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Updates on Safety and Efficacy of Robotic Distal Gastrectomy for Gastric Cancer: A Systematic Review

Yasir Mehmood[1*], Pakeeza Shafiq[2], Ghadah Ageel Almiglad[3], Dhay Ayed Alruwaili[4], Asil Saqr Alenezi[5], Ahlam Khulaif Alruwaili[6], Ibtihal Mnwer Alanazi[7], Danah Sabbar M. Almotrafi[8] and Muzun Fahad G. Alrawili[9]

[1]Department of Surgery, Faculty of Medicine, Northern Border University, Arar, Saudi Arabia
[2]Department of Surgery (Radiology Division), Faculty of Medicine, Northern Border University, Arar, Saudi Arabia
[3-9]College of Medicine, Northern Border University, Arar, Saudi Arabia

Author Designation: [1-2]Assistant Professor, [3-9]Medical Student

*Corresponding author: Yasir Mehmood (e-mail: dr.yasir@live.co.uk).

Abstract **Background:** Robotic distal gastrectomy (RDG) has emerged as an advanced minimally invasive technique for the treatment of gastric cancer. While it offers potential advantages over conventional approaches, questions remain regarding its safety, efficacy and cost-effectiveness. This systematic review was conducted to evaluate the clinical outcomes associated with RDG, including complication rates, recovery times and mortality. **Methods:** A systematic search of four electronic databases identified 512 articles. After duplicate removal using Rayyan QCRI and relevance screening, 32 full-text articles were reviewed. Ultimately, four studies met the inclusion criteria based on PRISMA guidelines. Data extracted included demographic information, complication and mortality rates and postoperative recovery outcomes. The quality of the included studies was assessed using the ROBINS-I and Cochrane risk of bias tools. **Results:** The four included studies involved 1,184 patients who underwent RDG, of whom 740 (62.5%) were male. The prevalence of postoperative complications ranged from 0% to 18.3%, with an overall rate of 8.8% (n = 105). Two studies reported zero mortality. Clinical findings suggested RDG reduces blood loss, shortens hospital stays and facilitates faster recovery. These benefits were consistently observed across Asian institutions. However, high equipment and procedural costs remain significant limitations, especially in complex cases and settings with limited access to robotic platforms. **Conclusion:** RDG demonstrates promising clinical outcomes for gastric cancer surgery, particularly in terms of patient recovery and postoperative safety. Despite its advantages, the high cost of robotic systems limits widespread implementation. Future research should emphasize cost-effectiveness, long-term oncological outcomes and broader international applicability to strengthen RDG's position in standard surgical practice.

Key Words Gastric cancer, Robotic distal gastrectomy, Minimally invasive surgery, Surgical outcomes, Systematic review

INTRODUCTION

Gastric cancer is currently the fifth most commonly diagnosed cancer and ranks as the fourth leading cause of cancer-related mortality worldwide [1]. Although global incidence has declined over the past three decades, the disease continues to pose a significant public health burden, especially in high-risk regions. Several risk factors contribute to the development of gastric malignancy, including dietary habits, genetic predisposition, Helicobacter pylori infection and advancing age. While screening programs can be beneficial in high-risk populations, they are not widely adopted in Western countries [2].

Histologically, gastric cancer is categorized primarily into intestinal and diffuse types. Most tumors are found in the lower regions of the stomach-namely the antrum and body-though there has been a notable increase in proximal gastric cancers involving the upper stomach in recent years [3,4]. Due to the asymptomatic nature of early disease, gastric cancer is often diagnosed at an advanced stage. Endoscopy remains the gold standard for diagnosis, enabling direct visualization, biopsy and early tumor resection.

The cornerstone of curative treatment is surgical resection, particularly gastrectomy, with the extent of surgery guided by the tumor's location and stage. In

addition, extensive lymphadenectomy is recommended for accurate staging and improved outcomes. Perioperative chemotherapy and occasionally radiotherapy are used as adjuncts to improve survival [5].

In recent years, many experienced laparoscopic surgeons have shifted toward robotic-assisted techniques in the surgical management of gastric cancer. Since its early implementation for early gastric cancer more than a decade ago, robotic gastrectomy has emerged as a safe and feasible alternative to conventional laparoscopic approaches [6,7].

Despite these advancements, gastric cancer remains a major global health concern, reinforcing the need to refine surgical strategies to improve patient survival, recovery time and quality of life. Robotic Distal Gastrectomy (RDG) has gained popularity for offering high precision, reduced intraoperative blood loss and shorter postoperative recovery periods when compared to traditional laparoscopic and open procedures. However, its high cost, limited access in some settings and variable evidence raise questions about its cost-effectiveness and long-term benefits.

Moreover, current literature on RDG includes methodologically diverse studies with varying sample sizes, outcome measures and reporting quality, leading to conflicting conclusions. These challenges underline the importance of conducting a comprehensive and systematic review to consolidate the existing evidence and provide updated insights into the safety, effectiveness and clinical outcomes of RDG in the treatment of gastric cancer.

The primary objective of this systematic review is to analyze and synthesize current research on robotic distal gastrectomy in gastric cancer management. Specifically, this review aims to evaluate the safety, efficacy and clinical outcomes of RDG, with a focus on postoperative complications, mortality rates, recovery times and the broader implications of its use compared to other surgical techniques.

METHODS

Search Strategy

This systematic review was conducted in accordance with the PRISMA and GATHER guidelines. A comprehensive and structured literature search was performed to identify studies evaluating the safety, efficacy and clinical outcomes associated with Robotic Distal Gastrectomy (RDG). The following four electronic databases were searched: Web of Science, SCOPUS, PubMed and Cochrane Library. The search was limited to studies published between 2022 and 2025.

Duplicates were automatically removed and titles and abstracts were screened using Rayyan QCRI software. Automated evaluation tools were employed to aid the selection process. Full texts of studies meeting the initial inclusion criteria were retrieved and reviewed in detail. Two independent reviewers assessed the eligibility of studies for final inclusion. Any disagreements between reviewers were resolved through discussion and mutual consensus.

Study Selection and Population

The inclusion criteria were based on the PICO framework:

- **Population:** Adult patients diagnosed with gastric cancer undergoing surgical intervention
- **Intervention:** Robotic distal gastrectomy (RDG)
- **Comparator:** Conventional laparoscopic distal gastrectomy (LDG)
- **Outcomes:** Clinical efficacy and safety of RDG, including complication and mortality rates

Only studies that directly compared RDG with other surgical methods and reported relevant outcomes were included in the final analysis.

Data Extraction

Data from the included studies were extracted using a standardized and predefined form. This process was carried out independently by two reviewers to ensure consistency and minimize bias. The following variables were documented: (i) First author's name, (ii) Year of publication, (iii) Study design, (iv) Country of origin, (v) Total sample size, (vi) Mean or median age, (vii) Gender distribution, (viii) Postoperative complication rates (%), (ix) Mortality rates (%) and (x) Other key surgical and clinical outcomes.

Quality Assessment

To evaluate the methodological quality and risk of bias in the included Randomized Controlled Trials (RCTs), the Cochrane Risk of Bias Tool was used. This instrument classifies risk across multiple domains as low, unclear, or high.

For non-randomized studies, the ROBINS-I (Risk of Bias in Non-randomized Studies - of Interventions) tool was applied. Each study's risk of bias was independently evaluated by two reviewers. Any inconsistencies were resolved through group discussion to reach a consensus.

RESULTS

The meticulously delineated search methodology yielded a comprehensive compilation of 512 publications, as depicted in Figure 1. Subsequently, the process of deduplication was undertaken, resulting in the removal of 266 duplicate publications. Subsequently, a rigorous evaluation of the remaining 246 trials was conducted, primarily based on the titles and abstracts provided. However, a significant number of these trials, namely 211, were found to be inapplicable to the research objectives and were consequently excluded from further consideration. Consequently, a refined selection

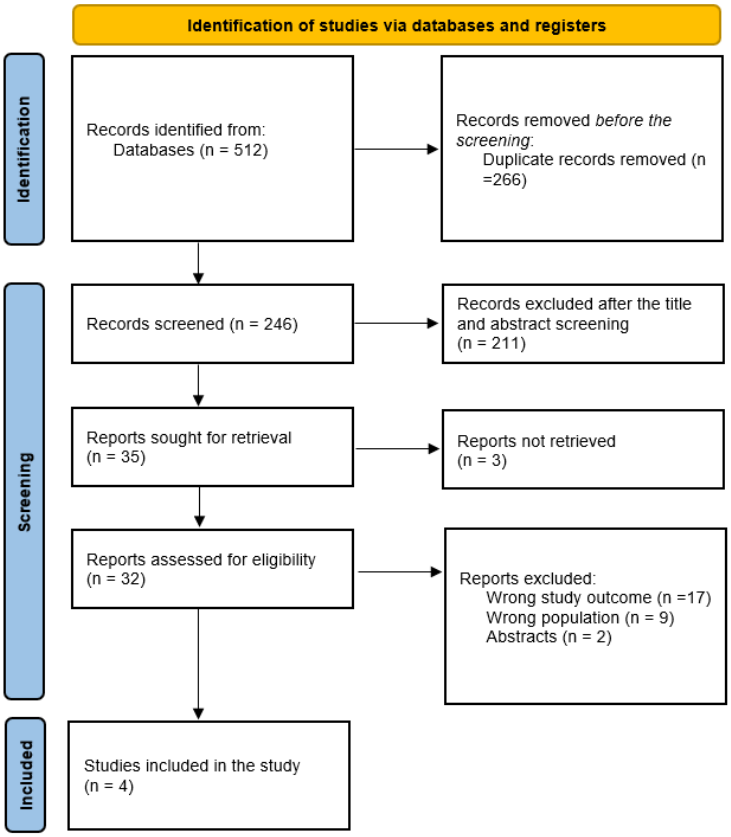

Figure 1: PRISMA flowchart [10]

process was employed to identify 35 full-text articles that were deemed suitable for an in-depth review. Ultimately, only 4 of these articles met the stringent criteria for evidence synthesis and analysis.

Sociodemographic and Clinical Results

We analyzed four studies comprising a total of 1,184 patients who underwent RDG, of which 740 (62.5%) were male. In terms of study design, two of the studies were randomized controlled trials (RCTs) [12,14] and two were retrospective cohorts [11,13]. Two studies were implemented in Japan [11,13], one in Korea [12] and one in China [14].

The prevalence of complications in RDG ranged from 0% [12] to 18.3% [13], with a total prevalence of 105 (8.8%). The reported mortality was 0% in two studies [11,13]. The studies presented highlight varying aspects and outcomes RDG in gastric cancer patients, reflecting its potential benefits and considerations across different contexts and patient demographics.

In a large Japanese cohort, RDG demonstrated a significant reduction in the postoperative length of stay, indicating an enhanced recovery profile which could contribute to decreased healthcare costs and improved patient satisfaction [11]. This outcome suggests that RDG may offer considerable advantages in postoperative recovery compared to traditional methods.

An RCT from Korea explored the feasibility of single-port RDG using advanced robotic systems, focusing on patient safety and esthetic benefits due to smaller incisions and potentially lesser visible scarring. The study reported no complications, underscoring the safety and potential cosmetic advantages of this minimally invasive approach, which could lead to higher patient satisfaction and quicker functional recovery [12].

Another retrospective study from Japan assessed the immediate surgical outcomes of RDG, finding it to serve as a secure and efficient therapeutic alternative. The advantages highlighted comprisereduced blood loss during surgery, less abdominal drainage and enhanced control of postoperative pain, which collectively improve the overall patient experience during recovery [13].

Lastly, an RCT conducted in China addressed the economic aspects alongside clinical outcomes in the context of locally advanced gastric cancer. While RDG was associated with improved short-term results and quality of life, the study cautions about the economic implications, suggesting a balanced consideration of cost alongside clinical benefits when opting for robotic surgery in complex cases [14] (Table 1, 2, Figure 2).

Table 1: Outcomes metrics of the involved studies

Study ID	Study design	Country	Sociodemographic	Complications (%)	Mortality (%)	Main outcomes
Hondo *et al.* [11]	Retrospective cohort	Japan	N = 988 Males: 632 (64%)	81 (8.2%)	0%	Across the country, RDG was carried out safely and resulted in a shortened postoperative length of stay
Park *et al.* [12]	RCT	Korea	N = 19 Mean age: 54.7 Males: 9 (47.4%)	0%	NM	the viability and safety of single-port RDG using the da Vinci SP system in a subset of gastric cancer patients. Due to its early recovery, safe discharge, and esthetic benefits, single-port RDG may be a viable substitute for conventional or reduced-port minimally invasive gastrectomy
Ye *et al.* [13]	Retrospective cohort	Japan	N = 60 Mean age: 59 Males: 41 (68.3%)	11 (18.3%)	0%	Totally RDG represents a secure and effective therapeutic approach, offering superior immediate outcomes in comparison to RADG, including reduced intraoperative blood loss, diminished abdominal drainage, and improved postoperative pain assessments
Lu *et al.* [14]	RCT	China	N = 117 Males: 58 (49.6%)	13 (11.1%)	NM	When making clinical decisions about the use of robotic surgery for patients with locally advanced gastric cancer, the economic burden should be taken into account, even though patients who underwent RDG showed improved short-term results and quality of life

Table 2: Risk of bias assessment using ROBINS-I

Study ID	Bias due to confounding	Bias in the selection of participants into	Bias in the classification of interventions	Bias due to deviations from the intended interval	Bias due to missing data	Bias in the measurement of outcomes	Bias in the selection of reported result	Overall bias
Hondo *et al.* [11]	Mod	Mod	Low	Low	Low	Low	Low	Low
Ye *et al.* [13]	Mod	Low	Low	Low	Low	Mod	Mod	Moderate

DISCUSSION

The reviewed studies collectively support the viability and growing acceptance of Robotic Distal Gastrectomy (RDG) as a safe and effective surgical option for the treatment of gastric cancer. The data consistently indicate that RDG offers several clinical advantages over conventional approaches, such as reduced intraoperative blood loss, faster postoperative recovery, shorter hospital stays, and improved pain control. These benefits can lead to improved patient satisfaction and optimized use of hospital resources. However, the widespread adoption of RDG is tempered by its high cost and the need for specialized equipment and training, making its economic feasibility an important consideration, particularly in low- to middle-income settings or complex surgical scenarios.

Kossenas *et al.* [15] observed that RDG, when performed with Billroth I or II reconstruction, is associated with a longer operative time compared to Laparoscopic Distal Gastrectomy (LDG). However, this was balanced by a faster postoperative recovery. Importantly, no significant differences were noted between RDG and LDG in terms of overall complication rates, number of lymph nodes harvested, or intraoperative blood loss, suggesting that RDG is oncologically equivalent to LDG while potentially offering better recovery outcomes.

Yu *et al.* [16] similarly demonstrated that RDG is associated with multiple intraoperative and postoperative advantages, including lower blood loss, shorter time to oral intake, wider distal resection margins, and fewer complications. These outcomes suggest that RDG may not only match but in some aspects improve upon LDG in terms of both surgical precision and postoperative recovery, reinforcing its role as a viable upgrade to conventional laparoscopic methods.

The technical strengths of RDG also lie in its enhanced maneuverability and visual clarity. As shown in previous studies, RDG enables precise dissection and safe ligation of gastric vessels, improving surgical durability and reducing intraoperative risk [17]. The use of articulating robotic instruments allows surgeons to avoid damaging critical vascular structures such as the celiac trunk, splenic artery, and common hepatic artery. This advantage is particularly important in anatomically challenging regions like the sub-pyloric and supra-pancreatic areas [18]. Additionally, complete mesenteric resection achieved through the robotic approach can further minimize blood loss. The robotic arm's stable tissue handling also reduces the likelihood of microvascular trauma during manipulation [19].

In a comparative study by Li *et al.* [20], RDG and LDG demonstrated similar results in terms of time to first flatus

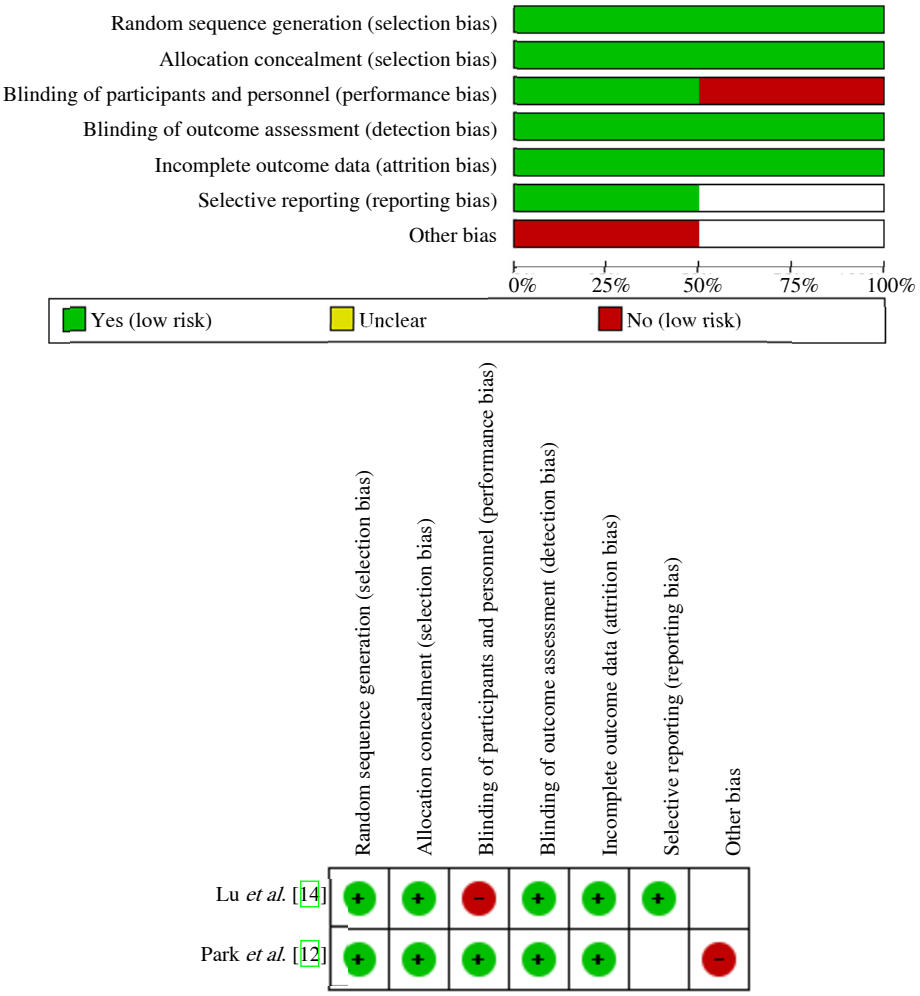

Figure 2: Risk of bias assessment

and complication rates, both overall and severe. Nevertheless, RDG yielded advantages such as less intraoperative bleeding, a greater number of lymph nodes harvested, and reduced hospital stay durations, despite having a longer operative time. These findings underscore the potential of RDG to enhance surgical and recovery outcomes without compromising safety.

This systematic review highlights RDG as a minimally invasive and technically advanced alternative to open or laparoscopic gastrectomy, with favorable short-term clinical outcomes. For institutions equipped with the necessary robotic infrastructure and trained personnel, RDG may become increasingly feasible as a standard option. From a patient perspective, the quicker recovery, lower complication rates, and smaller surgical scars make RDG an appealing choice. However, healthcare systems must carefully weigh these benefits against the significantly higher costs of robotic technology and its associated maintenance and training requirements.

The reviewed studies draw strength from their inclusion of varied geographic contexts and methodological designs, such as randomized controlled trials and large cohort analyses. This diversity provides a broader view of RDG outcomes across different healthcare environments. Nevertheless, several limitations persist. Most studies originate from high-resource settings, which may limit the applicability of findings in low-resource environments. Furthermore, long-term oncological outcomes, including survival and recurrence rates, remain underreported, limiting a comprehensive comparison between RDG and other surgical options. Finally, economic evaluations across studies are inconsistent, which obscures a clear understanding of RDG's cost-effectiveness on a global scale.

CONCLUSIONS

Robotic distal gastrectomy (RDG) appears to be a safe and clinically effective surgical approach for managing gastric cancer, offering advantages such as reduced intraoperative blood loss, quicker postoperative recovery, and fewer complications compared to traditional surgical techniques. These benefits make RDG a compelling option in the ongoing evolution of minimally invasive oncological surgery. However, its broader adoption must be weighed against challenges such as prolonged operative time, steep learning curves, and significant costs associated with robotic platforms. The review highlights the need for comprehensive

cost-effectiveness analyses and long-term oncological outcome data to establish RDG's role within routine surgical practice. While current findings are promising, especially from high-resource settings, future research should focus on expanding the evidence base across diverse populations and healthcare systems.

Conflicts of Interest

The authors declare no conflicts of interest relevant to the content of this study.

Ethical Considerations

This review was based entirely on previously published studies; hence, no new ethical approval or patient consent was required. All included studies were assumed to have obtained appropriate institutional review board approval and patient consent as per journal requirements. Future primary studies on RDG should continue to comply with ethical standards regarding informed consent and data transparency.

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