

ADVANCES AND APPLICATIONS OF ROBOTIC SURGERY IN PEDIATRIC PATIENTS: AN INTEGRATIVE REVIEW

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Abstract: The objective of this integrative review is to examine and synthesize the existing literature on the use of robotic surgery in pediatric patients, with a focus on several specialties, including neurosurgery, urology, spinal deformity corrections, and treatment of ectopic organs. The review evaluates the efficacy, safety, benefits and challenges of this innovative surgical approach. A comprehensive search was performed on PubMed, covering publications up to September 2023. The initial search resulted in 150 articles. Seven studies were selected for the final review. Data from selected articles were organized in a table for descriptive and comparative analysis. The results indicate that robotic-assisted laparoscopic surgery is technically feasible and comparable to traditional open surgery in pediatric patients. However, large case series and randomized clinical trials are needed to further validate these techniques. The review provides comprehensive insights into the current state and future prospects of robotic surgery in pediatrics, highlighting its benefits, limitations and clinical implications.

Keywords: robotic surgery, pediatric, neurosurgery, urology, spine surgery, ectopic organs, safety, efficacy, complications, results

INTRODUCTION

Robotic surgery has emerged as a revolutionary approach in medical practice, offering significant advances in the precision and effectiveness of various procedures. Although widely adopted in adult surgeries, its use in pediatric patients is gradually gaining recognition and acceptance. The advantages of robotic surgery, such as expanded three-dimensional vision, tremor filtering and range of motion, have allowed precise exposure and intracorporeal suturing, essential for complex procedures in pediatric urology (ANDOLFI et al., 2019).

Robotic-assisted surgery, particularly bladder neck procedures for incontinence in pediatric patients, has been shown to be safe and effective. Studies indicate that these techniques present continence rates equivalent to traditional open surgeries, with additional benefits, including less intraoperative blood loss, better cosmesis and decreased formation of intra-abdominal adhesions. However, longer operational times and the initial learning curve are recognized challenges, especially in the initial phases of implementing these techniques (GARGOLLO; WHITE, 2019).

The application of robotic surgery to infants, although challenging due to the reduced workspace and the need for delicate surgical instruments, has shown considerable benefits. Studies report less post-operative analgesic use, shorter hospital stays, and low complication rates, with the majority of adverse events being Clavien Grade 1 and 2. These findings are especially relevant in the pediatric setting, where rapid recovery and minimization of discomfort are priorities (KIM, 2019).

Review of current literature reveals that robotic-assisted laparoscopic surgery (RALS) is technically feasible and comparable to traditional open surgery in terms of surgical outcomes in pediatric patients. Procedures such as pyeloplasty, radical and partial nephrectomy, ureteral reimplantation and bladder neck reconstruction are some examples of interventions where RALS has been successfully applied. However, the need for large case series and randomized controlled trials is emphasized to further consolidate the efficacy and safety of these techniques (ANDOLFI et al., 2019).

This article aims to review and discuss the advances and applications of robotic surgery in pediatric patients, with a focus on urological procedures. The benefits, limitations and

future potential of this approach in pediatric medical practice will be addressed, aiming to provide a comprehensive understanding of the current state and future prospects of robotic surgery in this field.

METHODOLOGY

The objective of this integrative review was to analyze and synthesize the available literature on the use of robotic surgery in pediatric patients, focusing on several specialties such as neurosurgery, urology, corrections of spinal deformities and treatment of ectopic organs. The review sought to evaluate the efficacy, safety, benefits and challenges of this innovative surgical approach. The literature search was conducted in the PubMed database, covering publications from inception to September 2023. The search terms used were “robotic surgery,” “pediatric,” “neurosurgery,” “urology,” “spine surgery,” “ectopic organs,” “safety,” “efficacy,” “complications,” and “outcomes,” combined using Boolean operators (AND, OR) to refine the search and include all relevant variations on the theme. The inclusion criteria for selecting the studies were: articles published in English; studies that specifically addressed the use of robotic surgery in pediatric patients; studies that reported results on the efficacy, safety, complications and benefits of robotic surgery; and types of studies such as systematic reviews, meta-analyses, cohort studies, case-control studies and case series. The exclusion criteria were: articles that addressed robotic surgery in adults; studies carried out on animals; articles with inadequate methodology or pilot studies with very small samples; and publications without access to the full text.

The initial search resulted in 150 articles, and 120 articles were considered for screening titles and abstracts. Of these, 75 were excluded because they did not meet the inclusion criteria. The remaining 45 articles were read

in full, resulting in the exclusion of 38 articles that did not meet the inclusion criteria. Therefore, 7 studies were selected for the final review. Data were extracted from the selected articles and organized in a table, including the following information: authors and year of publication, objective of the study, type of study and methodology, main results and conclusions, and limitations of the study. Data analysis was conducted in a descriptive and comparative manner, synthesizing the findings on the effectiveness, safety and complications associated with robotic surgery in pediatric patients. Study results were synthesized to identify patterns and discrepancies in findings, providing a comprehensive view of the current state of robotic surgery in pediatrics. Discussion of the results included comparison of the benefits and challenges reported in the different studies, as well as the clinical implications of the findings.

The integrative review provided an in-depth understanding of the available evidence on robotic surgery in pediatric patients, offering valuable insights for clinical practice and pointing to directions for future research.

RESULTS

This table summarizes the evidence from several studies on the use of robotic surgery in pediatric patients, highlighting the effectiveness, safety, complications and economic aspects of robotic procedures compared to traditional approaches.

DISCUSSION

Robotic surgery has emerged as a significant innovation in several pediatric specialties, offering advances in precision and safety. Several studies provide detailed insight into the efficacy, safety, and challenges associated with using this technology in pediatric patients. In the research by Lu et al. (2023) performed a systematic review and meta-analysis on frameless and robot-assisted biopsy of pediatric brainstem lesions. The study analyzed eight cohort studies that involved 99 pediatric patients. The success rate in obtaining tumor diagnoses was 100%, with a 95% confidence interval between 97% and 100%, indicating high certainty. Transient complications occurred in 10% of cases, while there were no permanent complications, showing that the technique is safe when performed in specialized environments. These data highlight the effectiveness of robotic biopsy and the need to integrate robots and automated technologies into clinical protocols to further improve outcomes.

Ferong et al. (2020) sought in their research to evaluate robot-assisted laparoscopy in pediatric patients with ectopic organs and differences in sexual development (DSD). The analysis involved six patients, including three boys with uterine cysts, two girls with ectopic kidneys and one boy with pelvic embryological remains. Robotic surgery has proven to be a safe and viable option for these complex cases, allowing for deep dissections and precise reconstructions in limited surgical fields. This study reinforces the applicability of robotics in rare and complex conditions, providing better surgical results.

In the study by Satyanarayan and Peters (2020) they reviewed the evolution of robotic surgical technology in pediatric urological reconstruction, focusing on pyeloplasty and ureteral reimplantation. The results indicate significant variations in the use of these

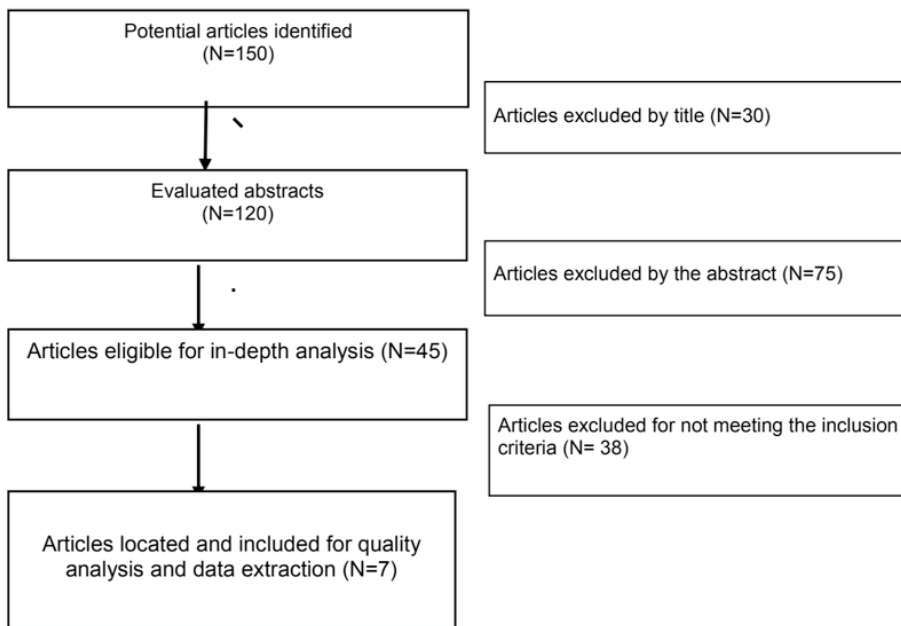


Figure 1.0: Flowchart of the distribution of articles found and selected

Source: Alves GR et al. (2024).

Study	Procedure/Indication	Main Results
Lu et al., 2023	Biopsy of brain stem lesions	High efficacy with 100% success rate in obtaining a diagnosis. Transient complications in 10% and no permanent complications. No procedure-related mortality.
Ferong et al., 2020	Resection of embryological remains, ectopic kidneys	Robotic surgery has been shown to be safe and feasible to treat DSD and ectopic kidneys, requiring deep dissection and reconstruction in a limited field.
Satyanarayan and Peters, 2020	Ureteropelvic junction obstruction, vesicoureteral reflux	Variation in patient selection and learning curve affect the utilization of pyeloplasty and ureteral reimplantation. Potential to reduce morbidity and increase efficacy.
Cirrincone et al., 2023	Spine surgery	Robotic navigation has shown high accuracy and safety in pedicle screw placement in children, with a moderate learning curve.
Vinit et al., 2023	Various pediatric surgical procedures	RALS is safe with a low complication rate (22%) and a 4% conversion rate. Clavien-Dindo complications \geq III in 5% of children.
Hou et al., 2023	Pediatric urological procedures	RALS is effective in procedures such as pyeloplasty, partial nephrectomy and ureteral reimplantation, with results comparable to or better than open/laparoscopic surgery.
O'Kelly et al., 2020	Training models and cost	Robotic platforms are safe and effective, but they are expensive. Benefits include magnification, dexterity, and tremor reduction.

Table 1.0: Studies used in the integrative review on the use of robotic surgery in pediatric patients.

Source: Alves GR et al. (2024).

techniques, influenced by patient selection and the surgeons' learning curve. They noted that despite initial challenges, robotic surgery can reduce morbidity and increase effectiveness in treating congenital conditions, demonstrating its potential in pediatrics.

The investigation by Cirrincione et al. (2023) focused on robotic-assisted surgery for pedicle screw placement in pediatric spinal surgeries. They reported high accuracy and safety in screw placement, with a moderate learning curve. Furthermore, they highlighted that, in addition to the thoracic and lumbar spine, the placement of screws in the pelvis and sacrum was also successful. Robotic navigation has proven to be a reliable tool for complex pediatric spine procedures, offering significant advantages compared to traditional techniques.

Vinit et al. (2023) investigated morbidity associated with robot-assisted laparoscopic surgery (RALS) in a pediatric multidisciplinary program. The study included 300 consecutive surgeries in various specialties, such as urology, digestive surgery, oncology, otolaryngology and thoracic surgery.

With a complication rate of 22% and a conversion rate of 4%, the results indicate that RALS is safe and effective, even in vulnerable children. Robot-specific complications were minimal, reinforcing the viability of this technology across a broad spectrum of pediatric procedures.

The study by Hou et al. (2023) reviewed the indications and outcomes of several

robot-assisted pediatric urological procedures. They concluded that RALS offers significant benefits in perioperative and postoperative outcomes, with results comparable to or superior to traditional approaches. However, they highlighted the need for more studies to validate these results, evaluate the learning curve and associated costs.

O'Kelly et al. (2020) discussed the cost, training, and simulation models for robotic-assisted surgery in pediatric urology. They noted that despite high costs, robotic platforms offer significant benefits, such as improved dexterity and reduced tremors. However, they emphasized the importance of considering costs and the need for adequate training to maximize the benefits of this technology.

FINAL CONSIDERATIONS

Pediatric robotic surgery demonstrates great potential in several specialties, offering high precision, safety and effectiveness. However, challenges such as the learning curve, costs and need for adequate training must be carefully considered. The continuous evolution of robotic platforms and the integration of new technologies are essential to further improve surgical outcomes and quality of life for pediatric patients. Comparing studies, it is clear that robotic surgery is advancing rapidly, but requires a balanced approach that considers both benefits and challenges to ensure safe and effective adoption into pediatric clinical practice.

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