Am J Transl Res 2026;18(10):9322-9335
www.ajtr.org /ISSN:1943-8141/AJTR0175532

Original Article

Laparoscopic versus open gastrectomy in gastric cancer patients aged 80 years or older: a propensity forscore-matched retrospective cohort study

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Received July 21, 2026; Accepted September 4, 2026; Epub October 15, 2026; Published October 30, 2026

Abstract: Objective: Evidence comparing laparoscopic gastrectomy (LG) and open gastrectomy (OG) in gastric cancer patients aged ≥ 80 years is limited. We compared the safety, recovery, and survival of LG versus OG in this oldest-old population. Methods: We retrospectively reviewed 305 consecutive patients aged 80 years or older treated at a single tertiary center (2015-2024). After propensity score matching (PSM), 200 patients were analyzed (100 LG, 100 OG). We assessed complications, overall survival (OS), 30- and 90-day mortality, adjuvant chemotherapy, recurrence, cause-specific death under a competing-risk framework, and recovery, and used multivariable Cox regression to adjust for covariates that remained imbalanced after matching. Results: After a median follow-up of 38.0 months, LG was associated with a lower complication rate than OG (21.0% vs 36.0%, P = 0.028), with fewer arrhythmias and shorter hospital (9.0 vs 12.0 days) and ICU stays. Median OS was 44.6 versus 26.5 months (unadjusted HR for OG 1.50, 95% CI 1.02-2.20; P = 0.038), but it was not significant after multivariable adjustment (HR 1.46, 95% CI 0.95-2.24; P = 0.084) or within pTNM strata, and the survival curves converged after approximately 30 months. LG showed lower 30-day (2.0% vs 9.0%) and 90-day (6.0% vs 12.0%) mortality, higher and earlier adjuvant chemotherapy, and faster recovery (all P < 0.001). Conclusions: In gastric cancer patients aged 80 years or older, LG may reduce complications and accelerate recovery. The apparent survival advantage was not robust to adjustment or stage stratification and likely reflects lower early mortality rather than a genuine oncologic benefit.

Keywords: Gastric cancer, laparoscopic gastrectomy, open gastrectomy, elderly patients, postoperative complications, survival, competing risks

Introduction

Gastric cancer is the fifth most common malignant tumor worldwide, and surgical resection remains the primary curative treatment [1]. Laparoscopic gastrectomy (LG) and open gastrectomy (OG) are the two most commonly used surgical approaches for gastric cancer in clinical practice. In a multicenter cohort of 220,304 patients with solitary primary gastric adenocarcinoma from 53 hospitals across 27 provinces in seven major geographic regions of China, 90,292 patients underwent surgical treatment; among them, LG accounted for 49.51% and OG for 47.67% [2]. OG has long been regarded as the standard approach for gastric cancer resection. However, given its relatively high postoperative complication rate, some investigators have reconsidered the indications for OG [3]. Compared to OG, evidence suggests that LG may be a preferable option for gastric cancer. The JCOG0912 trial demonstrated the non-inferiority of LG for early gastric cancer [4-6]. In addition, multiple studies have reported that LG is associated with less intraoperative blood loss and lower postoperative

https://doi.org/10.62347/TDEW4773

complication rates than OG. A multicenter comparative study from 17 institutions in Japan also found that LG resulted in less blood loss and a shorter hospital stay than OG, albeit with a longer operative time [7].

In regions with high life expectancy, the "oldest-old" are defined as individuals aged 80 years or older [8-11]. A demographic projection from Spain suggests that the population aged > 80 years will double approximately every 15 years [12]. In this very elderly population, postoperative complications are a major determinant of survival after surgery. Previous studies have reported that postoperative complications may reduce life expectancy in patients aged ≥ 80 years from 6.7 to 3.9 years [13]. Although approximately 60% of patients with gastric or esophageal cancer are aged ≥ 65 years and about 26% are ≥ 75 years, older adults have historically been underrepresented in clinical trials [14].

This study investigated whether LG reduced postoperative complications and improved survival in gastric cancer patients aged 80 years or older. We retrospectively analyzed patients treated surgically at a single tertiary center between 2015 and 2024. To provide a comprehensive evaluation of clinical benefit in this vulnerable population, we additionally examined short-term mortality, adjuvant therapy delivery, oncologic recurrence, cause-specific mortality under a competing-risk framework, and postoperative functional recovery. Our findings support more individualized surgical decision-making in this oldest-old population.

Materials and methods

Study design

This single-center retrospective cohort study was reviewed and approved by the Institutional Review Board of The First Affiliated Hospital of Nanjing Medical University (approval number 2024-SR-1108). The study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments, and informed consent was waived due to the retrospective design. The study is reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement.

Patients

We retrospectively collected data from consecutive patients who underwent gastrectomy for gastric cancer at The First Affiliated Hospital of Nanjing Medical University between January 2015 and June 2024. Inclusion criteria were: age ≥ 80 years; histopathological confirmation of gastric adenocarcinoma via endoscopic biopsy; no history of upper abdominal surgery; no neoadjuvant chemotherapy or other antitumor treatment prior to surgery; and R0 gastrectomy as a primary treatment without distant metastases. A total of 305 patients were included: 156 underwent OG and 149 underwent LG. Tumors were staged according to the 8th edition AJCC/UICC TNM (pTNM) classification. Postoperative complications were assessed using the Clavien-Dindo classification.

Surgery

Surgical procedures were performed primarily in accordance with the Japanese Gastric Cancer Treatment Guidelines (4th to 6th editions) issued by the Japanese Gastric Cancer Association (JGCA) [15-17]. These guidelines provide standardized recommendations on surgical approach, extent of resection, lymphadenectomy, and perioperative management according to tumor stage.

For OG, surgical indications were determined based on tumor stage, location, size, and the patient's general condition. The type of gastrectomy (e.g., distal or total) was selected according to tumor location, and D2 lymphadenectomy was performed as recommended. Intraoperative dissection emphasized protection of adjacent organs to ensure oncologic adequacy and procedural safety.

For LG, patient selection and operative techniques also followed the JGCA recommendations. Laparoscopy-assisted gastrectomy was performed in eligible patients while adhering to the same principles as OG. Standardized technical steps were applied to minimize surgical complications, facilitate postoperative recovery, and maintain operative safety. Lymph node dissection was performed within the guideline-specified extent to achieve oncologic outcomes comparable to those of OG.

Propensity score matching

Propensity score matching (PSM) was performed using the MatchIt package (version 4.3.0) to minimize bias between the OG and LG groups. Covariates included in the matching process were age, sex, body mass index (BMI), hypertension, diabetes, cardiovascular disease, cerebrovascular disease, T stage, N stage, and respiratory disease. Nearest-neighbor 1:1 matching without replacement was applied, with a caliper of 0.1 standard deviations of the logit of the propensity score. Covariate balance was evaluated using the absolute standardized mean difference (ASMD), with an ASMD ≤ 0.1 considered to indicate adequate balance. The covariates for the propensity model were prespecified on the basis of clinical relevance and availability at the time of the surgical decision. Because the number of matched pairs constrained the number of covariates that could be estimated reliably, variables that were strongly collinear with those already included (e.g., pTNM stage with T stage and N stage) or that had markedly unequal distributions that would have produced extreme weights and substantial loss of sample size (e.g., renal disease) were not included in the matching model. Renal disease, American Society of Anesthesiologists physical status (ASA-PS), Eastern Cooperative Oncology Group performance status (ECOG-PS), and pTNM stage were instead assessed for residual balance after matching and were adjusted for in multivariable analyses.

Supplementary outcome definitions

Overall survival (OS) was defined as the time from surgery to death from any cause. Thirty- and 90-day all-cause mortality were defined as death from any cause within 30 and 90 days after surgery, respectively. Adjuvant chemotherapy uptake was defined as the receipt of any postoperative systemic chemotherapy, and time to initiation was measured in weeks from the date of surgery. Tumor recurrence was defined as radiologically or pathologically confirmed locoregional or distant relapse during follow-up. For cause-specific analyses, deaths were classified as gastric-cancer-related or non-gastric-cancer-related, and the cumulative incidence of each was estimated within a competing-risk framework. Postoperative recovery indicators comprised pain intensity on a 10-point visual analogue scale (VAS) on postoperative days (POD) 1 and 3, white blood cell (WBC) count on POD 1 and 3, and time to first flatus and first defecation.

Statistical analysis

R (version 4.3.0) and relevant packages were used for data analysis. OS was analyzed by the Kaplan-Meier method, and survival was also assessed within pTNM stage subgroups and by postoperative complication severity (Clavien-Dindo grade ≥ III vs < III). One-, three-, and five-year survival periods were defined as 365, 1095, and 1825 days, respectively. Group differences in survival were assessed using the log-rank test, and hazard ratios (HRs) with 95% confidence intervals (CIs) were estimated using Cox proportional-hazards models. Kaplan-Meier curves were generated using the survminer package (version 0.4.9). For cause-specific mortality, cumulative incidence functions were estimated using the Aalen-Johansen estimator and compared with Gray's test, and subdistribution hazard ratios were obtained from the Fine-Gray model [18-20]. The median follow-up was estimated using the reverse Kaplan-Meier method. To address residual confounding after matching, a multivariable Cox proportional-hazards model was fitted for overall survival with surgical approach, renal disease, ASA-PS (III-IV vs I-II), ECOG-PS (≥ 2 vs < 2), and pTNM stage as covariates; the proportional-hazards assumption was assessed using scaled Schoenfeld residuals. A 90-day landmark analysis, restricted to patients alive 90 days after surgery, was performed to evaluate whether the survival difference persisted beyond the early postoperative period. The chi-square test was used for categorical variables when expected cell counts were at least five, and Fisher's exact test was used otherwise; continuous variables were compared using the Mann-Whitney U test because their distributions were non-normal, as assessed by the Shapiro-Wilk test. Covariate balance was quantified using the absolute standardized mean difference. Two-sided $P < 0.05$ was considered significant, and no adjustment was made for multiple comparisons, so secondary analyses are regarded as exploratory.

Results

Propensity score matching outcomes and baseline characteristics

After PSM, a total of 200 patients were included in the final analysis (100 per group). The

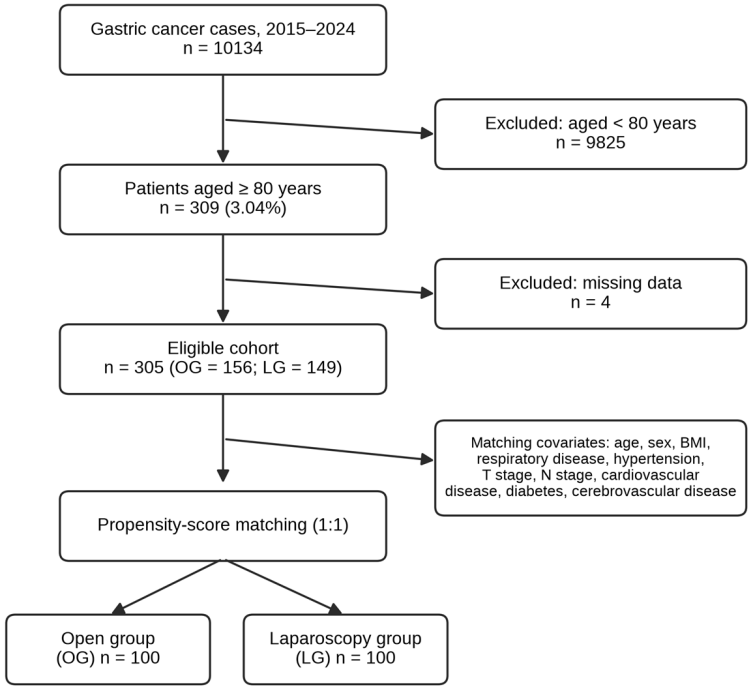


Figure 1. Flowchart of patient selection. OG, open gastrectomy; LG, laparoscopic gastrectomy; PSM, propensity score matching.

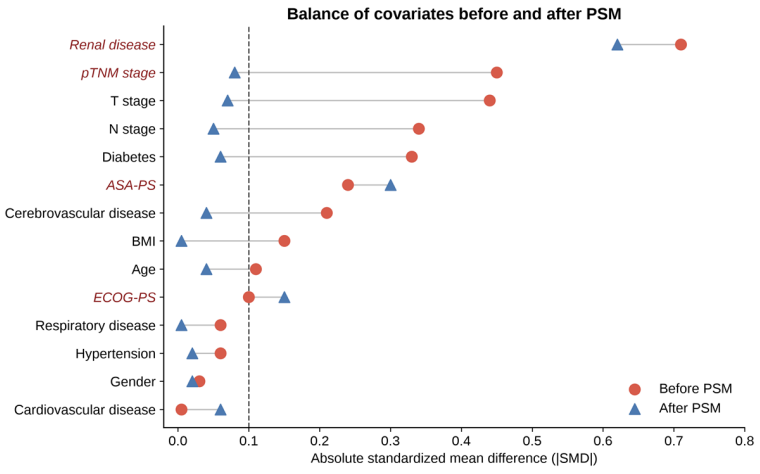


Figure 2. Absolute standardized mean differences (|SMD|) of covariates before and after propensity score matching (PSM). The dashed line marks the 0.1 balance threshold. Covariates shown in italic red (renal disease, ASA-PS, ECOG-PS, and pTNM stage) were not included in the matching model; renal disease and ASA-PS remained imbalanced after matching and were adjusted for in the multivariable analyses (**Table 6**).

patient selection process is illustrated in **Figure 1**. Nearest-neighbor 1:1 matching without replacement and with a caliper of 0.1 SD achieved good balance. The median follow-up was 38.0 months (interquartile range 22.5-52.1 months).

Figure 2 summarizes the absolute standardized mean differences before and after PSM. **Table 1** summarizes the patients' baseline clinical characteristics. Before PSM, the OG and LG groups differed significantly in renal disease ($P < 0.001$), diabetes ($P = 0.007$), T stage ($P = 0.001$), N stage ($P = 0.007$), and pTNM stage ($P < 0.001$). After PSM, most baseline characteristics were well balanced between the two groups; however, renal disease remained more frequent in the LG group (30.0% vs 7.0%, $P < 0.001$), and ASA-PS showed a residual imbalance of borderline significance ($P = 0.061$). These variables were carried forward into multivariable adjustment.

Intraoperative and postoperative factors before and after matching

Intra- and postoperative factors are presented in **Table 2**. The extent of resection, lymphatic invasion, vascular invasion, and nerve invasion differed to some degree between the LG and OG groups before PSM; after matching, the between-group differences diminished, yielding improved homogeneity. After matching, tumor diameter (4.4 ± 2.5 vs 4.5 ± 2.4 cm, $P = 0.617$), retrieved nodes (42.9 ± 12.7 vs 40.4 ± 12.1, $P = 0.162$), and metastatic nodes (6.2 ± 10.5 vs 6.1 ± 11.3, $P = 0.988$) were well balanced; the extent of resection ($P = 0.656$) and main tumor location ($P = 0.052$) also showed no significant differences, supporting oncologic comparability between the groups. Operative time was longer in the LG group than in the OG group (181.7 ± 38.8 vs 162.2 ± 49.3 minutes, $P = 0.002$).

Table 1. Baseline characteristics of patients in the OG and LG groups before and after matching

Variable	Before matching			After matching		
	LG	OG	P	LG	OG	P
n	149	156		100	100	
Age, mean (SD)	82.6 (2.7)	82.9 (2.7)	0.426	82.6 (2.6)	82.7 (2.2)	0.728
BMI, mean (SD)	22.7 (4.3)	22.1 (3.6)	0.249	22.8 (4.3)	22.8 (3.4)	0.964
Sex			0.926			1.000
Female	37 (24.8)	37 (23.7)		23 (23.0)	22 (22.0)	
Male	112 (75.2)	119 (76.3)		77 (77.0)	78 (78.0)	
ASA-PS			0.170			0.061
1	28 (18.8)	39 (25.0)		18 (18.0)	24 (24.0)	
2	66 (44.3)	58 (37.2)		47 (47.0)	37 (37.0)	
3	42 (28.2)	52 (33.3)		24 (24.0)	35 (35.0)	
4	13 (8.7)	7 (4.5)		11 (11.0)	4 (4.0)	
ECOG-PS			0.711			0.565
0	17 (11.4)	25 (16.0)		14 (14.0)	19 (19.0)	
1	45 (30.2)	44 (28.2)		34 (34.0)	26 (26.0)	
2	68 (45.6)	68 (43.6)		43 (43.0)	44 (44.0)	
3	19 (12.8)	19 (12.2)		9 (9.0)	11 (11.0)	
Comorbidity	100 (67.1)	116 (74.4)	0.206	69 (69.0)	76 (76.0)	0.342
Respiratory disease	53 (35.6)	60 (38.5)	0.686	39 (39.0)	39 (39.0)	1.000
Hypertension	76 (51.0)	84 (53.8)	0.703	55 (55.0)	56 (56.0)	1.000
Renal disease	49 (32.9)	10 (6.4)	< 0.001*	30 (30.0)	7 (7.0)	< 0.001*
Cardiovascular disease	68 (45.6)	71 (45.5)	1.000	51 (51.0)	45 (45.0)	0.479
Diabetes	50 (33.6)	30 (19.2)	0.007*	29 (29.0)	23 (23.0)	0.420
Cerebrovascular disease	58 (38.9)	45 (28.8)	0.082	35 (35.0)	37 (37.0)	0.883
Histology			0.697			0.315
MD	48 (32.2)	45 (28.8)		29 (29.0)	38 (38.0)	
PD	98 (65.8)	109 (69.9)		70 (70.0)	60 (60.0)	
WD	3 (2.0)	2 (1.3)		1 (1.0)	2 (2.0)	
T stage			0.001*			0.935
1	40 (26.8)	20 (12.8)		21 (21.0)	18 (18.0)	
2	21 (14.1)	17 (10.9)		12 (12.0)	16 (16.0)	
3	63 (42.3)	64 (41.0)		45 (45.0)	45 (45.0)	
4a	23 (15.4)	48 (30.8)		20 (20.0)	19 (19.0)	
4b	2 (1.3)	7 (4.5)		2 (2.0)	2 (2.0)	
N stage			0.007*			0.655
0	66 (44.3)	50 (32.1)		34 (34.0)	41 (41.0)	
1	31 (20.8)	21 (13.5)		22 (22.0)	16 (16.0)	
2	22 (14.8)	32 (20.5)		19 (19.0)	19 (19.0)	
3	30 (20.1)	53 (34.0)		25 (25.0)	24 (24.0)	
pTNM stage			< 0.001*			0.805
I	45 (30.2)	27 (17.3)		21 (21.0)	24 (24.0)	
II	55 (36.9)	44 (28.2)		38 (38.0)	34 (34.0)	
III	49 (32.9)	85 (54.5)		41 (41.0)	42 (42.0)	

OG, open gastrectomy; LG, laparoscopic gastrectomy; BMI, body mass index; ASA-PS, American Society of Anesthesiologists physical status; ECOG-PS, Eastern Cooperative Oncology Group performance status; MD, moderately differentiated; PD, poorly differentiated; WD, well differentiated. *P < 0.05.

Table 2. Intraoperative and postoperative factors in the OG and LG groups before and after matching

Variable	Before matching			After matching		
	LG	OG	P	LG	OG	P
n	149	156		100	100	
Tumor diameter, cm, mean (SD)	4.3 (2.4)	4.9 (2.6)	0.019*	4.4 (2.5)	4.5 (2.4)	0.617
Retrieved lymph nodes, mean (SD)	42.9 (16.7)	39.3 (12.1)	0.035*	42.9 (12.7)	40.4 (12.1)	0.162
Metastatic lymph nodes, mean (SD)	4.9 (9.5)	7.0 (10.4)	0.062	6.2 (10.5)	6.1 (11.3)	0.988
LNR, mean (SD)	0.1 (0.2)	0.2 (0.2)	0.006*	0.1 (0.2)	0.1 (0.2)	0.950
Operative time, min, mean (SD)	179.3 (40.5)	159.9 (47.1)	< 0.001*	181.7 (38.8)	162.2 (49.3)	0.002*
Postoperative hospital stay, days, median [IQR]	9.0 [8.0, 11.0]	11.5 [10.0, 15.0]	< 0.001*	9.0 [8.0, 10.2]	12.0 [10.0, 15.0]	< 0.001*
ICU stay, days, mean (SD)	0.5 (1.4)	1.1 (1.9)	0.002*	0.5 (1.5)	1.0 (2.0)	0.018*
Main tumor location			0.042*			0.052
Lower	73 (49.0)	72 (46.2)		39 (39.0)	49 (49.0)	
Middle	16 (10.7)	18 (11.5)		12 (12.0)	10 (10.0)	
Upper	49 (32.9)	64 (41.0)		40 (40.0)	40 (40.0)	
> 2 sites	11 (7.4)	2 (1.3)		9 (9.0)	1 (1.0)	
Extent of resection			0.005*			0.656
DG	56 (37.6)	64 (41.0)		35 (35.0)	40 (40.0)	
PG	36 (24.2)	16 (10.3)		18 (18.0)	14 (14.0)	
TG	57 (38.3)	76 (48.7)		47 (47.0)	46 (46.0)	
Lymphatic invasion	74 (49.7)	102 (65.4)	0.008*	54 (54.0)	54 (54.0)	1.000
Vascular invasion	68 (45.6)	84 (53.8)	0.187	53 (53.0)	49 (49.0)	0.671
Nerve invasion	60 (40.3)	74 (47.4)	0.252	52 (52.0)	43 (43.0)	0.257
Blood transfusion	45 (30.2)	80 (51.3)	< 0.001*	29 (29.0)	47 (47.0)	0.013*

OG, open gastrectomy; LG, laparoscopic gastrectomy; LNR, lymph node ratio; IQR, interquartile range; DG, distal gastrectomy; PG, proximal gastrectomy; TG, total gastrectomy. Data are n (%) unless otherwise indicated. *P* values were derived from the chi-square or Fisher's exact test for categorical variables and the Mann-Whitney U test for continuous variables. *P < 0.05.

Prior to matching, the lymph node ratio (LNR) was significantly higher in the OG group than in the LG group (P = 0.006). After matching, intergroup LNR equivalence was confirmed (P = 0.950), suggesting comparable lymphadenectomy. Significant differences persisted after PSM in blood transfusion rate, postoperative hospital stay, and ICU stay. After PSM, the transfusion rate was 29.0% in the LG group and 47.0% in the OG group (P = 0.013). The median postoperative hospital stay was 9.0 days in the LG group versus 12.0 days in the OG group (P < 0.001), and the ICU stay was 0.5 ± 1.5 days versus 1.0 ± 2.0 days (P = 0.018).

Postoperative complications

Postoperative complications are summarized in **Table 3**. No pancreatic fistula was observed in either cohort after PSM; before PSM, one case occurred in the OG group and none in the LG group. For all other complications, event rates were consistently lower in the LG group both before and after matching. After PSM (n = 100 per group), the overall complication rate was 21.0% in the LG group versus 36.0% in the OG group (P = 0.028). Postoperative arrhythmia occurred less frequently in the LG group (0.0% vs 8.0%, P = 0.012), whereas pneumonia or pleural effusion, although numerically lower in the LG group (7.0% vs 15.0%), did not reach statistical significance (P = 0.114). Patients in the LG group developed fewer Clavien-Dindo grade II complications than those in the OG group (18.0% vs 28.0%). The LG group had one Clavien-Dindo grade IIIa complication (1.0%), markedly fewer than the eight cases (8.0%) in the OG group (P = 0.039). At grade IIIb, one case occurred in the LG group and none in the OG group (P = 1.000).

Given the small number of events in these subcategories, this pattern should be interpreted cautiously and validated in larger cohorts. One postoperative death occurred in the LG group (1.0%), attributed to gastrointestinal hemorrhage and adjudicated as surgery-related.

Survival

The median OS for the entire cohort was 30.4 months. Median OS was 26.5 months in the OG

Table 3. Postoperative complications in the OG and LG groups before and after matching

Variable	Before matching			After matching		
	LG	OG	P	LG	OG	P
n	149	156		100	100	
Postoperative complication			0.017*			0.028*
No	115 (77.2)	100 (64.1)		79 (79.0)	64 (64.0)	
Yes	34 (22.8)	56 (35.9)		21 (21.0)	36 (36.0)	
Clavien-Dindo grade			0.017*			0.024*
II	28 (18.8)	46 (29.5)		18 (18.0)	28 (28.0)	
IIIa	3 (2.0)	10 (6.4)		1 (1.0)	8 (8.0)	0.039**
IIIb	2 (1.3)	0 (0.0)		1 (1.0)	0 (0.0)	1.000**
V	1 (0.7)	0 (0.0)		1 (1.0)	0 (0.0)	
Pneumonia/pleural effusion	14 (9.4)	28 (17.9)	0.045*	7 (7.0)	15 (15.0)	0.114
Duodenal stump leakage	0 (0.0)	2 (1.3)	0.498	0 (0.0)	2 (2.0)	0.477
Anastomotic leakage	4 (2.7)	2 (1.3)	0.639	3 (3.0)	2 (2.0)	1.000
Intra-abdominal abscess	7 (4.7)	11 (7.1)	0.530	5 (5.0)	7 (7.0)	0.766
Wound infection	5 (3.4)	10 (6.4)	0.333	4 (4.0)	6 (6.0)	0.746
Chylous ascites	4 (2.7)	2 (1.3)	0.639	3 (3.0)	2 (2.0)	1.000
Pancreatic fistula	0 (0.0)	1 (0.6)	1.000	0 (0.0)	0 (0.0)	1.000
Arrhythmia	1 (0.7)	9 (5.8)	0.029*	0 (0.0)	8 (8.0)	0.012*
Heart disease	4 (2.7)	6 (3.8)	0.804	2 (2.0)	3 (3.0)	1.000
Postoperative hemorrhage	3 (2.0)	3 (1.9)	1.000	1 (1.0)	3 (3.0)	0.614
Others	0 (0.0)	3 (1.9)	0.262	0 (0.0)	3 (3.0)	0.245

OG, open gastrectomy; LG, laparoscopic gastrectomy. Others, complications not listed above. *P < 0.05. **Between-group comparison for the specific Clavien-Dindo grade (IIIa or IIIb) by Fisher's exact test.

group and 44.6 months in the LG group. Kaplan-Meier analysis demonstrated a statistically significant OS advantage for LG (**Figure 3A**), with a significantly higher risk of death in the OG group (HR 1.50, 95% CI 1.02-2.20; P = 0.038). Stage-stratified survival curves were generated for pTNM stages I, II, and III (**Figure 3B-D**). No significant survival difference between the OG and LG groups was observed within any pTNM stage: stage I (HR 1.29, 95% CI 0.40-4.15; P = 0.667), stage II (HR 1.94, 95% CI 0.63-5.94; P = 0.246), and stage III (HR 1.79, 95% CI 0.91-3.53; P = 0.087) (HRs expressed for OG relative to LG). The 5-year OS rate was 34.4% (95% CI 19.0%-58.7%) in the LG group and 27.7% (95% CI 17.1%-44.8%) in the OG group. After multivariable adjustment for renal disease, ASA-PS, ECOG-PS, and pTNM stage, the association between surgical approach and overall survival was attenuated and no longer significant (adjusted HR for OG 1.46, 95% CI 0.95-2.24; P = 0.084; **Table 6**). In a 90-day landmark analysis, the between-group difference was attenuated (HR 1.21, 95% CI 0.78-1.88; P = 0.401), and the survival curves converged after approximately 30 months.

Short-term mortality, adjuvant therapy, and oncologic outcome

Short-term mortality, adjuvant therapy delivery, and oncologic outcomes are presented in **Table 4**. Thirty-day all-cause mortality was 2.0% in the LG group and 9.0% in the OG group (P = 0.058), and 90-day all-cause mortality was 6.0% versus 12.0% (P = 0.138). Adjuvant chemotherapy was administered more frequently in the LG group (55.0% vs 40.0%, P = 0.034) and was initiated earlier (5.6 ± 1.5 vs 6.6 ± 1.5 weeks after surgery, P = 0.011), consistent with faster postoperative recovery [21]. Tumor recurrence occurred in 26.0% of the LG group and 35.0% of the OG group (P = 0.167). Cause-specific analysis under a competing-risk framework showed a lower cumulative incidence of both gastric-cancer-related and non-gastric-cancer-related death in the LG group, with non-gastric-cancer-related death occurring in 11.0% versus 16.0% (P = 0.301) (**Figure 4**).

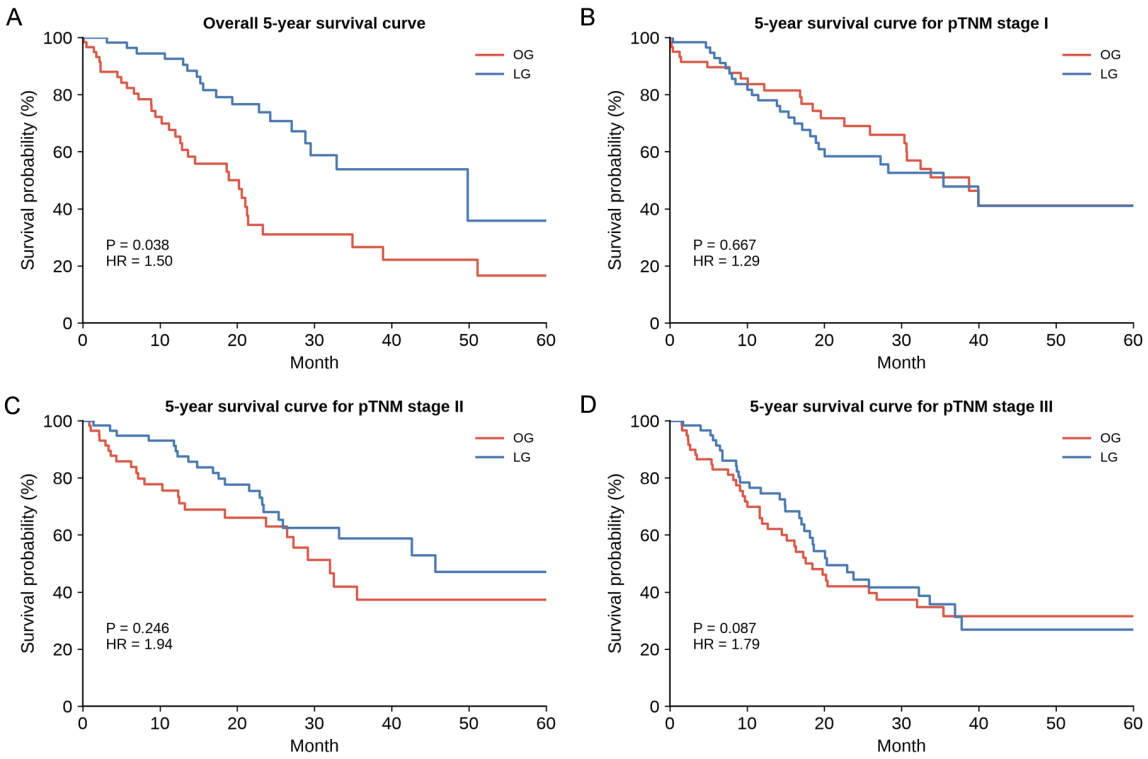


Figure 3. Kaplan-Meier survival curves. A. 5-year overall survival. B. 5-year survival for patients with pTNM stage I tumors. C. 5-year survival for patients with pTNM stage II tumors. D. 5-year survival for patients with pTNM stage III tumors. OG, open gastrectomy; LG, laparoscopic gastrectomy.

Table 4. Short-term mortality, adjuvant therapy, and oncologic outcomes in the LG and OG groups after matching

Variable	LG (n = 100)	OG (n = 100)	P
30-day all-cause mortality, n (%)	2 (2.0)	9 (9.0)	0.058
90-day all-cause mortality, n (%)	6 (6.0)	12 (12.0)	0.138
Adjuvant chemotherapy, n (%)	55 (55.0)	40 (40.0)	0.034*
Time to adjuvant chemotherapy, weeks, mean (SD)	5.6 (1.5)	6.6 (1.5)	0.011*
Tumor recurrence, n (%)	26 (26.0)	35 (35.0)	0.167
Non-gastric-cancer-related death, n (%)	11 (11.0)	16 (16.0)	0.301

LG, laparoscopic gastrectomy; OG, open gastrectomy. *P < 0.05.

Table 5. Postoperative recovery indicators in the LG and OG groups after matching

Variable	LG (n = 100)	OG (n = 100)	P
Postoperative pain VAS, POD1	4.5 (1.1)	5.6 (1.1)	< 0.001*
Postoperative pain VAS, POD3	2.3 (1.0)	3.3 (1.0)	< 0.001*
White blood cell count, POD1 (× 10^9/L)	10.4 (2.7)	12.5 (2.9)	< 0.001*
White blood cell count, POD3 (× 10^9/L)	7.7 (1.9)	9.3 (2.1)	< 0.001*
Time to first flatus, days	2.8 (0.9)	3.7 (0.9)	< 0.001*
Time to first defecation, days	3.6 (1.1)	4.4 (1.0)	< 0.001*

LG, laparoscopic gastrectomy; OG, open gastrectomy; POD, postoperative day; VAS, visual analogue scale; WBC, white blood cell count. *P < 0.05.

Postoperative recovery

Postoperative recovery indicators are summarized in **Table 5** and **Figure 5**. Compared to the OG group, the LG group reported lower pain scores on POD 1 (4.5 ± 1.1 vs 5.6 ± 1.1) and POD 3 (2.3 ± 1.0 vs 3.3 ± 1.0), lower WBC counts on POD 1 (10.4 ± 2.7 vs 12.5 ± 2.9 × 10^9/L) and POD 3 (7.7 ± 1.9

Table 6. Multivariable Cox proportional-hazards analysis of overall survival after matching

Variable	Adjusted HR (95% CI)	P
Surgical approach (OG vs LG)	1.46 (0.95-2.24)	0.084
Renal disease (yes vs no)	1.38 (0.86-2.21)	0.181
ASA-PS (III-IV vs I-II)	1.62 (1.06-2.48)	0.026*
ECOG-PS (≥ 2 vs < 2)	1.55 (1.01-2.38)	0.045*
pTNM stage (III vs I-II)	2.31 (1.49-3.58)	< 0.001*
Age (per 1-year increase)	1.05 (0.97-1.13)	0.214

HR, hazard ratio; CI, confidence interval; OG, open gastrectomy; LG, laparoscopic gastrectomy; ASA-PS, American Society of Anesthesiologists physical status; ECOG-PS, Eastern Cooperative Oncology Group performance status. The global proportional-hazards assumption was satisfied (scaled Schoenfeld residuals, global test P = 0.34). *P < 0.05.

vs 9.3 ± 2.1 × 10^9/L), and earlier return of bowel function, with shorter time to first flatus (2.8 ± 0.9 vs 3.7 ± 0.9 days) and first defecation (3.6 ± 1.1 vs 4.4 ± 1.0 days) (all P < 0.001). These findings indicate an attenuated surgical stress response and accelerated functional recovery after LG [22].

Survival according to postoperative complication severity

Overall survival stratified by postoperative complication severity is shown in **Figure 6**. In the whole cohort, patients with Clavien-Dindo grade ≥ III complications tended to have lower survival than those with grade < III complications, although the difference did not reach significance given the small number of severe events (log-rank P = 0.459). Similar non-significant patterns were observed within the LG and OG groups. Because major complications were infrequent in this matched cohort, these stratified estimates are exploratory and warrant confirmation in larger series.

Discussion

Prior to this study, the long-term outcomes of OG versus LG in gastric cancer patients aged ≥ 80 years have remained unclear. In our cohort, LG was associated with significantly higher 5-year OS than OG. However, this advantage was not maintained in stage-specific analyses, in which LG and OG showed similar 5-year survival across pTNM stages I-III. To our knowledge, this was one of the largest PSM studies to compare LG and OG outcomes in octogenarian gastric cancer patients.

On May 13, 2013, the WHO updated its global age classification as follows: young adults (< 44 years), middle-aged (45-59 years), young-old (60-74 years), old (75-89 years), and long-lived elderly (90 years) [23, 24]. While no universal standard defines “elderly” as ≥ 65 years, the WHO recommends region-specific criteria. In clinical research, older adults are commonly defined as aged ≥ 75 years [25-27]. Our study focused on patients aged ≥ 80 years to compare survival and postoperative complications between OG and LG. Our findings are consistent with several high-quality studies. The Italian LOGICA trial reported significantly lower median blood loss in the laparoscopic group (150 vs 300 mL, P < 0.001), albeit with a longer mean operative time (216 vs 182 min, P < 0.001) [28]. After adjustment for baseline characteristics, the LG group continued to show a significantly lower overall complication rate, with notably fewer anastomotic leaks, postoperative pneumonia, and atrial fibrillation. Clavien-Dindo grades were significantly lower in the LG group (P < 0.05), and hospital stay was shorter (6 vs 8 days, P < 0.001) [29], consistent with our observations.

Operative time was longer in the LG group (181.7 vs 162.2 minutes). In patients aged 80 years or older, prolonged anesthesia and operative time may increase the risk of postoperative delirium, hypothermia, and cardiovascular strain. The lower overall complication burden after LG should therefore be weighed against this longer intraoperative exposure, and operative efficiency remains an important consideration when selecting octogenarian candidates for a laparoscopic approach.

Beyond lower complication rates, laparoscopic surgery may confer broader postoperative benefits. Yuu et al. reported that laparoscopic procedures reduced intraoperative blood loss by 100-300 mL, shortened hospital stay by 3-6 days, accelerated recovery of bowel function (first flatus 1-2 days earlier), and relieved postoperative pain, thereby mitigating the postoperative stress response [30]. Our recovery data extend these observations to octogenarians, showing lower pain scores, a smaller WBC rise, and earlier bowel function recovery after LG,

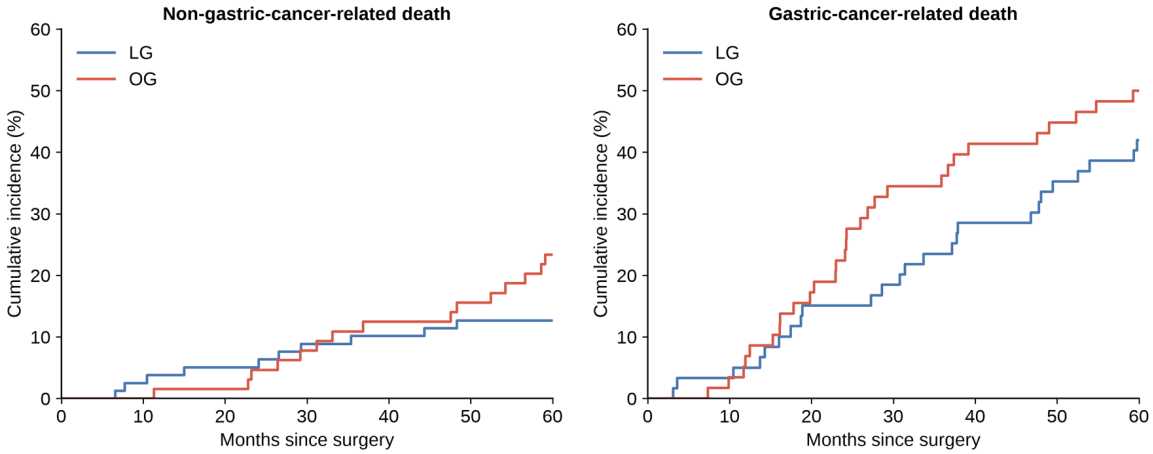


Figure 4. Cumulative incidence of cause-specific death. Left: non-gastric-cancer-related death; right: gastric-cancer-related death. LG, laparoscopic gastrectomy; OG, open gastrectomy.

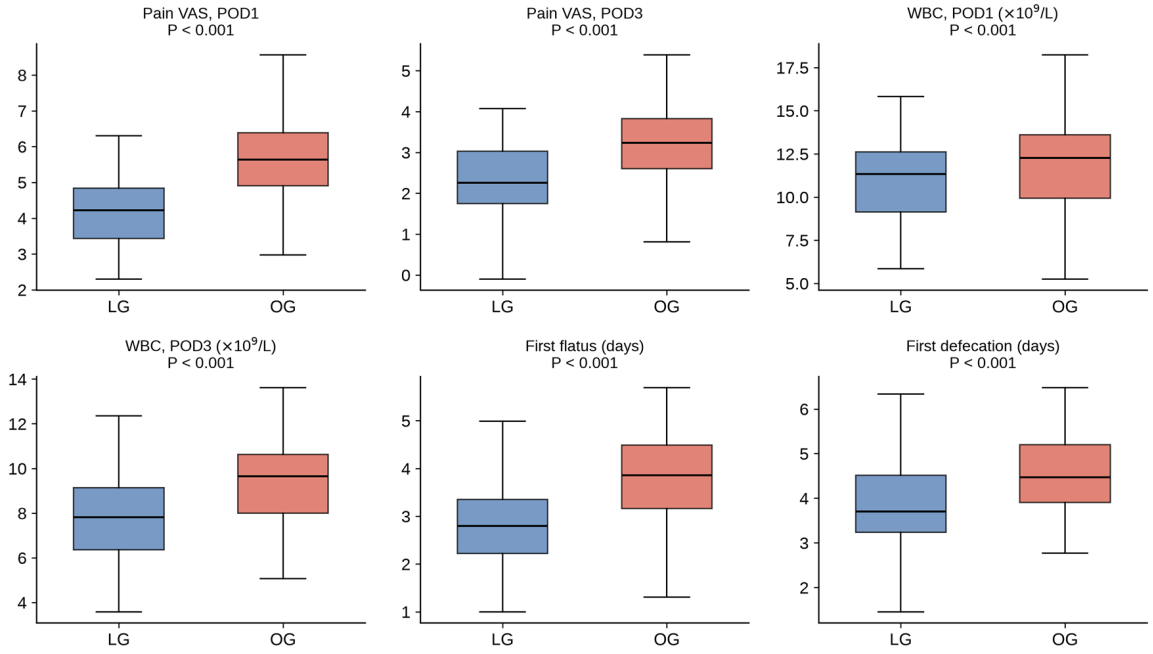


Figure 5. Postoperative recovery indicators in the LG and OG groups. POD, postoperative day; VAS, visual analogue scale; WBC, white blood cell count; LG, laparoscopic gastrectomy; OG, open gastrectomy.

consistent with enhanced-recovery principles [22].

Laparoscopic surgery may also provide longer-term advantages, including a lower risk of adhesion-related morbidity. Krielen et al. reported significantly reduced readmission for adhesive small-bowel obstruction after laparoscopic surgery [31]. Regarding analgesia, patients undergoing LG achieved adequate pain control without routine epidural analgesia and required fewer opioids [32]. In gastric cancer, high-quality randomized trials such as CLASS-01 have similarly shown that LG reduces overall complications, particularly wound-related events [33, 34]. The higher and earlier adjuvant chemotherapy delivery observed after LG is clinically relevant, because timely initiation of adjuvant therapy is associated with improved survival in resectable gastric cancer [21].

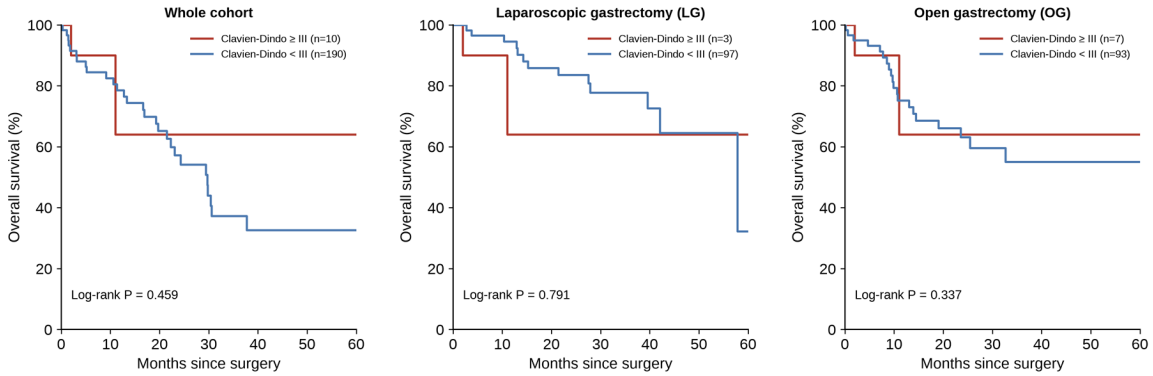


Figure 6. Overall survival stratified by postoperative complication severity (Clavien-Dindo grade ≥ III vs < III) in the whole cohort and within the LG and OG groups. LG, laparoscopic gastrectomy; OG, open gastrectomy.

Our results are consistent with studies focusing specifically on elderly gastric cancer patients. A Japanese PSM analysis of 162 patients aged ≥ 80 years reported a lower rate of postoperative complications (Clavien-Dindo grade II) in the LG group (18.5%) than in the OG group (27.3%) [35]. In terms of long-term outcomes, the CLASS-01 trial reported comparable 5-year OS between LG and OG (72.6% vs 76.3%) [33]; the KLASS-02 trial demonstrated equivalent 5-year survival for locally advanced gastric cancer (88.9% vs 88.7%, P = 0.99) [36]; and the JLSSG0901 study showed no significant differences in OS or recurrence-free survival, confirming non-inferiority of LG [37].

In contrast to this general pattern, we observed significantly higher survival in the LG group among octogenarians. In contrast, KLASS-01 reported nearly identical 5-year survival in early-stage disease (LG 94.2% vs OG 93.3%) [38], and JCOG0912 also showed no meaningful difference in recurrence-free survival (95.1% vs 94.0%) [6]. This discrepancy may reflect differences in study populations: our analysis focused specifically on octogenarians, a group underrepresented in major trials, highlighting the need for age-specific studies. Because renal disease remained more frequent in the LG group and ASA-PS showed a borderline imbalance after matching, the crude survival comparison was susceptible to residual confounding. After multivariable adjustment for these variables and for pTNM stage, and in a 90-day landmark analysis, the survival advantage of LG was no longer significant, which together with the stage-stratified results and the convergence of the survival curves after 30 months indicated that the apparent benefit was largely attributable to lower early postoperative mortality rather than to a direct oncologic effect of the laparoscopic approach.

A meta-analysis of two western randomized controlled trials (STOMACH and LOGICA) comparing minimally invasive with open gastrectomy for advanced gastric cancer reported broadly comparable postoperative recovery, oncologic outcomes, and quality of life; although LG was associated with less blood loss, and operative time was longer, with no significant differences in other key outcomes [39]. During the early postoperative period, the LG group showed better 1-year OS, consistent with a Swedish population-based cohort reporting improved OS and lower 30-day and 90-day mortality (1.8% vs 4.9%, P = 0.043) with LG [40]. Our lower 30- and 90-day mortality after LG (2.0% vs 9.0% and 6.0% vs 12.0%) are directionally concordant with these data. Reduced complications with minimally invasive techniques may partly explain these outcomes, particularly in older patients; however, some studies suggest that lower complication rates do not always translate into an early survival benefit [41]. We therefore caution against definitive conclusions about an early survival advantage of LG until potential confounders are more rigorously addressed.

Our study had several limitations. First, although deaths were adjudicated as gastric-cancer-related or non-gastric-cancer-related for the competing-risk analysis, cause-of-death attribution from retrospective records was imperfect and subject to misclassification.

Second, because this was an unblinded retrospective study, selection bias was unavoidable; although PSM was applied, residual confounding may have remained, particularly from the persistent imbalance in renal disease and borderline ASA-PS imbalance, which we addressed by multivariable adjustment. With 100 patients per group, the study had limited statistical power for several secondary outcomes, particularly severe complications, short-term mortality, and stage-specific survival. Some non-significant comparisons may reflect type II error and should be regarded as hypothesis-generating. Finally, some supplementary outcomes were derived from a single center and require external validation. These limitations support the need for large, multicenter randomized controlled trials to confirm a benefit of LG in older patients with gastric cancer.

Conclusion

Among gastric cancer patients aged ≥ 80 years, LG was associated with a significantly lower rate of postoperative complications and faster postoperative recovery than OG. The apparent overall survival advantage of LG was not robust to adjustment or stage stratification and is likely explained by lower early mortality rather than a direct oncologic effect. Although minimally invasive approaches may benefit octogenarians, these preliminary findings require confirmation in multicenter studies before clinical adoption.

Disclosure of conflict of interest

None.

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