%), ureterostomy de-derivation and ureteral neo-reimplantation 5 (4.3%), nephro-cystolithotomy 5 (4.3%), varicocelectomy 5 (4.3%), release of extrinsic UPJ obstruction 4 (3.4%), inguinal hernioplasty 3 (2.56%) and various techniques 13 (11.1%) of single cases, ureteroureterostomy, augmentation cystoplasty, bladder neck closure, heminephroureterectomy, perirenal abscess drainage, colostomy closure, enterovesical fistula closure, Mitrofanoff review, ureterostomy and ureteropyelography, bilateral gonadectomy, duplicated ureter ureterostomy, hysterosalpingectomy, bladder wall biopsy. In this robotic urologic surgery group, the conversion rate was 0.85%, intraoperative complications 0.85%, and postoperative complications 1.7%. In this group of RAS 20 different techniques were performed.

In the robotic thoracic surgery group, in order of frequency, the techniques performed were: lobectomy 4 (40%), diaphragmatic plication or plasty 4 (40%), a bronchogenic cyst resection (10%) and a pleural biopsies (10%). In this robotic thoracic surgery group, the conversion rate was 20% and postoperative complications 10%. In this group of RAS 5 different techniques were performed.

In the robotic oncological surgery group, the techniques performed were adrenalectomy 2 (for adenoma and another for pheochromocytoma) and single techniques of, anterior mediastinal teratoma resection, Ewing tumor resection, Wilms tumor stage 3 resection in horseshoe kidney, partial gastrectomy for carcinoid tumor, retroperitoneal lipoma resection and conservative resection of ovarian cyst. In this robotic cancer surgery group, the conversion rate was 12.5%, and there were no complications. In this group of RAS 8 different techniques were performed. The cases of adult patients were pheochromocytoma, adrenal adenoma and carcinoid tumor.

Previously, we published our experience with RALTS, the first 186 surgeries [14], the first 4 cases of choledochal cyst resection [109], redo Nissen fundoplication [114] and in thoracic surgery [133].

9. Implementation of a pediatric robotic surgery program

9.1 Planning

The success of a pediatric robotic surgery program (PRSP) depends on a well-structured plan. Implementing a PRSP requires institutional support and requires a comprehensive, detail-oriented plan that takes into account training, supervision, cost, and cases volume. Given the lower prevalence of robotic surgery in children, in many cases it may be more feasible to implement pediatric robotic surgery within an adult robotic surgery program. The pediatric surgery team determines its goals for volume expansion, surgical case selection, surgeons training, and surgical innovation within the specialty. In addition to the clinical model, a robust economic model that includes marketing must be present, especially in private hospitals [167].

9.2 Development of the program

The development of a robotic surgery program is associated with significant initial costs due to the initial investment in the robotic surgical system [168]. Adequate surgical volume is essential for both feasibility and ensuring adequate results for patients [64]. The surgeon should start with less complex index cases and gradually progress to more advanced reconstructive procedures with growing experience [61].

Less complex cases, such as a fundoplication, are excellent robotic training cases not only for surgeons and anesthesia personnel, but also for technical and nursing personnel assisting in the operating room [169].

Additionally, robotic cholecystectomy is a suitable procedure for first few surgeries when pediatric surgeons are beginning robotic surgery [125]. It is imperative to have a core group of specific personnel familiar with robotic procedures to increase efficiency. Adequate and systematic performance of the entire team in simple cases, then translates into better performance in more complex cases.

It is estimated that approximately 100 cases are required to obtain consistent results in pediatric robotic surgery cases by a surgical team [167]. The learning curve for each procedure varies, but is shorter than with laparoscopy, for example for robotic pyeloplasty there are 15 to 20 cases, to obtain similar results and surgical success [170]. Experience shows that in complex or reconstructive techniques, surgeons using the open approach switch to the robot-assisted approach, such as pyeloplasty, ureteral reimplantation, biliodigestive and pulmonary lobectomy, among others.

9.3 Robotic pediatric surgery team

There are three main actors involved in the implementation of a pediatric robotic surgery program: i. Surgeons and anesthetists, ii. Nurses and iii. Administration [168].

Successful robotic surgery is mentioned as requiring four elements, i. Good understanding of the surgical procedure, ii. Excellent surgical skills, iii. Frequent teamwork training, and iv. Trocar placement [171]. Adequate surgical volume is critical both for feasibility and to ensure good patient outcomes. Cases should be performed once a week to maintain surgical skill and advance to more advanced reconstructive procedures.

There has been a growing role for simulation and surgical training. Currently, the robotic surgery simulators available for training are the Mimic and da Vinci simulators. The simulators evaluate the skills in the different tasks that the surgeon performs. It is desirable that surgeons have previous experience in conventional laparo-thoracoscopy.

9.4 Training, accreditation and credentialing

Training and accreditation. In the present, the certification process to be a robotic surgeon depends on the manufacturer. Intuitive Surgical (Sunnyvale, CA, USA), the manufacturers of the da Vinci Surgical System, have a separate training program that takes surgeons from console setup to the monitoring phase for initial cases with support from a proctor.

This process should be more structured and create a curriculum for robotic surgeons, this is essential for the training and objective evaluation of future robotic surgeons. Defining results, specific training tasks and their validation; as well as, establishment of measurements and approval criteria to improve the quality of robotic surgery should be included in the plan [172]. Academic organizations and hospital institutions can lead the implementation of a structured curriculum.

An accreditation proposal for the robotic surgeon is the following; After the intuitive surgery training program (step 1), then do the first five cases with a co-surgeon (step 2), who has the dual role of preceptor and supervisor, assesses the surgeon who is learning and also imparts new skills and takes control of the operative case if the clinical situation warrants it (the tutor allows the trainee to gain robotic experience safely in the first index cases). This is followed by 6 to 10 cases in which the tutor / supervisor is a bedside assistant (step 3). The preceptor/supervisor reports the findings to the Institution's Robotics Committee on the skills and progress of the trainee, evaluating whether the independent practice can be continued by the surgeon (step 4), based on the favorable evaluation of the preceptor [167].

The author's experience supports this accreditation proposal so that the learning curve of the surgeon, who is starting his foray into robotic surgery, is a satisfactory experience for him, and the patient is offered the greatest security from the stage of the curve of learning.

9.5 Program information data log

Data collection is very important. Collecting, analyzing, and presenting data prospectively to Institutional colleagues, at a minimum, allow objective analysis of results for comparative studies against other approaches, as well as to publish them.

10. The future of robotic surgery in children

Recently, the Senhance Robotics System (Transenterix, Morrisville, NC) has begun offering 3 mm instrument sizes, which could make robotic surgery more technically feasible for even the smallest pediatric patient. Although not currently approved for use in pediatric surgery, the Transenterix platform, was evaluated in an experimental study where surgeons were able to successfully perform intracorporeal and knotted sutures in body cavities as small as 90 ml, and the instruments could be inserted directly without the need for ports, reducing the required distance between ports [5]. This Transenterix platform has haptic feedback.

With advancing technology and the demand for more compact robotic platforms, the future for robotic surgery will doubtlessly result in a reduction of instrument size and an improvement in haptic feedback. This puts the pediatric patient in particular, the newborn at the forefront. Reconstructive surgery such as esophageal and intestinal anastomosis, all of which require a delicate and more magnified approach will benefit enormously from these advances. The pediatric and neonatal patient must be at the forefront of research into the future of robotic surgery [173].

We are at a dawn of a new age in surgery, as we witness the dramatic growth in robotic surgery. The proliferation and commercialization of new robotic surgical systems over the next few years will drive competition, lower cost, and accelerate the adoption of these technologies [174].

Artificial intelligence. More sophisticated systems will track the surgeon's movements and patient data and synchronize with outcomes data to provide us with early warning systems for complications. One more interesting aspect is how these systems will participate in the surgical decision-making process in real time. We are already gathering data on tissue perfusion, helping us decide on the appropriate location for an anastomosis. Additionally, using artificial intelligence, real-time data will be collected from many sources, including electronic medical records, anesthesia monitoring systems, video images, and surgeon data for making decisions that we will increasingly rely on [174].

Digital surgery (Surgery 4.0), the next frontier of surgery, is defined as the convergence of surgical technology, real-time data and artificial intelligence. Following previous waves of disruption, which saw the transition from open (Surgery 1.0) to laparoscopic surgery (Surgery 2.0), and from laparoscopic surgery to robotic surgery (Surgery 3.0), the digital paradigm in surgery is bringing unprecedented changes to the century-old field. The power of linked data and advancements in artificial intelligence are beginning to make a real impact in the way surgeries are performed, reducing well-documented variability in surgical process and outcomes.

Companies, investors, surgeons and health systems are racing to accelerate the digitization of surgery in order to dramatically improve patient outcomes whilst reducing cost and inefficiencies; improve patient access; reduce inequities between populations; improve quality; and deliver more personalized surgical care, and the digital surgery is the next apex in surgery [175].

Verb Surgical is building a digital surgery platform that combines robotics, advanced visualization, advanced instrumentation, data analysis, and connectivity. Surgery 4.0 or digital, which seeks to achieve less invasive and smarter interventions, "marks the beginning of a true democratization of the discipline". The Verb Surgical platform will be an option in the near future of digital surgery [175, 176].

11. Conclusions

In this chapter, in relation to robot-assisted surgery, its definition, characteristics, advantages, benefits, limitations and applications in children are addressed. As well as, the surgical areas of its application in the pediatric population, which include urological, general, thoracic, oncological and otorhinolaryngological surgery.

To date, there are multiple publications that demonstrate that robotic surgery in children is safe and effective, and it is important to offer children its benefits. However, a frequent conclusion of published studies on robotic surgery in children is the impossibility of carrying out comparative studies with all the scientific rigor, which makes it impossible to reach solid conclusions about the advantages and benefits in the pediatric population.

Robotic surgery preferably applied to difficult and complex cases adds value to patient care, and is an important balancing factor against the apparently higher cost (main drawback), compared to open and laparo-thoracoscopic surgery.

The author included his results in pediatric robotic surgery, which compared to other series of similar published cases; the experience is favorable and encouraging.

Globally, to date, few pediatric surgeons have adopted the robot-assisted surgery, as opposed to more pediatric urologists who have benefited more children. To date, in malignant tumors in children, robotic surgery has been applied less.

Recommendations for the implementation of a pediatric robotic surgery program are included. With robotic assistance, it is important to mention that the learning curve is shorter than with laparo-thoracoscopic surgery. It is necessary for each institution to establish the curriculum for the accreditation and credentialing of the robotic surgeon. A proposal is included.

The future will be fascinating with upcoming advancements in robotic surgical systems, the use of artificial intelligence, and digital surgery.

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Conflict of interest

The author declares to be Proctor of the da Vinci Surgical System and sometimes receives salary for advice to Surgeons in their first robotic procedures. In relation to the execution of this manuscript, no economic financing was received.

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