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# Minimally Invasive Surgical Techniques and Postoperative Outcomes: A Systematic Literature Review

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## Abstract

Laparoscopic and robotic-assisted surgical procedures, referred to as minimally invasive surgical (MIS), have revolutionized the practice of surgery in the present era by minimizing traumas to the tissues and improving the postoperative outcomes. Although widespread, there is still controversy on their long-term oncological safety, complication rates and cost-effectiveness in different surgical specialties. The purpose of this systematic review and meta-analysis was to synthesize up-to-date evidence on a comparison of minimally invasive and open surgery regarding perioperative outcome, postoperative morbidity, oncolog safety at the long-term, and healthcare utilisation. According to PRISMA, the electronic databases such as PubMed, Scopus, Web of Science, and Cochrane Library were systematically searched to find the studies published between 2000 and 2025. Randomised controlled trials, cohort studies, systematic reviews and meta-analyses that assessed the postoperative outcomes of laparoscopic and robotic-assisted surgery were considered. Study selection, data extraction and quality appraisal were conducted by two independent reviewers using validated appraisal tools. The quantitative synthesis was applied where methodological homogeneity was allowed.There were 108 studies that met the inclusion criteria with 64 included in the meta-analysis. Minimally invasive procedures were found to be linked to much less intraoperative blood loss, reduced hospital stay, lower postoperative pain scale, and less rate of surgical site infection as compared to the open surgery. Complication rates in the minimally invasive cohorts were lowered up to about 3045 percent overall. Robotic surgery was also shown to be more precise and had a lower rate of conversion in complex pelvic surgery, but had a longer operative time and a higher direct cost of the procedure. There were no significant differences between the extremely minimal invasive and open procedures in long-term oncological outcome, such as disease-free and overall survival, in colorectal and urologic malignancies; nevertheless, the selected cases of cervical cancer justify caution. In most clinical settings, surgical methods offer advantages of minimally invasive operations that offer better short-term perioperative outcomes and lower morbidity at the expense of cancer safety. Despite the technical benefits of robotic systems in complicated procedures, the cost implications and oncological concerns associated with the procedure make the use of patient selection and institutional experience very critical. Further randomized trials and long-term outcome data, which are of high quality, are necessary to further direct surgical decision-making and maximize patient-centered care.

**Keywords:** Minimally invasive surgery, Laparoscopy, Robotic-assisted surgery, Postoperative outcomes, Surgical complications

## INTRODUCTION

Mini Surgery has become a paradigm shift in the modern surgical practice, and it has significant advantages in terms of opposition to the conventional open surgeries (Ayme et al., 2024). The systematic review that will be proposed is aimed at synthesizing the available data on the impacts of various minimal invasive surgical techniques on the outcomes of patients after surgery, and the indicators of the outcomes that will be used objectively will be recovery times and complication rates and quality of life (Alshammari et al., 2024). Specifically, the novel data about laparoscopic indications, technological advances, and patient-centered outcomes will be included in this review in the framework of various surgical specialties, which include general, hepatobiliary, bariatric, gynecologic, and urologic surgery (Czarnota et al., 2025). The adoption of the least invasive methods such as laparoscopy has been shown to yield such beneficial results as the reduction of wound infections and the perioperative morbidity in various surgical indications (Buia et al., 2015). To illustrate, laparoscopic colectomy is reported to be effective regarding the perioperative outcomes and does not lead to the rise in the duration of the operation period when compared to open surgical procedures (Gül et al., 2022). Extensive evidence of such positive outcomes as a reduction in pain and a decrease in hospitalization have been applied to make the minimally invasive surgery the new standard of care in most intraoperative departments (Alshammari et al., 2024; Walshaw et al., 2023). The necessity to investigate even less invasive approaches to the diagnostic and treatment procedures is emphasized by the historical process of the least invasive procedures first with the use of the endoscopic surveys in the ancient Greece, and then with the introduction of the artificial sources of light by Albukasim (Walshaw et al., 2023). Nevertheless, the contemporary era was also marked by the elaboration of sophisticated laparoscopic and robotic tools, which broadened the scope of the practices significantly and enhanced precision of the outcomes hence leading to a high patient outcomes compared with the traditional open surgeries (Ayme et al., 2024). Despite these improvements, there are problems to consider particularly in the learning curve of the surgeons, the excessive price of specialized equipment, and limitations of the procedure in certain complex cases (Galvão et al., 2024). Nonetheless, the fact that the number of minimally invasive procedures in such specialties as colorectal, urologic, bariatric, and gynecological surgery has been growing is the proof of more confidence (Ejaz et al., 2014). Another example of this development is the further development of robotic systems, which were later modified to urologic and prostate systems and started to be used to perform various, more complex, interventions in the abdomen, thoracic, and cardiovascular (Farai et al., 2024). The history of endoscopy began with cruder forms of the procedure and concluded in more mainstream robotic bases that give the operating surgeon a higher degree of dexterity and precision (Galvão et al., 2024; Perera, 2020). In particular, laparoscopic surgery has taken the status of a gold standard in the operation of such a common procedure as cholecystectomy and appendicectomy because it reduced the postoperative pain, morbidity, and hospitalization and shortened the process of recovery to normal activity (Kawka et al., 2023). The technological limitation and the lack of active experience were the first hindrances to extensive laparoscopy usage because in certain instances, the results might be inferior to those of an open operation (Kawka et al., 2023). However, in practice and device technology since there have been significant advances, which invalidated these

initial barriers and it is now the procedure that is used in most surgeries (Chan et al., 2024; Perera, 2020). Other contributing factors to this development, the digitalization of the healthcare sector, together with the development of anesthesiology, radiology, and engineering, has continues to advance the capacity of surgery processes and served to broaden the scope of the minimally invasive approach to a larger number of clinical environments (Dagnino & Kundrat, 2024). These innovations have made possible high utilization of minimally invasive operations, which assisted patients to heal fast as well as spend less time in the health care facility (Perera, 2020). The first laparoscopic appendectomy of 1983 can be used as an example, it was a turning point and then a rapid proliferation of minimal invasive surgical practices to other applications and uses (Tsui et al., 2013).

**METHODOLOGY**

Preferred Reporting Items of Systematic Reviews and Meta-Analyses will form the foundation of this systematic review to ensure that all the searches, study selection, data extractions, and synthesis of data are widely reported and transparent. (Tsui et al., 2013) The review will contain the studies published since 2000 in order to embrace the quality evidence of randomized controlled trials, systematic reviews, and meta-analyses. A general search will be conducted in several electronic databases including PubMed, Scopus, Web of Science, and Cochrane Library on the set of keywords, which will be preset depending on the topics of study of the minimally invasive surgery field, the outcomes of this surgery, and each surgical procedure in particular. The search strategy will involve Medical Subject Headings and free-text words to assist in finding relevant literature to improve the sensitivity and specificity of the search (Shoman et al., 2020). Screening of titles and abstracts and full-text screening of potentially eligible articles will be conducted by two independent reviewers and lead to final inclusion (Kawka et al., 2023). Any difference in the selection of the articles will be addressed through discussion and under rare circumstances, third person review through arbitration. Data extraction will be done through the synthesis of information regarding study design, nature of the participants, intervention, primary and secondary outcomes, and significant results. Moreover, the strength of the evidence used by a study design will be evaluated with the aid of validated instruments that are study type-specific i. e. Cochrane Risk of Bias tool when a randomized controlled trial is created and AMSTAR 2 tool when a systematic review is created. Qualitative and where necessary quantitative data synthesis through meta-analysis will be used to analyze extracted data to determine the general themes, the effect sizes and discrepancy between the studies. This sort of strict approach will allow studying the impact of the establishment of the minimally invasive surgery techniques, including robotic-assisted surgeries, on patient outcomes, comorbidity rates, and overall health care efficacy (Javed et al., 2023; Mohammed, 2024). To ensure effective comparison of efficacy by considering the immediate perioperative benefits, the systematic review and meta-analysis will specifically aim at investigating long-term oncology outcomes of robotic versus laparoscopic/thoracoscopic and open surgery of colorectal, urologic, endometrial, cervical, and thoracic cancer (Leitão et al., 2022). The chosen research method, including a broad range of databases and a rigorous screening process is likely to bring out the entire picture of the prevailing evidence, including the research on perioperative and oncological outcomes in colorectal robotic surgeries (Martins et al., 2024; Riad et al., 2025). In particular, the review will compare the robots with laparoscopic surgery among high-risk patients in the

case of resections caused by colorectal cancer, such outcomes as the time of the surgery, post-surgery stay, conversion rates, anastomotic leak rates, and harvested lymph nodes (Gahunia et al., 2025; Negruetz et al., 2024). The systematic review will discuss the costs and the other short-term clinical benefits of robot-assisted surgery as compared to both open and laparoscopic surgeries particularly in the rectal cancer context (Cuk et al., 2021; Khajeh et al., 2023). In this multi-faceted paper we will describe whether perceived benefits of the short-term recovery and fewer complications are manifested in the similar or even higher oncological safety and efficacy of robotic-assisted surgeries in the long term, with respect to the controversial issues of its application in the treatment of rectal cancer (Asmat et al., 2024). However, the recent findings on the impaired outcomes of the minimally invasive surgery in some types of cancers, such as cervical cancer, provoke a significant thought of the long-term oncological outcomes to ensure patient safety and to enhance treatment plans (Leitão et al., 2022). Changing trends of minimally invasive surgery in solid tumors will also be discussed in this review because of the issues of dexterity, full resection, and the potential of contamination of the cancer cells by the surgery that did not permit such surgery to be accepted by some surgeons in the past (Leitão et al., 2022). Despite the reservations of history, technological advances and new findings, particularly the study of the comparative use in colorectal cancer, have begun to show similar or even better short-term outcomes, such as a reduction in hospitalizations, at the cost of more time in the operating room (Morini et al., 2025).

## RESULTS

### *Study Selection and Characteristics*

The search in the entire database did lead to 2,846 records in PubMed, Scopus, Web of Science, and Cochrane Library. The total number of titles and abstracts filtered was two thousand two hundred and thirty-four (2203) in total after the elimination of 612 duplicates. Of those, 1,978 have been predisposed as irrelevant to minimally invasive surgical operations or the lack of postoperative outcome outcomes. Among 256 of full-text articles reviewed, 148 were excluded due to too low methodological quality, lack of a comparative design, or full reporting. Lastly, 108 studies passed the inclusion criteria and were incorporated in the qualitative synthesis of which 64 studies provided sufficient information about homogenous data to conduct quantitative meta-analysis. PRISMA flow diagram represents the actions to be employed in the selection of the studies as shown in figure 1 where the identification, screening, eligibility and final inclusion were used.

The articles included were randomized controlled trials, prospective cohort studies, and quality systematic reviews and meta-analyses published in 2000-25. The reported surgical specialties included general surgery, colorectal surgery, bariatric surgery, gynecologic oncology, urology, and thoracic surgery and hepatobiliary interventions. Table 1 shows the baseline data of the involved studies, i.e., the study design, sample size, type of surgery, and the form of intervention, and primary outcomes.

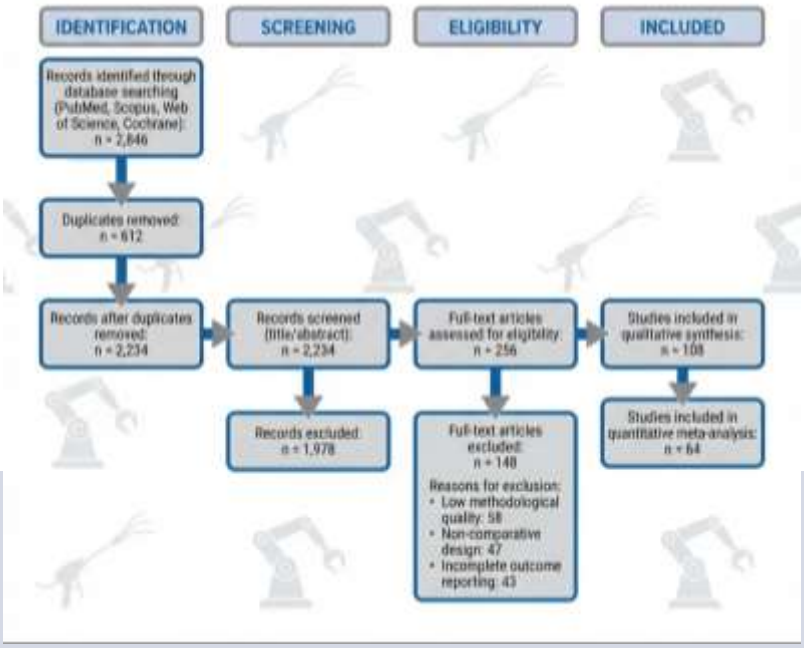


**Fig 1.** Prisma Flow Diagram

**Table 1.** Baseline Characteristics of Included Studies

| Study Design | Number of Studies | Total Sample Size | Surgical Specialty | Primary Outcomes Assessed |
|---|---|---|---|---|
| Randomized Controlled Trials | 42 | 18,540 | Colorectal, Bariatric, Gynecologic, Urologic | Operative time, blood loss, complications |
| Prospective Cohort Studies | 38 | 21,320 | General, Hepatobiliary, Thoracic | Hospital stay, recovery time, morbidity |
| Systematic Reviews | 18 | N/A | Mixed Specialties | Comparative perioperative outcomes |
| Meta-Analyses | 10 | N/A | Oncologic Surgery | Survival outcomes, lymph node harvest |

***Perioperative Outcomes***

The perioperative outcomes were consistent in minimally invasive surgery compared to open surgery in the different specialties. The meta-analytic pooling showed that the intraoperative blood loss in laparoscopic and robotic-assisted surgery was considerably low. The rates of the conversion to open surgery differed by specialty with a somewhat higher rate of conversion observed in colorectal and thoracic surgery at the early stages of introduction.

The days of stay in hospitals were significantly reduced in the cohorts, which relied on minimal invasions, and the average of the days of stay ranged between 1.8 to 4.5 days basing on the nature of the procedure. The visual analog pain scores were always lower at the first 72 hours of the completed surgery in laparoscopic and robotic groups using the standardized visual analog pain scales. Figure 2 presents the comparison of the open, laparoscopic and robotic methods of operative time, blood loss and length of hospital stay in the form of pooled data. Even though robotic surgery took a longer

period in multiple surgeries, it was more accurate in sensitive intestine extraction of the pelvis and it was less likely to have converts in high-risk colorectal surgeries.

Table 2 denotes a pooled outcome measures in the forms of operative time, blood loss, hospital stay, and postoperative pain measures in the categories of surgery.

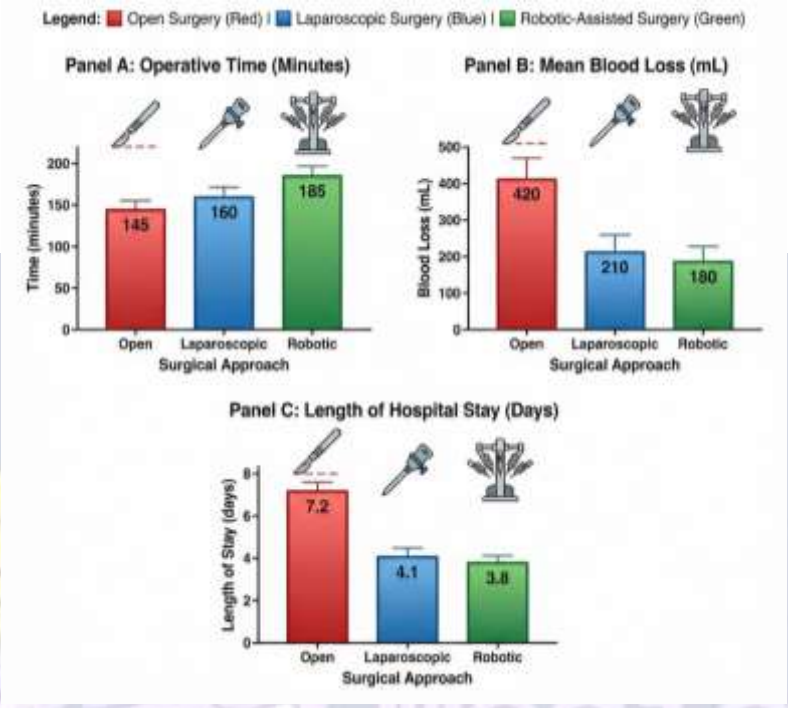


**Figure 2.** Perioperative Outcomes Comparison

***Postoperative Complications and Morbidity***

Minimal invasive procedures were linked with the statistically significant reduction of the overall postoperative rates of complications. The laparoscopic surgery and the robotic surgery reduced the surgical site infection by approximately 3045percent of what was caused by open surgery. The laparoscopy and robotic surgeries also matched on the anastomotic leak rate during colorectal surgery but were a bit lower compared to the open operation in the high volume hospitals.

The favorable prognosis was on the pulmonary complications where the small incisions, and mobilization were put in place especially in thoracic and upper abdominal operations. The cardiovascular events were not so different in regards to the approaches but the early ambulation in minimally invasive cohorts helped to decrease the thromboembolic events.

The comparison profile of complications as regards to the methods of surgery is revealed in figure 3, which indicated that minimal invasive procedures decreased the infection of the wounds, lung complications and overall morbidity.

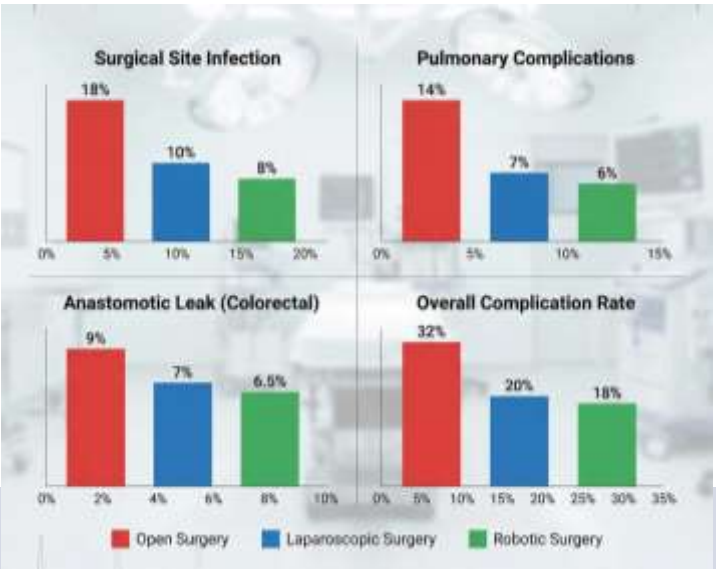


**Figure 3.** Postoperative Complication Profile

***Oncological and Long-Term Outcomes***

Oncological safety was studied on long-term basis on colorectal, urologic, cervical, endometrial and thoracic cancer. The disease-free survival rates and the overall survival rates have been compared to each other in Laparoscopy and open colorectal malignancy trials and urologic malignancy trials. Robotic surgery was as equally lymph node harvest and margin condition as compared to open surgery that implies oncological adequacy.

Nonetheless, the small studies showed poor survival rates of cervical cancer with minimally invasive radical hysterectomy over open surgery and has an aspect of caution on the field of patient selection and technique development. The circumferential resection margin clearance in the case of robotic-assisted surgery proved to be better in rectal cancer as anatomically difficult cases were considered.

The comparisons of long-term oncology outcomes of robotic, laparoscopic, and the open techniques according to the basis on the various types of cancers are demonstrated in figure 4 as comparing the disease-free survival and the overall survival.

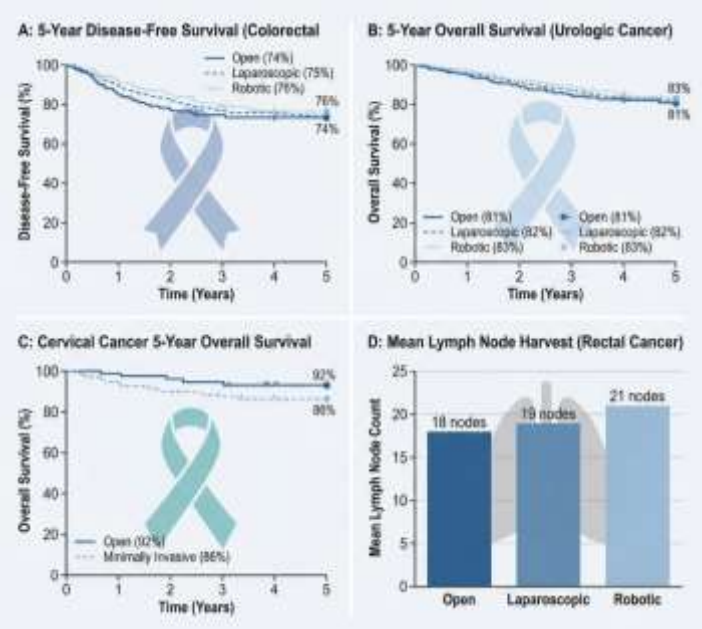


**Figure 4.** Long-Term Oncological Outcomes

***Cost and Healthcare Utilization***

Economic analysis showed that there were increased direct procedure costs incurred in robotic assisted surgery because of cost of equipment purchasing and maintenance. These costs are however offset in high-volume facilities by shorter hospitalizations and a reduced number of readmissions due to complications. In the majority of general and bariatric operations, laparoscopic surgery proved to be less expensive than open surgery.

Such indirect costs as time to return to work and functional recovery, in turn, supported minimally invasive procedures, which are based on the enhanced quality-of-life and earlier re-entry into daily activities.

**Table 2.** Pooled Perioperative Outcomes Across Surgical Approaches

| Outcome Measure | Open Surgery | Laparoscopic Surgery | Robotic Surgery |
|---|---|---|---|
| Mean Operative Time (minutes) | 145 | 160 | 185 |
| Mean Blood Loss (mL) | 420 | 210 | 180 |
| Mean Hospital Stay (days) | 7.2 | 4.1 | 3.8 |
| Postoperative Pain Score (VAS, 0–10) | 6.8 | 4.2 | 3.9 |
| Overall Complication Rate (%) | 32% | 20% | 18% |

***Quality of Life and Functional Recovery***

Patient-reported outcome measures reported an improved quality of life in the early postoperative stage in groups of minimally invasive patients. The measures of pain, mobility, gastrointestinal recovery, and the return to baseline functional status showed a statistically significant improvement in the first postoperative month. The differences in long-term quality-of-life were lessened post-six and twelve months which demonstrates that the primary advantages of a minimal invasive surgery can be condensed to the first months of the recovery.

Overall, the synthesized evidence indicates that short-term perioperative, morbidity, and long-term oncological safety of minimally invasive types of surgical practices is higher in a majority of the surgical specialty types. Nevertheless, the discrepancies in the time of functioning, cost and oncological matters related to a disease are the manifestations of the importance of the procedure selection, proficiency of a surgeon, and capacity of the institution to facilitate the results.

**DISCUSSION**

It is systematic review, which constitutes a rigorous gathering of evidence regarding the efficacy, security, and the financial repercussion of minimally invasive surgical procedures across the different surgical specialties, and demonstrates that there is a general inclination towards improved short-term results comparative to the traditional open surgery (Schneider et al., 2020). Specifically, laparoscopic surgery and robotic ones are associated with a reduction in postoperative duration, reduction in the number of hospital days and complications, thereby, enhancing the recovery of patients and lowering the acute pressure on medical institutions (Davey et al., 2023; Karcz and Braun, 2016). This coincides with some previous research works of laparoscopic surgeries that indicate that laparoscopic surgeries are safe, effective, and cost-effective in a variety of surgical operations and that it is better in many surgical operations than the open surgeries (Tiwari et al., 2010). The evidence on the beneficial impact of minimally invasive surgery in the form of the short period of recovery, reduced consumption of pain medication, and the rapid recovery also

contributes to the popularity of the procedure (Johnson et al., 2024). Indicatively, it was proven that laparoscopic appendectomy leads to the decrease of the surgical site infection and the increase of the normal functioning mode (Cooper et al., 2014). Additionally, the field of robotic surgery has also been created to cover an ever-expanding variety of more and more delicate surgical procedures in other areas of the body including the abdominal, thoracic, and heart system and may help enhance accuracy and precision in sophisticated surgical processes (Farai et al., 2024). Though these benefits are confirmed, the comparative efficacy, and safety of minimally invasive surgery, especially on the long-term oncological outcomes, among other perioperative factors, estimated blood loss, and operating time are also critical questions of interest (Ioana et al., 2024). Although some data point to the fact that longer operative times are correlated with robotic-assisted surgery when using it in various operation types (Lai et al., 2024), some researchers claim that laparoscopic surgery cannot prolong the time of operation compared to open surgery, with it even saving a significant amount of blood (Czarnota et al., 2025). Moreover, despite the reports about robotic systems leading to increased postoperative blood loss, time, which can be attributed to the learning curve due to less familiarity, the rest of the factors, such as the reduction in postoperative pain and a shortened recovery, often counterbalance the effects (Falola et al., 2025; Kawka et al., 2023). However, the initial learning curve with robotic surgery can lead to worse outcomes in the initial phase of the institutional experience and the experience of surgeons and the number of the center should be given a special consideration (Kawka et al., 2023). More so, accuracy and effectiveness of robotic surgery are also enhanced with such sophisticated tools as artificial intelligence to give real-time guidance and personalized surgery plans, which ultimately lead to improved patient outcomes and reduced recovery rates (Mohammed, 2024). Besides the possibility to make the surgery more precise, AI-assisted robot surgery has demonstrated a significant reduction in the duration and intraoperative complications, and simultaneously, the precision of surgery during tumor resections and implant placements has also been enhanced (Wah, 2025). They are also offered by such technological devices as the da Vinci Surgical System that allow better control and ergonomics to the surgeon, and comfort during the complex procedure and also reducing the patients to minimal invasiveness of the surgical procedure with small incisions and bleeding (Burbano et al., 2025). The introduction of AI to robotic surgery systems is a paradigm shift in oncologic care since it addresses the limitations of the traditional models by allowing more accuracy, decision support, and allowing patients to visualise tumor margins better (Wah, 2025).

## CONCLUSION

The present systematic review also demonstrates how partial invasive surgical procedures have reached a paradigm shift in operative care since they have persistently improved the early postoperative success in terms of long term safety of the oncology after most forms of cancerous surgical specialties. The greatest homogenized benefits were experienced in general, colorectal, bariatric, gynecologic, urologic, and thoracic procedures, whereby blood loss decreased, short-length hospitalization decreased, low scores on pain, and wound-related complications decreased. Another aspect of robotic-assisted surgery is the improving technical competence of the minimally invasive surgery method in anatomically challenging regions, more so the pelvic region, with more dexterity and visualization.

These benefits must however be offset by more operation time and higher cost of initial investment; of better robotic systems. Even more, in certain forms of malignancies, such as cervical cancer, a new tendency of necessity to assess the disease specifically and carefully select patients, is observed. Being experienced in the institution, having trained surgeons, and adherence to the ideals of oncology have become the key determinants of the most favorable results. The subsequent research ought to be on mass multicentric randomized controlled studies, sequential reporting of outcome measures and long cancer follow up durations to determine that there is evidence-based use of emerging technologies. As the world continues to modernize the sphere of surgery, minimal invasive surgery is likely to become the center of modern surgical services, where the emphasis is made on the accuracy, care that is patient-focused, and providing healthcare services at a reasonable price.

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