Review Article

Narrative review in learning curve and pediatric robotic training program

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Background and Objective: Studying learning curve (LC) for robotic procedures and developing an adequate training program are two fundamental steps to standardize robotic procedures. With this aim, we analyzed the literature to study the LCs of different robotic procedures and the availability of standardized training problems.

Methods: The PubMed database was searched in the period from January 1995 to September 2022. Articles presenting LC and potential training programs in the pediatric population were chosen.

Key Content and Findings: Twenty papers were screened describing LC of robotic-assisted laparoscopic pyeloplasty (n=12), fundoplication (n=4), cholecystectomy (n=2), choledochal cyst resection (n=1), nephrectomy/partial nephrectomy (n=1) and lingual tonsillectomy (n=1), with a total of 1,251 procedures. In 10 studies there was only one single surgeon; nine had more than one; one did not specify how many surgeons participated. Twelve papers were retrospective single-center, three multicentric retrospective, four prospective and one was compared a retrospective case series to a prospective cohort. Most of these studies focused on operative time as the primary outcome. It was analyzed as the only outcome in three articles, along with complications in 14, time to discharge in eight, blood loss in three and pain killer use in three. The selected studies analyzed LC impacting operative planning (n=20), training (n=10) and costs (n=2).

Conclusions: There is still a long way to go to complete a standardized functional training for robotic surgery procedures in pediatric surgery. Moreover, the progressive reduction in costs expected in the years to come will play a key role in progressing the diffusion of this technology enabling the collection of data necessary to create a standardized pediatric surgery robotic training program.

Keywords: Robotics; learning curve (LC); minimally invasive surgery (MIS); training

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Introduction

Background

Studying learning curve (LC) for robotic procedures and developing an adequate training program are two fundamental steps to standardize robotic procedures. Both goals are difficult to achieve in pediatrics because the use of robot-assisted surgery is only slowly increasing in pediatrics and training in it is the subject of few studies.

In pediatric surgery, the introduction of robotic surgical systems is highly limited by the weight of pediatric patients and also by the fine reconstruction necessary in many pediatric surgical procedures.

Although the key advantages of this new approach are well known, such as a magnified three-dimensional view, tremor reduction, much better ergonomics, and motion scaling that brings more precise intra-corporeal maneuvering and easier suturing even in narrow spaces. This new kind of surgery has also shown to minimize operative trauma leading to a reduction in postoperative pain, postoperative opioid use, and time of hospitalization. Robotic surgery has also been associated with a faster return to normal daily routines, a better cosmetic outcome; however, technological limitations, specific for pediatric patients, have emerged and may restrict their use (1). The most importance reason is the size of the robotic platform that limits its availability in newborns and in small infants due to the large diameter of trocars/instruments (8 mm), and also the huge costs of acquisition of a robot and robotic instruments, that limit their availability in countries with low resources and in hospitals exclusively dedicated to children. It is also important to consider the additional time necessary for the docking that may risk nullifying the reduced time of the actual operation in terms of fastness (1,2).

Rationale and knowledge gap

In the last few years, the widespread use of robotic approaches in pediatric surgery has been supported by the awareness that it would seem to facilitate LC achieving results in a faster and easier way compared with laparoscopy.

The intuitive nature of the manipulation/control of the robotic instruments is particularly advantageous for surgeons who have just started their training in minimally-invasive surgery.

In spite of this increase in usage, the LC has not yet been defined.

The LC is an important method of assessment of progression in the use of a new technique or devices in surgical fields, the LC represents the growing process of surgical techniques and in robotic surgery is described only in individual procedures (3).

Studying the learning process accomplished both overcoming the fear when starting a robotic-assisted surgery program, and also helps surgeons to understand the LC in the most safe and effective manner to improve the clinical outcomes during the learning process (3).

The literature does not provide guidelines yet on the LC for robotic surgery.

The majority of published papers regarding LC are retrospective with limited case series, which are not adequate to achieve statistical significance and cannot study the learning process of surgical robotic techniques in children (2).

Robotic training is expanding, however, to date no rigorous curricula have been developed to robotic pediatric surgery, the aim of this review is to analyze the LC of different robotic procedures and the availability of standardized training problems.

Robotic surgery has also found place in other specialties, such as the ROSA-ONE system for neuro-surgery or the MAKO system for orthopedics (4,5). However, these robotic systems differ too much from the ones used in pediatric general surgery, for these reasons they were excluded from our analysis.

Objective

With this review we hope to underline possible shortcomings on the standardization of data collection in literature, in the hope of stressing the importance of uniformity of the parameters analyzed when performing prospective and retrospective studies alike. We present this article in accordance with the Narrative Review reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-22-456/rc).

Methods

We analyzed literature on PubMed database using "robotic" and "learning curve" as key words for research in September 2022, with no date limit. A total of 2,326 results emerged. All studies regarding adult patients were excluded by a single reviewer, using a search for pediatric age mention. Selection was limited to English articles only. Papers selected were screened for the model of robot employed, number of patients, mean docking time (if present), mean operative time (OT) and operation type. When some of the variables were not present, it was specified. Being non standardized among different articles, definition of docking time was assessed to be equal to the time between incision and the end of the robot set-up, although both times were reported (*Table 1*). When processes of entering the abdomen and robot set-up were measured separately, they were summed as they are two consequential steps. Total OT was defined as the entire procedure right after the induction of anesthesia until the finishing suture. All data found in each article was averaged out (*Table 2*).

Results

The search resulted in 21 final articles took into consideration for this narrative analysis (*Table 1*). Among the studies in our analysis, 20 papers were screened describing LC of robotic-assisted laparoscopic pyeloplasty (RALP) (n=12), fundoplication (n=4), cholecystectomy (n=2), choledochal cyst resection (n=1), nephrectomy/partial nephrectomy (n=1) and lingual tonsillectomy (n=1). The robotic platform employed were the following: 16 studies used the DaVinci platform (among these only two of them were about the modern Xi model, one was regarding the Zeus platform and four did not specify. Twelve of the studies considered in the final analysis had less than 50 patient and only three had more than 100 patients. Most studies about LC focused on mean OT to assess LC, with six studies specifically made to assess LC for pyeloplasty and one for fundoplication. The mean OTs were: 154.1 min for fundoplication, 219 min for pyeloplasty, 34 min for lingual tonsillectomy, 109.5 min for cholecystectomy and 326 min for choledochal cyst resection.

Discussion

The biggest challenge in reviewing literature concerning robotics in pediatric surgery is the utmost variability found in different papers. Since many studies are constructed in a retrospective fashion, there are several limitations to consider: firstly, not every study analyzed was particularly recent. This problem causes the presence of different machinery used over a span of many years, as technology goes faster than pediatric surgery, with its reduced indications, can keep up with (6,7). The use of different robot models also impacts on the possibility to compare data published throughout the last two decades, as it is obvious that the docking procedure, for instance, changes radically between two different platforms. Furthermore, some studies focus only on isolated aspects of robotic surgery training and LC for procedures, without mentioning the machine used altogether (12,19,24,26); we believe that this detail is crucial to create more standardized data and to make a statistical analysis possible. Most studies, however, focus on the different evolutions of the same platform: the da Vinci® surgical system. But during the years, this platform has been changing, and very few studies mention its newest model in the entirety of the cases presented (22,25).

Table 1 Studies selected for review

Author	Journal	Year of publication	Robot model	Number of operations	Mean docking (if present) time	Mean operative time	Operation type
Knight *et al.* (6)	*J Pediatr Surg*	2004	Zeus robotic surgery system	24	Port placement 23 min; setup 11 min	195 min	Gastrostomy placement (n=9) and fundoplications (n=15)
Meehan *et al.* (7)	*J Pediatr Surg*	2007	da Vinci surgical robot	50	Port placement 17 min; setup 4 min	122 min	Fundoplication
Sorensen *et al.* (8)	*J Urol*	2011	da Vinci® standard surgical system	33	Not present (peripheral time, comprised of anesthesia, is 80 min)	326 min	Pyeloplasty
Chang *et al.* (9)	*J Laparoendosc Adv Surg Tech A*	2012	da Vinci robotic surgical system	14	Not present	570 min	Choledochal cyst resection

Table 1 (*continued*)

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Author	Journal	Year of publication	Robot model	Number of operations	Mean docking (if present) time	Mean operative time	Operation type
O'Brien *et al.* (10)	*J Pediatr Urol*	2012	The da Vinci robot system	20	Not present	270 min	Pyeloplasty
Herbst *et al.* (11)	*J Laparoendosc Adv Surg Tech A*	2013	da Vinci S surgical system	39	Not present	259.5 min	Pyeloplasty
Tasian *et al.* (12)	*J Urol*	2013	Not present	100 (80 fellows, 20 attending)	Not present	Not present (only console time was recorded)	Pyeloplasty
Leonardis *et al.* (13)	*JAMA Otolaryngol Head Neck Surg*	2013	da Vinci surgical system	13	6 min	34 min	Lingual tonsillectomy
Mason *et al.* (14)	*J Robotic Surg*	2014	da Vinci® standard and Si surgical system	134	Not present	228 min	Pyeloplasty
Cundy *et al.* (15)	*Int J Med Robot*	2015	da Vinci® standard surgical system	57	17.8 min	177.9 min	Fundoplication
Cundy *et al.* (16)	*J Pediatr Surg*	2015	da Vinci® standard surgical system	88	12.1 min	242.1 min	Pyeloplasty
Jones *et al.* (17)	*J Pediatr Surg*	2015	da Vinci Si single-site platform	17	Not present (peripheral time, comprised of anesthesia, is 53 min)	94 min	Cholecystectomy
Murthy *et al.* (18)	*Ann R Coll Surg Engl*	2015	da Vinci surgical system®	52	Not present	203 min	Pyeloplasty
Bowen *et al.* (19)	*J Robot Surg*	2017	Not present	28	Not present	224 min	Pyeloplasty
Radford *et al.* (20)	*J Laparoendosc Adv Surg Tech A*	2018	da Vinci robotic system	25	Not present	148.6 min	Pyeloplasty
Rosales-Velderrain *et al.* (21)	*J Laparoendosc Adv Surg Tech A*	2017	da Vinci Si single site surgical system	14	Not present (peripheral time, comprised of anesthesia, is 47.5 min)	125 min	Cholecystectomy
Binet *et al.* (22)	*Eur J Pediatr Surg*	2019	da Vinci XI system	60	7 min	121.6 min	Fundoplication
Kassite *et al.* (23)	*J Pediatr Urol*	2018	da Vinci surgical system	216	Not present	186.5 min	Pyeloplasty
Junejo *et al.* (24)	*Urol Ann*	2020	Not present	15	Not present (set-up including positioning 26.2 min	153.2 min	Pyeloplasty
Esposito *et al.* (25)	*J Pediatr Urol*	2019	da Vinci XI system	67	31 min (including positioning)	133 min	Pyeloplasty
Andolfi *et al.* (26)	*Front Surg*	2019	Not present	478	Not present	Not present	Multiple urology procedures (nephrectomy, part nephrectomy, pyeloplasty, reimplantation)

Table 2 The search strategy summary

Items	Specification
Date of search	Sep 12, 2022
Databases and other sources searched	PubMed
Search terms used	"robotic", "learning curve"
Timeframe	January 1995 to September 2022
Inclusion criteria	Adult patients, English language
Selection process	Selection was conducted independently

Moreover, even if indications have started to expand, there are still very few procedures thoroughly examined over the years to obtain a relatable idea of the LC for that type of operation. Data to analyze the LC also was various, with the most common parameter employed being the OT. As unspecific as this parameter might be, Tasian *et al.* (12) tried to employ it to create an objective projection of the number of procedures needed to reach proficiency in RALP using an analysis comparing OT from an experienced robotic surgeon with three fellows starting their activity in this field. Their analysis concluded that the OT of the fellows first starting was going to reach the experienced surgeon's around 37 procedures. As generic as it might seem, further studies during the years have tried to add to this examination, attempting to add more objective parameters to the evaluation of the LC. A good example was the cases presented by Kassite *et al.* (23) that started to implement complications and patient's complexity to the equation. Their analysis showed a more structured approach to the creation of a LC for RALP, with the three phases we are more familiar with: a first phase with a rise as the surgeon starts to consider approaching more difficult cases, a second phase where the results improve until a 3rd phase of plateau, where proficiency is considered reach. Still, in their study they show that the number of procedures needed to reach the 3rd phase is around 34 procedures, being close to the old results shown in previous attempts (16). However, it is clear that this kind of examination should also be able to consider many other parameters such as length of hospital stay, length of hospital stay, blood loss, resolution and pain killer use; but it is clearly very challenging to create an objective method to analyze such different variables. Where the possibility to achieve an objective result is instead tangible, is the examination of "docking" time. The problem lies, once again, in the lack of standardization: many papers analyzed in this review differ in the definition of set-up time for the robot. Some do not report this value at all, some consider it being the time between the first incision and the start of the use of the console, others believe that it should be considered from the moment the ports are already placed inside the abdomen (6,7,13,15,16,22,24,25). Also, docking time is greatly influenced by the platform used, therefore data is even less consistent among the years. However, as for the LC for docking, there are still the same three phases identified throughout literature with a much more rapid reach of proficiency. All these factors are crucial to the creation of an efficient training model to prepare young specialists to approach such a rapidly evolving field as robotic surgery, even more so in pediatrics considering the lower number of indications and cases. While approved training modules are being approved for adults, a clear curriculum for pediatric patients is still to be found. There is however general consensus in literature on the steps necessary to achieve proficiency in this field (2): simulators are the first step, with the da Vinci® console offering a wide spectrum of coordination exercises that help the novices grasp the fundamentals of robotic surgery; the second step is animal labs, which let understand the interaction between the robotic instruments and live tissues hands-on; finally, there is the experience in the OR. This last step is crucial as it begins with the observation at first, participating gradually as a bed-side surgeon, understanding all the practical features of the machine and mastering the docking at first. As for the console experience, the more recent versions of the da Vinci® platform, offer a second console that lets switch control back and forth between two operators, allowing proctors to follow their students more closely and reducing risk of mistakes, as both mentor and student share the 3D vision offered by the robot. An interesting way to validate a training model has been employed in a paper by Andolfi *et al.* (26) with a survey conducted among 29 former students of a pediatric urology robotic surgery course. This survey tried to take into account all the procedures performed by their participants, reaching a considerable number of procedures and cementing their training model divided into steps.

Conclusions

The definition of a completely accepted definition of LC and, subsequently, of an entirely sufficient training protocol in robotic surgery for pediatric patients is yet to be grasped. Numerous factors confound the standardization of these important processes, one of the most important being the incredible velocity at which this new technology moves. Still, many progresses have been achieved since the birth of this new field, with a widening spectrum of applications and reduction of the costs allowing to get close to reach the numbers necessary to create a robust training program for future robotic surgeons.

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Footnote

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