RESEARCH PAPER

The Role of Robotic Surgery Across the Age Spectrum: a Comparative Systematic Review of Paediatric and Geriatric Populations

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ABSTRACT
Background: Surgery is a cornerstone of contemporary healthcare, providing essential interventions that save lives and enhance the quality of life across diverse medical disciplines. Robotic surgery (RS), also known as robot-assisted surgery (RAS), is an advanced form of minimally invasive surgery that merges medical science with engineering. Originally developed through NASA and DARPA research in the 1970s, RS enables remote-controlled procedures in complex or high-risk environments. The technology enhances precision using systems like the Da Vinci robot, which operates on a master-slave model with a surgeon-controlled console. It offers benefits such as stereoscopic vision, fine tissue handling, and reduced recovery time, though limitations include cost and technical issues. RS is increasingly applied across age groups, especially in paediatric and geriatric patients due to their unique surgical challenges. Children benefit from quicker healing and minimal scarring, while elderly patients experience less trauma and better recovery.This review explores the global use of RS in these populations, comparing outcomes, complications, and healthcare efficiency. Methodology: Criteria : Studies published in English from 2014–2024 focusing on patients under 18 or 65 and older, involving RAS across specialties with detailed surgical outcome data were considered, with exclusion of studies without robotic surgery that lack specific outcome data for paediatric or geriatric patients. Strategy: A comprehensive electronic research was conducted across multiple databases, including PubMed and ResearchGate, to identify relevant articles using keywords such as Robot-Assisted Surgery(RAS) / Robotic Surgery (RS), Paediatric Surgery, Geriatric Surgery, Minimally Invasive Surgery. PRISMA 2020 guidelines were followed. Data Collection: Outcomes such as complication rates, conversion to open surgery, length of hospital stay, and mortality rates were extracted for comparative analysis. A total of 23 studies were included in the final analysis after screening 232 records from various databases. Conclusion: Robotic-assisted surgery (RAS) remains nascent in paediatric and geriatric care, even though it's ubiquitous in adult urologic, gynecologic, and colorectal operations. In children, it is chiefly applied to pyeloplasty and ureteral reimplantation, where its superior accuracy and minimally invasive profile manifesting as less bleeding, lower infection rates are most evident, while older patients likewise benefit from an accelerated return to independence. Steep expenses and a dearth of suitably sized instruments have curtailed broader uptake. Designed to overcome the limits of standard laparoscopy including poor depth perception, awkward positioning, hand tremors and challenging hand-eye coordination, robotic platforms continue to evolve and is expected to grow widely if limitations are overcome..

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1.INTRODUCTION

Surgery is a cornerstone of contemporary healthcare, providing essential interventions that save lives and enhance the quality of life across diverse medical disciplines. The continuous evolution of surgical methods, from traditional open surgeries to advanced minimally invasive procedures to the evolving robot-assisted surgeries (RAS), has significantly improved patient outcomes and recovery experiences. The trend in open surgeries has been declining, with application restricted to complex procedures, such as organ transplants and certain cardiac operations, where comprehensive access is necessary.

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Laparoscopic surgery has experienced significant growth over the past two decades driven by advancements in minimally invasive techniques and technology (1). This surge is attributed to the benefits of laparoscopic methods, such as reduced postoperative pain, shorter hospital stays, and faster recovery times. Additionally, the adoption of robotic-assisted laparoscopic surgery has further expanded the scope and precision of minimally invasive procedures (2).

Robotic surgery (RS) is an advanced evolution of minimally invasive surgery that integrates medical science with robotics and engineering. Also known as robot-assisted surgery, this highly developed technique utilizes specialized robotic platforms in order to enhance surgical precision, particularly in complex procedures and small anatomical spaces (3). A research in robotics financed by NASA and the United States Defense Research Advanced Projects Agency during the 1970s led to the invention of RS. The goal is to develop a system that allows surgical procedures to be remotely controlled, enabling operations to be performed without direct human intervention. This advancement aims to replace surgeons in high-risk or hard-to-reach environments, such as battlefields and space missions, where immediate medical intervention is critical but traditional surgical presence may not be feasible (3,4).

A variety of the RS systems have been developed. Each consists of two components - surgeon's console and control devices. The surgeon's console is fitted with a built-in, three-dimensional vision on a real-time image screen which gives a magnified view of the target area. The control devices include various tools and robotic instruments which work on the human tissues in a fine and precise manner (5). The Da Vinci system is one of the most populous, FDA approved surgery system. It is a teleoperated robotic platform operating on a master-slave principle, allowing the surgeon to control the four robotic arms from a console ensuring smooth and accurate movement (3). RS offers several advantages that enhance surgical precision, efficiency, and patient outcomes. One key benefit is stereoscopic vision with in-depth perception, allowing for enhanced visualization of anatomical structures. The drawbacks include limited availability, required training, and high costs. Mechanical failures may occur due to membrane wear, instrument or arm alterations, console defects, optical issues, and software problems (6).

Robot-assisted surgeries (RAS) are becoming increasingly common across all age groups, from children to the elderly. Paediatric and geriatric populations were chosen due to their unique surgical challenges. Paediatric patients have distinct anatomical and developmental factors, while geriatric patients often have comorbidities and reduced physiological reserves. The middle-aged group was not included because they generally have better physiological resilience and fewer surgical complexities compared to the other two age groups. In paediatrics, these advanced procedures offer precise, minimally invasive techniques leading to quicker recovery times and minimum scars. For geriatric patients, RAS provides significant benefits by minimizing surgical trauma, which is crucial for those with age-related health conditions. While RAS has been studied in high-risk populations separately, it remains unexplored as a comparative analysis.

The key purpose of the review is to analyze the global scope of robot-assisted surgeries in both paediatric and geriatric populations. It highlights the impact on surgical outcomes, recovery times, post surgery complications and overall healthcare efficiency in various branches.

AIM

A systemic review on advancements in robotic surgery for paediatric and geriatric population with the aim of :

Comparative evaluation of the advancements, benefits, and limitations of robotic technology in these age groups.

Examine the current trends and future directions in the adoption of robotic-assisted procedures for these vulnerable patient populations.

METHODOLOGY

Criteria considered for study selection: Randomized controlled trials, cohort studies, case-control studies, case series and narrative reviews were considered that evaluated the application of RAS across various surgical specialties.

Search strategies : A comprehensive electronic research was conducted across multiple databases, including PubMed and ResearchGate, to identify relevant articles discussing Robot-Assisted Surgery in both paediatric and geriatric populations using keywords such as Robot-Assisted Surgery(RAS) / Robotic Surgery (RS), Pediatric Surgery, Geriatric Surgery, Minimally Invasive Surgery. Furthermore, keywords were combined using and/or in order to refine search results. Moreover, filters like publication date after 2014 were applied. PRISMA 2020 guidelines were followed.

Study selection : In the systematic review of Robot-Assisted Surgery (RAS) in pediatric and geriatric populations, specific inclusion criteria were established to ensure the selection of relevant studies. Eligible studies were those published in English within the last 10 years (2014–2024) and focused on patients under 18 years of age for the paediatric group and 65 years or older for the geriatric group. This approach aimed to capture insights into the unique challenges, benefits, and outcomes of RAS in these age groups. Studies were required to provide detailed data on surgical outcomes, including metrics such as operative time, complication rates, conversion to open surgery, length of hospital stay, and mortality rates. Studies were excluded if they focused on non-robotic surgical interventions or lacked detailed data on surgical outcomes specific to pediatric or geriatric population

Findings : A total of 23 studies were ultimately included in the final analysis after reviewing 232 records from multiple databases. These studies encompassed various types of robot-assisted surgeries performed in both paediatric and geriatric populations, with sample sizes ranging from 3 to 950 participants. Most of the research was concentrated on the geriatric group, with fewer studies available on paediatric cases, highlighting a greater focus and data availability for RAS in older adults. This trend reflects increased clinical attention toward surgical outcomes in the elderly. The majority of procedures

involved gynecological, urological, and abdominal surgeries. Overall, postoperative complications were minimal, with only a few isolated instances reported.

Data extraction: After a thorough review and screening of the available literature, a total of 23 articles were deemed relevant and have been included as references for this study. These selected studies provide a comprehensive overview of the advancements, clinical applications, success rates, complications, and comparative effectiveness of RAS in paediatric and geriatric patients. Data extraction focused on key aspects. Study characteristics, including authors, publication year, country, and study design, were recorded to provide context and assess research validity. Patient demographics such as age, sex were documented to understand the study population and potential risk factors. Surgical details, including the type of procedure, operative time, were analyzed to evaluate procedural efficiency and advancements in particular fields. Outcomes such as complication rates, conversion to open surgery, length of hospital stay, and mortality rates were extracted to assess the safety and effectiveness of RAS in these aspects.

Heterogeneity : Heterogeneity refers to the differences in study findings that can arise from variations in design, population characteristics, interventions, and measured outcomes. Assessing heterogeneity is crucial to understand the generalizability of systematic review results. The studies included in this review may have employed varying methodologies, such as retrospective and prospective cohort designs, clinical trials, or randomized controlled trials (RCTs). These methodological differences can contribute to discrepancies in results, as observational studies are more prone to bias compared to RCTs. Additionally, variations in inclusion and exclusion criteria such as patient age or treatment methods can lead to the variable results of concerned populations across studies. Differences in the age range, sex, surgery type and predisposing factors can be a few factors to introduce variability in how robotic surgery impacts outcomes The heterogeneity is also seen in sample size like the number of patients involved varied significantly across studies, ranging from a few to hundreds.

RESULTS

A total of 23 studies were included in the final analysis after screening 232 records from various databases. The selected studies covered a range of robotic-assisted surgeries in paediatric and geriatric populations, with sample sizes varying from 3 to 950 patients. The majority of the included studies focused on the geriatric population with only limited studies on paediatric groups , indicating a higher prevalence of research on Robot-Assisted Surgery (RAS) in older patients. This suggests greater clinical interest and data availability for surgical outcomes in elderly individuals compared to pediatric patients. A substantial number of studies indicate that RAS is most commonly used in gynecological, urological, and abdominal surgeries. Overall, there were no major post operative complications that were observed except a few cases.

Figure 1. PRISMA 2020 flow diagram of the study selection process

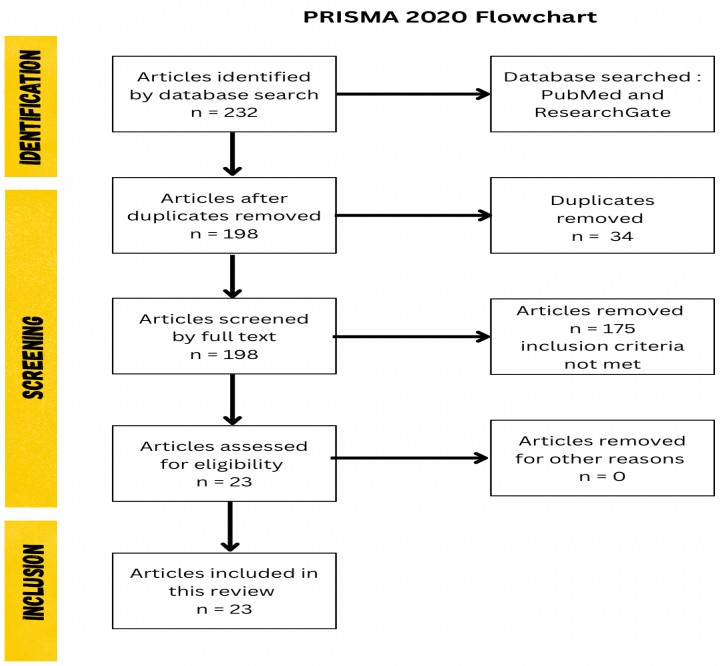


Table 1. Summary of included studies in the geriatric population

Title with geographical location	Author	Branch with concerned region	Total no. Of cases	Post surgery follow up	Findings
Robot-assisted surgery in elderly and very elderly population: our experience in oncologic and general surgery with literature review (Italy)	Graziano Ceccarelli et al.	General surgery +oncology (Abdomen)	402	High comorbidity among patients above 80 years.	Minimally invasive surgery (MIS) offers improved short-term outcomes over open surgery, including fewer perioperative complications, faster recovery, and better quality of life. Robotic-assisted surgery (RAS) is a safe and effective option for the aging population.
Robotic versus laparoscopic colorectal surgery in elderly patients in terms of recovery time: a monocentric experience (Italy)	Giuseppe Palomba et al.	Colorectal surgery (Abdomen)	L=51 R= 32	Post surgical fever, nausea, vomiting, transfusion and occlusion in 8 patients.	Colorectal robotic surgery in elderly patients is a safe and viable option compared to laparoscopic surgery, providing faster recovery and shorter hospital stays while maintaining comparable oncological outcomes, despite longer operating times.
Robotic-assisted Gynecological Surgery in Older Patients– a Comparative Cohort Study of Perioperative Outcomes (Germany)	Anke R. Mothes et al.	Gynaecology	63	No severe complications	Despite higher comorbidities and obesity rates, robotic-assisted gynecological surgery safely treats complex oncological cases in patients over 65 without increased postoperative morbidity.
Robotic-assisted Gynecological Surgery in Older Patients– a Comparative Cohort Study of Perioperative Outcomes (Germany)	Anke R. Mothes et al.	Gynaecology	179	No severe complications	Since perioperative parameters and complications showed no difference from the older comparison group, age should not be considered a limitation for robotic-assisted gynecological surgery.
Perioperative and continence outcomes of robotic radical prostatectomy in elderly Indian men (≥70 years): A sub-group analysis (India)	Rajiv Yadav et al.	Urology (Prostate)	39	Minor complications within 8 days: a minimal anastomotic site leak, requiring replacement and extension of Foley drainage.	The surgical outcomes of RAS in older men are largely similar to those in younger patients, aside from a temporary delay in recovery with low perioperative morbidity . Therefore, age alone should not be a barrier to RAS for clinically localized prostate cancer.

Is Robotic-Assisted Surgery Safe in the Elderly Population? An Analysis of Gynecologic Procedures in Patients ≥ 65 Years Old (New York)	Alessia Aloisi et al.	Gynaecology	R=982	Postoperative complications (Grades 1–5) related to the wound or skin, followed by genitourinary and gastrointestinal issues.	Robotic-assisted gynecologic surgery is a practical and safe approach for elderly patients. It should be an option for carefully selected individuals, including the very elderly.
Robotic Surgery in the frail elderly: analysis of perioperative outcomes. (New York)	Alessia Aloisi et al.	Gynaecology	Frail =71, non frail =911	Readmission due to gastrointestinal issues (30.6%) and wound-related problems.	RAS is a viable and safe option for frail elderly patients, no association between frailty and 90-day mortality is present. However, these patients should be considered high-risk due to prolonged hospital stays, increased postoperative and major complications.
Robotic versus open oncological gastric surgery in the elderly: a propensity score-matched analysis (Italy)	Giovanni Maria Garbarino et al.	Gastric surgery (Abdomen)	Open = 77, R=46	Reoperation in 2 patients for a duodenal stump leak and twisting of the gastrojejunal anastomosis. Endoscopic dilation for anastomotic stenosis in 3rd patient.	Robotic surgery for gastric cancer is safe and effective, with outcomes comparable to open surgery. It may reduce pain and complications but is not proven superior to conventional minimally invasive surgery.
Trends in the Adoption of Robotic Surgery for Common Surgical Procedures (US)	Kyle H. Sheetz et al.	General surgery	R=13500 L=85326 O=70587	-	Robotic surgery is rapidly expanding across various general surgical procedures, leading to a decline in the use of established minimally invasive techniques like laparoscopy, which was already regarded as a safe and effective option for most surgeons when feasible.
Impact of Age on Surgical Outcomes after Robot Assisted Laparoscopic Hysterectomies (US)	A. Eddib et al.	Gynaecology (Hysterectomy)	399	2 intraoperative conversions and extensive adhesions. ICU admission for a difficult intubation.	Although advanced age does not seem to increase the risk of morbidity or adverse perioperative outcomes in gynecologic robotic-assisted surgery, further research is needed to confirm its safety in the growing elderly population.

Table 2. Summary of included studies in the paediatric population

Title with geographical location	Author	Branch with concerned region	Total no. Of cases	Post surgery follow up	Findings
Robotic Surgery in Head and Neck in Pediatric Population: Our Experience (India)	C. Venkata karthikeyan et al.	Head and Neck	3	No complications	Paediatric robotic surgery is a safe and effective technique that can be performed in tertiary care centers by skilled surgeons. Larger multicenter studies are needed to compare it with other head and neck surgical approaches.
Robotic-assisted surgery in the pediatric surgeons' world: Current situation and future perspectives (China)	Hong Mei and Shaotao Tang	General surgery, Cardiac, Urology, Head and neck	-	Complications include biliary leakage, wound disruption and anastomotic stenosis along with conversion due to exposure difficulties.	Paediatric robotic-assisted surgery is now an established practice, but its advantages over traditional laparoscopic or open methods need further validation through robust prospective studies, with cost and technical limitations posing major challenges.
Paediatric robotic surgery: a narrative review (Ireland)	Lukas Padraig O'Brien et al.	Urology, General surgery, Cardiothoracic , ENT, neurosurgery, oncology	-	Comparable to laparoscopic surgery for the same procedure.	Paediatric robotic surgery is still in its early stages, requiring larger prospective studies to fully evaluate its benefits and limitations compared to open and laparoscopic surgery.
Robotic-assisted surgery for gynecological indications in children and adolescents: European multicenter report (Europe)	Ciro Esposito et al.	Gynaecology	23	Cyst recurrence occurred in 1 patient.	RAS is a viable and safe approach for pediatric gynecological surgery, though there is no clear evidence proving its advantage over traditional laparoscopy. Its use in pediatric surgery remains restricted, except in pediatric urology.
Robotic-assisted surgery in pediatrics: what is evidence-based?— a literature review (Italy)	Alessandro Boscarelli et al.	-	-	-	RAS is widely used in adults for urological, gynecologic, and colorectal surgery, but its role in paediatrics remains limited and controversial. In children, it is primarily indicated for pyeloplasty and ureteral reimplantation.
Examining the Potential of Advanced Robotic- Assisted Thoracic Surgery in Pediatric Cases (Turkey)	Ülgen Çeltik et al.	Thorax	31	Complications such as Horner syndrome, swallowing dysfunction, atelectasis, pleural effusion, prolonged air leakage in 8 patients.	RAS provides better visualization and precision in complex cases, but more research is needed to define its role in paediatric surgery. RAS may be useful for redo procedures.

Application and prospects of robotic surgery in children: a scoping review (China)	Lei Ting Shen et al.	Urology, Cardiothoracic, Oncology, General Surgery	-	Good post operative recovery with a few complications.	RAS is beneficial in pediatric surgery for complex anatomy in small spaces, offering advantages over laparoscopy. However, its use in children is still being explored.
Robotic surgery in paediatric patients: Our initial experience and roadmap for successful implementation of robotic surgery programme (India)	Arvind Sinha et al.	Urology, Gynaecology	111	Laparoscopic ileal perforation repair for postoperative intestinal obstruction in bladder diverticulum patient. No mortality occurred.	The limited number of paediatric cases suitable for robotic surgery makes it more cost-effective to share the robot with high-turnover specialties. Further miniaturization of trocars, instruments, and the docking system is needed to optimize surgery in young children.
Narrative review: robotic pediatric surgery—current status and future perspectives (London)	Amulya K. Saxena et al.	Genitourinary, Thorax, Oncology	7	Postoperative complications included twisted Roux limb, intestinal obstruction, intestinal perforation, and one redo surgery.	Despite its advantages over conventional minimally invasive surgery, robot-assisted procedures in children are still in their early stages. While RAS is safe, it has yet to become the gold standard.

DISCUSSION

Robotic-assisted surgery (RAS) is well-established in adult populations, owing to its demonstrated feasibility, safety, and advantages over traditional open surgical techniques. However, its application remains limited in both paediatric and geriatric populations. In recent years, the use of RAS in geriatric patients has become more common, supported by a growing body of research and evidence-based data confirming its safety and effectiveness in this age group. In contrast, the adoption of RAS in paediatric surgery remains minimal. This is primarily due to the lack of appropriately sized instruments and other technical and logistical challenges unique to this population.

RAS in Geriatric Population

A study conducted by A. Eddib evaluating hysterectomy procedures in elderly patients demonstrated that robotic-assisted surgery (RAS) effectively mitigated many of the limitations associated with traditional laparoscopic techniques. Despite a higher prevalence of comorbidities in this age group, no major complications were observed. Additionally, mean operative time and intraoperative blood loss were comparable to outcomes reported in younger cohorts undergoing the same procedure (7). A separate cohort study involving a range of gynecological surgeries further confirmed the safety of RAS in elderly patients, including those classified as frail. Compared to open surgery—which often necessitates adhesiolysis and is associated with longer operative times and higher rates of postoperative complications—RAS was associated with more favorable outcomes (9).

Subsequent large-scale studies reinforced these findings, identifying gastrointestinal complications as the most common cause of readmission following RAS in elderly patients, with rare instances resulting in mortality. Notably, patients over the age of 85 were at increased risk of adverse outcomes, even in the absence of surgical intervention. Within the geriatric population, frailty emerged as a significant predictor of postoperative risk. Frailty is typically defined by the presence of at least three of the following five criteria: more than five comorbidities, reduced physical activity, significant weight loss, persistent fatigue, and general physical weakness (8,10).

In the context of urologic procedures, a study by Rajiv Yadav on robotic-assisted prostatectomy revealed that with careful patient selection, only minor complications occurred. Other perioperative outcomes, such as estimated blood loss and length of hospital stay, were consistent with those seen in other RAS applications (11). Comparative studies between laparoscopic and robotic-assisted approaches have consistently demonstrated the advantages of RAS, including lower conversion rates, reduced incidence of postoperative complications, shorter hospitalization, and faster recovery (12).

In oncologic gastric surgery, Giovanni Maria Gabarino reported that RAS offered superior postoperative outcomes compared to open surgery. Benefits included faster return of bowel function, fewer postoperative fevers and wound infections, and reduced pain levels. Importantly, the use of

pneumoperitoneum in elderly patients did not result in any adverse effects (13). A literature review by Graziano Ceccarilli focusing on RAS in oncologic procedures echoed these findings, emphasizing the clear benefits of robotic approaches over open and laparoscopic methods. However, it also underscored that among frail patients, the overall complication rate remained high regardless of surgical technique (14).

RAS in Paediatric Population

Robotic-assisted surgery (RAS) has increasingly been explored across various paediatric surgical specialties, with growing evidence supporting its safety and feasibility. In a study conducted by Ciro Esposito involving gynecological procedures in children and adolescents, the use of the da Vinci Xi surgical system significantly improved both surgical coordination and visualization. Notably, there were no reported intraoperative or perioperative complications, establishing the procedure's safety profile in this age group (15).

In the context of head and neck surgeries, robotic systems have demonstrated technical advantages, particularly due to the multi-articulated arms that can navigate confined anatomical spaces such as the neck. This, combined with minimal incision sizes, has enabled functionally and cosmetically favorable outcomes, including scarless surgeries. Benefits such as reduced blood loss, shorter hospital stays, and fewer postoperative complications were also observed. Supporting these findings, research conducted in Turkey on robotic thoracic surgeries found no significant difference in conversion or complication rates due to variations in patient weight. The study further indicated that RAS could be safely utilized for redo procedures, emphasizing its precision and adaptability in complex cases (16,17).

Despite the promising outcomes, the implementation of RAS in paediatric surgical programs remains limited. Arvind Sinha noted a low number of pediatric cases in robotic surgery programs, potentially due to insufficient data demonstrating its benefits in this population. Moreover, challenges such as non-ideal instrumentation sizes and economic constraints were highlighted as key factors limiting its broader adoption. These challenges suggest the need for system optimization tailored specifically to pediatric anatomical and procedural requirements (18).

In urological procedures, RAS has shown notable advantages. Studies have demonstrated shorter operative times, decreased hospitalization durations, and comparable success rates when measured against open and laparoscopic techniques. Urology remains the most commonly represented specialty in paediatric robotic surgery. Additionally, RAS has gained traction in general paediatric surgery, especially for complex procedures, due to its enhanced dexterity and visualization. Nevertheless, complications such as wound disruption and anastomotic stenosis have been reported. Furthermore, the limited intra-abdominal space in pediatric patients continues to restrict its application in cardiothoracic surgeries (19,20).

The role of RAS in paediatric oncology remains under scrutiny. A literature review highlighted that its routine use is constrained by a lack of high-quality evidence and concerns regarding clear resection margins and the risk of tumor spillage. In neurosurgical applications, the incorporation of image-guided software is considered essential, particularly in paediatric populations where the developing brain is highly susceptible to injury (21).

The feasibility of RAS in neonates and low-weight infants remains controversial. Current literature presents conflicting evidence, underscoring the need for further research to establish clear guidelines and safety parameters (22). To comprehensively evaluate the advantages, limitations, and long-term outcomes of robotic-assisted procedures in paediatric surgery, large-scale, rigorously designed studies with standardized follow-up and strong evidence-based methodologies are imperative (23).

Challenges in adoption of RAS

Morbidities such as hypertension, diabetes mellitus (DM), and peripheral vascular disease can complicate robotic-assisted surgery (RAS), leading to potential intraoperative and postoperative morbidities if not properly managed (7). Although RAS is generally safe, concerns remain about the prolonged Trendelenburg position, hypercapnia due to pneumoperitoneum, and extended procedure duration, all of which can impact patient safety (9). Additionally, the steep learning curve for surgeons and the need for defined clinical guidelines for patient selection can delay broader RAS implementation. Financial and anesthesiologic challenges, including higher costs and increased anesthesia risks due to longer surgeries, also raise questions about the cost-effectiveness and safety of RAS in certain patient populations (12).

In the paediatric population, the effectiveness of robotic-assisted surgery (RAS) is often limited by anatomical and technical constraints. Improper placement of surgical instruments and internal conflicts due to the small size of the body cavity can adversely affect surgical outcomes. These challenges highlight the urgent need for the miniaturization of robotic instruments to better accommodate paediatric anatomy and optimize the use of RAS in this group (15,16). Additionally, the high cost of robotic systems presents a significant barrier to widespread adoption. The financial burden associated with acquiring and maintaining robotic platforms can be substantial, making it essential to promote resource-sharing among various specialties to maximize utilization and cost-efficiency. Another notable concern is the risk of hypercapnia during surgery, which mirrors issues observed in elderly patients. This risk is particularly pronounced in infants and neonates, who often have limited cardiopulmonary reserves and reduced tolerance to elevated CO_2 levels (20).

LIMITATIONS

The study has several key limitations that may impact the reliability of its findings. The small sample size reduces statistical power, making it harder to draw strong conclusions. Additionally, not all patients had their

outpatient recovery monitored, limiting insight into long-term outcomes. The lack of randomization between groups raises the risk of selection bias, as preexisting differences could influence results. Lastly, a few findings included a small subgroup of patients that should be interpreted cautiously and need validation in larger, more diverse cohorts.

One of the main limitations of this review is the potential for publication bias, as studies with positive outcomes of robotic surgery are more likely to be published, while those with neutral or negative findings may be underrepresented. Additionally, many of the available studies emphasize short-term results, leaving a gap in understanding the long-term outcomes and potential complications of robotic procedures. Lastly, variations in surgeon experience, patient characteristics, and surgical techniques across studies can make direct comparisons between robotic and laparoscopic surgery challenging.

CONCLUSION

Robotic-assisted surgery (RAS) remains in its early stages of adoption in both paediatric and geriatric populations, despite its well-established role in adult urology, gynecology, and colorectal procedures. In paediatric patients, RAS is primarily utilized for procedures such as pyeloplasty and ureteral reimplantation, where its advantages, such as enhanced precision, reduced blood loss, lower infection rates, shorter hospital stays, and faster recovery are most evident. Nevertheless, several challenges specific to the paediatric population, including anatomical limitations, lack of appropriately scaled instruments, and physiological vulnerabilities, must be addressed to enable broader application of this technology.

Geriatric patients also benefit from the minimally invasive nature of RAS, often experiencing faster recovery, earlier return to independence, and improved postoperative quality of life. However, widespread implementation in this population has been constrained by the high cost of robotic systems and the frequent presence of multiple comorbidities.

Robotic platforms were developed to address the limitations of conventional laparoscopy, including poor depth perception, restricted instrument mobility, hand tremors, and difficult hand–eye coordination. With continuous technological advancements and the gradual reduction in associated costs, coupled with growing long-term outcome data, the use of RAS is expected to expand—particularly in paediatric surgery, where its full potential has yet to be realized.

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