Review Article

Narrative review: robotic pediatric surgery—current status and future perspectives

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Background and Objective: Robot-assisted surgery has been progressively involved in various fields of adult and pediatric surgery, demonstrating many advantages over either mini-invasive or open surgery. The aim of this review is to provide the most recent evidence on robot-assisted pediatric surgery, in all its subspecialties.

Methods: A comprehensive electronic literature search of PubMed, Embase, and Cochrane Library was conducted using appropriate Medical Subject Headings (MeSH) terms and keywords. The interval time considered was a 5-year period [2017–2022], and no language restrictions were applied.

Key Content and Findings: A total of 685 titles were identified. After applying exclusion criteria, 73 articles for robotic pediatric surgery have been published and were included in this review. We extrapolated and summarized the current evidence on robot-assisted surgery in pediatric age through all the fields of applicability.

Conclusions: Robot-assisted surgery is technically feasible in case of a selected pediatric cohort, and it is going to achieve similar or better surgical results if related to the standard open or mini-invasive procedures. Copious case series and randomized trials are still required. Due to the great potential that this new technology is demonstrating, in the close future, the evolution of robotic platform will offer a valid and solid alternative in the treatment of various pediatric pathologies.

Keywords: Robot-assisted pediatric surgery; robotic pediatric surgery; pediatrics

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Introduction

Background

In the last 20 years, pediatric surgery has undergone major and important improvements, mainly thanks to the development of minimally invasive surgery (MIS) techniques (1). Laparoscopy, which can be considered the main expression of MIS, has reduced post-operative pain and hospitalization, improving recovery and wound appearance (2).

On the contrary, in laparoscopy, the lack of tridimensional visualization, the use of rigid and un-flexible instruments, the necessity of the surgeon to maintain a more erect position with rarer back movements, element which can cause pressure point injury, compression of the nerves, and upper extremity's weakness, lead this technique still challenging (3).

Rationale and knowledge gap

Robot-assisted surgical system has represented an avant-garde step in the field of mini-invasive surgery, thanks

to its informatics systems with a three-dimensional (3D) visualization, the improvement of wristed instrumentation, the absence of surgeon's tremor and the decrease of learning curve for intracorporeal suturing (4,5).

Even if all these advantages are presents, its feasibility still presents several limitations in pediatric age, mostly due to the high cost of purchase and maintenance of the Da Vinci robot and the important difficulty in adapting the big robotic platform with all its surgical instruments, at the beginning proposed for adult populations, to the small dimensions of pediatric patients (6).

The first case of robotic pediatric surgery was described in 2001 (7), almost a decade after its first appearance in adult population, regarding a case report of robot-assisted Nissen fundoplication. After first reports, robotic procedures for children started to be described in literature, with an occurrence that appears more slowly than in adults' age, possibly due to technical limitations in developing suitably sized instrument for pediatric age (8).

The majority of published reports concerns robotic pediatric urology with an exponential increase in number of works every year. Over time, more complex and wider variety of cases are being described using robotic approaches, such as thoracic, gastro-intestinal, gynecological and oncological procedures (8).

Objective

With this review, we aim to describe and analyze the current state of art of robotic surgery in pediatric age, providing an up-to-date available literature, focusing on evaluating the surgical fields in which robotics was presented and reported as an innovative technique with a rapid rise in these recent years, and those fields in which robotic surgery is obtaining above all the role of first surgical indication. We present this article in accordance with the Narrative Review reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-22-427/rc).

Methods

A comprehensive electronic literature search of PubMed, Embase, and Cochrane Library was conducted. The search terms used were "robotic pediatric surgery" or "robot-assisted pediatric surgery".

References of all included studies were also checked for potential records. To detect a current state of art of actual robotic pediatric surgery, the interval time considered was a 5-year period [2017–2022], and no language restrictions were applied.

All extracted abstracts and titles were selected for relevance and incongruities were resolved by consensus.

All studies providing the most recent evidence on robot-assisted surgery applied to pediatric age (from 0 to 18 years old) were included in this analysis. Abstracts, case reports, reviews or repeated publications were excluded. Studies regarding adult populations were excluded. Otolaryngologic, cardiosurgical, anesthesiologic and neurosurgical pediatric publications were excluded.

A total of 685 titles were identified. After applying exclusion criteria, since 2017, 73 articles for robotic pediatric surgery have been published and were included in this review. All studies included were published in English, although no language restrictions were imposed (*Figure 1*).

Out of the 73 included studies, 57 were designed as retrospective cohort studies, 15 as prospective cohort studies and 1 as randomized cohort study (*Table 1*).

These articles have been published to describe the surgical management of various conditions: miscellaneous of urological pathologies, management of uretero-pelvic junction obstruction (UPJO), management of megaureter or vesicoureteral reflux (VUR), thoracic pathology through robot-assisted thoracoscopy, Hirschsprung's disease, choledochal cysts, oncological diseases, esophageal diseases, inguinal canal's pathologies, anorectal malformations, Mitrofanoff procedure, urachal diseases, pancreatojejunostomy, management of kidney stones.

Most discussed topics were pyeloplasty and ureteral re-implantation (*Table 2*).

Discussion

The introduction of robotic surgery characterized an additional step in the evolution of minimal invasive surgery in pediatric age, presenting many advantages, such as a better ergonomics for surgeons, a 3D view, an easier intracorporeal suturing and knotting due to the seven grades of freedoms and much more (6).

Robotic procedures have been used in nearly all pediatric surgical subspecialties including urology, general and thoracic surgery, and oncologic surgery. As analyzed in different studies (5,9,10), pediatric urology is one of the most common and advantageous fields of robotic technology's application, both in reconstructive and demolishing procedures.

Otherwise, we can also notice some limitations to this

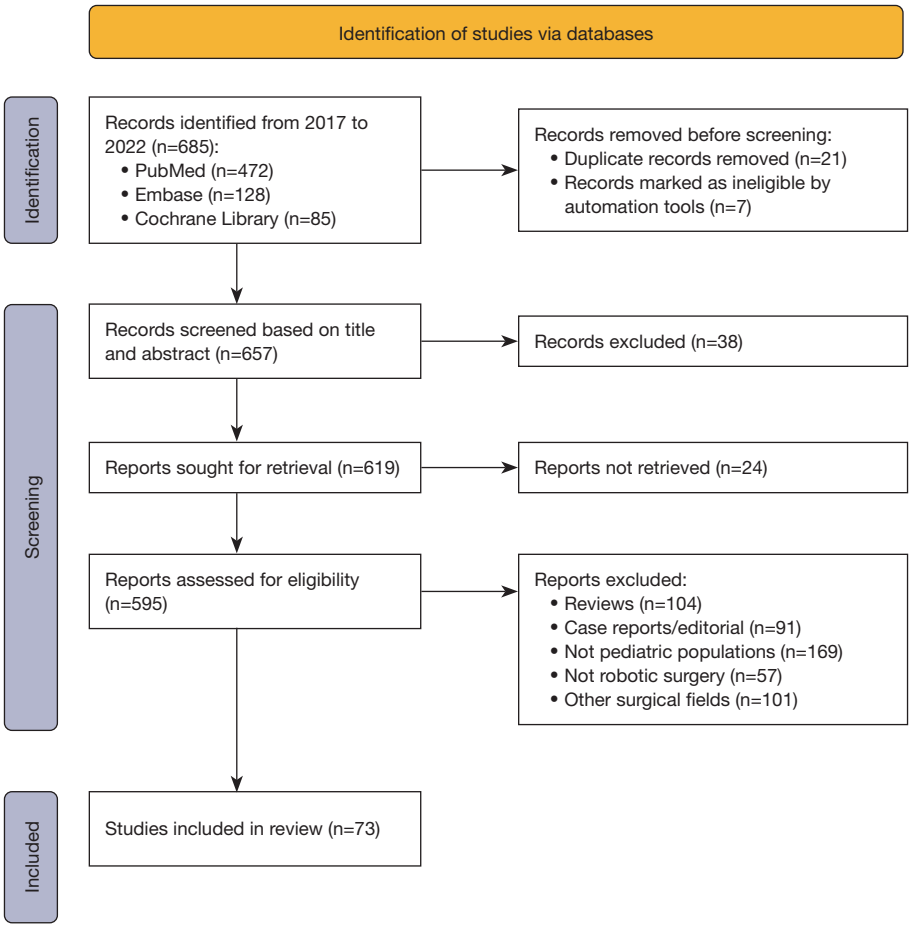

Figure 1 Study selection flow chart.

Table 1 Type of studies enrolled

Results	Value, n (%)
Retrospective cohort studies	57 (78.1)
Prospective cohort studies	15 (20.5)
Randomized cohort study	1 (1.4)

innovative procedure. For example, robotic surgery can be feasible for children weighting more than 15 kg in order to have the correct space to position the 8-mm robotic ports needed for the procedure (6).

To the best of our knowledge, this is the first narrative review which analyzes all the fields of robot-assisted pediatric surgery's appliance, aiming to assess a current status of literature regarding the use of this pioneering technology in pediatric surgery and in all its subspecialities.

A total of 73 articles were included in this review, permitting to analyze the most discussed topics and the new-introduced fields of application.

Section 1: *urologic procedures*

Sub-section 1: pyeloplasty

Robot-assisted Anderson-Hynes dismembered pyeloplasty, laparoscopically or retroperitoneoscopically performed, is considered the most common robotic procedure performed in pediatric population, and currently the only procedure in which we can demonstrate comparable or even best outcomes compared to the open or laparoscopic procedures (6,11,12).

For many years, open pyeloplasty has been considered the gold standard approach in patients with UPJO (13) but more recently, early reports on pediatric robot-assisted laparoscopic pyeloplasty (RALP) started comparing surgical outcomes to laparoscopic pyeloplasty (LP) and open techniques (OP) (12,14,15).

Table 2 Topics discussed in the enrolled studies

Results	Value, n (%)
UPJO	12 (16.4)
VUR	10 (13.7)
Urolithiasis	3 (4.1)
Neurological bladder	1 (1.4)
Inguinal canal Pathologies	2 (2.7)
Urachal remnant	1 (1.4)
Esophageal pathologies	3 (4.1)
Pancreatic pathologies	1 (1.4)
Choledochal cysts	5 (6.8)
Ano-rectal malformations	1 (1.4)
Hirschsprung disease	4 (5.5)
Ulcerative colitis	1 (1.4)
Thoracic pathologies	4 (5.5)
Oncology	4 (5.5)
Miscellaneous pathologies	21 (28.7)

UPJO, uretero-pelvic junction obstruction; VUR, vesicoureteral reflux.

Analyzing data, robotic procedure had presented several advantages.

Regarding the learning curve, it appears to be shorter compared to the open or laparoscopic procedures, with quicker operative times which exponentially decreased if the surgeon's experience increases (median: OP, 95 minutes; LP, 123 minutes; RALP, 89 minutes) (12,14).

Concerning surgical outcomes, we reported a cumulative success rate among different studies of 96–100% (11,16,17). It was also noticed that robotic procedure led to a lower post-operative and total narcotic use (11) and, as a related consequence, a lower hospital length (1–1.4 days) (11,12,18).

Furthermore, analyzing more recent multicenter studies, a lower rate of complications (range of 4–15.6%) (11,14,18,19) can be reported, if compared to the open or laparoscopic procedures.

Most of these compilations were low grade Clavien-Dindo I or II.

Other studies (17) demonstrate that robotic pyeloplasty is a safe and feasible technique, with good medium-term outcomes in expert hands also in patients with horseshoe kidney, standardizing an accurate pre-operative planning associated with a standardized technique in order to achieve good surgical outcomes even in these challenging cases.

More recent studies started focusing their attention also on the main limit of robotic surgery: patient's weight.

Specifically, Masieri *et al.* (20) tried to investigate the influence of the body weight on peri- and post-operative outcome in a series of pediatric patients treated with RALP, reporting favorable results also in the cohort of patients with a weight <15 kg, underling how the need for a different trocar's placement and limited space in this kind of patients did not affect surgical outcomes.

In patients in which a primary pyeloplasty has failed or anatomic situations such as malrotated or intrarenal pelvis occur, a robot-assisted ureterocalicostomy can be a crucial option in order to save the kidney. This procedure was described by Adamic *et al.* (21) as a feasible and safe technique with a surgical success rate of 100% in this cohort, without any post-operative complications.

Sub-section 2: ureteral reimplantation

In case of VUR, ureteral reimplantation is the most common pediatric robot-assisted procedure after pyeloplasty. Robot-assisted laparoscopic ureteral reimplantation (RALUR) may be accomplished through an extravesical or intravesical technique and, of these procedures, the extravesical one is the one reported mostly, following the Lich Gregoire procedure, compared to the intravesical one, reporting complications rates higher than the extravesical one (15–52%) (22,23).

Even though initial attempts related with a precipitous learning curve were described, multicentric recent studies present robot-assisted extravesical ureteral reimplantation (REVUR) as a feasible and safe technique (24,25). This procedure presents many advantages, as, for example, a post-operative required narcotic drugs' reduction and a shorter hospitalization (1–4.5 days) (26-28).

Focusing on surgical success rate, in the majority of studies defined radiographically through voiding cystourethrography (VCUG) in the post-operative period, a range of 77–100% was detected (24,26,27), a variability that can be related to case selection but mostly on surgeon's learning curve.

The main post-operative complication reported was urinary retention (0–7%) especially in case of bilateral reimplantation (5–13%) (26,28-30). Other rarer post-operative complications were urinary tract infections, post-operative ileus and persistent high-grade reflux (31-33). Concerning the intraoperative complication, ureteral damage was reported (26), as also bladder mucosa perforation during detrusorrhaphy.

The presented data show that RALUR can be a first surgical option for VUR, proven to be effective and feasible both in unilateral and bilateral reflux, though carefulness is required in bilateral cases in order to avoid the increased risk of urinary retention.

Sub-section 3: urolithiasis surgery

Endourological techniques, such as ureteroscopy (URS) and retrograde intrarenal surgery (RIRS) or percutaneous nephrolithotomy (PCNL) and extracorporeal shock wave lithotripsy (ESWL), mostly substituted open procedure for the treatment of urolithiasis, also in the pediatric age. However, with the recent advent of robotic surgery in an increased number of urological procedures, the principle of "open" renal surgery is being reconsidered. Few data available in literature shows that the robot-assisted kidney stone surgery can be useful in case of urolithiasis in large stone burdens, complex anatomy or associated renal reconstructive procedures, demonstrating to reduce bleeding and parenchymal damage (34,35).

Esposito *et al.* (36) described their experience with robot-assisted laparoscopic surgery (RALS) in a cohort of 15 pediatric patients with urinary tract stones, demonstrating a feasible and effective treatment option with a stone-free rate of 80% following the first procedure and a 100% success rate after a second treatment.

However, supplementary studies comparing the robotic procedure to other minimally invasive one is needed to confirm its role in urolithiasis.

Sub-section 4: Mitrofanoff procedure

Even nowadays, open Mitrofanoff appendicovesicostomy still remain the most performed technique on patients with neurological bladder.

With the advent of robotic technology, many pediatric surgeons are following the trend, performing more complex procedure, including reconstructive one.

In 2004, Pedraza *et al.* (37) were the first to describe their positive experience with robot-assisted laparoscopic Mitrofanoff appendicovesicostomy (RALMA) in a 7-year-old boy, with a diagnosis of posterior urethral valve, followed by Storm *et al.* in 2007 (38) and Famakinwa *et al.* in 2013 (39), with overlapping results.

Only one article was included in our review of the last 5 years (40), describing the experience of the American Center with RALMA technique, over a cohort of 24 patients, demonstrating a decreased post-operative pain with reduced post-operative opioid drugs, a better cosmesis, presenting a safe and feasible technique with comparable complication rates (35% of 30 day complication rate), functional and long-term outcome to the OP, with just increased operative time which can be decreased with the experience of the surgical equipe.

Sub-section 5: orchiopexy procedure for non-palpable testis

Even if laparoscopic orchiopexy represents the gold standard procedure in case of non-palpable testis, taking a correct decision between sacrificing testicular vessel in order to obtain sufficient length, preserving the vascularization or adopting a one and two-stage Fowler-Stephens orchiopexy can be a challenging decision. Shumaker *et al.* (41) describes a first stage Fowler-Stephens approach's change, adopting a robot-assisted laparoscopic method and obtaining an optimal mobilization of the testicular vessels with a correct ligation of the artery, noticing a 0% of conversion rate and no case of testicular atrophy in the follow-up period.

Keeping our focus on non-palpable testis, Higganbotham *et al.* (42) illustrate a robot-assisted laparoscopic orchiopexy, through an umbilical and two additional 8-mm ports, describing a feasible technique especially in case of bilateral undescended testis, with equivalent results in comparison to the laparoscopic approach.

Sub-section 6: urachal remnant excisions

One retrospective study (43) reported the first pediatric cohort of robot-assisted urachal remnant excision in children. An accurate excision of the urachus was performed in a 3-port transperitoneal fashion after a cystoscopic inspection of the bladder, with a mean operative time of 116 minutes, an hospitalization's length of 1.5 days and a post-operative rate of 6.3%.

Even if laparoscopic approach remains the gold standard technique for urachal remnant excision, robot-assisted laparoscopy can offer additional advantages in term of dissection or intracorporeal suturing, demonstrating a higher patient's satisfaction compared to the open or laparoscopic technique. Obviously, even though bigger cohorts reporting long-term outcome of surgical intervention are still needed, this experience represents an effective and safe approach in case of urachal remnant in pediatric patients.

Section 2*: *abdominal and pelvic procedures

Sub-section 1: esophageal procedure

In case of gastroesophageal reflux disease (GERD), even

if laparoscopic fundoplication is still considered the gold standard surgical approach in children (44,45), indications for robot-assisted fundoplication are increasing in these last years, bringing new important advantages for both the surgeon and the patient, compared to the laparoscopic technique.

Differently from previous studies, which presented few cases and a follow-up too short to be considered relevant, reporting longer operative time and demonstrating an absence of superiority compared to the laparoscopic approach (46,47), more recent analysis were enrolled for this review.

Binet *et al.* (48) reported a large series of robotic fundoplications in children, with the aim of flattening the learning curve (which arrived to be compared to the laparoscopic one after 20 procedures), decreasing the mean operative time and to demonstrate the efficiency of surgical technique, reporting no conversion to either an open or laparoscopic surgery and a post-operative complication rate comparable to the one reported in reviews on laparoscopic antireflux procedures.

Analyzing robotic application in hiatal hernia repair in children (49), one retrospective study was enrolled in this review, in order to describe obvious advantages over traditional laparoscopy, such as less operative pain, shorter hospitalization, a better 3D visualization, leading to encouraging surgical outcomes.

Regarding achalasia, one study (50) involving a small cohort of patients undergone robot-assisted Heller myotomy, was enrolled in the review, demonstrating how the use of robot during Heller myotomy could decrease the risk of esophageal mucosal perforation, due to the robotic 3D visualization and the augmented degree of instrument freedom, improving post-operative outcomes in terms of hospitalization's length and post-operative pain.

It is obvious that larger series need to confirm the efficiency and safety of this specific robotic procedure.

Sub-section 2: pancreatic procedure

Excluding case reports from our review, only one retrospective study regarding pancreatic robot-assisted pediatric surgery was included (51).

A cohort of patients, with a diagnosis of pancreatic ductal dilatations with stones as a complication of chronic pancreatitis was evaluated. Stones were totally removed through robotic surgery using a robotic lateral pancreaticojejunostomy, reporting no conversion to laparotomy and no recurrence of pancreatitis and neither stones reappearance.

Robotic surgery to treat pancreatic ductal dilatations could reduce the degree of difficulty of laparoscopic technique, make the anastomosis and the suture easier due to ergonomic improvements and, thanks to the 3D vision, help avoiding vascular damage and controlling the bleeding.

Sub-section 3: Roux-en-Y hepaticojejunostomy

With the beginning of pediatric mini-invasive surgery, many authors have described laparoscopic resection of choledochal cysts' feasibility and safety (52,53), reporting a main limit due to the rigid laparoscopic instruments and a technically challenging procedure (54).

The introduction of robotic platform offers prospective solutions through its more sophisticated aspect, providing flexible instruments and a 3D view of the operative fields, reducing surgeon's tremor, leading to an easier dissection and a precise anastomosis (55).

The retrospective studies enrolled in our review reported a range of conversion to either laparoscopic or open surgery of 0–1.3%, due to severe bleeding (56-59), with a median of hospitalization of 7.6 days (6–9 days).

Post-operative complications, such as twisted Roux limb, intestinal obstruction, intestinal perforation, and biliary complications were reported with a global range of 0–17.7%.

All patients, who underwent resection of congenital cyst, had a complete excision on the final pathologies, reporting a global surgical success rate of 100%.

The studies enrolled in our review suggest continued progresses beyond an initial steep learning curve, reporting no compromise in post-operative and long-term surgical outcomes and strong evidence in terms of feasibility of robotic-assisted laparoscopic choledochal cyst resection and hepaticojejunostomy, overcoming laparoscopic technical difficulties, in particular in the creation of the hepaticojejunostomy.

Sub-section 4: anorectal pull-through

Pediatric surgical procedures achieved in narrow fields, as for example the lower pelvis, could be a valid candidate for robotic approach. A low rectal dissection, an important task that is required in Hirschsprung's disease or in anorectal malformations, can be easily obtained through robot-assisted surgery (60).

In Hirschsprung's disease's case, robotic surgery combines traditional and basic concept of Soave pull-through open surgery with the advancement of robotics

instrumentation, leading to an easier dissection, decreasing intra or post-operative complications to a minimal rate, permitting a better view of the deep pelvis and increasing surgical movements' precision (61).

Four studies were enrolled in this review regarding robot-assisted Soave procedure (61-64), reporting a total operative time in a range of 80–290 min, no conversion to laparoscopic surgery or laparotomy, neither intraoperative complication, achieving a coloanal anastomosis in all patients.

Post-operative hospitalization ranged from 4 to 10 days. As for post-operative complication, all patients responded well to anal dilatation, presenting anastomotic stenosis just in one patient which was successfully dilated under general anesthesia (64), urinary incontinence or erectile disfunction in male weren't reported. Enterocolitis and mild soiling had been reported in a range of 4–7.3%. Continence was achieved in 100% of cases, reporting a range of 1–4 defecations/day. Post-operative pain persisted within the limits of optimal pain control during the entire hospitalization for all patients.

Regarding the surgical treatment in case of anorectal malformation, an interesting and innovating study was conducted (65), aiming to describe a series of patients undergoing robot-assisted anorectal pull-through. All the robotic procedure were completed without intraoperative complications, achieving an easier dissection through different anatomical layers, a more precise repair of the fistula and a rectal pouch's precise placement in the center of the striated muscle complex, with a pleasant appearance. The post-operative complications rate was 23.5%, reporting 2 cases of anal stenosis, treated only with anal dilatations, and 2 cases of incontinence, which, after repeated functional training and probiotics therapy, presented a promising evolution during follow-ups.

In case of ulcerative colitis in children, a retrospective study was enrolled in this review (66). Fifteen patients, undergone robot-assisted total proctocolectomy with ileal J-pouch-anorectal anastomosis, were analyzed, reporting no intraoperative complications or conversions to either laparoscopic or open surgery. Post-operative complication rate was 33%, resembling what was depicted in literature for the laparoscopic approach (67), but lower than the one for open approach (68).

This preliminary experience revealed that robotic ileal J-pouch-anorectal anastomosis could be safe and feasible in case of pediatric patients with ulcerative colitis, nevertheless bigger cohort and longer follow-up are needed to confirm these results.

Section 3: *thoracic procedure*

Video-assisted thoracoscopic surgery has been more frequently used in last decades, becoming the gold standard approach for a large number of pediatric procedures (69).

The advantages of thoracoscopy are well-knows, such as the reduction of post-operative pain, the shorter hospitalization, better cosmetic results, but still presenting a challenge due to a small working space related to the body size of the children and the lack of 3D vision.

Although robot-assisted thoracic surgery have not yet reached the greatness that it has in pediatric urology, in the last years, it has been useful to perform a variety of thoracic surgical procedures, as a new introduced but still limited field of application.

In case of localized bronchiectasis, a series of lobectomies performed by robot-assisted thoracic surgery were retrospectively analyzed, in comparison to the video-assisted thoracoscopic surgery (70). The study reported no conversion to open surgery with robotics procedures and five cases with thoracoscopy, no significant differences in term of peri-operative complications, length of thoracic drainage or length of hospitalization but a higher operative time in robotics cohort.

Robot-assisted thoracoscopic surgery in case of bronchiectasis improved the vision, permitting a more precise and finer manipulations for better dissection and suture, with clear advantages over thoracoscopic repair in terms of conversion rate and post-operative complication (70).

One study, describing a series of 20 patients undergone robot-assisted thoracoscopic diaphragmatic plication due to congenital eventration, was enrolled in this review (71).

Although traditional thoracoscopic plication is the preferable option in diaphragmatic eventration's case, ribs still present a limitation in the movement of trocars, leading to challenging and time-consuming suturing. Robot-assisted thoracic surgery is still difficult in children but in this short cohort of patients, robotics provides more precise movement, easier and faster suturing time, overcoming intercostal limitations, with a flatter learning curve after only 15 procedures (71). A retrospective multicenter French study (72) was conducted to analyze esophageal robot-assisted thoracoscopic surgery in order to discuss the most appropriate indications.

Sixty-eight patients were enrolled in the cohort, comprised esophageal duplications, Heller's myotomies,

esophagoplasty and esophageal atresias reported a rate of conversion of 11%, due to difficulties in exposure and a complication rate of 35%. A redo surgery was performed only for one patient. This limited study demonstrated the feasibility of robot-assisted thoracoscopic surgery in patients who weigh more than 5.0 kg.

In term of post-operative pain, an observational, retrospective, multicenter study (73), involving 204 children, was performed with the aim to compare the outcome of robot-assisted thoracoscopy versus the thoracoscopic approach. On the 1st, 2nd and 3rd day after surgery, pain was detected using Face, Legs, Activity, Cry, and Consolability (FLACC) scale or Numerical Rating Scale (NRS) and, evaluating the two different groups, the study described that pain after surgery does not diverge relating to the surgical approach, but it still preserves very low values, which is a standard advantage of the minimally invasive approach.

To strongly determine advantages and limitations of robot-assisted thoracoscopic surgery over thoracoscopy in children, however, larger and randomized studies, with a more consistent follow-up, are still needed.

Section 4: *oncological procedure*

Even if robot-assisted surgery in oncology has been demonstrated to be effective in adult population, in pediatric age its use is still limited with few studies conducted on this subject. This could be probably due to the scarce incidence of this disease and to the characteristic of pediatric tumors, which frequently presented a rapid growth, with the need of other non-surgical approach, such as neoadjuvant chemotherapy or radiotherapy (74).

In the last years some papers have been published on the topic, even reporting a small cohort of patient or case report experience.

The aim of the studies enrolled in this review was to evaluate the feasibility and in particular the safety of robot-assisted surgery in this field, with the future perspective to introduce valid guidelines to regulate the applicability of robotics in pediatric oncology, element which is still missing both in North America and Europe (75,76). Various oncological procedures for different kind of pediatric tumors were described in literature, such as nephroblastomas, adrenals tumors, pancreatic tumors, germ-cell tumors, thymic tumors, shifting through malignant, borderline or benign tumors. Nephroblastomas and ovarian tumors are most frequently illustrated (74-77). Robot-assisted laparoscopy for abdominal or pelvic tumors, robot-assisted retroperitoneoscopy or robot-assisted thoracoscopy were described. No robotics-related complications were reported in literature, neither intraoperative tumor rupture occurred during the robotic dissection.

Hospitalization range was 1–4 days with a range of post-operative complications that varies from 0 to 28%.

Our analysis focuses on the fact that a precise case selection is fundamental to obtain good oncological results, avoiding inappropriate utilization of this technique. In particular, Blanc *et al.* (75) depicted the largest nationwide experience with robotic pediatric oncology, trying to provide a practical and easy guideline for selected cases, with certain limitation due to the rare and heterogenous clinical presentation. In their cohort of 89 oncological patients, they performed 93 procedures, without reporting any intraoperative tumor ruptures and a conversion rate to an open approach of only the 8%.

Even if the gold standard in pediatric oncology is still the open surgery, robotic surgery, in precise selected cases, could be considered a safe option. Surgical indications must be discussed in the context of qualified tumor board with medical specialists in order to avoid boundless and non-valid applications, maintaining the robotic application as an optimal option to expand the availability of complex resection in pediatric cancer. More controlled trials are still needed to confirm its indications, with the aim of setting this innovative technology in the future of pediatric oncological surgery (78).

Conclusions

In this narrative review, we analyzed the current status of robotic surgery related to pediatric age through all its applications in pediatric surgery.

Although many advantages were previously depicted over conventional mini-invasive surgery, robot-assisted procedures in children are still in their infancy.

Performing procedures in small cavities, with difficult robotic docking, non-standardized pediatric trocars or port placement, lead to a hard non-intuitive adaptation. A significant issue with this platform still remains the high financial cost, even if the advent of simulation models or organized training program, a well-organized operating room turnover, are predictable elements that can lead to reduce all the costs.

Through this excursus, we depicted a robot-assisted surgery as a safe and effective approach to a miscellaneous

of pediatric surgical pathology, reporting an exponential increase in its uses across all pediatric surgical subspecialties. The surgical applications that can be performed with robotics are continuing to develop, including procedures in infants and neonates, with the aim to reach and to overtake the popularity and the feasibility of open and mini-invasive techniques, due to all the advantages previously reported.

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