Am J Transl Res 2026;18(7):6224-6237
www.ajtr.org /ISSN:1943-8141/AJTR0173715

Original Article

Safety and short-term oncological outcomes of multimodal modified overlap esophagojejunostomy in total laparoscopic total gastrectomy for elderly patients

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Received April 30, 2026; Accepted June 10, 2026; Epub July 15, 2026; Published July 30, 2026

Abstract: Objectives: To compare the safety and short-term oncological outcomes of a multimodal modified Overlap esophagojejunostomy versus the conventional Overlap technique in elderly patients undergoing total laparoscopic total gastrectomy (TLTG). Methods: This retrospective cohort study enrolled elderly gastric cancer (GC) patients who underwent TLTG combined with D2 lymphadenectomy. Patients were divided into two groups based on the digestive tract reconstruction method adopted: the conventional group (n = 154) receiving traditional Overlap esophagojejunostomy and the modified group (n = 103) receiving multimodal modified Overlap esophagojejunostomy. Perioperative and postoperative indicators were compared between the two groups, including total operative time, esophagojejunostomy time, intraoperative blood loss, postoperative complications, postoperative recovery parameters (time to ambulation, first flatus, and liquid diet initiation), length of hospital stay, two-year recurrence rate, as well as postoperative nutritional markers (albumin [ALB], hemoglobin [Hb]) and inflammatory markers (C-reactive protein [CRP], interleukin-6 [IL-6]). Results: The modified group demonstrated significantly shorter total operative time ($P = 0.008$) and esophagojejunostomy time ($P < 0.001$). Meanwhile, the modified group achieved faster postoperative recovery, with significantly earlier ambulation ($P = 0.008$), first flatus ($P = 0.036$), liquid diet initiation ($P = 0.024$), and shorter hospital stay ($P < 0.001$). In terms of postoperative biochemical indexes, the modified group exhibited significantly higher ALB levels ($P = 0.006$) and lower levels of CRP ($P < 0.001$) and IL-6 ($P < 0.001$). No significant differences were observed in postoperative complication rates and two-year recurrence rates between the two groups ($P > 0.05$). Conclusions: The multimodal modified Overlap esophagojejunostomy is a safe and efficient surgical technique for elderly patients undergoing TLTG. It can accelerate postoperative recovery, improve early postoperative nutritional status, and alleviate systemic inflammatory responses, without compromising short-term oncological outcomes.

Keywords: Gastric cancer, elderly, total laparoscopic total gastrectomy, overlap esophagojejunostomy, modified technique, short-term outcomes

Introduction

Gastric cancer (GC) is a global common malignancy, with a particularly high incidence in East Asian populations [1, 2]. The elderly population is disproportionately affected by GC, with advanced age associated with higher disease risk and a higher probability of late-stage diagnosis [3-5]. With the progressive aging of the global population, the number of elderly patients with resectable GC is continuously increasing [3, 4], highlighting the urgent need to optimize surgical strategies tailored for this vulnerable patient group.

Total laparoscopic total gastrectomy (TLTG) has been widely applied in the surgical treatment of proximal GC and Siewert type II/III esophagogastric junction (EGJ) tumors [6, 7]. As a minimally invasive surgical approach, TLTG offers multiple advantages over open gastrectomy, including reduced intraoperative blood loss, alleviated postoperative pain, shorter hospital stay, and faster postoperative recovery [8].

https://doi.org/10.62347/GNAW1233

However, intracorporeal esophagojejunostomy following TLTG remains a technical bottleneck, largely due to the narrow operating space in the upper abdominal cavity and lower mediastinum [9, 10].

The Overlap technique, first proposed by Tsujimoto et al. [11], is a mainstream side-to-side esophagojejunostomy method with a simple anatomical structure and favorable short-term application effects. Nevertheless, this conventional technique has inherent limitations, including the migration of the esophageal stump into the mediastinum, poor intraoperative visualization of the esophageal lumen, and difficulties in performing tension-free anastomosis [12, 13].

Elderly patients (aged ≥ 60 years) represent a high-risk subgroup in GC surgery due to age-related physiological deterioration. Frailty, characterized by reduced physiological reserve and increased stress vulnerability, is highly prevalent among elderly GC patients and independently correlates with postoperative complications, prolonged hospitalization, and poor postoperative prognosis after gastrectomy [14, 15]. Age-related declines in collagen synthesis, angiogenesis, and immune function impair wound healing, making anastomotic integrity a core clinical concern. Moreover, elderly patients have limited cardiopulmonary reserve and poor tolerance to prolonged operative time, pneumoperitoneum, and systemic inflammatory responses. Even minor postoperative complications, such as anastomotic leakage and pneumonia, may trigger irreversible functional decline, loss of self-care ability, and increased mortality. Consequently, surgical strategies that can shorten operative time, reduce tissue trauma, mitigate inflammatory responses, and accelerate postoperative recovery are particularly critical for elderly GC patients.

Notably, most existing studies on modified Overlap techniques have not specifically focused on elderly cohorts, resulting in a lack of targeted evidence-based clinical recommendations for this high-risk population. Accordingly, this study focused on elderly GC patients to explore the clinical advantages of the multimodal modified Overlap technique and provide practical references for clinical treatment.

Materials and methods

Research subjects

This study adopted a retrospective cohort design and enrolled elderly patients with EGJ cancer who underwent surgical treatment at the Department of Gastrointestinal Surgery, Shijiazhuang Maternal and Child Health Hospital, from January 2020 to June 2023. A total of 257 patients who met the predefined inclusion and exclusion criteria were included. All enrolled patients were diagnosed with EGJ cancer and underwent TLTG combined with D2 lymphadenectomy with Overlap esophagojejunostomy. Patients were divided into two groups based on different digestive tract reconstruction methods: the conventional group (n = 154) treated with traditional Overlap esophagojejunostomy, and the modified group (n = 103) treated with multimodal modified Overlap esophagojejunostomy.

Inclusion criteria: (1) Preoperative diagnosis of Siewert type II or III EGJ cancer confirmed by electronic gastroscopy, pathological biopsy, and imaging examination [16]; (2) Age ≥ 60 years; (3) Preoperative imaging confirming TNM stage I-III (2017 AJCC Cancer Staging Manual) [17] without distant metastasis (M0); (4) Eastern Cooperative Oncology Group Performance Status (ECOG PS) score of 0-2 [18]; (5) American Society of Anesthesiologists (ASA) physical status grade I-III [19]; (6) Complete clinical, pathological, surgical, and follow-up data.

Exclusion criteria: (1) Preoperative imaging detection of enlarged and fused perigastric lymph nodes; (2) Severe dysfunction of vital organs (heart, brain, liver, lung, kidney); (3) Intraoperative conversion to open surgery; (4) Concurrent malignant tumors of other systems.

Ethical statement

This retrospective study was conducted in accordance with the 2013 revised Declaration of Helsinki. The study protocol was approved by the Institutional Review Board (IRB) of Shijiazhuang Maternal and Child Health Hospital. Since this study only performed retrospective analysis of de-identified data extracted from electronic medical records, surgical logs, and follow-up databases without additional patient intervention or in-person contact, the IRB approved a waiver of written informed consent. Patient privacy and data confidentiality were strictly protected throughout the research process.

Treatment methods

Total laparoscopic total gastrectomy: In accordance with the Chinese Society of Clinical Oncology (CSCO) Gastric Cancer Diagnosis and Treatment Guidelines [16], patients with clinical stage cT3-4aN+M0 (stage cII-cIII) received preoperative neoadjuvant chemotherapy with the SOX regimen. During treatment, curative effect was comprehensively evaluated via detection of tumor markers (carcinoembryonic antigen [CEA], carbohydrate antigen 199 [CA199]), electronic gastroscopy, abdominal enhanced CT scans, and clinical symptom observation. The treatment regimen was adjusted dynamically according to patients' physical status and chemotherapy tolerance. Surgery was performed 3-6 weeks after the completion of neoadjuvant chemotherapy after excluding surgical contraindications.

All surgical procedures were performed by a single surgical team with over 10 years of experience in laparoscopic gastrointestinal surgery. Patients were placed in the supine split-leg position under general anesthesia, followed by routine surgical disinfection and sterile draping. The surgeon stood on the patient's left side, the assistant on the right side, and the laparoscopic operator between the patient's legs. A five-trocar technique was adopted to establish the operative channel: a 12-mm trocar was placed below the umbilicus as the observation hole to establish pneumoperitoneum and explore the abdominal cavity for distant metastasis. Subsequently, a 12-mm trocar was inserted 2 cm below the left costal margin at the anterior axillary line, a 5-mm trocar 2 cm above the left umbilical midclavicular line, and a 5-mm and a 12-mm trocar were placed at the corresponding right abdominal positions respectively. The liver was suspended via purse-string suture to fully expose the upper abdominal and lower esophageal surgical field. Standard TLTG procedures [20] were performed, including gastric vascular ligation and systematic D2 lymphadenectomy. After total gastric dissociation, the anterior esophageal hiatus and left diaphragmatic crus were incised to fully dissect the lower esophagus, followed by duodenal transection with a linear stapler. Finally, the two groups completed gastrointestinal reconstruction via different esophagojejunostomy methods.

Digestive tract reconstruction: Traditional overlap esophagojejunostomy: The totally laparoscopic antiperistaltic side-to-side Overlap esophagojejunostomy proposed by Inaba et al. [21] was adopted. After D2 lymphadenectomy and total gastrectomy, the duodenum and esophagus were transected with a linear stapler. Small incisions were made on the antimesenteric border of the jejunum (approximately 20 cm distal to the Treitz ligament) and the left wall of the esophageal stump, followed by stapler-assisted anastomosis of the two incisions. Subsequently, jejunojejunostomy was performed on the mesenteric border approximately 40 cm distal to the esophagojejunostomy site using a linear stapler. The anastomotic stoma was carefully examined for bleeding to complete gastrointestinal reconstruction.

Multimodal modified overlap esophagojejunostomy: ① Optimization of esophageal exposure and transection: After D2 lymphadenectomy, the lower esophagus was fully mobilized to the inferior pulmonary vein level. A 45-mm blue cartridge linear stapler (ECR45B, ETHICON, USA) was inserted along the esophageal axis from left to right, with the staple line reserved 5-8 mm lateral to the right esophageal border to form a mucosal bridge and prevent esophageal stump retraction into the mediastinum. Intraoperative frozen section examination confirmed that the proximal tumor margin was ≥ 3 cm. The resected gastric specimen was placed in a specimen bag and fixed in the right lower abdominal quadrant; the gravity of the specimen provided continuous and stable traction on the abdominal esophagus, maintaining esophageal luminal exposure without additional instrumental manipulation.

② Fixation of esophageal diaphragmatic angle: Prior to anastomosis, 3-0 barbed sutures (V-Loc 90, CONMED, USA) were used to fix the distal esophagus to the bilateral diaphragmatic crura in a W-shaped suture pattern, including two anchoring sutures on the left crus and one on the right crus with a suture spacing of 5-8 mm. This technique fixed the esophagus at least 2 cm above the diaphragmatic hiatus, eliminated longitudinal esophageal mobility, and reduced anastomotic tension to below 5 mmHg.

③ Three-directional traction-assisted anastomosis: The esophageal stump was adjusted to the sagittal plane, and three 3-0 silk traction sutures were placed 5 mm from the staple line on the anterior, posterior, and left lateral walls of the esophagus respectively to gently open the esophageal lumen and fully expose the mucosal surface. Under laparoscopic guidance, a 36-Fr nasogastric tube was placed at the esophageal stump as a marker to avoid stapler anvil misplacement into the submucosal false lumen. A 45-mm blue cartridge linear stapler was inserted into the antimesenteric border of the jejunum 20 cm distal to the Treitz ligament and the left esophageal wall, with the staple line parallel to the esophageal axis for anastomosis.

④ Double-layer barbed suture closure of the common opening: After stapler removal, the common anastomotic opening was inspected for bleeding, followed by knot-free double-layer closure with 3-0 barbed sutures. The first mucosal layer was closed via continuous inside-out suturing from the apex to the base of the opening, with a bite depth of 2-3 mm and spacing of 2 mm, ensuring full-thickness mucosal alignment without inversion. The second seromuscular reinforcement layer adopted continuous vertical mattress outside-in and outside-out suturing, 3 mm away from the first suture layer, with a bite depth of 3-4 mm and spacing of 3 mm, covering the entire staple line to evenly disperse anastomotic tension. After closure, normal saline was filled in the abdominal cavity, and air was injected through the nasogastric tube for a bubble test; no anastomotic leakage was defined as successful anastomosis.

Postoperative management: All patients received standardized postoperative management protocols: (1) Prophylactic anti-infection treatment: Broad-spectrum antibiotics were routinely administered for 48 hours postoperatively to prevent surgical site infection; (2) Gastrointestinal function management: Octreotide was used routinely to inhibit gastrointestinal fluid secretion until the recovery of oral feeding; (3) Laboratory monitoring: Routine blood tests and procalcitonin detection were continuously performed for 3 consecutive days after surgery to evaluate infection and inflammatory status; (4) Anastomotic safety evaluation: For patients with stable vital signs on postoperative day 3, upper gastrointestinal water-soluble contrast imaging was performed to exclude anastomotic leakage; (5) Rehabilitation guidance: Patients were encouraged to perform early ambulation to promote gastrointestinal function recovery. After the recovery of exhaust and defecation, patients received a gradual diet transition from liquid diet to semi-liquid diet and finally regular diet; (6) Drainage management: Abdominal drainage tubes were removed gradually after the exclusion of early postoperative complications; (7) Discharge criteria: Patients with stable vital signs, tolerable regular diet, no obvious postoperative discomfort, and normal laboratory indicators could be discharged after 1 day of observation; (8) Follow-up protocol: Standardized postoperative follow-up was implemented. Patients received outpatient or telephone follow-up every 3 months within 2 years after surgery, and every 6 months thereafter until June 30, 2025. Follow-up contents included tumor recurrence and metastasis, postoperative complications, and other adverse events.

Data collection

Baseline clinical data of all patients were collected, including age, gender, body mass index (BMI), ASA grade, ECOG PS score, Charlson comorbidity index (CCI), smoking history, drinking history, previous abdominal surgery history, maximum tumor diameter, Siewert classification, TNM stage, T stage, N stage, neoadjuvant chemotherapy history, neurovascular invasion, and preoperative tumor markers (CEA, CA199). CEA and CA199 levels were detected using a Cobas e 801 chemiluminescence immunoassay analyzer (Roche Diagnostics, Switzerland). Preoperative routine hematological indicators within one week before surgery, including white blood cell (WBC), neutrophil (NEUT), lymphocyte (LYM), and platelet (PLT) counts, were measured via an XN-9000 automated hematology analyzer (Sysmex, Japan).

Intraoperative observational indicators included total operative time, esophagojejunostomy time, intraoperative blood loss, incision length, R0 resection rate, and number of dissected lymph nodes.

Postoperative observational indicators included nutritional and inflammatory marker levels, postoperative complications, time to first ambulation, time to first flatus, time to liquid diet initiation, postoperative hospital stay, and two-year tumor recurrence rate. Preoperative and 24-hour postoperative albumin (ALB) and hemoglobin (Hb) levels were detected using a Cobas c 701 biochemical analyzer (Roche Diagnostics, Switzerland), while C-reactive protein (CRP) and interleukin-6 (IL-6) levels were measured via a Cobas e 601 fully automated chemiluminescence immunoassay system (Roche Diagnostics, Germany).

Postoperative complications were divided into early complications (occurring within 30 days after surgery) and late complications (occurring 30 days after surgery to the final follow-up). The diagnostic criteria for major complications were as follows: (1) Anastomotic leakage: Extravasation of contrast medium or digestive fluid at the esophagojejunostomy site confirmed by imaging, endoscopy or reoperation, or positive bubble test during reoperation; (2) Anastomotic hemorrhage: Hematemesis or melena accompanied by Hb decline ≥ 20 g/L, requiring endoscopic hemostasis, blood transfusion or reoperation; (3) Anastomotic stricture: Dysphagia requiring endoscopic dilation, or anastomotic lumen diameter < 10 mm on gastroscopy, with biopsy excluding tumor recurrence; (4) Intestinal obstruction: CT showing dilated small intestinal loops with air-fluid levels, requiring conservative treatment for > 72 h or surgical intervention; (5) Pulmonary infection: New pulmonary infiltrates on chest CT combined with at least two of the following symptoms: fever > 38°C, purulent sputum, leukocytosis (> 10×10^9/L), or positive sputum culture; (6) Incision infection: Superficial or deep incision purulence, erythema or dehiscence requiring antibiotic treatment or drainage, in line with CDC diagnostic criteria; (7) Reflux esophagitis: Los Angeles grade B or higher inflammatory changes on postoperative endoscopy, accompanied by typical heartburn and regurgitation symptoms; (8) Dumping syndrome: Typical postprandial symptoms (sweating, palpitations, syncope within 30 minutes after meals) confirmed by 75 g oral glucose tolerance test.

Statistics analysis

SPSS 29.0 software (IBM Corp, Chicago, IL, USA) was used for statistical analysis, and $P < 0.05$ was defined as statistically significant. All continuous variables in this study conformed to normal distribution and homogeneity of variance, and were expressed as mean ± standard deviation (M ± SD). Independent-samples t-test was used for inter-group comparison. Categorical variables were expressed as frequencies and percentages [n (%)], and χ^2 test was adopted for inter-group rate comparison. For samples with total sample size ≥ 40 but theoretical frequency < 5, continuity-corrected χ^2 test was used; Fisher's exact test was applied for samples with theoretical frequency < 1 or total sample size < 40.

The sample size was calculated based on the primary outcome indicator (esophagojejunostomy time). Preliminary experimental data showed that the esophagojejunostomy time was 53.35 ± 5.27 min in the conventional group and 42.36 ± 3.86 min in the modified group, with a Cohen's d effect size of 2.37. Post-hoc power analysis (G*Power 3.1) revealed that a minimum of 28 cases per group was required to achieve 80% statistical power with a two-sided α of 0.05. The final sample size of this study (154 cases in the conventional group, 103 cases in the modified group) far met the requirement, ensuring sufficient statistical power to identify clinically significant differences in all primary and secondary outcomes.

Results

Baseline clinical characteristics

As shown in **Table 1**, the baseline demographic characteristics were well balanced between the two groups. No significant differences were found in age (68.42 ± 3.34 vs. 69.15 ± 3.85 years, $P = 0.109$), gender composition ($P = 0.108$), BMI ($P = 0.643$), ASA grade ($P = 0.951$), ECOG PS score ($P = 0.927$), and CCI ($P = 0.883$). In addition, smoking history, drinking history, and previous abdominal surgery history were comparable between the two groups (all

Table 1. Comparison of demographic characteristics between the two groups

Parameter	Conventional group (n = 154)	Modified group (n = 103)	t/χ^2	*P*
Age (years)	68.42 ± 3.34	69.15 ± 3.85	1.609	0.109
Gender, n (%)			2.577	0.108
Male	109 (70.78%)	63 (61.17%)		
Female	45 (29.22%)	40 (38.83%)		
BMI (kg/m^2)	22.31 ± 2.87	22.48 ± 3.02	0.463	0.643
ASA grade, n (%)			0.101	0.951
I	28 (18.18%)	18 (17.48%)		
II	97 (62.99%)	64 (62.14%)		
III	29 (18.83%)	21 (20.39%)		
ECOG PS, n (%)			0.151	0.927
0	52 (33.77%)	33 (32.04%)		
1	89 (57.79%)	62 (60.19%)		
2	13 (8.44%)	8 (7.77%)		
CCI, n (%)			0.022	0.883
≤ 2	106 (68.83%)	70 (67.96%)		
> 2	48 (31.17%)	33 (32.04%)		
Smoking history, n (%)			0.007	0.934
Yes	62 (40.26%)	42 (40.78%)		
No	92 (59.74%)	61 (59.22%)		
Drinking history, n (%)			0.401	0.526
Yes	48 (31.17%)	36 (34.95%)		
No	106 (68.83%)	67 (65.05%)		
Abdominal surgery history, n (%)			0.003	0.954
Yes	25 (16.23%)	17 (16.50%)		
No	129 (83.77%)	86 (83.50%)		

Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists; ECOG PS, Eastern cooperative oncology group performance status; CCI, Charlson comorbidity index.

P > 0.05), indicating consistent baseline general conditions of the two cohorts.

Tumor-related pathological characteristics are summarized in **Table 2**. There were no significant inter-group differences in maximum tumor diameter (4.59 ± 1.26 cm vs. 4.41 ± 1.14 cm, *P* = 0.266), Siewert type distribution (*P* = 0.177), TNM stage (*P* = 0.815), T stage (*P* = 0.983), N stage (*P* = 0.992), or neoadjuvant chemotherapy rate (40.26% vs. 41.75%, *P* = 0.812). Preoperative nutritional status and tumor marker levels (CEA, CA199) were also similar between groups (all *P* > 0.05). The above results confirmed that the two groups had consistent preoperative tumor status and general baseline conditions.

As shown in **Table 3**, preoperative WBC, NEUT, LYM, and PLT counts showed no significant differences between the two groups (all *P* > 0.05), indicating comparable baseline hematological status.

Intraoperative outcomes

Intraoperative safety indicators are presented in **Figure 1**. The modified group had a significantly shorter total operative time than the conventional group (268.19 ± 18.15 min vs. 275.46 ± 25.72 min, *P* = 0.008) (**Figure 1A**). Notably, the esophagojejunostomy time in the modified group was approximately 11 minutes shorter than that in the conventional group (42.36 ± 3.86 min vs. 53.35 ± 5.27 min, *P* < 0.001) (**Figure 1B**). Although the modified group showed slightly lower intraoperative blood loss (102.78 ± 25.37 mL vs. 105.63 ± 32.41 mL, *P* = 0.430, **Figure 1C**) and marginally smaller incision length (5.08 ± 0.19 cm vs. 5.12 ± 0.25 cm, *P* = 0.092, **Figure 1D**). These results demonstrate that the multimodal modi-

Table 2. Comparison of oncological characteristics between the two groups

Parameter	Conventional group (n = 154)	Modified group (n = 103)	t/χ^2	*P*
Maximum tumor diameter (cm)	4.59 ± 1.26	4.41 ± 1.14	1.114	0.266
Siewert type, n (%)			1.820	0.177
Type II	82 (53.25%)	46 (44.66%)		
Type III	72 (46.75%)	57 (55.34%)		
TNM stage, n (%)			0.409	0.815
I	24 (15.58%)	17 (16.50%)		
II	55 (35.71%)	40 (38.83%)		
III	75 (48.70%)	46 (44.66%)		
T stage, n (%)			0.167	0.983
T1	15 (9.74%)	11 (10.68%)		
T2	22 (14.29%)	16 (15.53%)		
T3	70 (45.45%)	46 (44.66%)		
T4	47 (30.52%)	30 (29.13%)		
N stage, n (%)			0.095	0.992
N0	47 (30.52%)	33 (32.04%)		
N1	28 (18.18%)	19 (18.45%)		
N2	35 (22.73%)	23 (22.33%)		
N3	44 (28.57%)	28 (27.18%)		
Neoadjuvant chemotherapy, n (%)	62 (40.26%)	43 (41.75%)	0.057	0.812
Neurovascular invasion [n (%)]	58 (37.66%)	38 (36.89%)	0.016	0.901
Preoperative CEA (ng/ml)	3.86 ± 0.94	3.72 ± 0.75	1.307	0.192
Preoperative CA199 (U/ml)	17.53 ± 2.67	16.98 ± 2.21	1.807	0.072

Abbreviations: CEA, carcinoembryonic antigen; CA199, carbohydrate antigen199.

Table 3. Comparison of preoperative routine blood parameters between the two groups

Parameter	Conventional group (n = 154)	Modified group (n = 103)	t	*P*
WBC ($\times 10^9$/L)	6.38 ± 1.72	6.52 ± 1.65	0.661	0.51
NEUT ($\times 10^9$/L)	4.05 ± 1.34	4.18 ± 1.28	0.775	0.439
LYM ($\times 10^9$/L)	1.62 ± 0.51	1.58 ± 0.47	0.633	0.527
PLT ($\times 10^9$/L)	228.45 ± 65.31	235.12 ± 60.87	0.824	0.411

Abbreviations: WBC, white blood cell; NEUT, neutrophil; LYM, lymphocyte; PLT, platelet.

fied technique is safe and operable, with core advantages in shortening anastomosis time.

Postoperative complications

The incidence of early postoperative complications was lower in the modified group than in the conventional group (6.80% vs. 13.64%), but the difference did not reach statistical significance (*P* = 0.085) (**Table 4**). The incidence of specific complications including anastomotic leakage, anastomotic hemorrhage, anastomotic stricture, intestinal obstruction, pulmonary infection, and incision infection was numerically lower in the modified group, with zero cases of anastomotic leakage and anastomotic hemorrhage observed in this group. As shown in **Table 5**, the incidence of late postoperative complications was similar between the two groups (7.77% vs. 9.74%, *P* = 0.587), confirming that the modified technique does not increase the risk of long-term postoperative adverse events.

Short-term oncological outcomes

Both groups achieved radical tumor resection (**Table 6**), with a 100% R0 resection rate in all patients. The number of dissected lymph nodes was comparable between the conven-

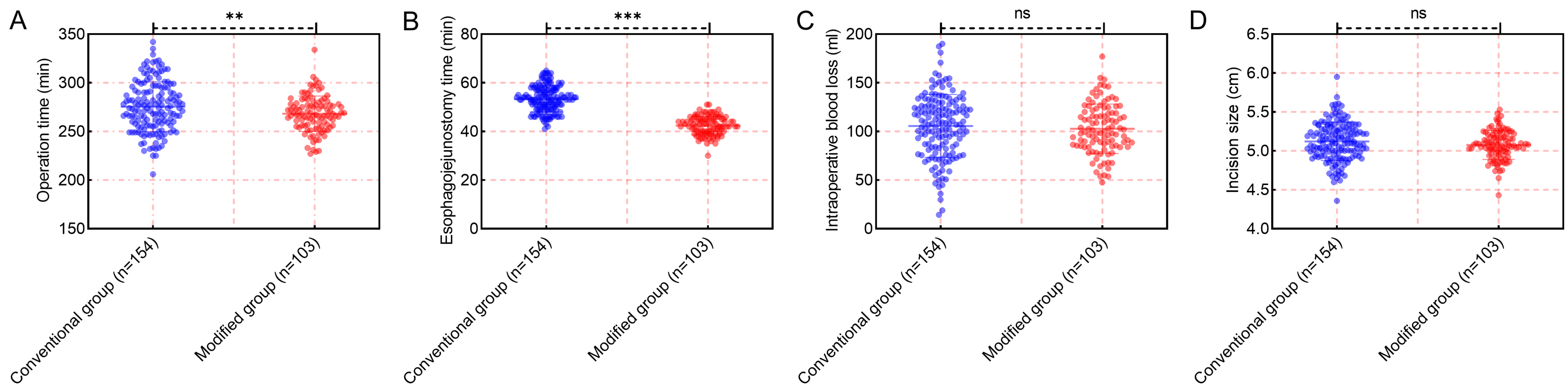

Figure 1. Comparison of intraoperative situations between the two groups. A. Operation time (min). B. Esophagojejunostomy time (min). C. Intraoperative blood loss (ml). D. Incision size (cm). ns: no statistically significant difference; **: $P < 0.01$; ***: $P < 0.001$.

Table 4. Comparison of postoperative early complications between the two groups (n (%))

Parameter	Conventional group (n = 154)	Modified group (n = 103)	χ^2	*P*
Postoperative early complications	21 (13.64%)	7 (6.80%)	2.975	0.085
Anastomotic fistula	4 (2.60%)	0 (0.00%)		
Anastomotic hemorrhage	2 (1.30%)	0 (0.00%)		
Anastomotic stricture	3 (1.95%)	1 (0.97%)		
Intestinal obstruction	4 (2.60%)	2 (1.94%)		
Pulmonary infection	5 (3.25%)	3 (2.91%)		
Incision infection	4 (2.60%)	1 (0.97%)		

Table 5. Comparison of postoperative late complications between the two groups (n (%))

Parameter	Conventional group (n = 154)	Modified group (n = 103)	χ^2	*P*
Postoperative late complications	15 (9.74%)	8 (7.77%)	0.295	0.587
Anastomotic stricture	4 (2.60%)	1 (0.97%)		
Intestinal obstruction	3 (1.95%)	2 (1.94%)		
Reflux esophagitis	5 (3.25%)	3 (2.91%)		
Dumping syndrome	3 (1.95%)	2 (1.94%)		

Table 6. Comparison of tumor resection quality between the two groups

Parameter	Conventional group (n = 154)	Modified group (n = 103)	t/χ^2	*P*
R0 resection rate, n (%)	154 (100.00%)	103 (100.00%)	-	-
Number of lymph nodes dissected	29.56 ± 8.63	31.28 ± 9.34	1.517	0.131

Table 7. Comparison of recurrence rate within postoperative two years between the two groups (n (%))

Parameter	Conventional group (n = 154)	Modified group (n = 103)	χ^2	*P*
Recurrence	18 (11.69%)	9 (8.74%)	0.571	0.450
Local recurrence	5 (3.25%)	2 (1.94%)		
Distant metastasis	9 (5.84%)	5 (4.85%)		
Mixed recurrence	4 (2.60%)	2 (1.94%)		

tional group and the modified group (29.56 ± 8.63 vs. 31.28 ± 9.34, $P = 0.131$), indicating that the modified anastomotic technique does not compromise the radicality of tumor resection.

The two-year postoperative recurrence rate is shown in **Table 7**. The modified group had a numerically lower total recurrence rate than the conventional group (8.74% vs. 11.69%), but the difference was not statistically significant ($P = 0.450$). No inter-group differences were observed in the types of recurrence (local, distant, and mixed recurrence). These findings verify that the modified technique has equivalent short-term oncological efficacy to the conventional method.

Postoperative recovery and biochemical indexes

The modified group achieved significantly better postoperative recovery outcomes (**Figure 2**). Compared with the conventional group, patients in the modified group had significantly earlier first ambulation (1.86 ± 0.53 days vs. 2.05 ± 0.57 days, $P = 0.008$), first flatus (3.44 ± 0.65 days vs. 3.63 ± 0.81 days, $P = 0.036$), and liquid diet initiation (5.53 ± 1.74 days vs. 5.96 ± 1.08 days, $P = 0.024$). Accordingly, the postoperative hospital stay of the modified group was significantly shorter (8.92 ± 2.31 days vs. 11.05 ± 2.68 days, $P < 0.001$).

As shown in **Table 8**, preoperative ALB, Hb, CRP, and IL-6 levels were comparable between

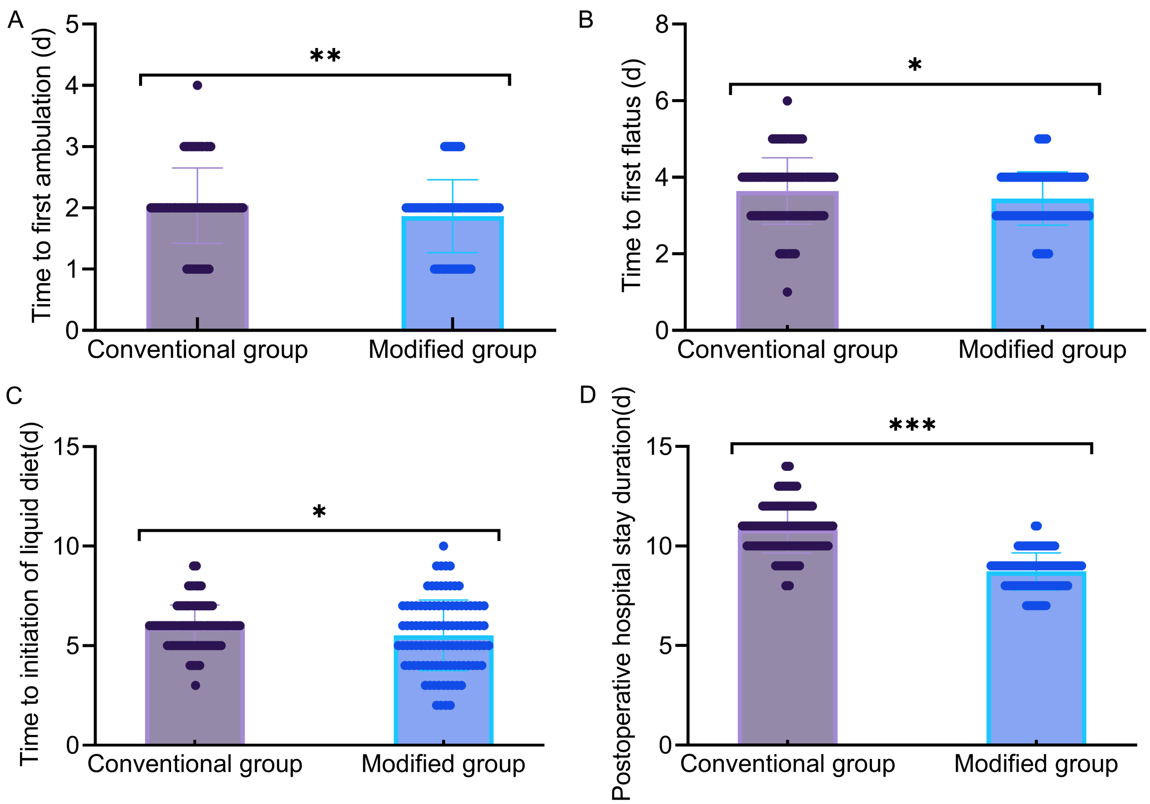

Figure 2. Comparison of postoperative recovery time between two groups. A. Time to first ambulation. B. Time to first flatus. C. Time to initiation of liquid diet. D. Postoperative hospital stay duration. *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

Table 8. Comparison of nutritional and inflammatory markers between the two groups

Parameter	Conventional group (n = 154)	Modified group (n = 103)	t	*P*
ALB (g/L)				
Preoperative	38.42 ± 4.35	38.67 ± 3.82	0.458	0.648
Postoperative	32.15 ± 3.87	33.48 ± 3.63	2.780	0.006
Hb (g/L)				
Preoperative	121.35 ± 15.62	122.48 ± 16.03	0.564	0.573
Postoperative	107.82 ± 13.45	108.96 ± 14.21	0.653	0.515
CRP (mg/L)				
Preoperative	8.42 ± 2.56	8.15 ± 2.24	0.871	0.384
Postoperative	182.36 ± 45.28	159.47 ± 38.61	4.209	< 0.001
IL-6 (pg/mL)				
Preoperative	67.38 ± 18.45	65.92 ± 19.13	0.612	0.541
Postoperative	252.84 ± 42.67	231.25 ± 36.42	4.211	< 0.001

Abbreviations: ALB, albumin; Hb, hemoglobin; CRP, C-reactive protein; IL-6, interleukin-6.

the two groups (all $P > 0.05$), with consistent baseline nutritional and inflammatory status. At 24 hours postoperatively, the modified group demonstrated significantly higher ALB levels (33.48 ± 3.63 g/L vs. 32.15 ± 3.87 g/L, P = 0.006), while Hb levels showed no significant inter-group difference (P = 0.515). Moreover, the modified group exhibited significantly lower postoperative CRP (159.47 ± 38.61 mg/L vs. 182.36 ± 45.28 mg/L, $P < 0.001$) and IL-6

(231.25 ± 36.42 pg/mL vs. 252.84 ± 42.67 pg/mL, $P < 0.001$) levels, suggesting a milder postoperative systemic inflammatory response in the modified group.

Discussion

This study aimed to evaluate the safety and efficacy of the modified Overlap technique in elderly GC patients undergoing TLTG in to comparison with the conventional Overlap procedure. Our results demonstrated that the modified approach shortened anastomotic and overall operative duration, accelerated postoperative recovery, and yielded comparable complication profiles and short-term oncological outcomes.

Baseline demographic, oncological and hematological parameters were well balanced between cohorts, enabling reliable intergroup comparison.

One of the primary findings was that the multimodal modified Overlap technique significantly shortened total operative time and, more notably, esophagojejunostomy time. Several mechanistic factors account for this efficiency. First, the partial esophageal transection (preserving a 5-8 mm right-side mucosal bridge) prevents proximal esophageal retraction into the mediastinum, eliminating the time-consuming step of repeated stump retrieval and re-exposure. The weight of the 200-400 g resected specimen generates sustained calibrated traction, maintaining unobstructed visualization of the esophageal lumen without extra instrumental manipulation [22, 23]. Second, diaphragmatic fixation via a W-shaped barbed suture anchors the esophagus above the diaphragmatic crura, minimizing intraoperative positional shifts induced by respiratory motion or instrument traction and creating a stable, tension-free platform for single-shot stapler deployment [9, 10]. Third, the three-directional traction opens the esophageal lumen along anterior, posterior and left lateral planes; combined with a nasogastric tube as an intraoperative landmark, this maneuver facilitates accurate stapler anvil placement into the true lumen and avoids time-consuming submucosal false passage formation [24]. Collectively, these structural optimizations shorten anastomotic time. In contrast, the conventional Overlap frequently requires repeated esophageal mobilization and stapler reposition due to poor operative exposure, prolonging overall surgery [15, 25].

Regarding surgical safety, the modified group had numerically fewer early complications including anastomotic leakage and hemorrhage, yet intergroup differences failed to reach statistical significance. Such findings still confirm the modified procedure does not add extra operative risks. Notably, no anastomotic leakage or bleeding occurred in the modified cohort; although statistically insignificant, this favorable trend warrants verification in larger patient cohorts. Double-layer barbed closure of the common anastomotic orifice enhances anastomotic integrity [26, 27] by tight apposition of mucosal and seromuscular layers, which is critical for leakage prevention and particularly beneficial for elderly patients with compromised wound-healing capacity [28, 29].

We further assessed oncological safety of the modified reconstruction. Both groups achieved 100% R0 resection and comparable numbers of harvested lymph nodes, confirming the modified anastomosis neither compromises surgical radicality nor reduces lymphadenectomy extent. The two-year recurrence rate was also similar across groups, verifying non-inferior short-term oncological outcomes. Consistent with existing literature, properly standardized anastomotic revision exerts no adverse impact on oncological prognosis [30-32].

The modified technique also facilitated faster postoperative functional recovery, manifested as earlier out-of-bed mobilization, first flatus, initiation of oral liquid feeding and shortened hospital stay. These benefits likely stem from expedited, less traumatic anastomosis with reduced visceral traction. Diaphragmatic esophageal fixation stabilizes the stoma in a tension-free state, alleviating perianastomotic edema and microinjury and accelerating restoration of intestinal peristalsis [33, 34]. Early postoperative feeding is clinically vital for elderly individuals, as prolonged nil per os status causes muscle wasting and impedes rehabilitation [35-37].

The modified group demonstrated significantly lower postoperative CRP and IL-6 levels, superior ALB preservation, and accelerated clinical recovery (earlier ambulation, first flatus, liquid diet initiation and shorter hospital stay). Several interconnected mechanisms explain these benefits. Reduced operative and anastomotic duration shortens pneumoperitoneum duration, anesthetic exposure and visceral manipulation, all established triggers of systemic inflammatory response. Minimized mediastinal dissection-attributable to avoidance of repeated intrathoracic esophageal traction-reduces local tissue damage and proinflammatory cytokine release. The tension-free, well-vascularized anastomosis secured by diaphragmatic fixation and double-layer barbed suture precludes perianastomotic microleakage and excessive inflammatory exudation [28, 29]. Lower CRP and IL-6 concentrations reflect a blunted acute-phase response, which improves gastrointestinal motility (earlier first flatus), alleviates postoperative pain (earlier ambulation), and permits earlier oral feeding. Better preserved ALB indicates diminished postoperative protein catabolism, supporting wound repair and immune function. For elderly patients with limited physiological reserve, even mild inflammatory attenuation translates to clinically meaningful faster recovery and shortened hospitalization.

Prior studies have reported refined Overlap modifications, but none integrate all four core optimizations (partial esophageal transection, diaphragmatic fixation, three-directional traction and double-layer barbed closure) into one multimodal protocol, nor target exclusively elderly patients. Inaba et al. [38] originally proposed the classic Overlap without anti-retraction or fixation measures, leading to frequent stump mediastinal migration and prolonged operative time, a drawback resolved by our combined transection and fixation strategy. Aslan and Topgül [14] modified stapler insertion angle but omitted esophageal stabilization and reinforced closure, with a longer anastomotic time (48 ± 6 min) than our cohort (42.36 ± 3.86 min). Song et al. [25] compared Overlap versus π-shaped anastomosis and documented a 9-minute disparity in anastomotic duration, yet their refinement was restricted to stapler configuration without soft-tissue fixation or suture reinforcement; their early anastomotic leakage rate reached 2.1%, versus zero in our modified group (statistically non-significant). Wang et al. [28] adopted a traction-first delayed transection technique to shorten operation time but omitted diaphragmatic fixation and double-layer closure, resulting in a longer mean hospital stay (10.5 days) than our modified cohort (8.92 days).

Our study bears several limitations. First, as a single-center retrospective cohort study, inherent selection bias exists. Despite balanced baseline demographic, oncological and hematological features verified via t-tests and χ^2 tests, univariate comparisons cannot fully eliminate confounding by indication or unmeasured variables such as frailty, baseline nutrition and intraoperative surgeon decision-making. Absence of multivariable regression or propensity score matching for confounder adjustment constitutes a major limitation. Second, only 2-year short-term recurrence data were collected without long-term OS or DFS follow-up. While 2-year recurrence serves as a valid surrogate for surgical radicality in GC, lack of long-term survival data prevents definitive conclusions regarding persistent oncological safety of the modified technique; extended ≥ 5-year follow-up is required for subsequent validation. Third, formal learning curve analysis was not performed. All surgeries were completed by a single experienced laparoscopic gastrointestinal team with > 10 years of relevant practice; 15 preliminary training cases (excluded from analysis) were completed until surgeons achieved proficiency defined by consistent anastomotic time < 50 min and zero anastomotic leaks. Without risk-adjusted CUSUM analysis across different learning phases, our favorable outcomes only reflect performance after full proficiency acquisition, and extrapolation to low-volume centers or novice surgeons remains uncertain. Future multicenter trials with formal CUSUM-based learning curve assessment and variable institutional case volumes, alongside large-scale prospective randomized controlled trials with long-term follow-up and patient-reported outcome metrics, are warranted to validate the safety and efficacy of this multimodal modified Overlap.

Summary

The multimodal modified Overlap esophagojejunostomy represents a valuable technical refinement for elderly patients receiving TLTG. Combined optimization of esophageal positioning, intraoperative luminal exposure and double-layer stomal closure shortens operative time, accelerates postoperative recovery, preserves early nutritional status and suppresses postoperative inflammation, thereby shortening hospital stay. Critically, this modified technique does not compromise anastomotic safety or short-term oncological outcomes, effectively mitigating surgical stress of intracorporeal esophagojejunostomy in elderly GC patients. Further multicenter investigations are required to corroborate our findings.

Disclosure of conflict of interest

None.

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