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RESEARCH ARTICLE
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TYPE OF MANUSCRIPT: SYSTEMATIC REVIEW ADVANCES IN ROBOTIC SURGERY IN GENERAL SURGERY - TRENDS, CHALLENGES, AND FUTURE DIRECTIONS: SYSTEMATIC REVIEW

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ABSTRACT:

Background: Robotic surgery (RS) as a big step forward in less invasive techniques. It combines robotics and engineering to make surgeries more precise, help surgeons avoid fatigue, and lower risks for patients. It's becoming popular in general surgery, but still there is questions about its benefits, cost, and safety when compared to traditional laparoscopic methods.

Objective: In this review, aimed to look at recent trends, outcomes, and challenges related to robotic surgery in general surgery.

Methods: This review conducted a thorough search of literature using databases like PubMed, EMBASE, Scopus, and Web of Science to find studies published between January 2015 and March 2025. This review followed the PRISMA guidelines, focusing only on English-language studies that were peer-reviewed. These included clinical trials, cohort studies, meta-analyses, and randomized controlled trials (RCTs). This review also registered on PROSPERO.

Results: seven studies that fit the inclusion criteria. The results show that the use of robotic surgery is increasing, especially for procedures like gallbladder removal, hernia repairs, and surgeries for rectal cancer. Robotic surgery seemed to offer benefits in complex cases, like less blood loss, quicker recovery of bowel function, and shorter hospital stays. However, it didn't show much advantage over laparoscopy for regular procedures. I also noted that robotic surgeries generally took longer and cost more. There were worries about a steeper learning curve and a slightly higher chance of complications, such as bile duct injuries during gallbladder surgery.

Conclusion: Robotic surgery has potential, especially for complex operations, but it still hasn't proven to be better than laparoscopy for standard surgeries. Future research should look into the cost-effectiveness, better training methods, and long-term results to improve its use in surgical practices.

Key words: Robotic surgery, Laproscopy, Advanced technology, General surgery, Conventional surgery.

INTRODUCTION:

Robotic surgery as a step forward in how we perform minimally invasive surgeries. It combines medicine, robotics, and engineering to create a new way of doing operations. This technology, often called robot-assisted surgery, uses special robotic tools to help surgeons be more precise during complicated procedures, especially in tight spaces of the body. It helps reduce mistakes and allows for more flexible movements, which means it can control hand shakes. Because of this, there are fewer problems after surgery, like infections, pain, blood loss, longer hospital stays, and it also leaves smaller, less noticeable scars.[1]Control devices and the surgeon's master console are the two primary parts of this system, which are connected to a computer via data connections. [2,3] The surgeon's master console, where it provide a clear 3D view of the area. This view comes from a special camera inside the patients body. Control devices such as handles and joysticks to move quickly sent to the robotic arms that work above the patient. These robotic arms have tiny joints that help to control the surgical tools and the camera through small openings in the patient's body. [4]The existing systems aren't made to function without human surgeons or to take their place. Rather, these devices are best characterized as master-slave manipulators that function as completely controlled distant extensions of the surgeon. The two main master-slave systems that have been approved by the United States Food and Drug Administration (FDA) and are in use are the da Vinci Surgical System (Intuitive Surgical, Mountain View, California) [5] and the ZEUS system (Computer Motion, Goleta, California). [6]

METHODS

SEARCH STRATEGY

To compile all of the articles that have been written about robotic surgery in general surgery, a thorough assessment of the literature was conducted. The search terms ["Robotics-assisted procedures in general surgery"] were used to search four databases: Web of Science, EMBASE, Scopus, and PubMed. Medical Subject Headings (MeSH) on PubMed and Embase Subject Headings (Emtree) on EMBASE help to search for articles. selection of articles based on the rules set by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).

STUDY SELECTION

INCLUSION CRITERIA:

Peer-reviewed papers on the application of robotic surgery in general surgery that were released in the recent ten years, specifically between January 2015 to March 2025. Clinical trials, observational studies, randomized controlled trials, and meta-analyses are only a few of the study designs that should be covered in these articles. Furthermore, the content should be limited to studies conducted in the English language to ensure clarity and accessibility for international readers.

EXCLUSION CRITERIA:

Studies that are published in languages other than English, along with those focusing exclusively on non-general surgical specialties, should be excluded. Additionally, case reports and articles sourced from non-peer-reviewed platforms are not to be considered, as they do not meet the required standards of academic rigor.

DATA EXTRACTION:

To gathered important information for the systematic review, including the authors' names, the year the work was published, the type of surgery, details about robotic surgery in general surgery, and the results. Two of us, D.P. and A.G, looked over the gathered data to find any mistakes. When we found any, we talked about them and came to an agreement.

DATA ANALYSIS:

To described each study in a narrative way. When wefound similar outcome data from two or more trials, we put that data together. We thought there would be some differences in how the studies were done and their clinical results, which could affect the outcomes. So, we used a random effects model for my meta-analysis and created a single comparison by combining data from related studies that had multiple groups. For the results that were measured continuously, it showed the outcomes as average differences along with a 95% confidence interval.

STUDY PROTOCOL REGISTRATION:
The study protocol was registered with PROSPERO CRD420251031109.

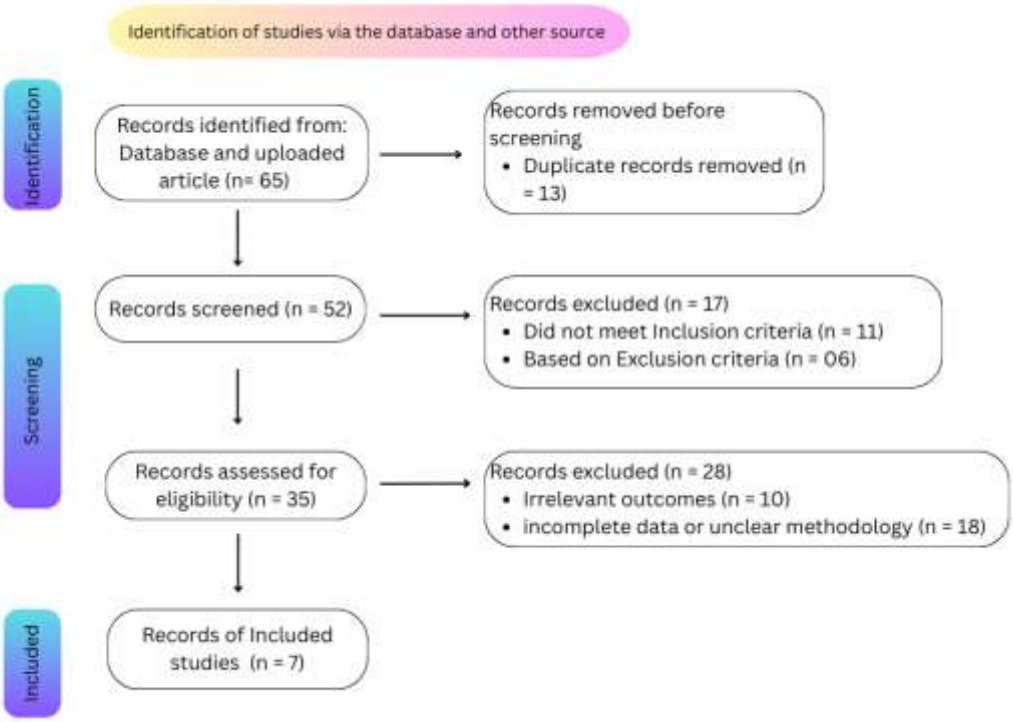

Figure.1 PRISMA FLOWCHART

RESULT:
STUDY CHARACTERISTICS:
Following the identification of 65 records from databases and uploaded publications, the research identification process got underway. Before screening, 13 duplicate records were eliminated. Following the screening of 52 records, 17 were eliminated due to the fact that they fulfilled either the exclusion criteria (n = 6) or the inclusion criteria (n = 11). Thirty-five records were evaluated for eligibility; 28 were disqualified because of either unclear technique or insufficient data (n = 18) or irrelevant results (n = 10). In conclusion, the review comprised seven studies (Figure.1).

STUDY (YEAR)	STUDY TYPE	TYPE OF SURGERY	ROBOTIC SURGERY IN GENERAL SURGERY	OUTCOME
Kyle H. Sheetz et.al., (2020)	Cohort Study	• Cholecystectomy • Colectomy • Ventral hernia repair • Inguinal hernia repair	The use of robotic surgery has spread to many routine general surgical procedures. It mentions that the	concentrate more on the adoption trends of robotic surgery than on its results. It

		• Reflux surgery • Complex cancer resections • Proctectomy	biggest market for surgical equipment in the US is general surgery. According to the study, hospitals that started robotic surgery programs saw a rise in robotic surgery usage, which was linked to a decline in conventional laparoscopy minimally invasive surgery.	implies that in order to guarantee robotic surgery's successful application in clinical settings, its uptake must be continuously monitored
Oscar A Olavarria, et.al., (2020)	Pragmatic, blinded randomized controlled trial	• Ventral Hernia Repair: This study compares robotic and laparoscopic ventral hernia repair, or RVHR and LVHR.	Among all types of surgery, general surgery is using robotic tools the most quickly. Repairing a hernia is one of the most common surgeries done in general surgery. My project plans to check the results from earlier studies by looking at patient outcomes in a fair trial. This study compares laparoscopic hernia repair and robotic hernia repair.	Primary Outcome (Days in Hospital): There was no clear difference between RVHR and LVHR when it came to how many days spent in the hospital within 90 days after the surgery. Secondary Results: • Operating Room Time: Compared to LVHR, RVHR required a substantially longer operating room period. • Healthcare Costs: In comparison to LVHR, RVHR had higher healthcare costs. • Complications: There were no appreciable variations in ER visits, wound issues, the

				hernia recurrence, or reoperation. Enterotomies, or incidental intestinal injuries, happened to two patients following RVHR but not to any in the LVHR group. • Quality of Life: After one month of surgery, the quality of life improved less with RVHR than with LVHR.
Bo Tang ,et.al., (2021)	a meta-analysis of randomized controlled trials	Analysis of Surgery Only rectal carcinoma excision (surgical surgically eliminating rectal tumors) is evaluated in this study, which contrasts two less invasive methods: 1. Rectal resection by robotic means 2. Rectal laparoscopic resection	For difficult pelvic operations like rectal cancer surgery, robotic surgery can be considered as a cutting-edge, less invasive substitute for laparoscopy. The following are some of the document's main benefits: • Technical viability: Robotic platforms may make tasks like sphincter preservation and pelvic dissection easier1. • Adoption trends: Robotic technologies facilitate better dexterity in small anatomical regions and offer a 3D view1. In the United States, the largest market for	There were no statistically significant variations between robotic and laparoscopic techniques in terms of complications following surgery within 30 days, according to the meta-analysis. Important analogies include of: Principal Results Type of Complication: Robotic Surgery Laparoscopic Procedures P-value Overall issues 26.6% 23.8% 0.27 Serious issues 4.5% 4.1% 0.83

			robotic systems is general surgery, which reflects its expanding significance .	Leakage from anastomosis 7.3% 5.8% 0.34 infection at the surgical site 3.7% 3.5% of 0.86 Switching to open surgery 4.3% 6.6% 0.08 Secondary Results • Pathological results (such as resection margins and lymph node yield) were comparable among groups1. • Functional results: Robotic surgery did not significantly improve the recovery of bowel or urine function.
Zhihua Song, et.al.,(2023)	Meta Analysis	• The surgical treatment of endometriosis is the main topic of the study. It contrasts with: • Robotic surgery Laparoscopic procedures The study specifically examines various surgical methods in relation to endometriosis. The text lists colorectal endometriosis and deep endometriosis (DE) as particular conditions for which surgery may be appropriate.	Robot-assisted laparoscopy is discussed in the paper as a potential substitute for conventional laparoscopy. Although not demonstrated to be better, it recognizes the frequently mentioned technical advantages: Magnification of vision and improved range of motion • Less tremor in the surgeon	Eight studies, involving 1741 patients, were meta-analyzed, and the results showed: • Operation Time: When compared to robotic surgery, laparoscopic surgery had a statistically significant shorter operation time (P =.01). • Hospitalization Time: When compared to robotic surgery, laparoscopic surgery resulted in a statistically

				significant shorter hospitalization time (P =.03). • Blood Loss: There is no discernible difference between laparoscopic and robotic surgery (P =.27). • There are no appreciable variations between the two approaches in terms of rehospitalization, postoperative and intraoperative complications, or conversion rates.
Wenju Chang,et.al., (2023)	random ised controll ed trial	• The study, known as a randomized controlled trial, compares two methods of surgery for individuals with metastatic rectal cancer (rectal cancer that has spread to the liver at the same time). • Surgery where the doctors removed both the cancer growths in the liver and the main tumor in the rectum at the same time. They used advanced robotic tools to help with the operation.	Robotic surgery as using robots to help doctors perform complicated surgeries. This includes removing liver tumors and rectal cancer at the same time during one operation.	Short-term Results: • Within 30 days following surgery, the robotic group experienced significantly fewer problems (31.4% vs to 57.6% in the open group). • The robotic group saw a lower mean blood loss (125.5 ml) compared to 211.6 ml. • The mean recovery time for bowel function was quicker (mean 63.7 hours vs. 93.8 hours) and

				the hospital stay was shorter (mean 8.0 days vs. 10.7 days) for patients under robotic care. By three months after surgery, the robotic group1 showed a quicker recovery of bladder and sexual function. Long-term Results: • There was no difference in how many people in the two groups stayed free from disease after three years (39.5% for robotic vs. 35.3% for open) or overall rates of survival (76.7% for robotic vs. 72.9% for open).
Yoon Jung Kim.et,al.,(2023)	random ised controll ed trial	• Participants in the trial are those having robotic or laparoscopic lower abdominal surgery who need the following: • Pneumoperitoneum (abdominal inflating for transparency). The head-down tilt is a steep Trendelenburg position that makes it easier to approach the pelvis.	Robotic surgery is considered a minimally invasive method for lower abdominal surgeries, along with laparoscopic techniques. The research emphasizes: 1. Common Challenges: Pneumoperitoneu m and Trendelenburg positions are used	Although the investigation did not directly contrast the results of robotic surgery and laparoscopy, it did find: 1. Complications with the lungs: • Overall PPCs: Individualized PEEP (14.0%) and fixed PEEP (19.5%) did not differ

		Common gynecological, urological, or colorectal surgical procedures are implied by the context, even though specific surgeries (such as prostatectomy and hysterectomy) are not specifically addressed.	in both robotic and laparoscopic procedures, which enhance the risk of pulmonary complications following surgery (PPC) and compromise respiratory mechanics1. 2. Ventilation Focus: The experiment focuses on maximizing ventilation techniques (such as directing pressure-guided PEEP) to reduce PPCs, independent of robotic versus laparoscopic methods.	significantly. 1. • The customized PEEP group experienced fewer difficulties related to desaturation (4.5% vs. 16.2%). 1. 2. Measures of Ventilation: • Mean driving pressure went down when we used individualized PEEP, measuring 14.7 compared to 18.4 cm H_2O. Also, there was no change in mortality rates, the need for intensive care unit admission, or how long patients stayed in the hospital.
Stanley Kalata, et.al., (2023)	Cohort study	• Robotic-Assisted Cholecystectomy • Laparoscopic Cholecystectomy	The application of robotic-assisted surgery has risen in acceptance with routine procedures like cholecystectomy because it affords advantages including enhanced sight and accuracy. Its safety and outcome benefits in contrast with laparoscopic surgery are yet unknown, despite its quick growth—a 37-fold rise from 2010 to 2019.	There were safety concerns while the possibility of bile duct damage requiring surgical intervention was higher with robotic-assisted cholecystectomy (0.7% vs. 0.2%) than with laparoscopic cholecystectomy. Additional postoperative biliary procedures, such as

			Although the technology seeks to increase surgical precision, as surgeons perform the learning curve, there might exist hazards	endoscopic stenting, were also associated with it (7.4% vs. 6.0%). The two methods' total 30-day complication rates, however, were comparable. Robotic surgery may not yet clearly offer safety benefits above laparoscopic surgery for cholecystectomy, as suggested by instrumental variable analysis that validated the elevated risk of bile duct injury.

DISCUSSION:

This systematic review aimed to understand how robotic surgery (RS) is being used in general surgery today. This review looked at current trends, results, and the challenges with this technology. The included studies reveal that hospitals are quickly adopting robotic systems, especially for common surgeries like gallbladder removal, hernia repair, and surgeries that involve multiple organs at once.

Trends and Adoption Patterns:

This is a big increase in using robotic systems, especially in the U.S., where it's the main area for surgical robotics. A study by Sheetz and others in 2020 showed that when hospitals start using robots, they often do fewer traditional laparoscopic surgeries. This change makes worry that some hospitals might be using robots too much or too soon without clear proof that they are better.

Clinical Efficacy and Outcome Comparison:

When we compare robotic surgery to regular laparoscopic surgery, the results are mixed. Some studies, like those by Olavarria and Bo Tang in 2020 and 2021, show that there aren't many differences in short-term results like complications, how long patients stay in the hospital, or the need to switch to open surgery. However, this trend saw that robotic procedures often take longer and cost more, especially for hernia repairs and surgeries for endometriosis.

In more complicated cases, like when performing multiple organ surgeries for cancer, robotic surgery can offer real benefits. It can lead to less blood loss, quicker recovery of bowel function, and better results after surgery, as shown in a study by Chang in 2023. This suggests that robotic surgery might be especially helpful for tough procedures where the anatomy is tricky.

Safety Considerations and Learning Curve:

There is some important safety issues and challenges when learning new procedures, especially with robotic-assisted surgeries like cholecystectomy. According to Kalata et al. (2023), there are higher rates of bile duct injuries with robotic systems compared to traditional laparoscopy. This shows that even though robotic tools can be more precise and controlled, the experience of the surgeon is really important for keeping patients safe.

Technical and Physiological Considerations:
We also learned that there are additional challenges during robotic surgeries due to physical stress on the body, such as the effects of pneumoperitoneum and the Trendelenburg position. Kim et al. (2023) pointed out that both robotic and laparoscopic surgeries can lead to problems with the lungs after surgery, which means we need to have the best ventilation strategies in place during that time.

CONCLUSION:

Robotic surgery in general surgery is moving forward quickly because it has some great technical benefits and more doctors are starting to accept it. However, the current studies don't always show that robotic surgery is better than laparoscopic surgery for regular operations. Robotic systems might be really helpful for more complicated surgeries because their extra precision can lead to better short-term results and recovery. Still, there are challenges need to tackle, like the high costs, the time it takes to learn how to use the robots, and the need for proper training programs. We have to work on these issues to make sure robotic surgery is safe, effective, and available to everyone. As this area develops, we believe that well-planned studies across multiple centers and real-life outcome research will be important to help us use robotic systems wisely in general surgery.

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