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Laparoscopic versus open gastrectomy for locally advanced gastric cancer: a comparative analysis of survival and prognostic factors

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ABSTRACT

Introduction: This retrospective study aimed to compare the outcomes of laparoscopic gastrectomy (LG) and open gastrectomy (OG) in patients undergoing gastrectomy with D2 lymph node dissection for locally advanced gastric adenocarcinoma.

Materials and Methods: A total of 159 patients who underwent surgery between 2014 and 2022 were analyzed. Patients were divided into two groups according to the surgical approach: LG (60%) and OG. Data on patient demographics, tumor characteristics, perioperative outcomes, and survival were collected. Overall survival (OS) was analyzed using the Kaplan–Meier method and Cox proportional hazards models.

Results: The LG group was significantly younger and had earlier tumor-node-metastasis (TNM) stages and N stages than the OG group (p<0.001). The median hospital stay was shorter in the LG group (8 vs. 8 days, p=0.042); however, postoperative morbidity was higher (29.2% vs. 6.3%, p<0.001). In the univariate analysis, LG was associated with improved OS compared with OG (hazard ratio [HR] 0.61, 95% confidence interval [CI] 0.41–0.90, p=0.014). However, in the multivariable analysis adjusted for age and TNM stage, age <65 years (HR 0.57, 95% CI 0.38–0.86, p=0.007) and stage II disease (HR 0.32, 95% CI 0.19–0.54, p<0.001) were identified as independent prognostic factors for better survival, whereas the surgical approach was no longer independently significant (HR 0.68, 95% CI 0.45–1.02, p=0.062).

Conclusions: Laparoscopic gastrectomy is a feasible approach for selected patients with locally advanced gastric cancer. Although it is associated with a shorter hospital stay, careful attention should be paid to postoperative morbidity. The observed survival benefit associated with laparoscopy appears to be influenced by patient age and tumor stage rather than by the surgical technique itself. Larger prospective studies are needed to evaluate the independent long-term survival impact of the laparoscopic approach.

Keywords: Gastric cancer, laparoscopic gastrectomy, open gastrectomy, prognostic factors, survival

Introduction

Gastric cancer remains a major global health burden, ranking as the fifth most frequently diagnosed malignancy and the fourth leading cause of cancer-related mortality worldwide.[1] Despite advances in diagnostic modalities and multimodal treatment strategies, a substantial proportion of patients are still diagnosed at a locally advanced stage, at which long-term survival remains poor, with reported 5-year survival rates of approximately 25%.[2] For patients with locally advanced gastric cancer, radi-

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cal gastrectomy combined with D2 lymph node dissection continues to represent the cornerstone of curative treatment according to international guidelines.

Open gastrectomy (OG) has long been considered the standard surgical approach for gastric cancer. However, since the first report of laparoscopy-assisted distal gastrectomy by Kitano et al.[3] in 1994, minimally invasive techniques have gained widespread acceptance. Continuous advances in surgical technology and increasing surgeon experience have expanded the application of laparoscopic gastrectomy (LG) beyond early-stage disease to include locally advanced tumors and total gastrectomy procedures.

Several comparative studies have demonstrated that LG offers potential short-term advantages over OG, including reduced surgical trauma, faster gastrointestinal recovery, decreased postoperative pain, and shorter hospital stays.[2,4] Nevertheless, concerns persist regarding the oncological adequacy of the laparoscopic approach in locally advanced disease. These concerns primarily relate to the technical complexity of D2 lymphadenectomy, the potential risk of inadequate lymph node retrieval and positive resection margins, and the impact of a prolonged learning curve, particularly in cases requiring conversion to open surgery.[5]

Although a growing body of literature suggests comparable long-term survival outcomes between LG and OG, the evidence remains heterogeneous, particularly with respect to locally advanced gastric cancer.[6] Moreover, data addressing prognostic factors that may influence survival outcomes according to the surgical approach are limited and inconsistent. Identifying such prognostic determinants is critical for optimizing patient selection, refining surgical strategies, and improving oncological outcomes.

Therefore, the present study aimed to comprehensively compare laparoscopic and open gastrectomy with D2 lymphadenectomy in patients with locally advanced gastric adenocarcinoma, focusing not only on perioperative outcomes and postoperative morbidity but also on long-term survival and prognostic factors affecting oncological outcomes.

Materials and Methods

Study Design and Setting

This retrospective cohort study was conducted at a tertiary referral center and included patients who underwent curative gastrectomy with D2 lymph node dissection for gastric adenocarcinoma between January 2014 and December 2022. The study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Participants

Patients aged ≥18 years who underwent distal or total gastrectomy with D2 lymphadenectomy for histologically confirmed gastric adenocarcinoma were eligible for inclusion. The exclusion criteria included age <18 years, distant metastatic disease at diagnosis, incomplete clinical data, or loss to follow-up.

Eligible patients were categorized into two groups according to the surgical approach: laparoscopic gastrectomy (LG) and open gastrectomy (OG).

Data Collection and Variables

Clinical and pathological data were retrospectively retrieved from the institutional hospital database. The collected variables included demographic characteristics (age and sex), preoperative risk assessment (American Society of Anesthesiologists [ASA] score), tumor-related factors (tumor location and pathological stage), operative details (type of gastrectomy and surgical approach), postoperative outcomes (length of hospital stay and complications), follow-up duration, and mortality outcomes.

Follow-up and Outcome Assessment

Patients were followed according to a standardized institutional surveillance protocol. Outpatient visits were scheduled every 3 months during the first 2 postoperative years, every 6 months between years 3 and 5, and annually thereafter. Follow-up assessments included clinical evaluation and symptom-oriented laboratory testing, such as complete blood count and biochemical parameters.

In patients who underwent total gastrectomy, serum vitamin B12 levels were assessed annually. Patients with high-risk pathological features (T3–T4 and/or node-positive disease) underwent thoracic, abdominal, and pelvic computed tomography at 6–12-month intervals for up to 5 years. Patients who underwent subtotal gastrectomy were monitored with upper gastrointestinal endoscopy every 1–2 years to assess the remnant stomach. Nutritional status was routinely evaluated with dietitian support. Mortality data were obtained from hospital records and follow-up visits.

The proportions of patients who received neoadjuvant treatment during the preoperative period were similar be-

tween the two groups, and all patients received adjuvant chemotherapy postoperatively.

Surgical Procedures

All surgical procedures were performed by experienced gastrointestinal surgeons with advanced expertise in laparoscopic surgery. The choice of surgical approach was based on patient characteristics, tumor resectability, and surgeon discretion.

Laparoscopic gastrectomy was preferentially performed in patients without a history of major abdominal surgery who were considered suitable for minimally invasive surgery, had no evidence of distant metastasis, and were considered candidates for R0 resection. Open gastrectomy was performed in patients who were suitable for curative surgery but were not candidates for laparoscopy.

Distal or total gastrectomy was selected according to tumor location. Standard gastrectomy with D2 lymph node dissection was performed in accordance with the Japanese Gastric Cancer Treatment Guidelines (5th edition). Reconstruction following distal gastrectomy was performed using Roux-en-Y or Billroth II gastrojejunostomy, whereas Roux-en-Y esophagojejunostomy was performed after total gastrectomy.

Patients whose procedures were initiated laparoscopically but subsequently converted to open surgery were excluded from the study.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from İnönü University Scientific Research and Publication Ethics Committee (Approval Number: 2025/8830, Date: 02.12.2025), and the requirement for informed consent was waived because of the retrospective nature of the study.

Statistical Analysis

All statistical analyses were performed using jamovi software, version 2.7.12.0 (The jamovi Project, Sydney, Australia). Continuous variables were tested for normality using the Shapiro–Wilk test. Non-normally distributed variables were expressed as the median (interquartile range [IQR]), and categorical variables were summarized as counts and percentages.

Comparisons between the open and laparoscopic gastrectomy groups were performed using the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate.

Overall survival (OS) was analyzed using the Kaplan–Meier method, and differences in survival were assessed using the log-rank test. Variables with $p<0.05$ in the univariate analysis were entered into a multivariable Cox proportional hazards regression model to identify independent prognostic factors for OS. The results were presented as hazard ratios (HRs) with 95% confidence intervals (CIs).

A post hoc power analysis was performed using the observed hazard ratio for OS (HR=0.68), a two-sided significance level of 0.05, and 102 observed death events among 159 patients. The achieved statistical power was approximately 67%, indicating moderate power but remaining below the conventional 80% threshold. Based on the observed effect size, approximately 165 events, corresponding to approximately 257 patients assuming a similar event rate, would be required to achieve 80% statistical power.

Results

Study Population

A total of 159 patients who met the eligibility criteria were included in the final analysis (Fig. 1). The median age of the study cohort was 64 years (interquartile range [IQR], 57–72), and 105 patients (66.0%) were male. Most patients were classified as American Society of Anesthesiologists (ASA) class II (68.6%). The distal stomach was the most frequent tumor location (52.0%), and total gastrectomy

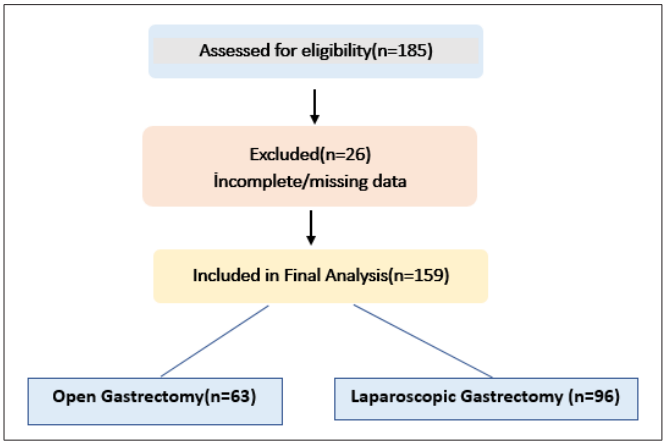

Figure 1. Flowchart of patient selection and grouping. Of the 185 patients assessed, 26 were excluded because of incomplete data, and 159 were included in the final analysis (open gastrectomy, n=63; laparoscopic gastrectomy, n=96).

was performed in 50.9% of cases. Laparoscopic gastrectomy (LG) was performed in 60.0% of patients. The median length of hospital stay was 8 days (IQR, 6–8), and the median follow-up duration was 35 months (IQR, 16–69.7). The overall 90-day mortality rate was 3.0% (Table 1).

Comparison Between Surgical Groups

Patients in the LG group were slightly younger than those in the open gastrectomy (OG) group (median age: 64 vs. 65 years, p=0.039). No statistically significant differences were observed between the groups in terms of sex distribution or ASA classification.

Table 1. Demographic and Clinical Characteristics of the Study Population

Variable	n (%)	Median (IQR)
Age, years		64 (57–72)
Sex		
Male	105 (66.0%)	
ASA classification		
I	14 (8.8%)	
II	109 (68.6%)	
III	35 (22.0%)	
IV	1 (0.6%)	
Tumor location		
Proximal	49 (31.0%)	
Corpus	25 (16.0%)	
Distal	83 (52.0%)	
Linitis plastica	1 (1.0%)	
Remnant	1 (1.0%)	
Type of gastrectomy		
Subtotal	77 (48.4%)	
Total	81 (50.9%)	
Proximal	1 (0.6%)	
Surgical approach		
Open	63 (40.0%)	
Laparoscopic	96 (60.0%)	
Hospital stay, days		8 (6–8)
Follow-up duration, months		35 (16–69.7)
90-day mortality	5 (3.0%)	

Values are expressed as median (interquartile range) or number (percentage). ASA: American Society of Anesthesiologists; IQR: interquartile range.

Laparoscopic gastrectomy was more frequently performed in patients with earlier tumor-node-metastasis (TNM) stages (p<0.001) and lower N stages (p=0.010). The median length of hospital stay was shorter in the LG group than in the OG group (8 [IQR, 6–10] vs. 8 [IQR, 7–11] days, p=0.042). Postoperative morbidity rates differed significantly between the groups and were lower in the OG group (6.3% vs. 29.2%, p<0.001). The 90-day mortality rate did not differ significantly between the LG and OG groups (p=0.362). No significant differences were identified with respect to tumor location, lymphovascular invasion (LVI), perineural invasion (PNI), or human epidermal growth factor receptor 2 (HER2) status. The number of positive lymph nodes retrieved was significantly higher in the OG group (p<0.001). The mean operative time was longer in the LG group (200 min [190–200]), whereas the amount of blood loss was greater in the OG group (mean, 50 cc [0–100]) (Table 2).

Survival Analysis

In the univariate Cox regression analysis, age <65 years was associated with improved overall survival (hazard ratio [HR], 0.52; p=0.001). Laparoscopic gastrectomy was also associated with better survival outcomes (HR, 0.61; p=0.014) (Fig. 2). In addition, patients with stage II disease demonstrated significantly better survival than those with stage III disease (HR, 0.28; p<0.001) (Fig. 3).

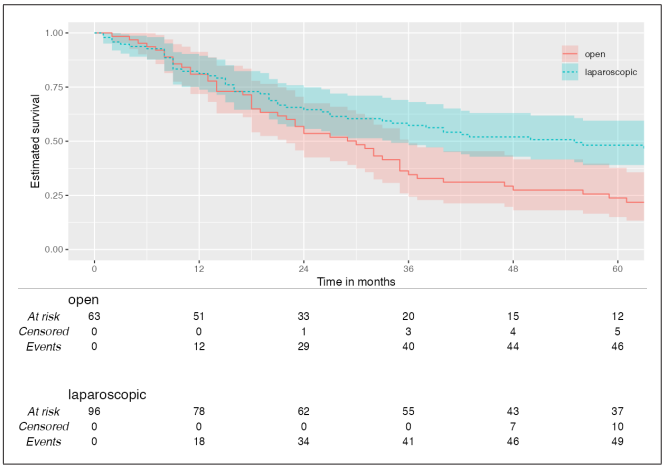

Figure 2. Kaplan–Meier survival curves comparing open and laparoscopic surgical approaches. Kaplan–Meier estimated overall survival curves for patients undergoing open surgery (solid red line) and laparoscopic surgery (dashed blue line) over a 60-month follow-up period. Shaded areas represent 95% confidence intervals. The laparoscopic group demonstrated a higher estimated survival probability than the open group throughout the observation period. Statistical significance between the groups was assessed using the log-rank test.

Table 2. Univariate Analysis of Clinicopathological Variables Between the Open and Laparoscopic Gastrectomy Groups

Variable	Open, n (%) / Median (IQR)	Laparoscopic, n (%) / Median (IQR)	p
Age, years	65 (59.5–75)	64 (54.8–71.3)	0.039*
Sex			
Male	44 (69.8%)	61 (63.5%)	0.412
ASA classification			
I	3 (4.8%)	11 (11.5%)	0.089
II	42 (66.7%)	67 (69.8%)	
III	18 (28.6%)	17 (17.7%)	
IV	0 (0%)	1 (1.0%)	
Tumor location			
Proximal	20 (31.7%)	29 (30.2%)	0.206
Corpus	14 (22.2%)	11 (11.5%)	
Distal	29 (46.0%)	54 (56.2%)	
Linitis plastica	0 (0%)	1 (1.0%)	
Remnant	0 (0%)	1 (1.0%)	
Neoadjuvant treatment	40 (63.5%)	72 (75.0%)	0.168
Additional resection	6 (9.5%)	10 (10.4%)	0.855
Total LAP	31 (22–42)	34 (27–46)	0.259
Pathological LAP	11 (4–18)	5 (1–12)	<0.001
T stage			
I	2 (3.2%)	3 (3.1%)	0.647
II	1 (1.6%)	5 (5.2%)	
III	26 (41.3%)	42 (43.8%)	
IV	34 (54.0%)	46 (47.9%)	
N stage			
0	2 (3.2%)	12 (12.5%)	0.010
I	8 (12.7%)	26 (27.1%)	
II	9 (14.3%)	14 (14.6%)	
III	44 (69.8%)	44 (45.8%)	
TNM stage			
II	11 (17.5%)	42 (43.8%)	<0.001
III	52 (82.5%)	54 (56.2%)	
c-erbB-2 positivity	11 (17.5%)	14 (14.6%)	0.626
LVI	58 (92.1%)	85 (88.5%)	0.470
PNI	46 (73.0%)	69 (71.9%)	0.875
Operative time, min	160 (160–185)	200 (190–210)	<0.001
Intraoperative blood loss, mL	50 (0–100)	0 (0–50)	0.014
Hospital stay, days	8 (7–11)	8 (6–10)	0.042*
Postoperative morbidity	4 (6.3%)	28 (29.2%)	<0.001

Table 2. Continued

Variable	Open, n (%) / Median (IQR)	Laparoscopic, n (%) / Median (IQR)	p
Clavien–Dindo classification			
Mild (I–II)	3 (75.0%)	24 (85.7%)	0.581
Severe (III–IV)	1 (25.0%)	4 (14.3%)	
90-day mortality	1 (1.6%)	4 (4.2%)	0.362

Variables marked with an asterisk (*) were analyzed using the Mann–Whitney U test; categorical variables were analyzed using the chi-square test. A p value <0.05 was considered statistically significant. ASA: American Society of Anesthesiologists; IQR: interquartile range; LAP: lymph nodes; LVI: lymphovascular invasion; PNI: perineural invasion; TNM: tumor-node-metastasis.

Multivariable Analysis

Multivariable Cox regression analysis was performed after adjustment for age, surgical approach, and TNM stage. Age <65 years (HR, 0.57; p=0.007) and stage II disease (HR, 0.32; p<0.001) remained independent predictors of favorable overall survival. Although laparoscopic gastrectomy was associated with a survival benefit in the univariate analysis, this association did not reach statistical significance in the multivariable model; however, a trend toward improved survival was observed (HR, 0.68; p=0.062) (Table 3).

Discussion

This study compared perioperative outcomes and long-term survival between laparoscopic gastrectomy (LG) and open gastrectomy (OG) in patients with locally advanced gastric adenocarcinoma undergoing D2 lymphadenectomy. With increasing surgical experience and technological advances, laparoscopic techniques have progressively expanded from early-stage gastric cancer to locally advanced disease, including total gastrectomy and extended lymph node dissection.[7,8]

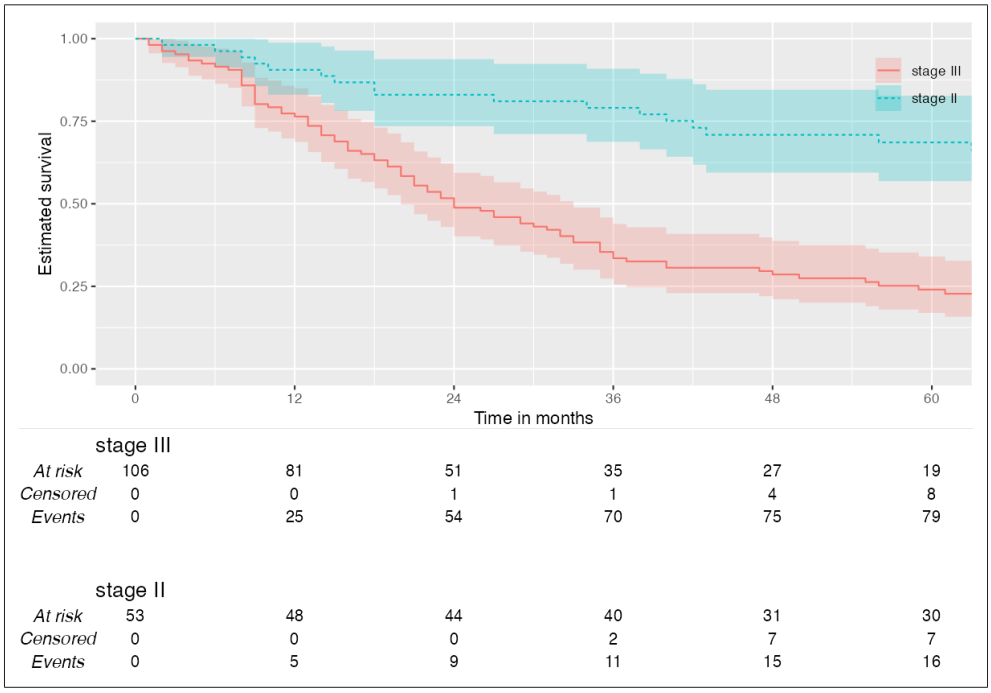

Figure 3. Kaplan–Meier survival analysis according to tumor stage (stage II vs. stage III). Kaplan–Meier survival curves showing the estimated overall survival of patients with stage II disease (dashed blue line) and stage III disease (solid red line) over a 60-month follow-up period. Shaded areas represent 95% confidence intervals. Patients with stage II disease demonstrated significantly higher survival probabilities than those with stage III disease throughout the observation period. Statistical comparison between the survival curves was performed using the log-rank test.

Table 3. Univariable and Multivariable Cox Proportional Hazards Regression Analysis for Overall Survival in Patients With Gastric Cancer

Variable	Level	Univariable HR (95% CI)	p	Multivariable HR (95% CI)	p
Age	≥65 years	1.00 (ref)	–	1.00 (ref)	–
	<65 years	0.52 (0.35–0.77)	0.001	0.57 (0.38–0.86)	0.007
Surgical approach	Open	1.00 (ref)	–	1.00 (ref)	–
	Laparoscopic	0.61 (0.41–0.90)	0.014	0.68 (0.45–1.02)	0.062
TNM stage	Stage III	1.00 (ref)	–	1.00 (ref)	–
	Stage II	0.28 (0.17–0.46)	<0.001	0.32 (0.19–0.54)	<0.001

Univariable and multivariable Cox proportional hazards regression analyses were performed to evaluate the effects of age, surgical approach, and TNM stage on overall survival. Variables with p<0.05 were considered statistically significant. Reference categories are indicated by "ref." CI: confidence interval; HR: hazard ratio; TNM: tumor-node-metastasis.

In the present cohort, LG was more frequently performed in patients with earlier tumor-node-metastasis (TNM) and N stages. This likely reflects a selection tendency influenced by surgeons' concerns regarding oncological safety, particularly the achievement of R0 resection and adequate D2 lymphadenectomy in patients with more advanced tumors. Similar stage-related selection patterns have been reported in previous retrospective studies evaluating minimally invasive approaches in advanced gastric cancer.[9]

Several studies and meta-analyses have demonstrated that LG does not increase postoperative morbidity compared with OG and may even provide perioperative advantages because of reduced surgical trauma.[9–11] Smaller incisions, decreased postoperative pain, and improved respiratory mechanics may theoretically contribute to lower complication rates. Contrary to these expectations, postoperative morbidity was significantly higher in the LG group in our study. Given that the study period spanned 8 years, this finding may be explained by the laparoscopic learning curve, particularly for technically demanding procedures such as D2 lymphadenectomy and total gastrectomy. Early laparoscopic experience and case complexity may have contributed to higher complication rates, a phenomenon also reported in other long-term institutional series.[10,11]

Consistent with the existing literature, the length of hospital stay was significantly shorter in the LG group.[9–12] Faster recovery, earlier mobilization, and earlier resumption of oral intake are well-recognized benefits of minimally invasive surgery. Reduced hospitalization may also translate into lower healthcare costs and a faster return to daily and social activities, supporting the feasibility of LG in selected patients with locally advanced gastric cancer.

In the survival analyses, LG was associated with improved overall survival in the univariate analysis. However, this association did not remain statistically significant after adjustment for age and TNM stage in the multivariable analysis, although a trend toward improved survival persisted (p=0.062). This attenuation suggests that the apparent survival benefit of LG may be largely attributable to confounding factors, particularly the younger age and earlier disease stage of patients in the LG group. Importantly, our findings are consistent with previous reports indicating that LG provides oncological outcomes comparable to those of OG without compromising long-term survival.[9–13]

Tumor-node-metastasis stage emerged as the strongest independent prognostic factor in both the univariate and multivariable analyses, underscoring its central role in gastric cancer prognosis.[13] Patients with stage II disease had significantly longer overall survival than those with stage III disease, emphasizing the critical importance of early diagnosis and timely surgical intervention.

Age was also identified as an independent predictor of survival, with patients younger than 65 years demonstrating better outcomes. Although some studies have reported no significant survival differences between younger and older patients,[14,15] the association observed in our cohort may reflect differences in physiological reserve, comorbidity burden, and tolerance to major surgery. Nevertheless, the retrospective design of the study raises the possibility of selection bias, as younger patients may have been preferentially selected for laparoscopic surgery.

Overall, our findings suggest that patient age and tumor stage play important roles in determining both the surgical approach and survival outcomes. Laparoscopic gastrectomy appears to be a feasible and safe option for selected patients with locally advanced gastric cancer when performed by experienced surgeons, offering perioperative advantages without compromising oncological outcomes.

Limitations

This study has several limitations. Its retrospective, single-center design limits generalizability and introduces the potential for selection bias. The relatively small sample size and imbalanced distributions of age and tumor stage between the surgical groups may have influenced the comparative analyses. In addition, changes in surgical expertise and perioperative management over the extended study period may have affected the outcomes. Prospective, multicenter randomized controlled trials with standardized surgical protocols and larger patient cohorts are warranted to more definitively clarify the long-term oncological equivalence of laparoscopic and open gastrectomy in locally advanced gastric cancer.

Conclusion

Laparoscopic gastrectomy is a feasible approach for selected patients with locally advanced gastric adenocarcinoma and provides acceptable perioperative outcomes. However, long-term survival is primarily determined by tumor stage and patient age rather than by the surgical approach itself. These findings underscore the need for well-designed prospective studies to adequately assess the oncological equivalence of laparoscopic and open gastrectomy.

Disclosures

Ethics Committee Approval: Ethics committee approval was obtained from İnönü University Scientific Research and Publication Ethics Committee (Approval Number: 2025/8830, Date: 02.12.2025).

Informed Consent: The requirement for informed consent was waived by the ethics committee due to the retrospective nature of the study.

Conflict of Interest: The authors have no conflicts of interest to declare.

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