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Systematic Review

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Abstract

Aim of the study: This study examines evidence-based indications for robotic-assisted surgery (RAS) in the different fields of pediatric surgery.

Methods: A systematic database search (MEDLINE, Scopus, Web of Science) was performed to identify articles covering any aspect of RAS in the pediatric population. Using Boolean operators AND/OR, all possible combinations of the following search terms were used: robotic surgery, pediatrics, neonatal surgery, thoracic surgery, abdominal surgery, urologic surgery, hepatobiliary surgery, and surgical oncology. The selection criteria were limited to the English language, pediatric patients (under 18 years of age), and articles published after 2010.

Main Results: A total of 239 abstracts were reviewed. Of these, 10 published articles met the purposes of our study with a level of evidence I/II and therefore were analyzed. Notably, most of the articles included in this review reported evidence-based indications in urological surgery.

Conclusions: According to this study, the exclusive indications for RAS in the pediatric population are pyeloplasty for ureteropelvic junction obstruction in older children and ureteral reimplantation according to the Lich-Gregoire technique in selected cases for the need to access the pelvis with a narrow anatomical and working space. All other indications for RAS in pediatric surgery are still under discussion to date, and cannot be supported by papers with a high level of evidence. However, RAS is certainly a promising technology. Further evidence is strongly encouraged in the future.

1. Background

The use of the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) has increased up to 40-fold over the past decade when compared to traditional laparoscopic procedures in general surgery [1]. Improved dexterity, precision, 3D visualization, and ergonomics are robotic-assisted surgical features that allow surgeons to overcome the disadvantages of the traditional (2D) laparoscopic surgery, leading to better surgical results [2]. In addition, several training curricula, on-site training programs, and robotic surgery virtual reality simulators have been developed and are currently being implemented for surgeons and trainees to gain adequate surgical competence [3, 4].

The use of robotic-assisted surgery (RAS) has increased more slowly in pediatrics than in the adult population [5, 6]. Despite the many advantages of robotic instruments, such as the ability to mimic the movements of the human wrist, highly magnified 3D visualization, and tremor filtration, the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) still presents some limitations for use in pediatric surgery. The principal reasons for the low use of this new technology in children are: 1) the difficulty in developing surgical robots and related instruments appropriately sized for smaller children and neonates, and 2) the elevated costs for pediatric hospitals correlated with the smaller volume of patients eligible for robotic procedures [6, 7]. Even though new platforms are being developed, the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) is the leading robotic surgical technology
approved for pediatric use; instruments are available in sizes of 8 and 5 mm and the recommended
distance between the ports is at least 8 cm [7, 8].

The aim of this study was to describe through a narrative synthesis the evidence-based indications for
RAS in the different fields of pediatric surgery according to the published literature.

2. Methods

2.1 Eligibility criteria and information sources

This systematic review was conducted accordingly to the Preferred Reporting Items for Systematic
Reviews and Meta-Analyses (PRISMA) statement (Fig. 1). An electronic search was conducted of
MEDLINE, Scopus, and Web of Science. Using Boolean operators AND/OR, all possible combinations of
the following search terms were used: robotic surgery, pediatrics, neonatal surgery, thoracic surgery,
abdominal surgery, urologic surgery, hepatobiliary surgery, and surgical oncology. The selection criteria
were limited to the English language, pediatric patients (under 18 years of age), and articles published
after 2010.

2.2 Study selection

Titles and abstracts were screened for relevance by two reviewers independently (E.G., MR. C.). All
relevant articles meeting inclusion criteria were selected and any disagreement was resolved by a senior
reviewer (A.B). Commentaries, editorials, short notes, and letters to the editor were excluded.

3. Results

The search retrieved 824 abstracts on pediatric robotic-assisted surgery from electronic databases. Of
these, 75 (9%) focused on thoracic RAS, 80 (10%) on the use of RAS in neonates, 171 (21%) on RAS for
pediatric abdominal procedures, 439 (53%) on RAS in urology, 41 (5%) on the use of RAS in hepatobiliary,
and 18 (2%) on oncological diseases. Primary screening excluded 585 articles consisting of duplicates,
off-topic works, and original languages other than English. Subsequently, 239 abstracts were reviewed.
The selected abstracts included 23 (10%) on pediatric thoracic diseases, 192 (80%) on pediatric urologic
anomalies, and 14 (6%), 8 (3%), and 2 (1%), respectively, on the treatment of pediatric tumors, abdominal
surgical pathologies, and hepatobiliary diseases. Interestingly, none of the articles addressed specific
indications for the use of the da Vinci surgical system in newborns. Figure 2 summarizes the distribution
of RAS publications among the current pediatric literature. Ultimately, 10 published articles with the
highest level of evidence according to the guidelines for therapeutics studies and Oxford Score [9, 10] met
the purpose of our work and were examined. Most of the articles included in this review reported
evidence-based indications in pediatric urological surgery.

4. Discussion
Since the 1980s, minimally invasive surgery (MIS) has demonstrated its feasibility and safety in the adult population compared to open surgery. However, this evidence has not been confirmed in pediatric surgery, and MIS is considered feasible and safe in childhood only when performed by experienced surgeons [11, 12]. RAS is largely adopted in the adult population for urological, gynecologic, and colorectal surgery due to better outcomes in operative time, conversion rate, and length of hospital stay (LOS) [13, 14]. Conversely, the use of RAS in pediatrics is still controversial and evidence-based indications in the current literature are lacking.

This review aimed to describe in a narrative manner the different applications of RAS in pediatrics and to identify evidence-based indications according to the current literature. In the absence of specific literature, the current state of MIS in a subspecialty has been reported in brief.

MIS in neonates and infants is a relatively new field, evolving over the last two decades and requiring the development of new techniques and instruments. The attention of surgeons and industries is focused on developing robotic instruments (3mm or less) able to work in small body cavities and requiring shorter distance between the ports or a single-port access, which could lead to wider use of RAS in newborns and small infants [15, 16]. Furthermore, the use of RAS in some subspecialties, such as for hepatobiliary diseases, is still limited by the lack of comparative studies and large-scale case series that confirm the advantages of laparoscopy in these patients [17]. Interestingly, recent studies including systematic reviews, meta-analyses, comparative studies, and prospective case-series showed the safety and feasibility of laparoscopic surgery for choledochal cyst excision and cholecystectomy [18–21]; however, it cannot be recommended for infants with biliary atresia and pediatric hepatobiliary tumors [22, 23]. Overall, the literature provides evidence supporting the use of MIS; in particular, the indications for RAS in pediatric patients presenting hepatobiliary diseases remain very scarce [17, 24, 25]. Additionally, although a panel of experts recently stated that for pediatric living donor liver transplantation MIS should be the standard approach for left lateral section donor hepatectomies, RAS for living donor hepatectomy could be considered an alternative for skilled surgeons but requires further investigation [26, 27].

The use of the da Vinci surgical system has been reported in the general thoracic field since the beginning of this century. The first report of RAS for the treatment of thoracic pathologies in adults was published in 2002. However, controversy remains about the application of RAS, with a lack of evidence in the adult population [28]. In the pediatric population, video-assisted thoracoscopic surgery (VATS) seems to have many advantages when compared with traditional thoracic surgery. Nonetheless, the level of evidence is not high enough [29]. Further, robotic-assisted thoracoscopic surgery (RATS) in children presents several technical difficulties for neonatal surgeries in particular. In two retrospective multicentric studies recently published, the authors concluded that RATS could be suitable for older children with a body weight of at least 15–20 kg, and currently there is a persistent lack of evidence that lower weight children and neonates are candidates for RATS due to an incompatibility between the size of the robotic instruments, the intercostal space, and the small thoracic working space [30, 31].
To date, the most common procedures described using the da Vinci Surgical System are pyeloplasty and ureteral reimplantation, followed by fundoplication of the stomach [5, 32]. Interestingly, a review of the literature and a meta-analysis reporting outcomes of children undergoing mini-invasive fundoplication found no significant difference in terms of operating time, length of hospital stay, and postoperative complications. Nevertheless, the results are significantly limited by the absence of long-term follow-up [33, 34]. Moreover, numerous case reports and series in the current pediatric literature document diverse successful applications of RAS for abdominal surgical procedures such as splenectomy, Heller’s myotomy, intestinal anastomosis, anorectal pull-through (e.g., for Hirschsprung disease), ovarian cystectomy, and salpingo-oophorectomy [35–39]. However, further studies are needed to evaluate whether RAS in these procedures gives a real advantage over MIS. Conversely, an analysis of the literature shows that the main indication of RAS in pediatrics is represented by pediatric urology indications. Specifically, the main indications for RAS in pediatric urology are: 1) pyeloplasty for ureteropelvic junction obstruction, and 2) ureteral reimplantation according to the Lich-Gregoire technique, principally in case of bilateral reflux or high degree reflux with megaureter [35, 40–42]. Notably, even though several studies have documented advantageous outcomes in older children, the application of RAS in infants with urological diseases weighing less than 10 kg is still being investigated and a cut-off weight has yet to be determined [6, 43, 44].

Lastly, oncological pediatric surgery deserves a special mention about RAS. Undoubtedly, RAS is rare in pediatric oncology due to the rarity of pediatric tumors, and the principal matter of debate remains whether the fundamental oncological principles of no spillage and total resection of the margins can be fulfilled with the use of RAS [6, 35, 45].

The future of RAS in pediatrics depends on advancing technologies and the demand for smaller robotic devices. This will probably result in a reduction of instrument size, an improvement in haptic feedback, and development of a more cost-effective surgery, in turn leading to the adoption of new robotic platforms able to work in small cavities and so extending this promising technology to infants and neonates [7, 8, 46, 47].

5. Conclusions

To date the indications for RAS in the pediatric population are limited to pyeloplasty for ureteropelvic junction obstruction in older children and ureteral reimplantation according to the Lich-Gregoire technique in selected cases for the need to access the pelvis with a narrow anatomical and working space. All other indications for RAS in pediatric surgery are still under discussion to date, and cannot be supported by papers with a high level of evidence. However, RAS is a promising technology and further evidence is strongly encouraged in the future.

Abbreviations

RAS = robotic-assisted surgery;
MIS = minimally invasive surgery;
RATS = robotic-assisted thoracoscopic surgery;

Declarations

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References


Figures
Figure 1

PRISMA flow chart of literature review.
Figure 2

The prevalence of RAS publications among the different pediatric surgical subspecialties.