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Review Article

Outcomes and complications of Mini-Invasive Surgery for Gastric Cancer: a Narrative Review

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Abstract:

Minimally invasive surgery (MIS) has become an increasingly adopted approach in the treatment of gastric cancer (GC), with laparoscopic and robotic techniques emerging as viable alternatives to traditional open surgery. This narrative review explores the outcomes and complications associated with MIS in GC treatment, comparing laparoscopic gastrectomy (LAG), robotic gastrectomy (RG), and open gastrectomy (OG) based on the latest literature.

A search was conducted for the most recent international guidelines, randomized controlled trials (RCTs), meta-analyses, and narrative reviews on the topic, focusing on the outcomes and complications of the different surgical techniques for treating gastric cancer. This review examines the laparoscopic, robotic, and traditional open approaches, considering factors such as blood loss, length of hospital stay, and the learning curve required to achieve optimal results.

While gastric resection remains the standard treatment for GC, minimally invasive techniques, particularly laparoscopy, have shown significant advantages in reducing postoperative complications such as blood loss and hospital stay length. However, long-term outcomes, including disease recurrence and overall survival, are comparable between laparoscopic and open surgery. Robotic surgery, despite higher costs and longer operative times, offers improved precision and may be a valid option, particularly in high-specialty centers. Additionally, the learning curve is a critical factor for the success of minimally invasive techniques, with a minimum number of cases required to achieve optimal results.

Finally, lymph node dissection and the extent of nodal resection (D1, D2) are key determinants of prognosis and survival, regardless of the surgical approach adopted.

Key words: mininvasive, surgery; laparoscopy; robotic; gastrectomy; outcomes; complications; learning curve

Introduction

Gastric Cancer: Epidemiology and Etiology

Gastric cancer (GC) is the fifth most commonly diagnosed cancer worldwide and the third leading cause of cancer-related deaths [1]. The incidence of GC exhibits significant global variation, with the highest rates observed in Eastern Asia, Central and Eastern Europe, and South America [2]. Notably, its incidence is increasing in both high- and low-risk countries.

Gastric cancer (GC) has a range of risk factors that can vary depending on geographic and individual characteristics. The main risk factors include genetic predisposition, *Helicobacter pylori* infection, and lifestyle habits [3]. *Helicobacter pylori* is one of the most studied etiological agents, as it has been significantly associated with the development of gastric cancer, especially in non-cardiac carcinoma. Chronic infection can lead to inflammation, peptic ulcers, and, in the long term, increase the risk of malignant transformation.

In addition to *H. pylori* infection, several other factors have been identified as potentially oncogenic. These include:

- **Diet**: A diet high in salt, smoked, preserved, or processed foods, and low in fruits and vegetables increases the risk of gastric cancer. Excessive consumption of spicy or irritating foods, as well as red meat, has been linked to a higher risk, particularly for non-cardial gastric carcinoma. [4]

- **Alcohol consumption and smoking**: Both are well-known risk factors for gastric cancer. Excessive alcohol consumption has been associated with an increased risk, likely due to its irritating effect on the gastric mucosa and its ability to promote *H. pylori* infection. Smoking increases the risk, especially for cancer in the upper part of the stomach (cardia). [5]
- **Obesity and metabolic diseases**: Obesity, especially abdominal obesity, has been associated with an increased risk of cardia gastric cancer. Additionally, metabolic diseases such as type 2 diabetes, hypertension, and dyslipidemia are considered risk factors for gastric carcinoma, particularly in Western populations. [6]
- **Gastroesophageal reflux disease (GERD) and esophagitis**: Individuals with gastroesophageal reflux disease (GERD) or chronic esophagitis have an increased risk of developing gastric cancer in the proximal stomach area, especially in Western countries. Chronic exposure of the esophagus to acidic content can promote malignant transformation of esophageal and gastric cells. [6]
- **Family history and genetic predisposition**: Family history plays a significant role in the etiology of gastric cancer. In particular, mutations in the *CDH1* and *TP53* genes have been linked to an increased risk of hereditary gastric carcinoma. The presence of genetic syndromes like Lynch syndrome or familial adenomatous polyposis can also predispose individuals to gastric cancer.[7]
- **Exposure to chemicals**: Occupational exposure to chemicals like benzene, nickel, and vinyl chloride can increase the risk of developing gastric cancer. Exposure to these substances has been associated with a higher incidence of gastric tumors, especially in workers in chemical industries and areas with high pollution.
- **Oncogenic viruses**: Some viruses, such as Epstein-Barr virus (EBV), have been associated with a specific form of gastric cancer, particularly EBV-induced gastric carcinoma, which tends to localize in the upper part of the stomach. EBV has been identified in a significant percentage of gastric cancer cases, particularly those with a diffuse histological profile. Its prevalence appears consistent across Asia, Europe, and the Americas [8].
- **Age and sex**: The risk of gastric cancer increases with age, with the highest rates observed in individuals over 60 years old. Moreover, gastric cancer is more common in men than in women, with a male-to-female ratio of approximately 2:1. [9]

These risk factors are closely related to environmental, lifestyle, and genetic predispositions. In many high-risk areas, primary prevention, such as reducing salt and alcohol consumption, eliminating *H. pylori*, and promoting healthy dietary habits, could significantly reduce the incidence of gastric cancer.

In Western countries, GC is often diagnosed at an advanced stage, primarily due to inadequate screening protocols [10].

Gastric Cancer: Treatment (11)

Surgical intervention remains the cornerstone of curative treatment for GC, frequently combined with systemic therapies, including novel chemotherapeutic regimens, radiotherapy, and immunomodulatory agents. These treatments are typically tailored to the individual patient and the tumor's characteristics.

SURGICAL APPROACH	DESCRIPTION
Total Gastrectomy (TG)	Complete removal of the stomach, including the cardia and pylorus.
Distal Gastrectomy (DG)	Removal of the lower portion of the stomach, including the pylorus, while preserving the cardia. Two-thirds of the stomach is resected in standard DG.
Pylorus-Preserving Gastrectomy (PPG)	Removal of the lower stomach while preserving the pylorus and the upper third of the stomach, including a portion of the antrum.
Proximal Gastrectomy (PG)	Removal of the upper portion of the stomach, including the cardia (esophagogastric junction), while preserving the pylorus.
Segmental Gastrectomy	Circumferential resection of the stomach, preserving both the cardia and pylorus.
Local Resection	Non-circumferential resection of the stomach.
Non-resectional Surgery	Procedures such as bypass surgery, gastrostomy, and jejunostomy.
Completion Gastrectomy	Total resection of the remnant stomach, including the cardia or pylorus, depending on the type of previous gastrectomy.
Subtotal Resection of the Remnant Stomach	Distal resection of the remnant stomach, preserving the cardia.

Table 1: synopsis of different surgical approaches.

Aim and Purpose of The Study

This narrative review aims to critically analyze the outcomes and complications associated with minimally invasive surgery (MIS) for the treatment of gastric cancer, specifically comparing laparoscopic gastrectomy (LAG), robotic gastrectomy (RG), and open gastrectomy (OG). Through a synopsis of the latest literature, the review explores the advantages and limitations of each surgical approach in terms of postoperative complications, oncological outcomes, and procedural feasibility. A key focus is the impact of surgical technique on postoperative recovery, morbidity, and long-term survival, with particular attention to the role of the learning curve in achieving optimal outcomes.

Surgical Approach: Description

- **Total Gastrectomy (TG):** Complete removal of the stomach, including the cardia and pylorus.
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- **Segmental Gastrectomy:** Circumferential resection of the stomach, preserving both the cardia and pylorus.
- **Local Resection:** Non-circumferential resection of the stomach.
- **Non-resectional Surgery:** Procedures such as bypass surgery, gastrostomy, and jejunostomy.
- **Completion Gastrectomy:** Total resection of the remnant stomach, including the cardia or pylorus, depending on the type of previous gastrectomy.
- **Subtotal Resection of the Remnant Stomach:** Distal resection of the remnant stomach, preserving the cardia.

Extent of Gastric Resection (12-19)

A sufficient resection margin is crucial for curative intent in gastrectomy.

Surgery for T1 Tumors:

T1 tumors that do not meet the criteria for endoscopic resection require surgical intervention, though the procedure can be less extensive than for other gastric cancers. A gross resection margin of at least 2 cm is required. If the tumor border is unclear, preoperative endoscopic marking of the tumor by clips based on biopsy results can help guide the resection.

Lymph node dissection for T1 tumors may be limited to perigastric lymph nodes, including local N2 nodes (D1+ lymphadenectomy), with the specific nodal groups dissected depending on the tumor's site.

Surgery for cN+ or T2-T4a Tumors:

For clinically node-positive (cN+) or T2–T4a tumors, the standard surgical procedure is either total or distal gastrectomy. A proximal margin of 3 cm is recommended for tumors with an expansive growth pattern (including intestinal histotypes) and 5 cm for those with an infiltrative growth pattern (including poorly cohesive/diffuse histotypes). If these guidelines cannot be met, frozen section examination of the entire thickness of the proximal resection margin is recommended.

Distal gastrectomy is chosen if a satisfactory proximal resection margin can be achieved. If this is not possible, total gastrectomy is preferred.

In cases of pancreatic invasion by the tumor requiring pancreatosplenectomy, total gastrectomy is indicated regardless of tumor location. Total gastrectomy with splenectomy should also be considered for tumors located along the greater curvature. For adenocarcinoma of the esophagogastric junction, proximal gastrectomy may be an appropriate option.

Lymph Node Dissection in Total Gastrectomy

The extent of nodal dissection in radical gastrectomy has been a subject of considerable debate. D1 resection includes removal of the perigastric lymph nodes and those along the left gastric artery. D1+ and D2 resections involve additional lymph nodes along the proper or common hepatic artery, splenic artery, or celiac axis.

The AJCC/UICC TNM classification (8th edition) recommends excising at least 15 lymph nodes for reliable staging.

For cN+ or ≥ cT2 tumors, D2 lymphadenectomy is indicated, while D1 or D1+ is typically performed for cT1N0 tumors. As preoperative and intraoperative diagnoses regarding tumor invasion and nodal involvement are often unreliable, D2 lymphadenectomy should be performed if nodal involvement cannot be definitively excluded.

In Asian countries, studies have shown that D2 resection results in superior outcomes compared to D1 resection. [13] In Western countries, patients with resectable disease should undergo D2 resection in specialized, high-volume centers with appropriate surgical expertise and postoperative care. [20].

	Extent of Surgery	Lymph node dissection
T1*	Resection with margin of at least 2 cm.	D1(+)
cN+ or T2-T4a	Distal or total gastrectomy.	D2

*not meeting criteria for endoscopic resection

Table 2: Surgical indications according to the clinical stage of the disease. (13)

Surgical Approaches

Open total gastrectomy (OTG) with D2 lymphadenectomy remains the gold standard for the treatment of locally advanced gastric cancer.

Since the introduction of laparoscopic and robotic techniques for total gastrectomy, these minimally invasive approaches have gained widespread acceptance and are increasingly used worldwide. Despite this, the optimal surgical approach remains a subject of ongoing debate.

A recent nationwide survey from Korea documented a shift from open surgery to minimally invasive approaches. The frequency of open surgery decreased from 49.8% in 2014 to 27.6% in 2019, while laparoscopic total gastrectomy (LTG) increased from 18.2% to 44.3% over the same period. [21-22]

Definitions: Laparoscopic-Assisted vs Totally Laparoscopic Gastrectomy
Laparoscopic-assisted distal gastrectomy (LADG), first introduced by Kitano in 1994, combines laparoscopic assistance with traditional open surgery. In contrast, **totally laparoscopic gastrectomy** (TLG) involves complete laparoscopic surgery without any open components.

Table 3: definition of LADG and TLG. (18)

Laparoscopic Vs Open Gastrectomy (21-29)

For cStage I gastric cancer

The non-inferiority of laparoscopic distal gastrectomy (LDG) compared to open distal gastrectomy (ODG) for clinical stage I gastric cancer has been established in phase 3, randomized controlled trials conducted in Japan and Korea (JCOG0912, KLASS01). Additionally, the feasibility of laparoscopy-assisted total or proximal gastrectomy has been confirmed in a single-arm, confirmatory clinical trial (JCOG1401). Recently the update of JCOG1401 trial was published (2024): the long-term outcomes of LATG and LAPG were acceptable and comparable to previous OTG/OPG results, therefore **it** can be considered one of the standard treatments for cStage I proximal gastric cancer.

The KLASS-07 RCT proved that totally laparoscopic distal gastrectomy (TLDG) is comparable to laparoscopy-assisted distal gastrectomy in terms of postoperative morbidities within 30 days when used for clinical stage I gastric cancer treatment and has benefits in terms of reducing ileus (0.9% vs. 5.7%, P= 0.006) and pulmonary complications.

For advanced gastric cancer

International guidelines still consider open total or distal gastrectomy the gold standard for clinically node-positive or T2–T4a tumors. In the meanwhile, for advanced gastric cancer, large-scale randomized clinical trials in Japan, Korea, and China (JLSSG0901, KLASS-02, CLASS-01) have confirmed the safety and long-term survival outcomes of laparoscopic distal gastrectomy. Safety analyses have shown no significant increase in complications with laparoscopic approaches. However, while the JLSSG0901 trial reported a significant reduction in blood loss (to as low as 30 mL), the operation took longer (over 60 minutes) compared to the CLASS and KLASS trials. This difference may reflect variations in surgical techniques across the countries involved.

Further results of the JLSSG0901 trial published in 2023 show that on the basis of 5-year follow-up data, LADG with D2 lymph node dissection for locally advanced gastric cancer, when performed by qualified surgeons, was proved noninferior to ODG. This laparoscopic approach could become a standard treatment for locally advanced gastric cancer.

Robotic Gastrectomy [30-33]

Robot-assisted minimally invasive gastrectomy (RAMIG) was first introduced by Hashizume et al. in 2002 to address the technical limitations of conventional minimally invasive gastrectomy (MIG), such as the restricted range of motion and discomfort due to the surgeon's positioning during the procedure. This innovation allows for a three-dimensional, tenfold magnified view of the operating field, which significantly enhances the precision of the surgery. In addition, the robotic system replicates the natural hand-eye coordination axis through the ergonomically designed surgeon's console, provides a high degree of freedom with its articulating surgical instruments, stabilizes the surgeon's tremor, and scales motion, further improving the accuracy and effectiveness of the procedure.

The widespread adoption of robotic surgery in a relatively short period highlights its growing significance, particularly in countries like Japan and China, where most of the recent studies have been conducted. RG has become an essential tool for curative resection of gastric cancer (GC) in these regions, demonstrating significant advantages over conventional laparoscopic techniques.

The evaluation of surgical procedures is inherently complex, influenced by factors such as the complexity of the surgical techniques, variability in surgeon experience, and differences between hospitals. Furthermore, surgical methods are constantly evolving, and their outcomes may change over time, even after they have been widely implemented in clinical practice.

Recent long-term studies, including IDEAL-3 and IDEAL-4, as well as systematic reviews and meta-analyses, have shown that total or subtotal RAMIG provides favorable or comparable short-term outcomes compared to conventional laparoscopic gastrectomy (LG) or open gastrectomy (OG) in patients with cardia and non-cardia gastric cancer. These advantages include reduced intraoperative blood loss, shorter hospital stays, and fewer postoperative complications. Moreover, many studies have reported that the oncologic outcomes, such as total lymph node yield, radicality of resection, and mortality rates, are either comparable or even improved with RAMIG. However, it does come with some drawbacks, including longer procedural time (approximately 20–50 minutes) and higher costs (approximately 1000–5000 US dollars).

Based on these findings, the technical feasibility and oncological safety of RG seem to be at least comparable to those of LG and, in some cases, may even surpass them.

A randomized controlled trial (JCOG1907) is currently underway to confirm whether robot-assisted gastrectomy can reduce morbidity compared to laparoscopic gastrectomy for clinical T1–2 N0–2 gastric cancer. It is important to note that performing robot-assisted gastrectomy requires the surgeon and facility to meet specific quality standards.

Outcomes

(34; 11; 42)

- ***POST-OPERATIVE OUTCOMES***

1. **Disease Recurrence**

LAG seems to have a higher recurrence rate compared to OG. On the other hand, RG is considered non-inferior and in some recent studies even slightly superior compared to LAG in terms of 3-years RFS (recurrence free survival).

2. **Overall Complications (OC)**

The latest RCT network meta-analysis shows OC rates of 18/% for OTG and LATG, 17% for TLTG and 16% for RTG.

These results may be theoretically explained by the reduced surgical trauma for minimally invasive gastrectomy with smaller surgical incisions, less surgical stress, and finest surgical dissection determining a lower risk of postoperative SSI and bleeding.

The incidence of anastomotic leakage (AL) after total gastrectomy for GC has been previously reported to be up to 6.6%. The latest analysis showed that OTG, LATG, TLTG, and RTG were associated with 8%, 6%, 4%, and 2% AL rates, respectively. The surgical technique used to perform TG seems to have no influence on AL. Contrarily, AL may depend on other factors such as anastomotic tension, malnutrition, inadequate blood supply, and comorbidities.

In particular, rates for wound infection, cardiac complications, respiratory complications, VTE, pancreatic complications, anastomotic leak and stenosis are similar between techniques.

3. **Perioperative Mortality**

Compared with OG, there is similar perioperative mortality in those undergoing LAG and RG.

4. **Overall Survival**

OS rates are identical for both OG and LAG. Recent and ongoing studies show a potentially increased OS in RG than LAG and OG.

5. **Morbidity**

Compared with OG, there is a significant **reduction** in morbidity in those undergoing LAG and RG, respectively. Compared with LAG, those undergoing RG have a significant reduction in overall morbidity.

Compared with OG, there is similar *major* morbidity in those undergoing LAG and RG. Compared with LAG, there is a significant reduction in major morbidity in those undergoing RG.

- ***Intra Operative Outcomes***

1. **Operative Time**

Laparoscopic gastrectomy (LAG) and robotic gastrectomy (RG) are generally associated with longer intraoperative times compared to open gastrectomy (OG). However, this finding contrasts with the results of Garbarino et al. and Trastulli et al., who reported longer operative times for open gastrectomy than for laparoscopic and robotic approaches. These discrepancies highlight the need for careful interpretation, as the total operative time (OT) for minimally invasive techniques includes both the "effective" surgical time—encompassing the dissection and reconstruction phases—and "non-productive" time, which involves tasks such as setup, docking of the robotic system, and adjustment of surgical instruments.

Liu et al. previously found that the effective operative time for robotic and laparoscopic distal gastrectomy was similar (145.9 minutes vs. 130.6 minutes). In contrast, Omori et al. reported shorter operative times for robotic gastrectomy compared to laparoscopic gastrectomy. Longer operative durations have been associated with a higher risk of postoperative complications. Specifically, Park et al. identified a cut-off time of 240 minutes, beyond which the risk of complications significantly increases.

It is important to consider that the differences in operative times, particularly for robotic and laparoscopic procedures, may also be influenced by the learning curve associated with these techniques. Surgeons with less experience in robotic or laparoscopic surgery may require additional time to perform the procedure, which could contribute to the observed variability in operative duration.

2. Number Of Lymph Nodes: Impact of learning curve

Compared with OG, LAG shows a significantly decreased LN yield, whereas there is a non-significant difference in LNs harvested for those who undergo RG.

Conversely, Trastulli et al. stated a statistically significant higher number of lymph nodes harvested in robotic vs. open gastrectomy.

3. IBL - Intraoperative Blood Loss

Compared with OG, there is a significant reduction in IBL for those who underwent LAG and the robotic group. Furthermore, there seems to be a non-significant reduction in IBL in those undergoing RG compared with those undergoing LAG.

4. Distance From Proximal And Distal Margin

This distance from the proximal margin is significantly lower in those undergoing LAG compared with OG.

The distance from distal margin is similar to those who underwent LAG and OG.

- ***Recovery Outcomes***

Minimally invasive techniques have been associated with a trend toward improved postoperative outcomes, including a shorter time to first flatus, earlier initiation of liquid intake, and more rapid ambulation. These findings likely reflect the reduced surgical trauma to the abdominal wall and gastrointestinal tract, which minimizes pain and facilitates earlier mobilization, ambulation, and passage of flatus.

However, it is important to note that there is moderate to high heterogeneity in the results for secondary outcomes. Several factors may contribute to this variability, including the patients' comorbid conditions, body mass index, ASA classification, smoking status, use of postoperative antibiotics, tumor characteristics (such as type and size), techniques for intestinal reconstruction, extent of lymphadenectomy (D1 vs. D1+ vs. D2), type of omentectomy (total, partial, or none), hospital protocols, the implementation of enhanced recovery after surgery (ERAS) programs, the surgeon's level of experience, and hospital case volumes.

When comparing laparoscopic gastrectomy (LAG) with open gastrectomy (OG), a significant reduction in the length of hospital stay has been observed for LAG patients. However, for patients undergoing robotic gastrectomy (RG), hospital stay is similar to that of OG patients. Additionally, no significant difference in hospital stay has been found between LAG and RG.

In terms of time to first liquid intake, both LAG and RG show a non-significant reduction compared with OG. Similarly, the time to first liquid intake is comparable between RG and LAG.

For the initiation of solid food intake, there is no significant difference.

The time to first passage of flatus is significantly reduced in both LAG and RG compared with OG. In contrast, no significant difference has been observed between RG and LAG in this outcome.

There is no significant difference in the time to first ambulation between LAG or RG compared to OG.

Finally, the rates of readmission seem to be similar.

Criterion	LAG (Laparoscopic)	RG (Robotic)	OG (Open)
Operative Time	Longer than OG	Similar or slightly longer	Shorter
Blood Loss (IBL)	Reduced compared to OG	Further reduced	Higher
Complications	Lower morbidity and complications	Even fewer complications	More frequent complications
Survival	Comparable to OG	Preliminary positive data	Reference standard
Recovery	Improved (early flatus, shorter stay)	Improved but similar to LAG	Slower
Learning Curve	Long	Longer (requires specialized centers)	Shorter

Table 4: synopsis of outcomes and differences (based on the overall data).

Technique	Ideal Patient Selection Criteria
LAG	Early-stage tumors (cStage I-II), young, stable patients
RG	Advanced tumors, need for anatomical precision
OG	Complex patients, advanced-stage tumors

Table 5: The proper technique for the proper patient (based on the overall data).

The Impact of Learning Curve (35- 41)

Laparoscopic gastrectomy is classified as advanced laparoscopic surgery and is associated with a substantial learning curve. The learning curve reflects the process through which a surgeon masters a new procedure, which is considered complete when key monitored parameters reach a steady state.

The learning curve is a critical consideration when evaluating the short-term outcomes of laparoscopic-assisted gastrectomy. Multidimensional learning curves, which encompass operation time, conversion rates, major complications, and in-hospital mortality, are particularly valuable for assessing improvements in surgical performance. Additional relevant monitoring parameters in oncological surgery include the achievement of R0 status (absence of residual tumor) and the adequacy of lymph node dissection. The experience of the treating institution and the surgical team are independent prognostic variables that significantly affect the likelihood of locoregional recurrence and overall survival. Both Japanese and Western studies have demonstrated a clear survival benefit associated with systematic lymph node dissection (D2 lymphadenectomy) in the treatment of gastric cancer. Therefore, proficiency in both D1 and D2 lymph node dissection is essential to achieving the oncological objectives of LAG for EGC.

It is generally accepted that surgeons performing LADG with D1 resection must have completed at least **30** laparoscopic gastrectomy procedures to overcome the learning curve.

On the other hand, a minimum of **50** cases of LADG with systemic lymphadenectomy for early gastric cancer is necessary to achieve optimal proficiency. As a matter of fact, there seems to be a clear reduction in mean operative time in surgeons after that number of cases is achieved.

To ensure continuous improvement and maintain high clinical standards, we recommend the use of Cumulative Sum (CUSUM) charting as a personal audit tool. This method allows surgeons to systematically monitor their clinical parameters, assess their performance, identify emerging trends, evaluate the effects of patient selection, and track success rates in achieving oncological goals. To successfully complete the learning curve while maintaining optimal clinical outcomes, surgeons should delay the introduction of broader surgical indications until they have gained sufficient experience.

Conclusion

Minimally invasive surgery, both laparoscopic and robotic, represents the future of gastric cancer treatment due to its advantages in terms of recovery and reduced complications. However, the choice of technique should be tailored and guided by surgical experience, patient characteristics, and the stage of the disease.

Robotic surgery is emerging as a valid option in highly specialized centers, thanks to its technical advantages. However, costs and the learning curve remain significant obstacles. Laparoscopy, particularly total laparoscopy, represents a well-established choice for both early and advanced tumors with reduced morbidity.

The choice of lymphadenectomy type (D2 vs D1+) is crucial to improving long-term survival. Operative time and surgical volume remain key factors to minimize complications and optimize outcomes.

Criteria	LAG (Laparoscopic)	RG (Robotic)	OG (Open)	Clinical Considerations
Operative Time	Longer	Long	Short	High-volume centers improve time.
Recovery	Improved	Improved	Slower	Important for frail patients.
Lymph Node Dissection	Effective, requires skill	Precise, technologically aided	Effective	Optimal results with D2 dissection.

Table 6: Basic clinical considerations based on the main features of the three approaches as stated in the mentioned studies.

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Authors' contributions

Battista A.

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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References

1. Sung, H.; Ferlay, J.; Siegel, R.L.; Laversanne, M.; Soerjomataram, I.; Jemal, A.; Bray, F. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. CA Cancer J. Clin. 2021, 71, 209–249. [CrossRef] [PubMed].
2. Ferlay J, Ervik M, Colombet M, et al. Global Cancer Observatory: Cancer Today. Lyon, France: International Agency for Research on Cancer. Available at https://gco.iarc.fr/today. Published 2020. Accessed September 30, 2021.
3. Guan, W.L.; He, Y.; Xu, R.H. Gastric Cancer Treatment: Recent Progress and Future Perspectives. J. Hematol. Oncol. 2023, 16, 57. [CrossRef]
4. Krejs, G. J. (2010). Gastric cancer: epidemiology and risk factors. Digestive Diseases, 28(4-5), 600-603.
5. Yusefi, A. R., Bordbar, S., Mehralian, G., Lankarani, K. B., Khammarnia, M., Kavosi, Z., & Bastani, P. (2023). Ranking and prioritizing risk factors for gastric cancer. The Open Public Health Journal, 16(1).
6. Man, J., Ni, Y., Yang, X., Zhang, T., Yuan, Z., Chen, H., … & Ye, W. (2021). Healthy lifestyle factors, cancer family history, and gastric cancer risk: a population-based case-control study in china. Frontiers in Nutrition, 8.
7. Cai HQ, Zhang LY, Fu LM, Xu B, Jiao Y. Mutational landscape of TP53 and CDH1 in gastric cancer. World J Gastrointest Surg. 2024 Feb 27;16(2):276-283. PMID: 38463349; PMCID: PMC10921187.)
8. Cancer Genome Atlas Research Network. Comprehensive molecular characterization of gastric adenocarcinoma. Nature. 2014;513(7517): 202-209
9. Rawla P., Barsouk A. Epidemiology of gastric cancer: Global trends, risk factors and prevention. Prz. Gastroenterol. 2019;14:26–38.
10. Ajani, J.A.; D'Amico, T.A.; Bentrem, D.J.; Chao, J.; Cooke, D.; Corvera, C.; Das, P.; Enzinger, P.C.; Enzler, T.; Fanta, P.; et al. Gastric Cancer, Version 2.2022, NCCN Clinical Practice Guidelines in Oncology. J. Natl. Compr. Cancer Netw. 2022, 20, 167–192. [CrossRef]
11. Manara, M.; Aiolfi, A.; Bonitta, G.; Schlanger, D.; Popa, C.; Lombardo, F.; Manfredini, L.; Biondi, A.; Bonavina, L.; Bona, D. Short-Term Outcomes Analysis Comparing Open, Lap-Assisted, Totally Laparoscopic, and Robotic Total Gastrectomy for Gastric Cancer: A Network Meta-Analysis. Cancers 2024, 16, 3404.
12. Lordick, F.; Carneiro, F.; Cascinu, S.; Fleitas, T.; Haustermans, K.; Piessen, G.; Vogel, A.; Smyth, E.C. Gastric Cancer: ESMO Clinical Practice Guideline for Diagnosis, Treatment and Follow-Up. Ann. Oncol. 2022, 33, 1005–1020. [CrossRef] [PubMed].
13. Japanese Gastric Cancer Association. Japanese Gastric Cancer Treatment Guidelines 2021 (6th Edition). Gastric Cancer 2023, 26, 1–25. [CrossRef]].
14. Lei, X.; Wang, Y.; Shan, F.; Li, S.; Jia, Y.; Miao, R.; Xue, K.;

Li, Z.; Ji, J.; Li, Z. Short-and Long-Term Outcomes of Laparoscopic versus Open Gastrectomy in Patients with Gastric Cancer: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. World J. Surg. Oncol. 2022, 20, 405. [CrossRef] [PubMed].

15. Claassen YHM, van Amelsfoort RM, Hartgrink HH, et al. Effect of hospital volume with respect to performing gastric cancer resection on recurrence and survival: results from the CRITICS trial. Ann Surg. 2019;270(6):1096–1102.
16. Kim HH, Han SU, Kim MC, et al. Effect of laparoscopic distal gastrectomy vs open distal gastrectomy on long-term survival among patients with stage I gastric cancer: the KLASS-01 randomized clinical trial. JAMA Oncol. 2019;5(4):506–513.
17. Katai H, Mizusawa J, Katayama H, et al. Survival outcomes after laparoscopy-assisted distal gastrectomy versus open distal gastrectomy with nodal dissection for clinical stage IA or IB gastric cancer (JCOG0912): a multicentre, non-inferiority, phase 3 randomised controlled trial. Lancet Gastroenterol Hepatol. 2020;5(2):142–151.
18. Hyung WJ, Yang HK, Han SU, et al. A feasibility study of laparoscopic total gastrectomy for clinical stage I gastric cancer: a prospective multi-center phase II clinical trial, KLASS 03. Gastric Cancer. 2019;22(1):214–222.
19. Hyung WJ, Yang HK, Park YK, et al. Long-term outcomes of laparoscopic distal gastrectomy for locally advanced gastric cancer: the KLASS-02-RCT randomized clinical trial. J Clin Oncol. 2020;38(28):3304–3313.
20. Allum W, Lordick F, Alsina M, Andritsch E, Ba-Ssalamah A, Beishon M, Braga M, Caballero C, Carneiro F, Cassinello F, Dekker JW, Delgado-Bolton R, Haustermans K, Henning G, Hutter B, Lövey J, Netíková IŠ, Obermannová R, Oberst S, Rostoft S, Saarto T, Seufferlein T, Sheth S, Wynter-Blyth V, Costa A, Naredi P. ECCO essential requirements for quality cancer care: Oesophageal and gastric cancer. Crit Rev Oncol Hematol. 2018 Feb;122:179-193. Epub 2018 Jan 2. PMID: 29458786
21. Eom, B.W.; Ahn, H.S.; Lee, I.S.; Min, J.S.; Son, Y.G.; Lee, S.E.; Kim, J.H.; Lee, S.Y.; Kim, J.H.; Ahn, S.H.; et al. Korean Gastric Cancer Association Nationwide Survey on Gastric Cancer in 2014. J. Gastric Cancer 2016, 16, 131–140. [CrossRef]
22. Ryu, S.W.; Eom, B.W.; Kim, D.J.; Huh, Y.J.; Jeong, S.H.; Suh, Y.S.; Kim, J.W.; Kwon, I.G.; Kwon, O.K.; Lee, I.S. Korean Gastric Cancer Association-Led Nationwide Survey on Surgically Treated Gastric Cancers in 2019. J. Gastric Cancer 2021, 21, 221–235. [CrossRef].
23. Kitano S, Iso Y, Moriyama M, Sugimachi K. Laparoscopy-assisted Billroth I gastrectomy. Surg Laparosc Endosc. 1994;4(2):146–148.
24. Etoh T, Ohyama T, Sakuramoto S, Tsuji T, Lee SW, Yoshida K, Koeda K, Hiki N, Kunisaki C, Tokunaga M, Otsubo D, Takagane A, Misawa K, Kinoshita T, Cho H, Doki Y, Nunobe S, Shiraishi N, Kitano S; Japanese Laparoscopic Surgery Study Group (JLSSG). Five-Year Survival Outcomes of Laparoscopy-Assisted vs Open Distal Gastrectomy for Advanced Gastric Cancer: The JLSSG0901 Randomized Clinical Trial. JAMA Surg. 2023 May 1;158(5):445-454. PMID: 36920382; PMCID: PMC10018406.
25. Markar SR, Visser MR, van der Veen A, Luyer MDP, Nieuwenhuijzen G, Stoot JHMB, Tegels JJW, Wijnhoven BPL, Lagarde SM, de Steur WO, Hartgrink HH, Kouwenhoven EA, Wassenaar EB, Draaisma WA, Gisbertz SS, van Berge Henehouwen MI, van der Peet DL, Ruurda JP, van Hillegersberg R; LOGICA Study Group, Dutch Upper Gastrointestinal Cancer Audit Group. Evolution in Laparoscopic Gastrectomy from a Randomized Controlled Trial Through National Clinical Practice. Ann Surg. 2024 Mar 1;279(3):394-401.. Epub 2023 Nov 23. PMID: 37991188; PMCID: PMC10829898.
26. Kunisaki C, Katai H, Sakuramoto S, Mizusawa J, Katayama H, Kadoya S, Yamada T, Kinoshita T, Yoshikawa T, Terashima M; Stomach Cancer Study Group of Japan Clinical Oncology Group. A nonrandomized controlled trial: long-term outcomes of LATG/LAPG for cStage I gastric cancer: Japan Clinical Oncology Group Study JCOG1401. Gastric Cancer. 2024 Jan;27(1):164-175. Epub 2023 Oct 25. PMID: 37875696.
27. Huang C, Liu H, Hu Y, Sun Y, Su X, Cao H, Hu J, Wang K, Suo J, Tao K, He X, Wei H, Ying M, Hu W, Du X, Yu J, Zheng C, Liu F, Li Z, Zhao G, Zhang J, Chen P, Li G; Chinese Laparoscopic Gastrointestinal Surgery Study (CLASS) Group. Laparoscopic vs Open Distal Gastrectomy for Locally Advanced Gastric Cancer: Five-Year Outcomes From the CLASS-01 Randomized Clinical Trial. JAMA Surg. 2022 Jan 1;157(1):9-17. PMID: 34668963; PMCID: PMC8529527.
28. Park SH, Lee CM, Hur H, Min JS, Ryu SW, Son YG, Chae HD, Jeong O, Jung MR, Choi CI, Song KY, Lee HH, Kim HG, Jee YS, Hwang SH, Lee MS, Kim KH, Seo SH, Jeong IH, Son MW, Kim CH, Yoo MW, Oh SJ, Kim JG, Hwang SH, Choi SI, Yang KS, Huang H, Park S. Totally laparoscopic versus laparoscopy-assisted distal gastrectomy: the KLASS-07: a randomized controlled trial. Int J Surg. 2024 Aug 1;110(8):4810-4820. PMID: 38716987; PMCID: PMC11325945.
29. Park SH, Lee CM, Hur H, Min JS, Ryu SW, Son YG, Chae HD, Jeong O, Jung MR, Choi CI, Song KY, Lee HH, Kim HG, Jee YS, Hwang SH, Lee MS, Kim KH, Seo SH, Jeong IH, Son MW, Kim CH, Yoo MW, Oh SJ, Kim JG, Hwang SH, Choi SI, Yang KS, Huang H, Park S. Totally laparoscopic versus laparoscopy-assisted distal gastrectomy: the KLASS-07: a randomized controlled trial. Int J Surg. 2024 Aug 1;110(8):4810-4820. PMID: 38716987; PMCID: PMC11325945.
30. Hashizume M, Shimada M, Tomikawa M, Ikeda Y, Takahashi I, Abe R, et al. Early experiences of endoscopic procedures in general surgery assisted by a computer-enhanced surgical system. Surg Endosc. 2002;16(8):1187–1191.
31. Shibasaki S, Suda K, Hisamori S, Obama K, Terashima M, Uyama I. Robotic gastrectomy for gastric cancer: systematic review and future directions. Gastric Cancer. 2023 May;26(3):325-338. Epub 2023 Apr 3. PMID: 37010634.
32. Triemstra L, den Boer RB, Rovers MM, Hazenberg CEVB, van Hillegersberg R, Grutters JPC, Ruurda JP. A systematic review on the effectiveness of robot-assisted minimally invasive gastrectomy. Gastric Cancer. 2024 Sep;27(5):932-946. Epub 2024 Jul 11. PMID: 38990413; PMCID: PMC11335791.
33. Ojima T, Nakamura M, Hayata K, Kitadani J, Katsuda M, Takeuchi A, Tominaga S, Nakai T, Nakamori M, Ohi M, Kusunoki M, Yamaue H. Short-term Outcomes of Robotic

Gastrectomy vs Laparoscopic Gastrectomy for Patients With Gastric Cancer: A Randomized Clinical Trial. JAMA Surg. 2021 Oct 1;156(10):954-963. PMID: 34468701; PMCID: PMC8411361.

34. Davey, M.G., Temperley, H.C., O'Sullivan, N.J. *et al.* Minimally Invasive and Open Gastrectomy for Gastric Cancer: A Systematic Review and Network Meta-Analysis of Randomized Clinical Trials. *Ann Surg Oncol* 30, 5544–5557 (2023).
35. Jin SH, Kim DY, Kim H, et al. Multidimensional learning curve in laparoscopy-assisted gastrectomy for early gastric cancer. Surg Endosc 2007;21:28–33.
36. Kim MC, Jung GJ, Kim HH. Learning curve of laparoscopy-assisted distal gastrectomy with systemic lymphadenectomy for early gastric cancer. World J Gastroenterol. 2005 Dec 21;11(47):7508-11. PMID: 16437724; PMCID: PMC4725181.
37. Shibasaki S, Suda K, Obama K, Yoshida M, Uyama I. Should robotic gastrectomy become a standard surgical treatment option for gastric cancer? Surg Today. 2020 Sep;50(9):955-965. Epub 2019 Sep 11. PMID: 31512060.
38. Aiolfi A, Bona D, Bonitta G, Lombardo F, Manara M, Sozzi A, Schlanger D, Popa C, Cavalli M, Campanelli G, Biondi A, Bonavina L; OGSA Group for Esophagogastric Surgery. Long-Term Impact of D2 Lymphadenectomy during Gastrectomy for Cancer: Individual Patient Data Meta-Analysis and Restricted Mean Survival Time Estimation. Cancers (Basel). 2024 Jan 19;16(2):424. PMID: 38275865; PMCID: PMC10814228.
39. Coratti A, Annecchiarico M, Di Marino M, Gentile E, Coratti F, Giulianotti PC. Robot-assisted gastrectomy for gastric cancer: current status and technical considerations. World J Surg. 2013 Dec;37(12):2771-81.. PMID: 23674257.
40. Berlth F, Yang HK. Minimal-invasive gastrectomy: what the west can learn from the east? Updates Surg. 2018 Jun;70(2):181-187. Epub 2018 Jun 18. PMID: 29916040.
41. Zhou D, Quan Z, Wang J, Zhao M, Yang Y. Laparoscopic-assisted versus open distal gastrectomy with D2 lymph node resection for advanced gastric cancer: effect of learning curve on short-term outcomes. a meta-analysis. J Laparoendosc Adv Surg Tech A. 2014 Mar;24(3):139-150. PMID: 24625347.
42. Stillman MD, Yoon SS. Open and minimally invasive gastrectomy in Eastern and Western patient populations: A review of the literature and reasons for differences in outcomes. J Surg Oncol. 2022 Aug;126(2):279-291. Epub 2022 Apr 13. PMID: 35416303; PMCID: PMC9276624.

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