International Journal of Surgery 71 (2019) 140–148

Contents lists available at ScienceDirect

International Journal of Surgery

journal homepage: www.elsevier.com/locate/ijsu

Original Research

# Systematic assessment of complications after robotic-assisted total versus distal gastrectomy for advanced gastric cancer: A retrospective propensity score-matched study using Clavien–Dindo classification

Wen-Jie Wang[a,b,d,1], Rui Li[a,b,1], Chang-An Guo[a,d,e,1], Hong-Tao Li[c], Jian-Ping Yu[c], Jing Wang[c,f], Zi-Peng Xu[a,c], Wei-Kai Chen[c,f], Zhi-Jian Ren[a,b], Peng-Xian Tao[a,b], Ya-Nan Zhang[a,b], Chen Wang[a,b,**], Hong-Bin Liu[a,c,*]

[a] Second Clinical Medical College, Lanzhou University, Lanzhou, 730030, Gansu, PR China
[b] Department of General Surgery, Lanzhou University Second Hospital, Lanzhou, 730030, Gansu, PR China
[c] Department of General Surgery, The 940th Hospital of Joint Logistics Support Force of Chinese People's Liberation Army, Lanzhou, 730050, Gansu, PR China
[d] Key Laboratory of Stem Cells and Gene Drugs of Gansu Province, Lanzhou, 730050, PR China
[e] Department of Emergency, Lanzhou University Second Hospital, Lanzhou, 730030, Gansu, PR China
[f] Clinical Medical College, Gansu University of Traditional Chinese Medicine, Lanzhou, 730000, Gansu, PR China

ARTICLE INFO

*Keywords:*
Gastric cancer
Robot-assisted distal gastrectomy
Robot-assisted total gastrectomy
Postoperative complications
Clavien–Dindo classification

ABSTRACT

*Background:* Despite increasing evidence demonstrated robot-assisted distal gastrectomy (RADG) is safe and feasible for the treatment of advanced gastric cancer (AGC), robot-assisted total gastrectomy (RATG) remains a challenging procedure due to its technical difficulties and possible postoperative complications (POCs). This study aimed to systematically evaluate POCs following RATG.

*Methods:* Between January 2017 and January 2019, 319 AGC patients with pathological stage T2-4aN0-3M0 who underwent RADG or RATG were enrolled. POCs were stratified using the Clavien–Dindo classification. One-to-one propensity score matching was performed to reduce confounding differences.

*Results:* After matching, 266 patients met the criteria for further analysis. Ultimately, 64 patients (24.1%) who developed POCs had 126 clinical manifestation events. Overall the POCs rate was significantly greater after RATG in comparison with RADG (29.3% vs. 18.8%; $P = 0.045$), and more major POCs (Clavien–Dindo grade ≥ IIIa) were observed in the RATG group (14.3% vs. 5.3%; $P = 0.013$). The POCs were then classified into local and systemic POCs. The rates of local POCs (35.3% vs. 19.5%; $P = 0.004$) and systemic POCs (24.8% vs. 15.0%; $P = 0.046$) were significantly higher in the RATG group than the RADG group. Subgroup analysis showed that the anastomotic leakage rate was higher after RATG (5.3% vs. 0.8%; $P = 0.031$), whereas the remaining POCs were similar between the two groups. Patients with higher POCs significantly had longer postoperative length of stay ($R = 0.895$, $P = 0.003$). Multivariate analysis confirmed age, extent of resection, and TNM stage were risk factors for all POCs.

*Conclusions:* These findings demonstrated that RATG is technically feasible and safe for treatment of AGC with acceptable morbidity and mortality rates. The POCs rate of RATG was higher than RADG, especially for anastomotic leakage. More effective anastomotic techniques are needed in RATG to prevent leakage.

## 1. Introduction

Gastric cancer ranks the fourth most common malignancy and the second leading cause of cancer-related mortality worldwide [1,2]. Reportedly, there are approximately 679,100 new cases of gastric cancer and 498,000 related deaths each year in China [3]. However, unfortunately, more than 80% of Chinese patients are diagnosed with locally advanced gastric cancer (AGC) at the time of initial diagnosis

* Corresponding author. Second Clinical Medical College, Lanzhou University, No. 82 Chuiying Gate, Chengguan District, Lanzhou, 730030, Gansu, PR China.
** Corresponding author. Department of General Surgery, Lanzhou University Second Hospital, No. 82 Chuiying Gate, Chengguan District, Lanzhou, 730030, Gansu, P.R. China.
*E-mail addresses:* chenwang@lzu.edu.cn (C. Wang), liuhongbin999@163.com (H.-B. Liu).
[1] Wen-Jie Wang, Rui Li, and Chang-An Guo have contributed equally to this work.

https://doi.org/10.1016/j.ijsu.2019.09.029
Received 22 March 2019; Received in revised form 11 July 2019; Accepted 24 September 2019
Available online 27 September 2019

[4]. At present, radical gastrectomy with regional lymph node (LN) dissection remains the mainstay treatment for AGC.

Minimally invasive surgery (MIS) has gradually become a globally accepted surgical procedure for patients with AGC [5–7]. Since the first robot-assisted gastrectomy (RAG) case was reported in 2003, it has been increasingly performed because of its remarkable superiorities over traditional laparoscopic gastrectomies: three-dimensional visualization, tremor filtering, less fatigue, and free device movement [8,9]. RAG mainly consists of robot-assisted distal gastrectomy (RADG) and robot-assisted total gastrectomy (RATG). Accumulating evidence has revealed RADG is technically feasible and safe for the treatment of AGC and is associated with benefits such as accelerated recovery, decreased blood loss, and shorter postoperative stay [9–12]. However, RATG remains a challenging procedure due to its technical difficulties and possible postoperative complications (POCs).

The POCs are important indicators for assessing the safety and efficacy of surgical treatment [13–15]. The Clavien-Dindo classification (CDC) system, initially proposed by Clavien et al. [16] and modified by Dindo et al. [17], and has been widely used to classify the severity and incidence of POCs in many surgical fields [18–21]. To date, few reports have assessed the surgical outcomes and technical feasibility of RATG for AGC, and have not systematically analyzed POCs.

In doing so, we retrospectively analyzed surgical outcomes and incidence and types of 30-day POCs following RATG at our high-volume institution to systematically evaluate the safety and feasibility of RATG for the treatment of AGC.

## 2. Materials and methods

### 2.1. Patients and data collection

This study was approved by the Ethics Committee of the 940th Hospital of Joint Logistics Support Force of Chinese People's Liberation Army in accordance with the principles of the Declaration of Helsinki (2019XYLL013), and written informed consent was not required for all patients. The trial was registered at the Chinese Clinical Trial Registry. This study was carried out in accordance with the Strengthening the Reporting of Cohort Studies in Surgery (STROCSS) guideline [22].

We retrospectively reviewed patients with AGC after RAG from a prospective database of Western China Gastric Cancer Collaboration (WCGCC) group participated by Department of General Surgery, 940th Hospital of Joint Logistics Support Force of Chinese People's Liberation Army, between January 2017 and January 2019. Inclusion criteria were as follows: (1) patients were pathologically diagnosed with AGC (pT2-4aN0-3M0); (2) patients who underwent R0 resection with systematic D2 lymphadenectomy; (3) patients without other malignancy; (4) patients without chemotherapy and/or radiotherapy; and (5) availability of sufficient clinical information for analysis. Exclusion criteria are shown in Fig. 1. The classification of pathological stage was based on the 8th edition of the American Joint Committee on Cancer (AJCC) Staging Manual for Gastric Cancer [23,24].

### 2.2. Operative procedures

D2 lymphadenectomy was performed in accordance with the guidelines of the Japanese Gastric Cancer Association [6]. The extent of resection (total or distal subtotal gastrectomy) selected depending on the tumor location. All operations were performed by the same senior surgeon with the assistance of an assistant using the da Vinci® surgical system (Intuitive Surgical, Sunnyvale, CA, USA). In the operation, a linear anastomat was used for intra-corporeal anastomosis. After reconstruction, a single abdominal drainage tube was inserted into the left subphrenic cavity. The detail procedures of RAG have been described previously [11,25].

### 2.3. Definition and assessment of complications

The CDC was adopted to grade the severity of POCs from I to V for each patient (Table S1) [16–18]. POCs that occurred within 30 days after surgery were assessed retrospectively by three independent surgeons, and any divergences on grade were solved by discussion. In this study, all POCs were graded into overall POCs (OPOCs, Grade I–V), major POCs (MPOCs, Grade ≥ IIIa), and mortality (Grade V). Subsequently, POCs were classified largely into local POCs (LPOCs) and systemic POCs (SPOCs). LPOCs mainly included the following: wound problem, fluid collection, subcutaneous emphysema, intra-abdominal bleeding, intra-luminal bleeding, anastomosis stenosis and leakage, and postoperative ileus etc. SPOCs included fever, atelectasis, pleural effusion, pneumonia, transient elevation of serum creatinine, transient hepatic function abnormality, pancreatitis, and urinary tract infection etc. Patients experienced multiple POCs after RAG, and the most serious POC was used as a reference for calculating OPOCs and MPOCs. However, all of the POCs events were counted when calculating LPOCs and SPOCs.

### 2.4. Propensity score matching analysis

Propensity score matching (PSM) was used to reduce sampling bias and potential confounding. The individual propensity score was calculated for each of the 319 patients using a logistic regression model that included all the possible clinicopathological variables. A total of nine variables used for subsequently matching were as follows: age, gender (male/female), BMI, ASA (I/II/III), tumor size, previous abdominal operation (PAO, no/yes), histology (well differentiated/moderately differentiated/poorly differentiated/mucinous or signet ring cell carcinoma), pT stage (T2/T3/T4a), pN stage (N0/N1/N2/N3a/N3b), and pTNM stage (IB/IIA/IIB/IIIA/IIIB/IIIC). A one-to-one nearest neighbour matching (NNM) without replacement was applied based on the propensity score of each patient. In NNM, a caliper width equal to 0.2 of the standard deviation of the logit (propensity score) was used as the matching criteria [26,27]. After PSM, the balance of variables between two groups was assessed by calculating the standardized mean difference (SMD). A SMD $< 0.1$ of the absolute value was considered to be a sufficient balance [28]. All statistical analyses were performed using the Statistical Package for Social Science (SPSS, version 23.0) software and the SPSS-R plugin developed by felixthoemmes, wliao229 (https://sourceforge.net/proje cts/psmsp ss/files/).

### 2.5. Statistical analysis

All statistical analyses were conducted using the SPSS version 23.0 software (SPSS Inc., Chicago, IL, USA). Categorical variables are presented as counts and percentages and were compared using the Pearson's $\chi^2$ test or Fisher's exact test as appropriate. Continuous variables normally distributed are expressed as the mean ± standard deviation (SD) and were analyzed using Student's t-test. Non-normally distributed data are shown as median (inter quartile range, IQR) and were analyzed using Mann-Whitney test. The one-sample Kolmogorov–Smirnov test was used to assess normality of distribution for continuous variables. Multivariate logistic regression analysis was employed to identify independent risk factors for POCs and odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. A two-tailed $P$ value $< 0.05$ was considered statistically significant.

## 3. Results

### 3.1. Demographics and surgical outcomes before matching

The demographics and surgical outcomes of patients are summarized in Table 1. Of these 319 patients, 161 (50.5%) patients were treated with RADG while 158 (49.5%) were operated by RATG. Patients

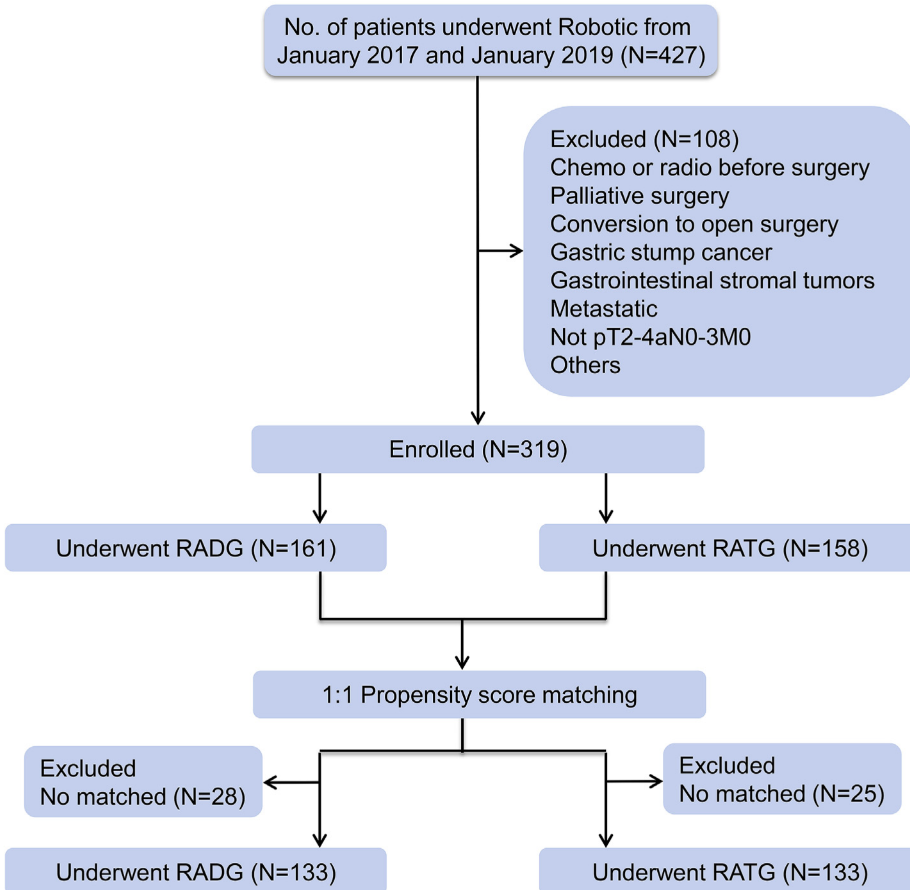


**Fig. 1.** Consolidated Standards of Reporting Trials diagram of patient enrollment in the present study. Abbreviations: RADG, robot-assisted distal gastrectomy; RATG, robot-assisted total gastrectomy.

who underwent RATG tended to have larger tumor size (RATG vs. RADG: 4.9 ± 2.1 cm vs. 4.5 ± 2.3 cm, $P = 0.047$) and increased PAO (RATG vs. RADG: 16.5% vs. 8.1%, $P = 0.022$). No significant difference was observed in age, gender, body mass index (BMI), American Society of Anesthesiologist (ASA), histologic type, or pathological stage between two groups (Table 1). In the RATG group, significantly longer operative time ($P = 0.009$), greater intraoperative blood loss ($P = 0.042$), larger number of retrieved LNs ($P = 0.002$), longer postoperative length of stay (PLOS, $P < 0.001$), and longer time to ambulation and first flatus ($P = 0.031$ and $< 0.001$, respectively) were observed. No significant difference was found in the two groups in the time to first liquid intake ($P = 0.203$) and in the time to first soft intake ($P = 0.082$).

### 3.2. Demographics and surgical outcomes after matching

After PSM, 266 patients (each group contained 133 patients) maintained with 1:1 matching, and the two groups tended to be closely similar on these variables ($P > 0.05$, Table 1). Fig. 2 showed a successful match between the two groups after matching. Furthermore, similar difference regarding surgical outcomes was also observed after matching (Table 1).

### 3.3. Postoperative morbidity and mortality after matching

Totally, 64 (24.1%) patients experienced OPOCs and 26 (9.8%) patients exhibited MPOCs (Grade ≥ IIIa) within 30 days after RAG. Detailed POCs data after RAG are presented in Table 2. In the RATG group, 13 (9.8%) grade I, 7 (5.3%) grade II, 11 (8.3%) grade IIIa, 3 (2.3%) grade IIIb, 2 (1.5%) grade IVa, 1 (0.8%) grade IVb and 2 (1.5%) grade V POCs were observed. The rates of OPOCs after RATG and RADG were 29.3% (39/133) and 18.8% (25/133), respectively ($P = 0.045$). Higher MPOCs occurred after RATG than after RADG (RATG vs. RADG: 14.3% vs. 5.3%; $P = 0.013$). The incidence of grade IIIa was significantly higher in the RATG group (RATG vs. RADG: 8.3% vs. 2.3%; $P = 0.028$) and no significant difference in the incidence of grade I, II, IIIb, IVa, IVb, and V between the two groups (all $P > 0.05$, Table 2).

Subsequently, POCs were classified largely into LPOCs and SPOCs. The details of LPOCs following RAG are summarized in Table 3. Sixty four patients who developed POCs had 73 events of local POCs and 53 events of systemic POCs. LPOCs were also rated as overall LPOCs (I–V) and major LPOCs (Grade ≥ IIIa). The RATG group had a higher rate of overall LPOCs (RATG vs. RADG, 35.3% vs. 19.5%, $P = 0.004$) and major LPOCs (RATG vs. RADG, 21.8% vs. 9.8%, $P = 0.007$). The most common LPOC was wound problem (6.8%, 18/266), followed by fluid collection (5.6%, 15/266) and subcutaneous emphysema (3.8%, 10/266). Anastomotic leakage rate was higher after RATG group compared to the RADG group (RATG vs. RADG, 5.3% vs. 0.8%, $P = 0.031$), whereas the remaining POCs was similar between the two groups. In terms of SPOCs, the rates of overall SPOCs (I–V) and major SPOCs (Grade ≥ IIIa) were 19.9% (53/266) and 10.5% (28/266), respectively. Similarly, there was significant difference in overall SPOCs (RATG vs. RADG, 24.8% vs. 15.0%, $P = 0.046$) and major SPOCs (RATG vs. RADG, 15.0% vs. 6.0%, $P = 0.017$) between the two groups. The most frequent SPOC was transient hepatic function abnormality with that occurring in 4.9% (13/266) of patients. Fever was the second most common (3.4%, 9/266). Pleural effusion followed as the next most prevalent SPOCs (3.0%, 8/266). The detailed SPOCs following RAG are listed in Table 4.

**Table 1**
Demographics and surgical outcomes before and after matching.

| Variables | Entire cohort (n = 319) | | P value | PSM cohort (n = 266) | | P value |
|---|---|---|---|---|---|---|
| | RADG (n = 161) | RATG (n = 158) | | RADG (n = 133) | RATG (n = 133) | |
| Age (years) | 57.7 ± 11.0 | 56.9 ± 11.1 | 0.517[b] | 56.7 ± 10.9 | 57.3 ± 11.0 | 0.623[b] |
| Gender | | | 0.309[c] | | | 0.662[c] |
| Male | 127 (78.9) | 117 (74.1) | | 104 (78.2) | 101 (75.9) | |
| Female | 34 (21.1) | 41 (25.9) | | 29 (21.8) | 32 (24.1) | |
| BMI (kg/m$^2$) | 22.2 ± 3.7 | 22.3 ± 3.3 | 0.781[b] | 22.2 ± 3.6 | 22.32 ± 3.2 | 0.764[b] |
| ASA | | | 0.480[c] | | | 0.937[c] |
| I | 77 (47.8) | 65 (41.1) | | 69 (51.9) | 70 (52.6) | |
| II | 56 (34.8) | 61 (38.6) | | 45 (33.8) | 46 (34.6) | |
| III | 28 (17.4) | 32 (20.3) | | 19 (14.3) | 17 (12.8) | |
| Tumor size (cm) | 4.5 ± 2.3 | 4.9 ± 2.1 | 0.047[b] | 4.5 ± 2.3 | 4.7 ± 1.9 | 0.604[b] |
| Previous abdominal operation | | | 0.022[c] | | | 0.542[c] |
| No | 148 (91.9) | 132 (83.5) | | 121 (91.0) | 118 (88.7) | |
| Yes | 13 (8.1) | 26 (16.5) | | 12 (9.0) | 15 (11.3) | |
| Histologic type | | | 0.327[c] | | | 0.705[c] |
| Well differentiated | 12 (7.5) | 13 (8.2) | | 11 (8.3) | 8 (6.0) | |
| Moderately differentiated | 46 (28.6) | 44 (27.8) | | 39 (29.3) | 38 (28.6) | |
| Poorly differentiated | 89 (55.3) | 95 (60.1) | | 74 (55.6) | 81 (60.9) | |
| Mucinous or signet ring cell carcinoma | 14 (8.7) | 6 (3.8) | | 9 (6.8) | 6 (4.5) | |
| pT stage[a] | | | 0.659[c] | | | 0.605[c] |
| T2 | 46 (28.6) | 51 (32.3) | | 41 (30.8) | 45 (33.8) | |
| T3 | 81 (50.3) | 79 (50.0) | | 70 (52.6) | 62 (46.6) | |
| T4a | 34 (21.1) | 28 (17.7) | | 22 (16.5) | 26 (19.5) | |
| pN stage[a] | | | 0.554[c] | | | 0.960[c] |
| N0 | 65 (40.4) | 53 (33.5) | | 52 (39.1) | 48 (36.1) | |
| N1 | 21 (13.0) | 20 (12.7) | | 17 (12.8) | 16 (12.0) | |
| N2 | 26 (16.1) | 33 (20.9) | | 24 (18.0) | 28 (21.1) | |
| N3a | 30 (18.6) | 27 (17.1) | | 22 (16.5) | 21 (15.8) | |
| N3b | 19 (11.8) | 25 (15.8) | | 18 (13.5) | 20 (15.0) | |
| pTNM stage[a] | | | 0.394[c] | | | 0.867[c] |
| IB | 42 (26.1) | 36 (22.8) | | 38 (28.6) | 34 (25.6) | |
| IIA | 16 (9.9) | 22 (13.9) | | 15 (11.3) | 17 (12.8) | |
| IIB | 21 (13.0) | 15 (9.5) | | 18 (13.5) | 16 (12.0) | |
| IIIA | 23 (14.3) | 29 (18.4) | | 17 (12.8) | 23 (17.3) | |
| IIIB | 31 (19.3) | 22 (13.9) | | 21 (15.8) | 17 (12.8) | |
| IIIC | 28 (17.4) | 34 (21.5) | | 24 (18.0) | 26 (19.5) | |
| Operation time (min) | 236.5 ± 41.2 | 248.1 ± 37.3 | 0.009[b] | 237.7 ± 37.6 | 245.7 ± 34.0 | 0.047[b] |
| Intraoperative blood loss (ml) | 143.7 ± 48.9 | 155.2 ± 51.5 | 0.042[b] | 144.3 ± 50.5 | 156.8 ± 52.1 | 0.048[b] |
| Number of retrieved LNs | 41.3 ± 15.4 | 46.9 ± 16.7 | 0.002[b] | 42.9 ± 15.5 | 47.7 ± 15.1 | 0.011[b] |
| Time to ambulation (day) | 2.1 ± 0.3 | 2.2 ± 0.5 | 0.031[b] | 2.1 ± 0.4 | 2.3 ± 0.7 | 0.005[b] |
| Time to first flatus (day) | 2.5 ± 0.7 | 2.9 ± 0.8 | < 0.001[b] | 2.5 ± 0.7 | 2.9 ± 0.9 | < 0.001[b] |
| Time to first liquid intake (day) | 3.9 ± 1.3 | 4.2 ± 2.5 | 0.203[b] | 3.8 ± 1.2 | 4.0 ± 1.8 | 0.370[b] |
| Time to first soft intake (day) | 5.0 ± 1.2 | 5.3 ± 1.8 | 0.082[b] | 5.1 ± 1.3 | 5.3 ± 1.5 | 0.246[b] |
| Postoperative hospital stay (day) | 10.9 ± 2.8 | 13.2 ± 5.9 | < 0.001[b] | 10.7 ± 2.7 | 13.1 ± 4.8 | < 0.001[b] |

Abbreviations: RADG, robot-assisted distal gastrectomy; RATG, robot-assisted total gastrectomy; BMI, body mass index; ASA, American Society of Anesthesiologist; TNM, Tumor-Node-Metastases.
[a] Based on the Eighth American Joint Committee on Cancer classification.
[b] Student's t-test.
[c] Pearson's $\chi^2$ test.

### 3.4. Correlating PLOS and POCs

Since POCs may lead to prolonged PLOS and increased treatment costs, we further evaluated the correlation between PLOS and POCs. As shown in Table 5, patients without POCs had an average PLOS of 11.3 days, and those with varying degrees of POCs had an average PLOS of 12.5–32.5 days. The Pearson analysis showed a significant correlation between PLOS and CDC grades (R = 0.895, $P = 0.003$).

### 3.5. Risk factors associated with POCs following RAG

To identify the factors associated with POCs, univariate and multivariate logistic regression analyses were performed. The factors with P value < 0.05 in the univariate analysis were selected as covariables for multivariate analysis. In terms of OPOCs, age, ASA, extent of resection, pT stage, pN stage, pTNM stage, operation time and retrieved LNs were significantly correlated with OPOCs in univariate analysis (Fig. 3A). Multivariate analysis demonstrated that age ≥65 years, ASA class III, total gastrectomy, stage T3–T4a, stage N1–N3b, stage II–III, operation time ≥250 min and retrieved LNs ≥30 were independent risk factors for OPOCs (Fig. 4A). As for MPOCs, except for gender, BMI, tumor size, PAO, histologic type, and blood loss, the remaining variables were associated with MPOCs in the univariate analysis (Fig. 3B). Multivariate analysis proved age ≥65 years, total gastrectomy, stage T3–T4a, stage N1–N3b, and stage II–III to be important risk factors that affected MPOCs (Fig. 4B).

With respect to LPOCs, age, ASA, extent of resection, pT stage, pN stage, pTNM stage, and operation time were identified as significant risk factors by univariate analysis (Fig. 3C). Then multivariate analysis showed age ≥65 years, total gastrectomy, stage T3–T4a, stage N1–N3b, and stage II–III were the independent predictors of higher LPOCs (Fig. 4C). Similarly, univariate analysis showed age, ASA, extent of resection, pTNM stage, operation time and retrieved LNs were associated with SPOCs (Fig. 3D). Multivariate analysis revealed age ≥65 years, ASA class III, total gastrectomy, stage II–III, and operation time ≥250 min were independent risk factors for SPOCs (Fig. 4D).

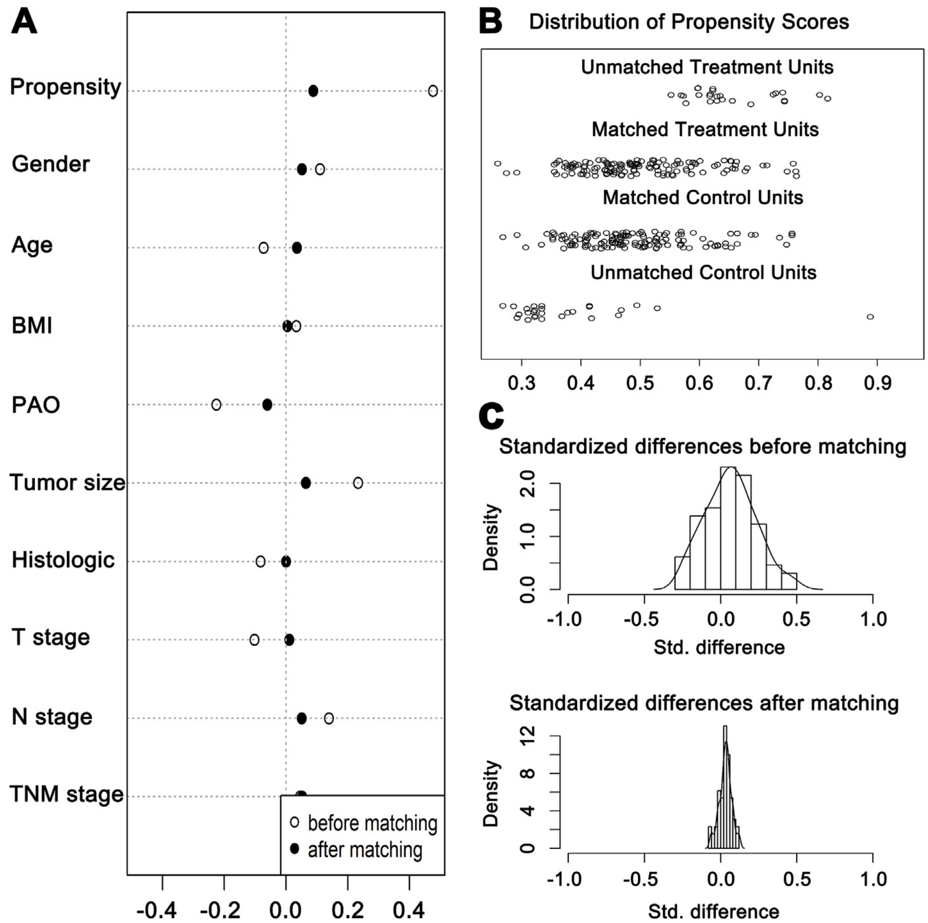


**Fig. 2.** Distribution of covariates balance (A) and propensity scores (B) and density distributions of standardized differences (C) before and after matching in the present study. Abbreviations: BMI, body mass index; PAO, previous abdominal operation; TNM, Tumor-Node-Metastases.

**Table 2**
Comparison of POCs following RADG and RATG after matching.

| Grades | Total (n = 266) | RADG (n = 133) | RATG (n = 133) | *P* value |
|---|---|---|---|---|
| OPOCs (%) | 64 (24.1) | 25 (18.8) | 39 (29.3) | 0.045[a] |
| MPOCs (%) | 26 (9.8) | 7 (5.3) | 19 (14.3) | 0.013[a] |
| Grade I (%) | 23 (8.6) | 10 (7.5) | 13 (9.8) | 0.513[a] |
| Grade II (%) | 15 (5.6) | 8 (6.0) | 7 (5.3) | 0.790[a] |
| Grade IIIa (%) | 14 (5.3) | 3 (2.3) | 11 (8.3) | 0.028[a] |
| Grade IIIb (%) | 5 (1.8) | 2 (1.5) | 3 (2.3) | 1.000[b] |
| Grade IVa (%) | 3 (1.1) | 1 (0.8) | 2 (1.5) | 1.000[b] |
| Grade IVb (%) | 2 (0.8) | 1 (0.8) | 1 (0.8) | 1.000[b] |
| Grade V (%) | 2 (0.8) | 0 (0.0) | 2 (1.5) | 0.498[b] |

Abbreviations: POCs, postoperative complications; RADG, robot-assisted distal gastrectomy; RATG, robot-assisted total gastrectomy; OPOCs, overall postoperative complications; MPOCs, major postoperative complications.

[a] Pearson's $\chi^2$ test.

[b] Fisher's exact test.

## 4. Discussion

Accumulating evidence demonstrated that RADG is technically feasible and safe for AGC [29,30]. However, RATG remains a challenging procedure due to its technical difficulties and possible POCs. It is well known that the incidence of POCs is still the most commonly used surrogate for evaluating the safety and feasibility of surgical treatment. The CDC system has been widely accepted as a powerful tool for assessing POCs after surgery in clinical trials because of its simplicity, repeatability and logical architecture [20,31–33]. Furthermore, it has increasingly been used to evaluate the severity of POCs following gastric cancer [34,35]. Accordingly, we selected it to analyze the incidence and types of 30-day POCs following RATG at our high-volume institution to systematically evaluate the safety and feasibility of RATG for the treatment of AGC.

In our cohort, the RATG group had a larger tumor size and increased PAO in comparison to the RADG group. By comparing the results between the matched groups with similarly distributed baseline features, PSM can be effectively used to eliminate the effects of confounding [36]. Therefore, we conducted PSM analysis to reduce confounding differences and estimate POCs grades more accurately. Finally, 266 patients maintained with 1:1 matching, and no significant difference between the two groups was observed in tumor size and PAO.

To the best of our knowledge, the present study for the first time compared POCs between RATG and RADG in AGC patients. Previous studies demonstrated that POCs rate after RAG range from 13.5 to 47.3% [37–39]. In our study, the rates of OPOCs and MPOCs were 24.1% and 9.8%, respectively, which was comparable with previously published results [37–39]. Lee et al. [40] reported that SPOCs following gastrectomy were associated with the vulnerability of surgical stress. Therefore, we further classified POCs into LPOCs and SPOCs, and the rates were 27.4% and 20.3%, respectively. Taken together with the results of the current study, we found that POCs in various classifications after RATG were significantly higher than those RADG. To date, many studies have focused on comparing POCs between total gastrectomy and distal gastrectomy at the laparoscopic level, while few studies have compared them at the robot level [41–44].

The major concern following RATG is anastomotic leakage. In our study, anastomotic leakage tended to be more frequent after RATG. Seven cases (5.3%) of anastomotic leakage were observed in the RATG

**Table 3**
Comparison of LPOCs following RADG and RATG after matching.

| LPOCs | Overall LPOCs (I–V) | | | *P* value | Major LPOCs (IIIa-V) | | | *P* value |
|---|---|---|---|---|---|---|---|---|
| | Total | RADG | RATG | | Total | RADG | RATG | |
| Wound problem[c] | 18 (6.8) | 7 (5.3) | 11 (8.3) | 0.329[a] | 13 (4.9) | 5 (3.8) | 8 (6.0) | 0.394[a] |
| Fluid collection[d] | 15 (5.6) | 8 (6.0) | 7 (5.3) | 0.790[a] | 10 (3.8) | 4 (3.0) | 6 (4.5) | 0.519[a] |
| Subcutaneous emphysema | 10 (3.8) | 4 (3.0) | 6 (4.5) | 0.519[a] | 6 (2.3) | 2 (1.5) | 4 (3.0) | 0.684[b] |
| Intra-abdominal bleeding | 4 (1.5) | 1 (0.8) | 3 (2.3) | 0.614[b] | 2 (0.8) | 0 (0.0) | 2 (1.5) | 0.478[b] |
| Intra-luminal bleeding | 2 (0.8) | 0 (0.0) | 2 (1.5) | 0.498[b] | 1 (0.4) | 1 (0.8) | 0 (0.0) | 1.000[b] |
| Anastomosis stenosis | 4 (1.5) | 1 (0.8) | 3 (2.3) | 0.614[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Anastomosis leakage | 8 (3.0) | 1 (0.8) | 7 (5.3) | 0.031[b] | 6 (2.3) | 0 (0.0) | 6 (4.5) | 0.030[b] |
| Duodenal stump fistula | 2 (0.8) | 1 (0.8) | 1 (0.8) | 1.000[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Leakage of lymphatics | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] | 1 (0.4) | 1 (0.8) | 0 (0.0) | 1.000[b] |
| Pancreatic leakage | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] | 0 (0.0) | 0 (0.0) | 0 (0.0) | – |
| Postoperative ileus | 3 (1.1) | 1 (0.8) | 2 (1.5) | 1.000[b] | 0 (0.0) | 0 (0.0) | 0 (0.0) | – |
| Remnant gastric infarction | 1 (0.4) | 1 (0.8) | 0 (0.0) | 1.000[b] | 0 (0.0) | 0 (0.0) | 0 (0.0) | – |
| Small-bowel perforation | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] | 0 (0.0) | 0 (0.0) | 0 (0.0) | – |
| Others | 3 (1.1) | 1 (0.8) | 2 (1.5) | 1.000[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Total | 73 (27.4) | 26 (19.5) | 47 (35.3) | 0.004[a] | 42 (15.8) | 13 (9.8) | 29 (21.8) | 0.007[a] |

Abbreviations: LPOCs, local postoperative complications; RADG, robot-assisted distal gastrectomy; RATG, robot-assisted total gastrectomy.
[a] Pearson's $\chi^2$ test.
[b] Fisher's exact test.
[c] Wound problem was defined as seroma, hematoma, infection, or cracking of the wound. Among them, superficial surgical site infection (SSI), deep SSI and organ occupying SSI were included in the wound infection.
[d] Fluid collection was mainly defined as abdominal and pelvic fluid collection and confirmed by computed tomography scan.

group, whereas one (0.8%) was observed in the RADG group. The difference in anastomotic leakage between the two groups may be explained by insufficient blood supply around the anastomosis [45]. The anastomotic method is the most important issue for surgeons performing RATG. Although various anastomotic methods have been introduced, the method most familiar to surgeons is still the most effective anastomosis technique. According to our center's experience, maintaining the integrity of the anastomosis and reducing the tension of the anastomosis is the key to prevent anastomotic leakage. With regard to detailed POCs, we found that wound problem (6.8%), fluid collection (5.6%), and subcutaneous emphysema (3.8%) were the top three LPOCs. Meanwhile, transient hepatic function abnormality (4.9%), fever (3.4%), and pleural effusion (3.0%) were identified as the three most common SPOCs. However, the rate of these POCs was not statistically different between the two groups. In terms of the rate of morbidity and mortality, RATG is technically feasible and safe for the

**Table 5**
Correlating PLOS and frequency of CDC grades after matching.

| Grades | Total | Percentage overall (%, n = 266) | Mean PLOS (days) | Pearson Correlation | *P* value |
|---|---|---|---|---|---|
| None | 202 | 75.9 | 11.3 | 0.895 | 0.003 |
| Grade I | 23 | 8.6 | 12.5 | | |
| Grade II | 15 | 5.6 | 14.8 | | |
| Grade IIIa | 14 | 5.3 | 15.2 | | |
| Grade IIIb | 5 | 1.8 | 18.6 | | |
| Grade IVa | 3 | 1.1 | 29.1 | | |
| Grade IVb | 2 | 0.8 | 32.5 | | |
| Grade V | 2 | 0.8 | 25.8 | | |

Abbreviations: PLOS, postoperative length of stay; CDC, Clavien-Dindo classification.

**Table 4**
Comparison of SPOCs following RADG and RATG after matching.

| SPOCs | Overall SPOCs (I–V) | | | *P* value | Major SPOCs (IIIa-V) | | | *P* value |
|---|---|---|---|---|---|---|---|---|
| | Total | RADG | RATG | | Total | RADG | RATG | |
| Fever | 9 (3.4) | 4 (3.0) | 5 (3.8) | 1.000[b] | 5 (1.9) | 2 (1.5) | 3 (2.3) | 1.000[b] |
| Atelectasis | 3 (1.1) | 2 (1.5) | 1 (0.8) | 1.000[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Pleural effusion | 8 (3.0) | 2 (1.5) | 6 (4.5) | 0.282[b] | 3 (1.1) | 1 (0.8) | 2 (1.5) | 1.000[b] |
| Pneumonia | 5 (1.9) | 3 (2.3) | 2 (1.5) | 1.000[b] | 2 (0.8) | 0 (0.0) | 2 (1.5) | 0.498[b] |
| Transient elevation of serum creatinine | 1 (0.4) | 1 (0.8) | 0 (0.0) | 1.000[b] | 0 (0.0) | 0 (0.0) | 0 (0.0) | – |
| Transient hepatic function abnormality | 13 (4.9) | 4 (3.0) | 9 (6.8) | 0.155[a] | 6 (2.3) | 1 (0.8) | 5 (3.8) | 0.213[b] |
| Pancreatitis | 2 (0.8) | 0 (0.8) | 2 (1.5) | 0.498[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Urinary tract infection | 1 (0.4) | 1 (0.8) | 0 (0.0) | 1.000[b] | 0 (0.0) | 0 (0.0) | 0 (0.0) | – |
| Transient ischemic attack | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] | 1 (0.4) | 1 (0.8) | 0 (0.0) | 1.000[b] |
| Stroke | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Myocardial infarction | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Intra-abdominal infection | 2 (0.8) | 1 (0.8) | 1 (0.8) | 1.000[b] | 2 (0.8) | 1 (0.8) | 1 (0.8) | 1.000[b] |
| Postoperative psychological problem | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] | 1 (0.4) | 0 (0.0) | 1 (0.8) | 1.000[b] |
| Others | 5 (1.9) | 2 (1.5) | 3 (2.3) | 1.000[b] | 4 (1.5) | 2 (1.5) | 2 (1.5) | 1.000[b] |
| Total | 53 (19.9) | 20 (15.0) | 33 (24.8) | 0.046[a] | 28 (10.5) | 8 (6.0) | 20 (15.0) | 0.017[a] |

Abbreviations: SPOCs, systemic postoperative complications; RADG, robot-assisted distal gastrectomy; RATG, robot-assisted total gastrectomy.
[a] Pearson's $\chi^2$ test.
[b] Fisher's exact test.

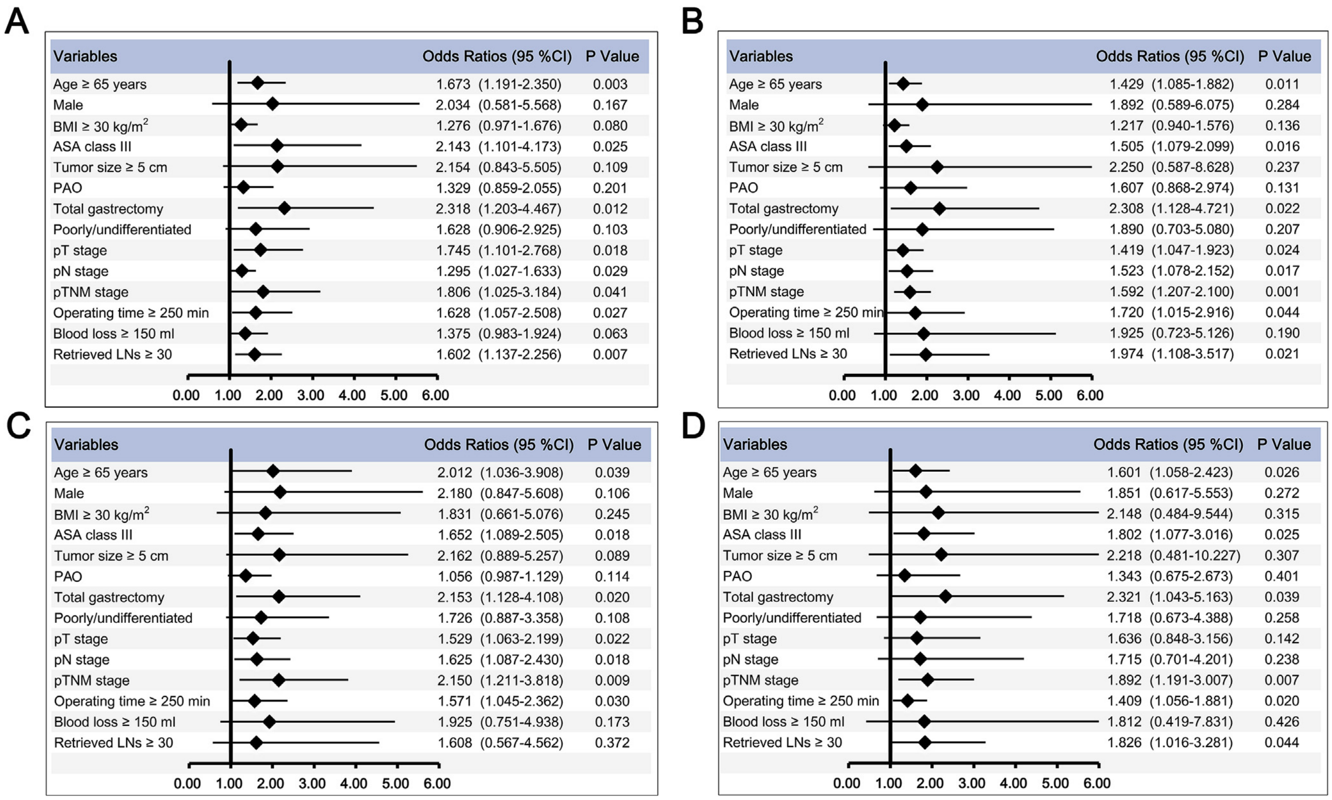


**Fig. 3.** Univariate analysis of risk factors associated with POCs following RAG in the present study. (A). OPOCs. (B). MPOCs. (C). LPOCs. (D). SPOCs. Abbreviations: POCs, postoperative complications; RAG, robot-assisted gastrectomy; BMI, body mass index; ASA, American Society of Anesthesiologist; PAO, previous abdominal operation; TNM, Tumor-Node-Metastases; LNs, lymph nodes; OPOCs, overall postoperative complications; MPOCs, major postoperative complications; LPOCs, local postoperative complications; SPOCs, systemic postoperative complications.

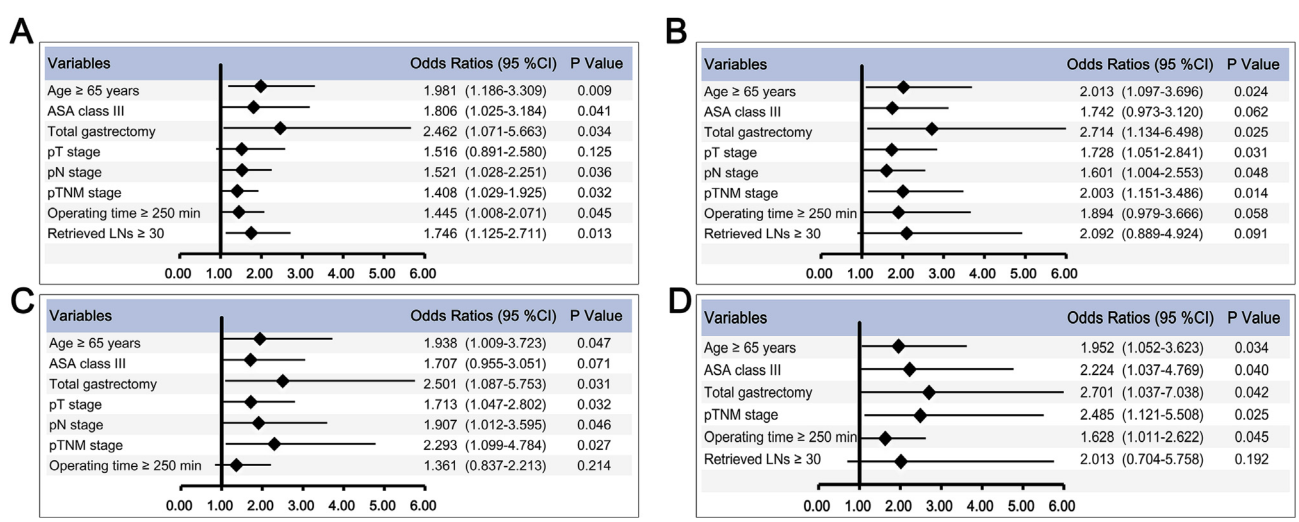


**Fig. 4.** Multivariate analysis of risk factors associated with POCs following RAG in the present study. (A). OPOCs. (B). MPOCs. (C). LPOCs. (D). SPOCs. Abbreviations: POCs, postoperative complications; RAG, robot-assisted gastrectomy; ASA, American Society of Anesthesiologist; TNM, Tumor-Node-Metastases; LNs, lymph nodes; OPOCs, overall postoperative complications; MPOCs, major postoperative complications; LPOCs, local postoperative complications; SPOCs, systemic postoperative complications.

treatment of AGC. However, more effective anastomotic techniques during RATG are needed to prevent leakage.

Understanding the associated risk factors is critical to reducing the incidence of POCs. By performing multivariate analysis, age ≥65 years was identified as one of the independent risk factors for OPOCs, MPOCs, LPOCs, and SPOCs, which was similar to previously reported studies [41,46]. The reason for this result may be that elderly patients have lower ability to withstand surgical stress than younger patients. On the other hand, the extent of gastrectomy was also identified as an independent risk factor for POCs. Kim et al. [44] reported that the extent of gastrectomy was a risk factor for POCs after laparoscopic gastrectomy. Our previous data also showed that patients who underwent laparoscopic total gastrectomy had more POCs than those who underwent laparoscopic distal gastrectomy [19]. One possible reason is that total gastrectomy requires more LNs to be resected and more tissue to be removed. Other possible reason might be that this process causes greater trauma to the human body and may damage the blood vessels around the duodenal stump, thereby increasing the occurrence of anastomotic leakage. Besides, the present study identified TNM stage was another significant risk factor for POCs. Previous studies also showed that patients with TNM high stage are more prone to POCs after surgery, such as anemia, hypoproteinemia, and malnutrition [46–48].

Reportedly, POCs are frequently associated with prolonged PLOS and increasing treatment costs [49]. In the present study, patients without POCs had an average PLOS of 11.3 days, and those with varying degrees of POCs had an average PLOS of 12.5–32.5 days. Increasing CDC scores correlated significantly with PLOS. A possible explanation may be that patients with higher CDC scores have more complicated POCs, which results in longer PLOS than patients with less POCs.

Our study has some limitations. First, the present study was influenced by inherent limitations due to the nature of retrospective observational cohorts. Although we used PSM analysis to reduce selection bias, doing so did not eliminate all potential confounding differences between the two groups. Second, this study was performed at a single institution, which limited the generalizability of our results. Third, POCs were captured within 30 days after surgery and did not include long-term POCs such as malnutrition or dumping syndrome in the present study. Fourth, we did not perform further subgroup analyses regarding the treatment of fluid collection (conservatively treated, or percutaneously, or surgically), which could introduce biases into the study. Therefore, large-scale prospective clinical studies are required to evaluate long-term POCs in the future. Nonetheless, we believe our findings could contribute to providing the clinical evidence for RATG treatment of AGC.

## 5. Conclusions

In summary, our study provides evidence demonstrating that RATG is technically feasible and safe for the treatment of AGC with acceptable rate of morbidity and mortality. However, its POCs rate is higher than RADG, especially anastomotic leakage. More effective anastomotic techniques during RATG are needed to prevent leakage. Nevertheless, further multicenter, prospective and randomized studies are required to confirm our results.

*Provenance and peer review*

Not commissioned, externally peer-reviewed.

## Author contribution

HBL, WJW, and CW designed the study. HTL, JPY, JW, and ZPX were responsible for data acquisition. WKC, ZJR, and PXT were responsible for quality control of data and algorithms. WJW, JW, and CAG assessed POCs for each patient. WJW, RL, and YNZ analyzed and interpreted the data. WJW, RL, and CAG wrote the article. All authors have seen and approved the final version of the manuscript.

## Ethical approval

This study was approved by the Ethics Committee of the 940th Hospital of Joint Logistics Support Force of Chinese People's Liberation Army (PLA) in accordance with the principles of the Declaration of Helsinki. This article does not contain any studies with animals performed by any of the authors.

## Sources of funding

This study was supported by Cuiying Graduate Supervisor Applicant Training Program of Lanzhou University Second Hospital, Huimin plan of Ministry of Science and Technology of the People's Republic of China (2012GS620101), and Key Science and Technology Foundation of Gansu Province (2011GS04390).

## Research registration Unique Identifying number (UIN)

Chinese Clinical Trial Registry (Number: ChiCTR1900022017).

## Guarantor

Hong-Bin Liu.

## Data statement

Due to the raw data of study included potentially sensitive information, all raw data of patients would remain confidential and would not be shared.

## CRediT authorship contribution statement

**Wen-Jie Wang:** Conceptualization, Methodology, Writing - review & editing, Funding acquisition. **Rui Li:** Software, Formal analysis, Visualization. **Chang-An Guo:** Writing - original draft, Validation, Investigation, Data curation. **Hong-Tao Li:** Writing - original draft, Validation, Investigation, Data curation. **Jian-Ping Yu:** Writing - original draft, Validation, Investigation, Data curation. **Jing Wang:** Writing - original draft, Validation. **Zi-Peng Xu:** Writing - original draft, Validation, Investigation, Data curation. **Wei-Kai Chen:** Writing - original draft, Validation, Investigation, Data curation. **Zhi-Jian Ren:** Writing - original draft, Validation, Investigation, Data curation. **Peng-Xian Tao:** Writing - original draft, Validation, Investigation, Data curation. **Ya-Nan Zhang:** Writing - original draft, Validation, Investigation, Data curation. **Chen Wang:** Resources, Supervision, Project administration, Investigation, Data curation. **Hong-Bin Liu:** Conceptualization, Methodology, Writing - review & editing, Funding acquisition.

## Declaration of competing interest

The authors declare that they have no competing interests.

## Acknowledgements

The authors would like to thank medical staff of Department of General Surgery, The 940th Hospital of Joint Logistics Support Force of Chinese People's Liberation Army for their management of database.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.09.029.

## References

[1] R.L. Siegel, K.D. Miller, A. Jemal, Cancer statistics, 2019, CA A Cancer J. Clin. 69 (2019) 7–34 https://doi.org/10.3322/caac.21551.
[2] F. Bray, J. Ferlay, I. Soerjomataram, R.L. Siegel, L.A. Torre, A. Jemal, Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries, CA A Cancer J. Clin. 68 (2018) 394–424 https://doi.org/10.3322/caac.21492.
[3] W. Chen, R. Zheng, P.D. Baade, S. Zhang, H. Zeng, F. Bray, et al., Cancer statistics in China, 2015, CA A Cancer J. Clin. 66 (2016) 115–132 https://doi.org/10.3322/caac.21338.
[4] W. Wang, X.W. Sun, C.F. Li, L. Lv, Y.F. Li, Y.B. Chen, et al., Comparison of the 6th and 7th editions of the UICC TNM staging system for gastric cancer: results of a Chinese single-institution study of 1,503 patients, Ann. Surg. Oncol. 18 (2011) 1060–1067 https://doi.org/10.1245/s10434-010-1424-2.
[5] I. Songun, H. Putter, E.M. Kranenbarg, M. Sasako, C.J. van de Velde, Surgical treatment of gastric cancer: 15-year follow-up results of the randomised nationwide Dutch D1D2 trial, Lancet Oncol. 11 (2010) 439–449 https://doi.org/10.1016/

S1470-2045(10)70070-X.
[6] A. Japanese, Gastric cancer, Japanese gastric cancer treatment guidelines 2014 (ver. 4), Gastric Cancer 20 (2017) 1–19 https://doi.org/10.1007/s10120-016-0622-4.
[7] S. Mocellin, P. McCulloch, H. Kazi, J.J. Gama-Rodrigues, Y. Yuan, D. Nitti, Extent of lymph node dissection for adenocarcinoma of the stomach, Cochrane Database Syst. Rev. (2015) CD001964 https://doi.org/10.1002/14651858.CD001964.pub4.
[8] M. Hashizume, K. Sugimachi, Robot-assisted gastric surgery, Surg. Clin. N. Am. 83 (2003) 1429–1444 https://doi.org/10.1016/S0039-6109(03)00158-0.
[9] K. Obama, Y.M. Kim, D.R. Kang, T. Son, H.I. Kim, S.H. Noh, et al., Long-term oncologic outcomes of robotic gastrectomy for gastric cancer compared with laparoscopic gastrectomy, Gastric Cancer 21 (2018) 285–295 https://doi.org/10.1007/s10120-017-0740-7.
[10] W.J. Seo, T. Son, C.K. Roh, M. Cho, H.I. Kim, W.J. Hyung, Reduced-port totally robotic distal subtotal gastrectomy with lymph node dissection for gastric cancer: a modified technique using Single-Site((R)) and two additional ports, Surg. Endosc. 32 (2018) 3713–3719 https://doi.org/10.1007/s00464-018-6208-y.
[11] H.B. Liu, W.J. Wang, H.T. Li, X.P. Han, L. Su, D.W. Wei, et al., Robotic versus conventional laparoscopic gastrectomy for gastric cancer: a retrospective cohort study, Int. J. Surg. 55 (2018) 15–23 https://doi.org/10.1016/j.ijsu.2018.05.015.
[12] S. Lee, J.K. Kim, Y.N. Kim, D.S. Jang, Y.M. Kim, T. Son, et al., Safety and feasibility of reduced-port robotic distal gastrectomy for gastric cancer: a phase I/II clinical trial, Surg. Endosc. 31 (2017) 4002–4009 https://doi.org/10.1007/s00464-017-5435-y.
[13] B.T. Bucher, J.P. Ferraro, S.R.G. Finlayson, W.W. Chapman, A.V. Gundlapalli, Use of computerized provider order entry events for postoperative complication Surveillance, JAMA Surg. 154 (2019) 311–318 https://doi.org/10.1001/jamasurg.2018.4874.
[14] N. Lou, C.H. Chi, X.D. Chen, C.J. Zhou, S.L. Wang, C.L. Zhuang, et al., Sarcopenia in overweight and obese patients is a predictive factor for postoperative complication in gastric cancer: a prospective study, Eur. J. Surg. Oncol. 43 (2017) 188–195 https://doi.org/10.1016/j.ejso.2016.09.006.
[15] F. Rosa, G. Quero, C. Fiorillo, M. Bissolati, C. Cipollari, S. Rausei, et al., Total vs proximal gastrectomy for adenocarcinoma of the upper third of the stomach: a propensity-score-matched analysis of a multicenter western experience (On behalf of the Italian Research Group for Gastric Cancer-GIRCG), Gastric Cancer 21 (2018) 845–852 https://doi.org/10.1007/s10120-018-0804-3.
[16] P.A. Clavien, J.R. Sanabria, S.M. Strasberg, Proposed classification of complications of surgery with examples of utility in cholecystectomy, Surg. 111 (1992) 518–526.
[17] D. Dindo, N. Demartines, P.A. Clavien, Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey, Ann. Surg. 240 (2004) 205–213.
[18] P.A. Clavien, J. Barkun, M.L. de Oliveira, J.N. Vauthey, D. Dindo, R.D. Schulick, et al., The Clavien-Dindo classification of surgical complications: five-year experience, Ann. Surg. 250 (2009) 187–196 https://doi.org/10.1097/SLA.0b013e3181b13ca2.
[19] W.J. Wang, H.T. Li, P. Chen, J.P. Yu, Z.Y. Jiao, X.P. Han, et al., A propensity score-matched comparison of laparoscopic distal versus total gastrectomy for middle-third advanced gastric cancer, Int. J. Surg. 60 (2018) 194–203 https://doi.org/10.1016/j.ijsu.2018.11.015.
[20] L.C. Duraes, L. Stocchi, S.R. Steele, M.F. Kalady, J.M. Church, E. Gorgun, et al., The relationship between clavien-dindo morbidity classification and oncologic outcomes after colorectal cancer resection, Ann. Surg. Oncol. 25 (2018) 188–196 https://doi.org/10.1245/s10434-017-6142-6.
[21] G. Rac, A. Greiman, A. Rabley, T.J. Tipton, L.R. Chiles, D.A. Freilich, et al., Analysis of complications of pelvic mesh excision surgery using the clavien-dindo classification system, J. Urol. 198 (2017) 638–643 https://doi.org/10.1016/j.juro.2017.04.078.
[22] R.A. Agha, M.R. Borrelli, M. Vella-Baldacchino, R. Thavayogan, D.P. Orgill, S. Group, The STROCSS statement: Strengthening the reporting of cohort studies in surgery, Int. J. Surg. 46 (2017) 198–202 https://doi.org/10.1016/j.ijsu.2017.08.586.
[23] S.F. Huang, T.H. Chien, W.L. Fang, F. Wang, C.Y. Tsai, J.T. Hsu, et al., The 8th edition American Joint Committee on gastric cancer pathological staging classification performs well in a population with high proportion of locally advanced disease, Eur. J. Surg. Oncol. 44 (2018) 1634–1639 https://doi.org/10.1016/j.ejso.2018.05.036.
[24] H., I. Solsky, B. Palis, M. Langdon-Embry, J. Ajani, T. Sano, Validation of the 8th edition of the AJCC TNM staging system for gastric cancer using the national cancer database, Ann. Surg. Oncol. 24 (2017) 3683–3691 https://doi.org/10.1245/s10434-017-6078-x.
[25] W.J. Wang, H.T. Li, J.P. Yu, L. Su, C.A. Guo, P. Chen, et al., Severity and incidence of complications assessed by the Clavien-Dindo classification following robotic and laparoscopic gastrectomy for advanced gastric cancer: a retrospective and propensity score-matched study, Surg. Endosc. 33 (2019) 3341–3354 https://doi.org/10.1007/s00464-018-06624-7.
[26] U. Benedetto, S.J. Head, G.D. Angelini, E.H. Blackstone, Statistical primer: propensity score matching and its alternatives, Eur. J. Cardiothorac. Surg. 53 (2018) 1112–1117 https://doi.org/10.1093/ejcts/ezy167.
[27] P.C. Austin, N. Jembere, M. Chiu, Propensity score matching and complex surveys, Stat. Methods Med. Res. 27 (2018) 1240–1257 https://doi.org/10.1177/0962280216658920.
[28] P.C. Austin, Assessing the performance of the generalized propensity score for estimating the effect of quantitative or continuous exposures on binary outcomes, Stat. Med. 37 (2018) 1874–1894 https://doi.org/10.1002/sim.7615.
[29] K. Hosoda, H. Mieno, A. Ema, H. Ushiku, M. Washio, I. Song, et al., Safety and feasibility of robotic distal gastrectomy for stage IA gastric cancer: a phase II trial, J. Surg. Res. 238 (2019) 224–231 https://doi.org/10.1016/j.jss.2019.01.049.
[30] I. Uyama, K. Suda, M. Nakauchi, T. Kinoshita, H. Noshiro, S. Takiguchi, et al., Clinical advantages of robotic gastrectomy for clinical stage I/II gastric cancer: a multi-institutional prospective single-arm study, Gastric Cancer 22 (2019) 377–385 https://doi.org/10.1007/s10120-018-00906-8.
[31] C. Mariette, S.R. Markar, T.S. Dabakuyo-Yonli, B. Meunier, D. Pezet, D. Collet, et al., Hybrid minimally invasive esophagectomy for esophageal cancer, N. Engl. J. Med. 380 (2019) 152–162 https://doi.org/10.1056/NEJMoa1805101.
[32] G.L. Baiocchi, S. Giacopuzzi, D. Marrelli, D. Reim, G. Piessen, P. Matos da Costa, et al., International consensus on a complications list after gastrectomy for cancer, Gastric Cancer 22 (2019) 172–189 https://doi.org/10.1007/s10120-018-0839-5.
[33] J. van Hilst, T. de Rooij, S. Klompmaker, M. Rawashdeh, F. Aleotti, B. Al-Sarireh, et al., Minimally invasive versus open distal pancreatectomy for Ductal adenocarcinoma (diploma): a pan-european propensity score matched study, Ann. Surg. 269 (2019) 10–17 https://doi.org/10.1097/SLA.0000000000002561.
[34] W.J. Hyung, H.K. Yang, S.U. Han, Y.J. Lee, J.M. Park, J.J. Kim, et al., A feasibility study of laparoscopic total gastrectomy for clinical stage I gastric cancer: a prospective multi-center phase II clinical trial, KLASS 03, Gastric Cancer 22 (2019) 214–222 https://doi.org/10.1007/s10120-018-0864-4.
[35] D. Stefanidis, S.B. Bailey, T. Kuwada, C. Simms, K. Gersin, Robotic gastric bypass may lead to fewer complications compared with laparoscopy, Surg. Endosc. 32 (2018) 610–616 https://doi.org/10.1007/s00464-017-5710-y.
[36] B. Lu, D. Cai, X. Tong, Testing causal effects in observational survival data using propensity score matching design, Stat. Med. 37 (2018) 1846–1858 https://doi.org/10.1002/sim.7599.
[37] J. Lu, H.L. Zheng, P. Li, J.W. Xie, J.B. Wang, J.X. Lin, et al., A propensity score-matched comparison of robotic versus laparoscopic gastrectomy for gastric cancer: oncological, cost, and surgical stress analysis, J. Gastrointest. Surg. 22 (2018) 1152–1162 https://doi.org/10.1007/s11605-018-3785-y.
[38] Y. Gao, H. Xi, Z. Qiao, J. Li, K. Zhang, T. Xie, et al., Comparison of robotic- and laparoscopic-assisted gastrectomy in advanced gastric cancer: updated short- and long-term results, Surg. Endosc. 33 (2019) 528–534 https://doi.org/10.1007/s00464-018-6327-5.
[39] M.H. Hyun, C.H. Lee, Y.J. Kwon, S.I. Cho, Y.J. Jang, D.H. Kim, et al., Robot versus laparoscopic gastrectomy for cancer by an experienced surgeon: comparisons of surgery, complications, and surgical stress, Ann. Surg. Oncol. 20 (2013) 1258–1265 https://doi.org/10.1245/s10434-012-2679-6.
[40] K.G. Lee, H.J. Lee, J.Y. Yang, S.Y. Oh, S. Bard, Y.S. Suh, et al., Risk factors associated with complication following gastrectomy for gastric cancer: retrospective analysis of prospectively collected data based on the Clavien-Dindo system, J. Gastrointest. Surg. 18 (2014) 1269–1277 https://doi.org/10.1007/s11605-014-2525-1.
[41] M. Ri, N. Hiki, N. Ishizuka, S. Ida, K. Kumagai, S. Nunobe, et al., Duodenal stump reinforcement might reduce both incidence and severity of duodenal stump leakage after laparoscopic gastrectomy with Roux-en-Y reconstruction for gastric cancer, Gastric Cancer. 22 (2019) 1053–1059 https://doi.org/10.1007/s10120-019-00946-8.
[42] C. Kunisaki, H. Miyamoto, S. Sato, Y. Tanaka, K. Sato, Y. Izumisawa, et al., Surgical outcomes of reduced-port laparoscopic gastrectomy versus conventional laparoscopic gastrectomy for gastric cancer: a propensity-matched retrospective cohort study, Ann. Surg. Oncol. 25 (2018) 3604–3612 https://doi.org/10.1245/s10434-018-6733-x.
[43] C.J. Huang, R.C. Zhang, Y.P. Mou, Y.C. Zhou, Y.Y. Wang, C. Lu, et al., Short and long-term outcomes of laparoscopic total gastrectomy for gastric cancer: a single-center experience (retrospective cohort study), Int. J. Surg. 51 (2018) 109–113 https://doi.org/10.1016/j.ijsu.2018.01.027.
[44] D.J. Kim, J.H. Lee, W. Kim, Comparison of the major postoperative complications between laparoscopic distal and total gastrectomies for gastric cancer using Clavien-Dindo classification, Surg. Endosc. 29 (2015) 3196–3204 https://doi.org/10.1007/s00464-014-4053-1.
[45] R.H. Tu, J.X. Lin, C.H. Zheng, P. Li, J.W. Xie, J.B. Wang, et al., Development of a nomogram for predicting the risk of anastomotic leakage after a gastrectomy for gastric cancer, Eur. J. Surg. Oncol. 43 (2017) 485–492 https://doi.org/10.1016/j.ejso.2016.11.022.
[46] J. Zhou, P. Yu, Y. Shi, B. Tang, Y. Hao, Y. Zhao, et al., Evaluation of Clavien-Dindo classification in patients undergoing total gastrectomy for gastric cancer, Med. Oncol. 32 (2015) 120 https://doi.org/10.1007/s12032-015-0573-3.
[47] M. Cho, T. Son, H.I. Kim, S.H. Noh, S. Choi, W.J. Seo, et al., Similar hematologic and nutritional outcomes after proximal gastrectomy with double-tract reconstruction in comparison to total gastrectomy for early upper gastric cancer, Surg. Endosc. 33 (2019) 1757–1768 https://doi.org/10.1007/s00464-018-6448-x.
[48] J.H. Kim, Y.J. Bae, K.H. Jun, H.M. Chin, The prevalence and clinical significance of postgastrectomy anemia in patients with early-stage gastric cancer: a retrospective cohort study, Int. J. Surg. 52 (2018) 61–66 https://doi.org/10.1016/j.ijsu.2018.02.037.
[49] F. Zhu, D. Feng, T. Zhang, L. Gu, W. Zhu, Z. Guo, et al., Toward a more sensitive endpoint for assessing postoperative complications in patients with inflammatory bowel disease: a comparison between Comprehensive complication index (CCI) and Clavien-Dindo classification (CDC), J. Gastrointest. Surg. 22 (2018) 1593–1602 https://doi.org/10.1007/s11605-018-3786-x.