Retrospective Cohort Study

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Assessment of modified textbook outcomes following gastrectomy based on survival benefits: a multicenter observational study

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Background: Textbook outcome (TO) is an increasingly utilized metric for evaluating perioperative treatment quality. However, a standardized and universally accepted definition of TO in gastrectomy has not yet been established. This multicenter study aimed to evaluate the incidence of a modified definition of TO (mTO) and its association with long-term oncologic survival following gastrectomy.

Methods: Data from all consecutive patients undergoing curative-intent resection for gastric cancer were analyzed from institutional databases of seven high-volume centers in China between 7 January 2010, and 30 September 2019. The achievement rates of TO and mTO were measured. mTO was defined as achieving all of the following: pR0 resection, retrieval of at least 15 lymph nodes, absence of severe postoperative complications (Clavien-Dindo grade ≥IIIa) within 90 days, length of hospital stay below the 75th percentile, no 90-day mortality, and no 90-day readmission. The primary outcomes were the associations between mTO and 5-year overall survival (OS) and disease-free survival (DFS). The secondary outcome was to determine the rate of mTO and identify independent factors associated with its achievement.

Results: Among 2608 eligible patients, the rates of mTO and TO were 62.4% (1628 patients) and 72.0% (1877 patients), respectively. Achieving mTO was independently associated with reduced hazards of death in Cox regression analysis for 5-year OS and DFS (HR 0.565 [95% CI: 0.504–0.633] and HR 0.561 [95% CI: 0.502–0.628], respectively). Similarly, achieving TO was independently associated with reduced hazards of death for 5-year OS and DFS (HR 0.737 [95% CI: 0.653–0.831] and HR 0.735 [95% CI: 0.65–0.827], respectively). Subgroup analyses demonstrated that mTO was consistently associated with a greater reduction in death hazards compared to TO for both OS and DFS.

Conclusion: mTO serves as a more comprehensive and beneficial indicator for assessing perioperative quality, providing superior survival benefits compared to TO.

Keywords: gastric cancer, modified textbook outcome, prognosis, risk factors

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Introduction

Gastric cancer ranks as the fifth most frequently diagnosed malignancy worldwide and the fourth leading cause of cancer-related mortality, with an estimated 769 000 deaths globally in 2020[1]. Surgical resection remains the cornerstone treatment for nonmetastatic gastric cancer. However, despite advancements in perioperative management and surgical techniques, the procedure still carries substantial morbidity risk[2,3].

Previous research on postoperative outcomes in cancer patients often focused on individual metrics such as mortality, hospital readmission rates, and length of stay (LOS). While informative, these measures have relatively low incidence rates and fail to capture the multidimensional aspects of the entire surgical process[4,5]. Moreover, individual metrics often vary

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across hospitals, reflecting inherent limitations in assessing surgical quality. To address these shortcomings, composite outcome measures have been introduced, offering a more comprehensive approach to evaluating surgical performance.

Textbook outcome (TO) is one such composite metric, first introduced in colorectal cancer surgery in 2013 and subsequently applied to complex procedures in gastric, hepatobiliary, and pancreatic surgeries[6–11]. TO integrates desirable surgical outcomes into a single measure based on an all-or-none principle, representing an ideal perioperative course[12]. This metric provides a holistic evaluation of surgical care, emphasizing patient-centered outcomes and facilitating comparisons across hospital performance[13,14].

Several studies have assessed TO in gastric cancer surgery, demonstrating its utility in evaluating perioperative quality[9,15–18]. However, inconsistent definitions of TO across studies limit its reliability and generalizability[19]. While standardized definitions of TO have been proposed in other surgical fields, such as liver surgery and endoscopy[20,21], TO in gastric surgery has largely been defined by small groups of surgeons or individual experts, limiting its widespread acceptance. Recently, a systematic review proposed a modified textbook outcome (mTO) for gastric surgery, incorporating a common set of metrics to enable inter-institutional comparisons[22]. However, mTO has not been validated in gastric cancer patients, and its potential advantages over traditional TO remain uncertain.

This study represents the first attempt to evaluate mTO as a quality indicator for perioperative care and its association with long-term survival in gastric cancer patients undergoing curative-intent resection. Using data from a multicenter prospective database maintained by seven high-volume gastrointestinal centers in China, we aimed to investigate the incidence of mTO, identify independent risk factors for achieving mTO, and examine the relationship between mTO and long-term oncologic outcomes.

HIGHLIGHTS

- mTO and TO were achieved in 62.4% and 72.0% of patients, respectively.
- Older age (≥65 years), presence of comorbidities, larger tumor size (>4 cm), combined organ resection, and greater estimated blood loss (≥180 mL) were significantly associated with a decreased likelihood of achieving both mTO and TO.
- Achieving mTO or TO significantly improved 5-year OS and DFS, with these benefits persisting after adjusting for covariates in Cox regression analysis.
- The rate of mTO was comparable to TO; however, mTO simplifies the TO definition from eight to six parameters while offering a greater reduction in the hazard of death compared with TO.

Methods

Study design and patient cohorts

This retrospective observational study utilized data from a multicenter database prospectively maintained by seven professional gastrointestinal centers in China. The database included 3238 patients who underwent gastrectomy for gastric cancer between 7 January 2010, and 30 September 2019. Each participating center designated a local manager responsible for data collection and coordination with the project coordinator. The project coordinator had access only to anonymized medical data collected by the local managers to ensure confidentiality and standardization.

To maintain data integrity and consistency, all centers adhered to uniform inclusion and exclusion criteria. The inclusion criteria were as follows: histologically confirmed gastric adenocarcinoma and pathological staging of T1-T4b, N0-N3b, M0 according to the 8th edition of the American Joint Committee on Cancer (AJCC) staging system[23]. Additionally, data on surgical margins, lymph nodes retrieved, reinterventions, length of hospital stay, unplanned intensive care unit (ICU) admissions, 30- and 90-day readmissions, and 30- and 90-day postoperative mortality were required for study inclusion. Exclusion criteria included the presence of distant metastasis, emergency surgery, prior endoscopic mucosal resection (EMR) or endoscopic submucosal dissection (ESD), concurrent multiple malignancies, gastrectomy for remnant gastric cancer, insufficient data, and loss to follow-up. After applying these criteria, 2608 patients who underwent gastrectomy for gastric cancer were included in the final analysis Supplementary Digital Content, Figure S1, available at: http://links.lww.com/JS9/E954. This study was approved by the Ethics Committees of all participating institutions. This trial is registered with ResearchRegistry.com. The work has been reported in line with the STROCSS 2025 criteria[24].

Surgical procedure

After being informed of the potential complications and risks associated with open, laparoscopic, and robotic surgical approaches, each patient with gastric cancer independently selected their surgical approach based on their physical condition. Each participating center performed at least 200 gastrectomies for gastric cancer annually. All operating surgeons had completed over 100 gastrectomies during the study period, indicating that they had surpassed the learning curve for the procedure. Robotic surgeries were performed using the da Vinci S, Si, or Xi Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). The extent of gastrectomy and D1+or D2 lymphadenectomy was determined in accordance with the 5th and 6th editions of the Japanese gastric cancer treatment guidelines[25,26]. The details of the surgical procedures for gastrectomy have been described in previous publications[27,28]. For patients with pathological stage II or higher, a six-month course of fluorouracil-based adjuvant chemotherapy was routinely prescribed. The regimens included oxaliplatin plus S-1 (SOX) or oxaliplatin plus capecitabine (XELOX).

Definition of modified textbook outcome

A recent systematic review of 12 studies, encompassing 44 581 gastric cancer patients who underwent curative resection, aimed to establish a consensus on the metrics of textbook outcome (TO) in gastric surgery and to propose a modified TO (mTO). The mTO comprised six criteria: pathologic complete tumor resection (pR0), no severe postoperative complications, retrieval of ≥15

lymph nodes, length of stay (LOS) below the 75th percentile, no 90-day readmissions due to surgery-related morbidity, and no mortality within 90days after surgery[22]. To compare and validate the applicability of mTO, the classic TO definition from the Population Registry of Esophageal and Stomach Tumors in Ontario (PRESTO) study was used as a reference. This definition included the following metrics: pR0 resection, retrieval of ≥15 lymph nodes, LOS ≤21days, no 30-day readmissions due to surgery-related complications, no reinterventions, no unplanned ICU admissions, no 30-day mortality after surgery, and no severe postoperative complications[17,29]. Patients were considered to have achieved mTO or TO only if all predefined criteria were met. Postoperative complications were assessed using the Clavien-Dindo classification, with "Clavien-Dindo IIIa" or higher defined as severe complications[30]. The pathologic status of pR0 resection was confirmed by microscopic evaluation, ensuring tumor-negative surgical margins. In contrast to the TO, which comprises eight parameters as initially proposed in the PRESTO study, the mTO adopted in our study contains only six parameters. Specifically, "no reinterventions" and "no unplanned ICU admissions" were excluded because these factors are likely correlated with other existing metrics within the textbook outcome, particularly severe postoperative complications[17,22]. According to the Clavien-Dindo classification for postoperative complications, patients undergoing reintervention or unplanned ICU admission during perioperative care would typically be classified as grade IIIb or IVa-b, indicating failure of one or more organs[30,31]. Thus, removing these two parameters reduces redundancy and interdependence with the criterion of "no severe postoperative complications" (Clavien-Dindo ≥IIIa), thereby enhancing the reliability and clarity of the outcomes measured. Moreover, this refined definition of mTO aligns with previous literature, in which these two parameters have similarly been excluded from definitions of textbook outcomes[19,32,33].

Follow-up

The follow-up period began on the date of surgery and concluded on 30 September 2024, ensuring a minimum postoperative follow-up duration of 60 months for each patient. A prospectively designed follow-up protocol was implemented, which included regular physical examinations and laboratory tests, such as carcinoembryonic antigen (CEA) and CA 19-9. These assessments were conducted every 3 months during the first 2 years, every 6 months from 2 to 5 years, and annually thereafter[25]. Additionally, patients were advised to undergo chest and abdominopelvic computed tomography (CT) scans every 6 months during the first postoperative year and at least annually in subsequent years. An annual gastroscopy was also recommended for all patients who underwent surgery to ensure comprehensive postoperative surveillance.

Outcome parameters

The primary outcomes of this study were to evaluate the relationship between the modified textbook outcome (mTO) and 5-year overall survival (OS) and 5-year disease-free survival (DFS). OS was defined as the time from the date of surgery to the date of death from any cause or the last follow-up. DFS was defined as the time from the date of surgery to the first documented occurrence of tumor recurrence or death, whichever occurred first. The secondary outcome was to determine the rate of mTO achievement and identify factors independently associated with achieving mTO.

Statistical analysis

Continuous variables were presented as medians with interquartile ranges (IQR) or means with standard deviations (SD) and were analyzed using the Mann-Whitney *U* test or *t*-test, as appropriate. Categorical variables were expressed as counts with percentages and analyzed using the χ^2 test or Fisher's exact test. Logistic regression analysis was performed to identify independent risk factors for achieving mTO and TO. Cox regression analysis was conducted to assess independent risk factors for 5-year DFS and OS. Variables with a *P*-value of less than 0.10 in the univariable analysis were included in the multivariable analysis to adjust for potential confounding factors. Survival curves were estimated using the Kaplan-Meier method, and comparisons between survival curves were made using the log-rank test. A forest plot was created using the R software (x64 version 3.6.1) with the "survival" package. All statistical analyses were performed using GraphPad Prism version 10.0 (GraphPad, La Jolla, CA, USA) and SPSS version 23.0 (SPSS, Chicago, IL, USA). All tests were two-sided, with statistical significance defined as *P*-values <0.05.

Results

A total of 2608 gastric cancer patients who underwent curative-intent resection met the study criteria, of whom 1628 (62.4%) achieved mTO, and 1877 (72.0%) achieved TO. Among the included patients, 70.6% were male, and 72.4% were under 65 years of age. In this cohort, 78.8% had a BMI below 25 kg/m^2, 91.1% had an ASA score of 1 or 2, and 91.0% had no prior abdominal surgery. Tumor size was ≤4 cm in 72.3% of cases, while 68.0% of patients received adjuvant chemotherapy, and 68.0% had no comorbidities. Neoadjuvant chemotherapy was not administered in 94.5% of cases, and 97.2% did not require combined organ resection.

Distal gastrectomy was performed in 68.2% of patients, with a laparoscopic approach utilized in 54.9%. The predominant tumor location was the antrum-pylorus (61.6%), followed by the body of the stomach (21.7%). Over half of the patients were classified as pathological T4 stage, 58.6% had lymph node metastasis, 48.0% were TNM stage III, and 66.4% had an undifferentiated histological type.

Regarding surgical outcomes, 51.3% of patients had an operative time of less than 250 minutes, 59.2% had an estimated blood loss of less than 180 mL, and 16.0% required blood transfusions. The median numbers of harvested and metastatic lymph nodes were 26 (range: 19–35) and 1 (range: 0–1), respectively. The median proximal and distal resection margins were both 5 cm (range: 4–5 cm). The median postoperative hospital stay was 9 days (range: 8–11 days), and the mean incision length was 8.2 ± 5.4 cm. Detailed patient, tumor, and treatment characteristics of groups achieving and not achieving mTO and TO are presented in Table 1.

Distribution of mTO and TO

The incidence of each parameter comprising the definitions of mTO and TO is presented in Figure 1. The primary barrier to

Table 1

Baseline characteristics of patients achieving TO and modified TO

		Textbook outcome			Modified textbook outcome		
Variables	**Total**	**Achieved**	**Failed**	**P**	**Achieved**	**Failed**	**P**
Number of patients	2608	1877 (72.0%)	731 (28%)	-	1628 (62.4%)	980 (37.6%)	-
Sex				0.110			0.017
Male	1842 (70.6%)	1309 (69.7%)	533 (72.9%)		1123 (69.0%)	719 (73.4%)	
Female	766 (29.4%)	568 (30.3%)	198 (27.1%)		505 (31.0%)	261 (26.6%)	
Age, yr				<0.001			<0.001
<65	1888 (72.4%)	1431 (76.2%)	457 (62.5%)		1268 (77.9%)	620 (63.3%)	
≥65	720 (27.6%)	446 (23.8%)	274 (37.5%)		360 (22.1%)	360 (36.7%)	
BMI, kg/m^2				0.040			0.082
<25	2056 (78.8%)	1499 (79.9%)	557 (76.2%)		1301 (79.9%)	755 (77.0%)	
≥25	552 (21.2%)	378 (20.1%)	174 (23.8%)		327 (20.1%)	225 (23.0%)	
ASA grade				<0.001			<0.001
I-II	2375 (91.1%)	1759 (93.7%)	616 (84.3%)		1530 (94.0%)	845 (86.2%)	
III	233 (8.9%)	118 (6.3%)	115 (15.7%)		98 (6.0%)	135 (13.8%)	
Previous abdominal surgery				0.112			0.154
No	2374 (91.0%)	1719 (91.6%)	655 (89.6%)		1492 (91.6%)	882 (90.0%)	
Yes	234 (9.0%)	158 (8.4%)	76 (10.4%)		136 (8.4%)	98 (10.0%)	
Comorbidities				<0.001			<0.001
No	1905 (73.0%)	1442 (76.8%)	463 (63.3%)		1277 (78.4%)	628 (64.1%)	
Yes	703 (27.0%)	435 (23.2%)	268 (36.7%)		351 (21.6%)	352 (35.9%)	
Histological type				0.699			0.901
Differentiated	877 (33.6%)	627 (33.4%)	250 (34.2%)		546 (33.5%)	331 (33.8%)	
Undifferentiated	1731 (66.4%)	1250 (66.6%)	481 (65.8%)		1082 (63.1%)	649 (66.2%)	
Tumor location				<0.001			0.001
GEJ	380 (14.6%)	241 (12.8%)	139 (19.0%)		204 (12.5%)	176 (18.0%)	
Fundus of stomach	69 (2.6%)	53 (2.8%)	16 (2.2%)		44 (2.7%)	25 (2.6%)	
Body of stomach	566 (21.7%)	399 (21.3%)	167 (22.8%)		347 (21.3%)	219 (22.3%)	
Antrum-pylorus	1593 (61.1%)	1184 (63.1%)	409 (56.0%)		1033 (63.5%)	560 (57.1%)	
Tumor size, cm				<0.001			<0.001
≤4	1886 (72.3%)	1405 (74.9%)	481 (65.8%)		1226 (75.3%)	660 (67.3%)	
>4	722 (27.7%)	472 (25.1%)	250 (34.2%)		402 (24.7%)	320 (32.7%)	
pT stage				<0.001			0.003
T1	562 (21.5%)	432 (23.0%)	130 (17.8%)		379 (23.3%)	183 (18.7%)	
T2	470 (18.0%)	359 (19.1%)	111 (15.2%)		310 (19.0%)	160 (16.3%)	
T3	274 (10.5%)	186 (9.9%)	88 (12.0%)		163 (10.0%)	111 (11.3%)	
T4	1302 (50.0%)	900 (48.0%)	402 (55.0%)		776 (47.7%)	526 (53.7%)	
pN stage				0.879			0.795
N0	1080 (41.4%)	779 (41.5%)	301 (41.2%)		671 (41.2%)	409 (41.7%)	
N+	1528 (58.6%)	1098 (58.5%)	430 (58.8%)		957 (58.8%)	571 (58.3%)	
pTNM stage (AJCC 8th)				0.005			0.085
I	754 (28.9%)	575 (30.6%)	179 (24.5%)		494 (30.3%)	260 (26.5%)	
II	601 (23.1%)	414 (22.1%)	187 (25.6%)		360 (22.1%)	241 (24.6%)	
III	1253 (48.0%)	888 (47.3%)	365 (49.9%)		774 (47.6%)	479 (48.9%)	
Neoadjuvant chemotherapy				0.037			0.068
No	2465 (94.5%)	1785 (95.1%)	680 (93.0%)		1549 (95.1%)	916 (93.5%)	
Yes	143 (5.5%)	92 (4.9%)	51 (7.0%)		79 (4.9%)	64 (6.5%)	
Extent of resection				<0.001			<0.001
Distal gastrectomy	1777 (68.2%)	1341 (71.4%)	436 (59.6%)		1170 (71.9%)	607 (61.9%)	
Proximal gastrectomy	105 (4.0%)	61 (3.2%)	44 (6.0%)		57 (3.5%)	48 (4.9%)	
Total gastrectomy	726 (27.8%)	475 (25.4%)	251 (34.4%)		401 (24.6%)	325 (33.2%)	
Surgical approach				<0.001			<0.001
Open	431 (16.5%)	313 (16.7%)	118 (16.1%)		277 (17.0%)	154 (15.7%)	
Laparoscopic	1431 (54.9%)	989 (52.7%)	442 (60.5%)		840 (51.6%)	591 (60.3%)	
Robotic	746 (28.6%)	575 (30.6%)	171 (23.4%)		511 (31.4%)	235 (24.0%)	
Combined organ resection				0.001			<0.001
No	2536 (97.2%)	1838 (97.9%)	698 (95.5%)		1598 (98.2%)	938 (95.7%)	
Yes	72 (2.8%)	39 (2.1%)	33 (4.5%)		30 (1.8%)	42 (4.3%)	
Adjuvant chemotherapy				<0.001			<0.001
No	834 (32.0%)	541 (28.8%)	293 (40.1%)		463 (28.4%)	371 (37.9%)	
Yes	1774 (68.0%)	1336 (71.2%)	438 (59.9%)		1165 (71.6%)	609 (62.1%)	

(*Continues*)

Table 1
(Continued).

Variables	Total	Textbook outcome			Modified textbook outcome		
		Achieved	Failed	P	Achieved	Failed	P
Operation time, min				0.036			0.020
<250	1338 (51.3%)	987 (52.6%)	351 (48.0%)		864 (53.1%)	474 (48.4%)	
≥250	1270 (48.7%)	890 (47.4%)	380 (52.0%)		764 (46.9%)	506 (51.6%)	
Estimated blood loss, ml				<0.001			<0.001
<180	1544 (59.2%)	1176 (62.7%)	368 (50.3%)		1039 (63.8%)	505 (51.5%)	
≥180	1064 (40.8%)	701 (37.3%)	363 (49.7%)		589 (36.2%)	475 (48.5%)	
Transfusion of blood				<0.001			<0.001
No	2191 (84.0%)	1613 (85.9%)	578 (79.1%)		1407 (86.4%)	784 (80.0%)	
Yes	417 (16.0%)	264 (14.1%)	153 (20.9%)		221 (13.6%)	196 (20.0%)	
No. of harvested LNs, median (IQR)	26 [19, 35]	28 [21, 35]	21 [13, 33]	<0.001	28 [21, 35]	23 [14, 34]	<0.001
No. of metastatic LNs, median (IQR)	1 [0, 7]	2 [0, 7]	1 [0, 6]	0.536	2 [0, 7]	1 [0, 6]	0.436
Length of incision, cm, median (IQR)	8.2±5.4	8.0±5.3	8.6±5.8	0.018	8.0±5.3	8.5±5.6	0.022
Proximal margin, cm, median (IQR)	5 [4, 5]	5 [4, 5]	5 [4, 5]	0.080	5 [4, 5]	5 [4, 5]	0.066
Distal margin, cm, median (IQR)	5 [4, 5]	5 [4, 5]	5 [4, 5]	0.641	5 [4, 5]	5 [4, 5]	0.445
Postoperative LOS, d, median (IQR)	9 [8, 11]	9 [8, 11]	11 [9, 17]	<0.001	9 [8, 10]	11 [9, 15]	<0.001

ASA: American Society of Anesthesiologist; AJCC: American Joint Commission on Cancer; BMI: body mass index; GEJ: gastroesophageal junction; IQR: interquartile range; TNM: pathologic tumor node metastasis.

achieving mTO was "LOS <75th percentile" (74.9%, 1954/2608), followed by "lymph nodes retrieved ≥15" (89.9%, 2344/2608), while the most frequently achieved mTO parameter was "no 90-day mortality" (98.1%, 2558/2608). The 75th percentile for length of hospital stay was calculated as 18 days in this study. For TO, the least commonly achieved parameter was "LOS ≤21 days" (85.6%, 2233/2608), while the most frequently achieved parameters were "no 30-day mortality" (99.4%, 2593/2608) and "no reinterventions" (98.7%, 2573/2608). Achievement rates for other TO parameters were as follows: no 30-day readmission (97.6%, 2546/2608), no unplanned ICU admission (97.6%, 2545/2608), pR0 resection margins (96.6%, 2519/2608), no 90-day readmission (96.4%, 2515/2608), and no severe postoperative complications (94.4%, 2462/2608). Subgroup analyses for mTO by surgical approach and extent of resection were shown in Supplementary Digital Content, Figures S2-5, available at: http://links.lww.com/JS9/E954. Our results displayed that the mTO was higher in the robotic gastrectomy group than in the laparoscopic group (68.5% vs 58.7%, Supplementary Digital Content, Fig S2, available at: http://links.lww.com/JS9/E954) In addition, the robotic distal and total gastrectomy group had a higher percentages of mTO compared to the laparoscopic distal and total gastrectomy group (71.6% vs 62.0%; 62.2% vs 52.5%, Supplementary Digital Content, Figs. S4 and 5, available at: http://links.lww.com/JS9/E954).

Predictors of mTO and TO

An important objective of this study was to identify independent risk factors associated with not achieving mTO and TO. Multivariable logistic regression analysis revealed several clinical factors independently associated with a lower likelihood of achieving mTO after gastrectomy. These included age ≥65 years (OR: 0.566, 95% CI: 0.471–0.681, *P*<0.001), presence of comorbidities (OR: 0.583, 95% CI: 0.484–0.702, *P*<0.001), tumor size >4 cm (OR: 0.757, 95% CI: 0.625–0.918, *P* = 0.005), combined organ resection (OR: 0.557, 95% CI: 0.338–0.917, *P* = 0.021), and estimated blood loss ≥180 mL (OR: 0.678, 95% CI: 0.570–0.807, *P*<0.001). Additionally, laparoscopic gastrectomy was significantly associated with a reduced probability of achieving mTO compared to robotic gastrectomy (OR: 0.653, 95% CI: 0.537–0.795, *P*<0.001). However, tumors located in the antrum-pylorus were independently associated with a higher likelihood of achieving mTO compared to tumors in the gastroesophageal junction (GEJ) (OR: 1.289, 95% CI: 1.007–1.651, *P* = 0.044) (Table 2).

Similarly, independent factors associated with a lower likelihood of achieving TO included age ≥65 years (OR: 0.600, 95% CI: 0.494–0.728, *P*<0.001), comorbidities (OR: 0.618, 95% CI: 0.508–0.751, *P*<0.001), tumor size >4 cm (OR: 0.741, 95% CI: 0.605–0.906, *P* = 0.004), pTNM stage II (OR: 0.741, 95% CI: 0.576–0.954, *P* = 0.020), combined organ resection (OR: 0.608, 95% CI: 0.371–0.998, *P* = 0.049), and estimated blood loss ≥180 mL (OR: 0.692, 95% CI: 0.575–0.834, *P*<0.001). Laparoscopic surgery was also independently associated with a lower likelihood of achieving TO compared to robotic surgery (OR: 0.664, 95% CI: 0.537–0.822, *P*<0.001). Conversely, tumors located in the fundus of the stomach (OR: 1.984, 95% CI: 1.074–3.667, *P* = 0.029) and antrum-pylorus (OR: 1.347, 95% CI: 1.041–1.742, *P* = 0.023) were significantly associated with a higher likelihood of achieving TO compared to GEJ tumors (Table 3).

Long-term survival

Patients who achieved mTO had significantly better 5-year OS and DFS compared to those who did not (58.8% vs. 39.2%, *P*<0.0001, Figure 2A; 57.1% vs. 37.4%, *P*<0.0001, Figure 2C, respectively). Similarly, the 5-year OS and DFS were significantly higher in the TO group compared to the non-TO group (55.5% vs. 41.0%, *P*<0.0001, Figure 2B; 53.9% vs. 39.0%, *P*<0.0001, Figure 2D, respectively). After adjustment for covariates, Cox regression analysis demonstrated that achieving mTO and TO was associated with a 43.5% and 26.3% reduction, respectively, in the hazard of death based on 5-year OS (Table 4). Similarly, mTO and TO were independently associated with a 43.9% and 26.5% reduction, respectively, in the hazard of death based on

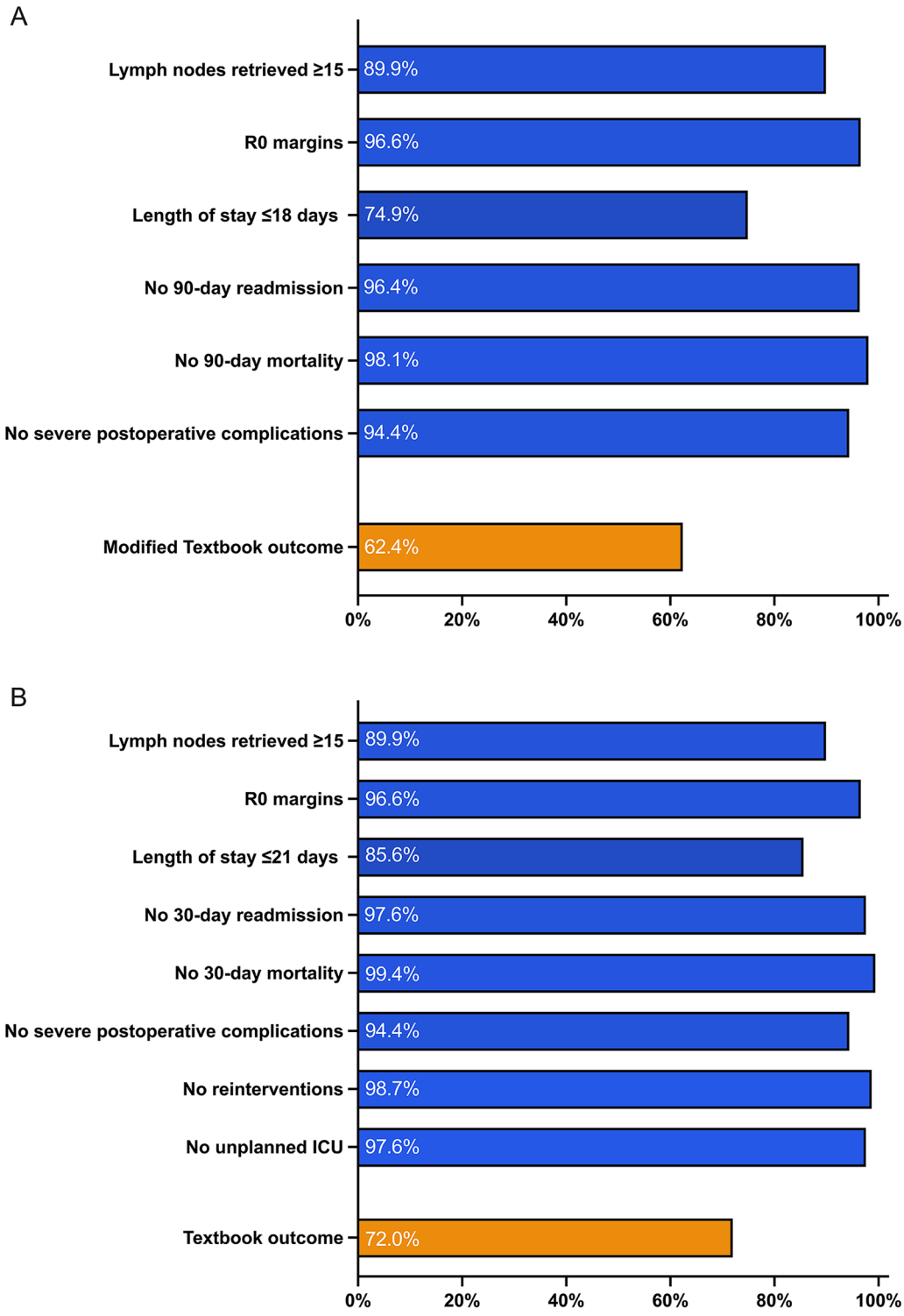


Figure 1. Distribution of mTO, TO and its parameter (A) modified textbook outcome (B) textbook outcome.

5-year DFS after adjusting for potential confounders (Table 5). Subgroup analyses for 5-year OS and DFS revealed that in most variables, achieving mTO consistently led to a greater reduction in the hazard of death compared to TO, except in patients who received neoadjuvant chemotherapy or underwent robotic surgery (Fig. 3).

Discussion

We conducted a retrospective observational cohort study to evaluate the incidence of mTO and TO in 2608 gastric cancer patients who underwent curative-intent resection across seven centers in China. This study yielded four major findings. First,

Table 2

Univariable and multivariable logistic regression analyses of risk factors for modified TO

	Univariable		Multivariable	
Variable	**OR (95%CI)**	**P**	**OR (95%CI)**	**P**
Sex				
Male	Ref.		Ref.	
Female	1.239 (1.039–1.478)	0.017	1.129 (0.938–1.360)	0.199
Age, yr				
<65	Ref.		Ref.	
≥65	0.489 (0.411–0.582)	<0.001	0.566 (0.471–0.681)	<0.001
BMI, kg/m^2				
<25	Ref.		Ref.	
≥25	0.843 (0.696–1.022)	0.082	0.885 (0.722–1.084)	0.237
Comorbidities				
No	Ref.		Ref.	
Yes	0.490 (0.411–0.585)	<0.001	0.583 (0.484–0.702)	<0.001
Previous abdominal surgery				
No	Ref.		NA	
Yes	0.820 (0.625–1.078)	0.155	NA	
Histological type				
Differentiated	Ref.		NA	
Undifferentiated	1.011 (0.855–1.195)	0.901	NA	
Tumor size, cm				
≤4	Ref.		Ref.	
>4	0.676 (0.568–0.805)	<0.001	0.757 (0.625–0.918)	0.005
pTNM stage (AJCC 8th)				
I	Ref.		Ref.	
II	0.786 (0.630–0.981)	0.003	0.844 (0.668–1.066)	0.154
III	0.850 (0.704–1.027)	0.092	1.025 (0.832–1.264)	0.815
Neoadjuvant chemotherapy				
No	Ref.		Ref.	
Yes	0.730 (0.520–1.025)	0.069	0.886 (0.614–1.278)	0.516
Tumor location				
GEJ	Ref.		Ref.	
Fundus of stomach	1.518 (0.893–2.581)	0.123	1.550 (0.894–2.686)	0.118
Body of stomach	1.367 (1.051–1.779)	0.020	1.217 (0.922–1.608)	0.166
Antrum-pylorus	1.591 (1.269–1.996)	<0.001	1.289 (1.007–1.651)	0.044
Surgical approach				
Robotic	Ref.		Ref.	
Open	0.827 (0.644–1.063)	0.137	0.851 (0.646–1.120)	0.248
Laparoscopic	0.654 (0.542–0.788)	<0.001	0.653 (0.537–0.795)	<0.001
Combined organ resection				
No	Ref.		Ref.	
Yes	0.419 (0.261–0.674)	<0.001	0.557 (0.338–0.917)	0.021
Operation time, min				
<250	Ref.		Ref.	
≥250	0.828 (0.707–0.971)	0.020	0.899 (0.754–1.073)	0.237
Estimated blood loss, ml				
<180	Ref.		Ref.	
≥180	0.603 (0.513–0.708)	<0.001	0.678 (0.570–0.807)	<0.001
Transfusion of blood				
No	Ref.		Ref.	
Yes	0.628 (0.509–0.776)	<0.001	0.824 (0.654–1.039)	0.102

ASA: American Society of Anesthesiologist; AJCC: American Joint Commission on Cancer; BMI: body mass index; CI: confidence interval; GEJ: gastroesophageal junction; NA: not available; OR: odds ratio; TNM: pathologic tumor node metastasis.

mTO and TO were achieved in 62.4% and 72.0% of patients, respectively. Second, older age (≥65 years), presence of comorbidities, larger tumor size (>4 cm), combined organ resection, and greater estimated blood loss (≥180 mL) were significantly associated with a decreased likelihood of achieving both mTO and TO. Third, achieving mTO or TO significantly improved 5-year OS and DFS, with these benefits persisting after adjusting for covariates in Cox regression analysis. Lastly, the rate of mTO was comparable to TO; however, mTO simplifies the TO definition from eight to six parameters while offering a greater reduction in the hazard of death compared with TO.

Table 3

Univariable and multivariable logistic regression analyses of risk factors for TO

	Univariable		Multivariable	
Variable	**OR (95%CI)**	**P**	**OR (95%CI)**	**P**
Sex				
Male	Ref.		NA	
Female	1.168 (0.965–1.413)	0.110	NA	
Age, yr				
<65	Ref.		Ref.	
≥65	0.520 (0.433–0.625)	<0.001	0.600 (0.494–0.728)	<0.001
BMI, kg/m^2				
<25	Ref.		Ref.	
≥25	0.807 (0.658–0.990)	0.040	0.827 (0.667–1.024)	0.082
Comorbidities				
No	Ref.		Ref.	
Yes	0.521 (0.433–0.627)	<0.001	0.618 (0.508–0.751)	<0.001
Previous abdominal surgery				
No	Ref.		NA	
Yes	0.792 (0.594–1.057)	0.113	NA	
Histological type				
Differentiated	Ref.		NA	
Undifferentiated	1.036 (0.865–1.241)	0.699	NA	
Tumor size, cm				
≤4	Ref.		Ref.	
>4	0.646 (0.537–0.778)	<0.001	0.741 (0.605–0.906)	0.004
pTNM stage (AJCC 8th)				
I	Ref.		Ref.	
II	0.689 (0.542–0.877)	0.002	0.741 (0.576–0.954)	0.020
III	0.757 (0.616–0.932)	0.009	0.916 (0.729–1.150)	0.448
Neoadjuvant chemotherapy				
No	Ref.		Ref.	
Yes	0.687 (0.483–0.978)	0.037	0.829 (0.567–1.213)	0.335
Tumor location				
GEJ	Ref.		Ref.	
Fundus of stomach	1.911 (1.052–3.470)	0.033	1.984 (1.074–3.667)	0.029
Body of stomach	1.378 (1.046–1.816)	0.023	1.231 (0.921–1.645)	0.160
Antrum-pylorus	1.670 (1.317–2.116)	<0.001	1.347 (1.041–1.742)	0.023
Surgical approach				
Robotic	Ref.		Ref.	
Open	0.789 (0.601–1.035)	0.087	0.814 (0.605–1.096)	0.175
Laparoscopic	0.665 (0.542–0.816)	<0.001	0.664 (0.537–0.822)	<0.001
Combined organ resection				
No	Ref.		Ref.	
Yes	0.449 (0.280–0.719)	0.001	0.608 (0.371–0.998)	0.049
Operation time, min				
<250	Ref.		Ref.	
≥250	0.833 (0.702–0.988)	0.036	0.899 (0.744–1.087)	0.272
Estimated blood loss, ml				
<180	Ref.		Ref.	
≥180	0.604 (0.509–0.718)	<0.001	0.692 (0.575–0.834)	<0.001
Transfusion				
No	Ref.		Ref.	
Yes	0.618 (0.496–0.771)	<0.001	0.820 (0.644–1.043)	0.105

ASA: American Society of Anesthesiologist; AJCC: American Joint Commission on Cancer; BMI: body mass index; CI: confidence interval; GEJ: gastroesophageal junction; NA: not available; OR: odds ratio; TNM: pathologic tumor node metastasis.

Despite advancements in surgical techniques and perioperative treatment strategies over the past decades, the optimal method for effectively measuring surgical quality remains a topic of debate. Traditional short-term postoperative outcomes in surgical oncology are typically characterized by metrics such as morbidity, mortality, margin status, and readmission[34,35]. However, individual surgical indicators often exhibit compliance rates exceeding 90%, leaving limited room for further improvement and potentially discouraging efforts to reform clinical practice. The introduction of composite metrics, such as TO, has provided a more comprehensive benchmarking tool for comparing surgical approaches across different diseases[6]. Görgec *et al* proposed the first standardized definition of TO for liver surgery, based on an international four-round survey comprising 26 questions

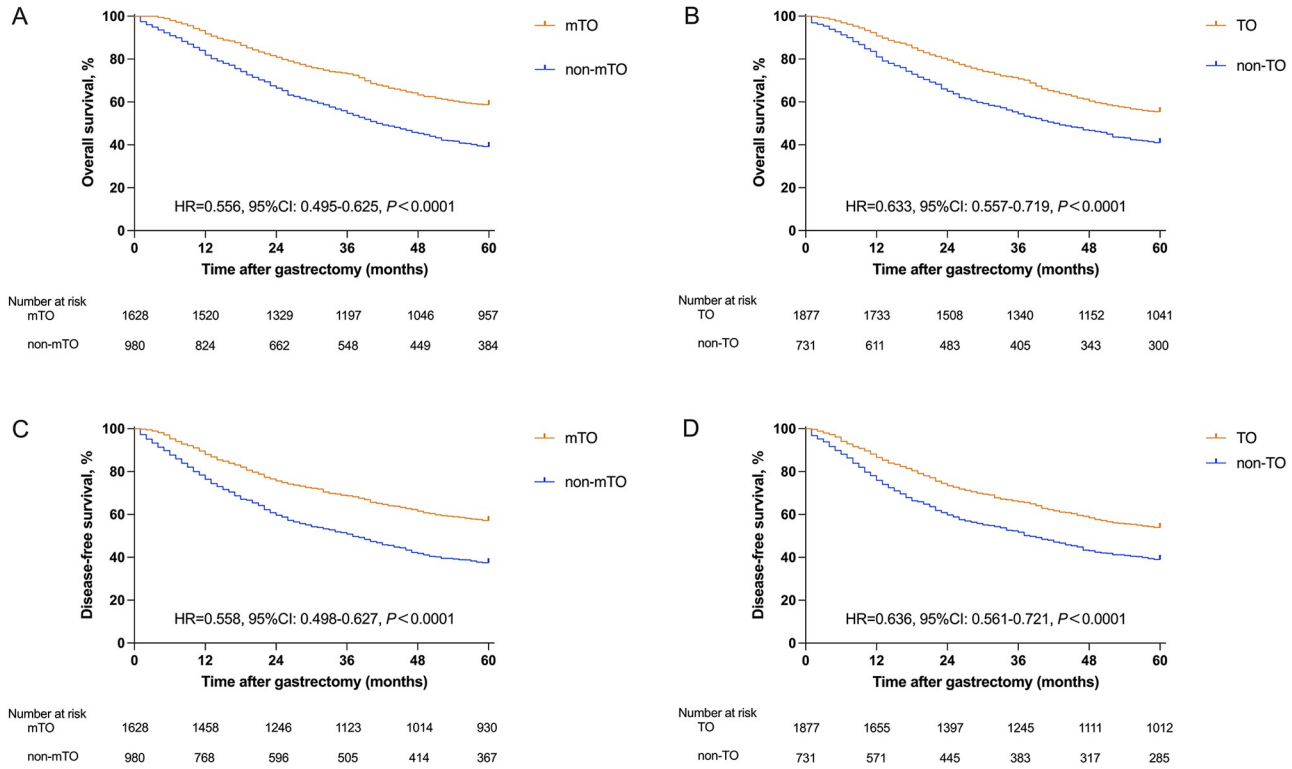


Figure 2. Comparison of 5-year OS and DFS for patients with and without mTO and TO (A) 5-year OS of patients with and without mTO (B) 5-year OS of patients with and without TO (C) 5-year DFS of patients with and without mTO (D) 5-year DFS of patients with and without TO.

across six surgical domains[36]. Similarly, a consensus-based definition of TO for pancreatic surgery was recently developed by an international group of experts, enabling its application to patients undergoing pancreatoduodenectomy or distal pancreatectomy[37]. Additionally, Nass *et al* invited 27 expert endoscopists from European countries to define the "textbook process" for optimal colonoscopy and to evaluate its prevalence in clinical practice[21]. In contrast, most definitions of TO in gastric surgery have been derived from the opinions of small groups of surgeons or individual experts, leading to the absence of a standardized consensus. Consequently, reported TO rates in gastric surgery have varied widely, ranging from 22% to 84% in recent years[7,8,17,18,38–40]. These discrepancies may result not only from differing clinical factors but also from variations in registry characteristics, such as single-center versus multicenter or high-volume center studies. Moreover, comparisons of TO rates between studies must account for differences in the definitions of TO parameters.

A recent systematic review identified a set of common metrics and proposed a modified textbook outcome (mTO) for gastric surgery, facilitating comparisons across institutions[22]. The mTO definition excluded reintervention and unplanned ICU admission, adjusted the 30-day readmission and mortality metrics to 90-day intervals, and modified the length of stay (LOS) threshold from ≤21 days to the 75th percentile. It is critical to acknowledge the potential interrelationships between composite outcome indicators. For instance, including severe complications (defined as Clavien-Dindo ≥IIIa) in the TO definition may render parameters such as reintervention (Clavien-Dindo IIIb) and unplanned ICU admission (Clavien-Dindo IVa-b) redundant. A previous study in pancreatic surgery showed that patients with the longest LOS had significantly lower readmission rates, while those with the shortest LOS experienced the highest readmission rates[41]. Consequently, LOS <75th percentile was selected for mTO to minimize the interdependence of parameters. Additionally, including severe complications (defined as Clavien-Dindo grade ≥IIIa) in the textbook outcome (TO) definition might appear to render parameters such as 30-day mortality (Clavien-Dindo grade V) redundant. Nevertheless, in clinical practice, the Clavien-Dindo classification primarily evaluates complications occurring during hospitalization. In contrast, the 30-day postoperative mortality indicator typically encompasses patients who experience complications after discharge, thus not captured by the inpatient Clavien-Dindo assessment. Furthermore, assessing mortality at 90 days postoperatively is critical, as previous studies have demonstrated significant differences between mortality rates at 30 and 90 days[22]. Extending the follow-up to 90 days allows inclusion of complications occurring after discharge, thereby providing a more comprehensive and accurate assessment of surgical treatment quality. Additionally, readmission was assessed at 90 days rather than 30 days, given that approximately one-third of postoperative readmissions occur beyond the 30-day mark[42].

To date, no studies have validated the applicability of mTO in gastric surgery or assessed its efficacy in evaluating treatment quality compared to TO. To the best of our knowledge, this study is the first to use mTO as a quality measure to evaluate both short- and long-term outcomes in patients with gastric cancer following surgery. In our cohort, the mTO achievement rate (62.4%) was comparable to the TO rate (72.0%).

Table 4

Univariable and multivariable analyses of prognostic factors for 5-year OS

	Univariable model		Multivariable model I		Multivariable model II	
Variable	**HR (95%CI)**	**P**	**HR (95%CI)**	**P**	**HR (95%CI)**	**P**
Sex						
Male	Ref.		Ref.		Ref.	
Female	0.886 (0.784–1.001)	0.053	0.917 (0.809–1.040)	0.178	0.906 (0.799–1.027)	0.124
Age, yr						
<65	Ref.		Ref.		Ref.	
≥65	1.534 (1.366–1.723)	<0.001	1.201 (1.063–1.357)	0.003	1.261 (1.117–1.424)	<0.001
BMI, kg/m^2						
<25	Ref.		NA		NA	
≥25	0.903 (0.788–1.034)	0.141	NA		NA	
Comorbidities						
No	Ref.		NA		NA	
Yes	1.011 (0.894–1.143)	0.863	NA		NA	
Neoadjuvant chemotherapy						
No	Ref.		Ref.		Ref.	
Yes	1.724 (1.403–2.119)	<0.001	1.602 (1.292–1.985)	<0.001	1.639 (1.323–2.031)	<0.001
Histological type						
Differentiated	Ref.		Ref.		Ref.	
Undifferentiated	1.350 (1.198–1.522)	<0.001	1.104 (0.974–1.251)	0.122	1.114 (0.983–1.263)	0.090
Tumor size, cm						
≤4	Ref.		Ref.		Ref.	
>4	1.909 (1.704–2.139)	<0.001	1.247 (1.107–1.403)	<0.001	1.253 (1.113–1.411)	<0.001
pTNM stage (AJCC 8th)						
I	Ref.		Ref.		Ref.	
II	1.925 (1.586–2.337)	<0.001	1.940 (1.585–2.374)	<0.001	1.961 (1.603–2.400)	<0.001
III	4.598 (3.909–5.409)	<0.001	4.549 (3.802–5.443)	<0.001	4.450 (3.719–5.324)	<0.001
Surgical approach						
Open	Ref.		Ref.		Ref.	
Laparoscopic	0.906 (0.779–1.054)	0.203	0.959 (0.821–1.120)	0.596	0.982 (0.841–1.147)	0.820
Robotic	0.845 (0.714–0.999)	0.048	0.960 (0.808–1.140)	0.640	0.959 (0.808–1.139)	0.634
Extent of resection						
Distal gastrectomy	Ref.		Ref.		Ref.	
Proximal gastrectomy	1.121 (0.825–1.524)	0.465	1.482 (1.082–2.030)	0.014	1.457 (1.063–1.997)	0.019
Total gastrectomy	2.063 (1.509–2.820)	<0.001	1.756 (1.279–2.411)	<0.001	1.731 (1.261–2.378)	0.001
Combined organ resection						
No	Ref.		Ref.		Ref.	
Yes	1.405 (1.025–1.925)	0.034	1.008 (0.732–1.387)	0.961	1.070 (0.778–1.473)	0.677
Operation time, min						
<250	Ref.		NA		NA	
≥250	0.981 (0.879–1.094)	0.727	NA		NA	
Estimated blood loss, ml						
<180	Ref.		Ref.		Ref.	
≥180	1.308 (1.172–1.460)	<0.001	1.109 (0.988–1.246)	0.080	1.148 (1.022–1.288)	0.020
Transfusion of blood						
No	Ref.		Ref.		Ref.	
Yes	1.424 (1.238–1.637)	<0.001	1.000 (0.863–1.160)	0.997	1.008 (0.870–1.168)	0.919
Adjuvant chemotherapy						
No	Ref.		Ref.		Ref.	
Yes	0.853 (0.760–0.957)	0.007	0.644 (0.570–0.728)	<0.001	0.636 (0.563–0.719)	<0.001
Modified textbook outcome						
No	Ref.		Ref.			
Yes	0.531 (0.476–0.592)	<0.001	0.565 (0.504–0.633)	<0.001		
Textbook outcome						
No	Ref.				Ref.	
Yes	0.650 (0.579–0.730)	<0.001			0.737 (0.653–0.831)	<0.001

ASA: American Society of Anesthesiologist; AJCC: American Joint Commission on Cancer; BMI: body mass index; CI: confidence interval; NA: not available; HR: hazard ratio; OS: overall survival; TNM: pathologic tumor node metastasis.

Table 5

Univariable and multivariable analyses of prognostic factors for 5-year DFS

	Univariable model		Multivariable model I		Multivariable model II	
Variable	**HR (95%CI)**	***P***	**HR (95%CI)**	***P***	**HR (95%CI)**	***P***
Sex						
Male	Ref.		Ref.		Ref.	
Female	0.909 (0.806–1.024)	0.118	0.942 (0.833–1.065)	0.341	0.931 (0.823–1.053)	0.254
Age, yr						
<65	Ref.		Ref.		Ref.	
≥65	1.478 (1.318–1.657)	<0.001	1.160 (1.028–1.308)	0.016	1.221 (1.083–1.377)	0.001
BMI, kg/m^2						
<25	Ref.		Ref.		Ref.	
≥25	0.888 (0.777–1.015)	0.083	0.930 (0.812–1.066)	0.296	0.938 (0.819–1.075)	0.357
Comorbidities						
No	Ref.		NA		NA	
Yes	1.034 (0.917–1.166)	0.585	NA		NA	
Neoadjuvant chemotherapy						
No	Ref.		Ref.		Ref.	
Yes	1.667 (1.358–2.046)	<0.001	1.561 (1.261–1.932)	<0.001	1.598 (1.291–1.978)	<0.001
Histological type						
Differentiated	Ref.		Ref.		Ref.	
Undifferentiated	1.365 (1.214–1.536)	<0.001	1.097 (0.970–1.241)	0.142	1.106 (0.978–1.252)	0.108
Tumor size, cm						
≤4	Ref.		Ref.		Ref.	
>4	1.878 (1.679–2.102)	<0.001	1.227 (1.092–1.380)	0.001	1.234 (1.097–1.388)	<0.001
pTNM stage (AJCC 8th)						
I	Ref.		Ref.		Ref.	
II	1.959 (1.620–2.368)	<0.001	1.969 (1.616–2.399)	<0.001	1.987 (1.631–2.421)	<0.001
III	4.691 (3.999–5.503)	<0.001	4.629 (3.881–5.521)	<0.001	4.517 (3.787–5.387)	<0.001
Surgical approach						
Open	Ref.		Ref.		Ref.	
Laparoscopic	0.919 (0.792–1.067)	0.268	0.981 (0.842–1.143)	0.807	1.002 (0.861–1.167)	0.977
Robotic	0.853 (0.724–1.007)	0.060	0.986 (0.832–1.168)	0.866	0.980 (0.827–1.161)	0.816
Extent of resection						
Distal gastrectomy	Ref.		Ref.		Ref.	
Proximal gastrectomy	1.177 (0.866–1.599)	0.299	1.522 (1.112–2.084)	0.009	1.497 (1.093–2.050)	0.012
Total gastrectomy	2.144 (1.569–2.930)	<0.001	1.787 (1.302–2.452)	0.002	1.764 (1.285–2.422)	<0.001
Combined organ resection						
No	Ref.		Ref.		Ref.	
Yes	1.316 (0.961–1.802)	0.087	0.932 (0.677–1.282)	0.664	0.988 (0.718–1.360)	0.942
Operation time, min						
<250	Ref.		NA		NA	
≥250	0.988 (0.887–1.100)	0.829	NA		NA	
Estimated blood loss, ml						
<180	Ref.		Ref.		Ref.	
≥180	1.318 (1.183–1.468)	<0.001	1.131 (1.009–1.168)	0.034	1.170 (1.045–1.312)	0.007
Transfusion of blood						
No	Ref.		Ref.		Ref.	
Yes	1.402 (1.221–1.609)	<0.001	0.978 (0.845–1.132)	0.763	0.988 (0.854–1.143)	0.868
Adjuvant chemotherapy						
No	Ref.		Ref.		Ref.	
Yes	0.885 (0.790–0.991)	0.035	0.668 (0.592–0.753)	<0.001	0.659 (0.584–0.743)	<0.001
Modified textbook outcome						
No	Ref.		Ref.			
Yes	0.533 (0.479–0.594)	<0.001	0.561 (0.502–0.628)	<0.001		
Textbook outcome						
No	Ref.				Ref.	
Yes	0.652 (0.582–0.731)	<0.001			0.735 (0.653–0.827)	<0.001

ASA: American Society of Anesthesiologist; AJCC: American Joint Commission on Cancer; BMI: body mass index; CI: confidence interval; NA: not available; HR: hazard ratio; OS: overall survival; TNM: pathologic tumor node metastasis.

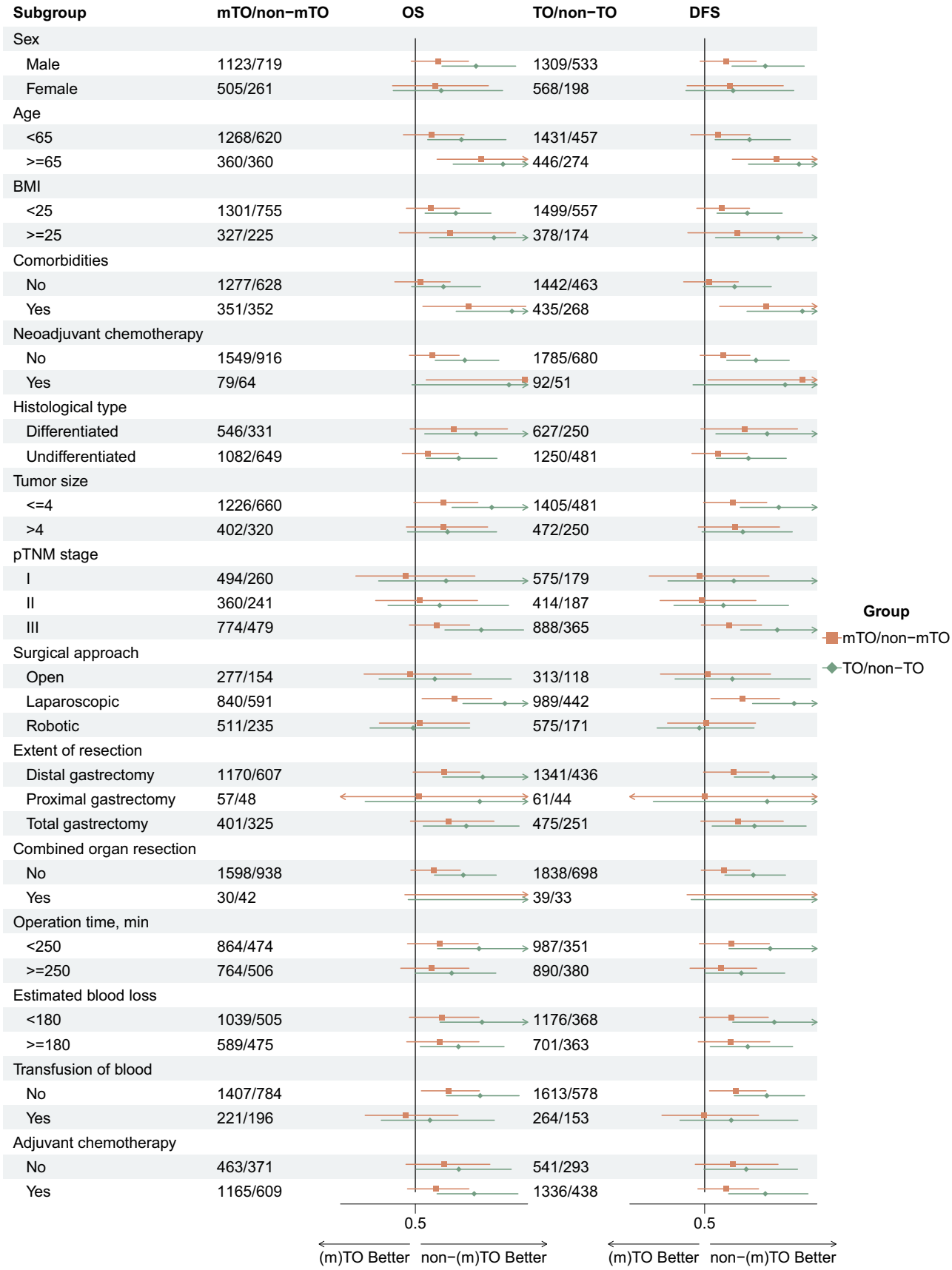


Figure 3. Subgroup analyses for 5-year OS and DFS between patients with and without mTO and TO.

Identifying areas for improvement requires understanding the factors associated with mTO. Our multivariable analysis demonstrated that achieving mTO was significantly influenced by several patient and treatment-related factors indicative of vulnerability, including age, comorbidities, tumor size, combined organ resection, and surgical approach. These findings are consistent with previous studies[7,8,43]. Elderly patients and those with comorbidities often exhibit poor tolerance for invasive or complex procedures, making an "ideal" treatment process challenging to achieve. Larger tumor size and combined organ resection are generally associated with advanced TNM stages, necessitating more extensive resections and lymph node dissections to achieve oncologic control. These procedures increase surgical complexity, operative time, and the risk of complications, ultimately reducing the likelihood of achieving mTO. Furthermore, the technical advantages of robotic surgery over laparoscopic approaches-such as flexible instrumentation, three-dimensional visualization, and tremor filtration-may reduce complication rates[44], improve postoperative recovery, shorten the length of hospitalization, and enhance the achievement of mTO and TO. In addition to limited surgical operating space, complex anatomical relationships, and challenges posed by esophagogastric or esophagojejunal anastomosis at higher-than-usual levels, there remain several barriers to the widespread adoption of laparoscopic total or proximal gastrectomy. Robotic gastrectomy, characterized by advantages such as tremor filtration, three-dimensional visualization, articulating wristed instruments, and motion scaling, may theoretically overcome these technical limitations inherent to laparoscopic approaches. Emerging evidence suggests robotic gastrectomy may facilitate harvesting a greater number of lymph nodes, potentially enhancing the achievement of both mTO and TO. Several studies have demonstrated significantly fewer lymph nodes harvested during laparoscopic gastrectomy compared with robotic gastrectomy in gastric cancer[45–47]. Our previous findings also indicated a significantly lower yield of harvested lymph nodes, particularly in the suprapancreatic area, during laparoscopic gastrectomy compared to robotic gastrectomy[48]. Conventional straight laparoscopic instruments frequently pose difficulties in accessing and dissecting the posterior aspect of the suprapancreatic region. In contrast, robotic systems, owing to their unique instrument articulation and enhanced stability, enable consistent and controlled compression of the pancreas, facilitating precise suprapancreatic lymph node dissection. Furthermore, robotic gastrectomy has been associated with shorter hospital stays and increased probabilities of achieving both mTO and TO[47,49].

Textbook outcome (TO) has been reported as a marker of improved survival outcomes in gastric cancer patients following surgery. Van der Kaaij *et al* examined 105 gastric cancer patients and identified a direct correlation between a higher TO achievement rate and improved median OS, highlighting TO as a reliable measure for comparing overall cancer care quality[15]. However, the small sample size limited the generalizability of the findings. A multicenter retrospective study by Levy *et al*, involving 1836 gastric cancer patients, demonstrated that TO patients had significantly better 3-year OS compared to non-TO patients[17]. Similarly, the Dutch Upper Gastrointestinal Cancer Audit (DUCA) revealed that achieving TO was significantly associated with improved 3-year OS and a reduced risk of death in gastric cancer patients[16]. While these studies provided valuable insights, they were limited by variable parameters, relatively short follow-up periods, small sample size, and a lack of data on DFS. To address these limitations, the present multicenter, large-sample study evaluated the association between mTO, TO, and long-term oncologic outcomes, ensuring a minimum follow-up period of 60 months for each gastric cancer patient undergoing curative-intent resection. Consistent with previous findings, achieving mTO and TO in our study was independently associated with favorable 5-year OS and DFS. Achieving TO indicated more curative resections, adequate lymph node dissection, faster and better postoperative recovery, fewer complications, and reduced recurrence risk. The large sample size of our study allowed for subgroup analyses, which provided additional insights into the potential advantages of mTO. Across all variables, achieving mTO was associated with a greater reduction in the risk of death compared to TO, except in patients receiving neoadjuvant chemotherapy or robotic surgery. This highlights mTO as a valuable and promising tool for assessing the quality of treatment in gastric cancer patients.

Our findings also underscore the advantages of mTO over TO, including its simplified definition and superior ability to predict reduced mortality risks. By extending the measurement window for mortality and readmission from 30 to 90 days, non-mTO captures patients who would otherwise be included in TO metrics. Additionally, the LOS threshold for mTO was set at 18 days compared to 21 days for TO. Prolonged LOS often reflects poorer postoperative recovery and more complications, which can delay adjuvant chemotherapy initiation and adversely affect long-term prognosis[8]. Further studies are needed to validate whether mTO offers consistent advantages over traditional TO in gastric cancer patients.

The limitations of our study should be considered. First, the retrospective design introduces potential selection bias. Second, neoadjuvant chemotherapy was weakly recommended in the Japanese gastric cancer treatment guidelines, resulting in a limited number of patients receiving this treatment. Third, as all participating institutions were high-volume academic centers specializing in gastric cancer, the generalizability of our findings to other settings may be limited. Multicenter randomized controlled trials are needed to further validate the mTO definition and support its widespread application in clinical practice.

Conclusion

In summary, this multicenter, large-sample study demonstrates that mTO is a promising and reliable indicator for assessing the multidimensional quality of treatment in gastric cancer patients. It is independently associated with favorable prognoses. Surgeons should focus on addressing the identified risk factors to improve mTO achievement rates and optimize patient outcomes.

Ethical approval

All procedures followed were in accordance with the ethical standards of the responsible committee on human

experimentation (Ethics Committee of the First. Affiliated Hospital of Army Medical University, PLA, China, approval number: KY2023077) and with the Helsinki Declaration of 1964 and later versions.

Consent

The requirement for written informed consent for this retrospective study was waived by the Ethics Committee of the First Affiliated Hospital of Army Medical University, PLA, China.

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Author contributions

X.L.: contributed to study design, data collection, writing. W. Y. and W.Z.: contributed to writing. W.Y., W.Z., H.H., C.J., F. Q., Y.S., J.Y., and B.W.: contributed to data collection. C.T. and Z. L.: contributed to data collection. Y.Z.: contributed to study design.

Conflicts of interest disclosure

The authors deny any conflict of interests.

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Data are available upon reasonable request to corresponding authors.

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