Short-term Outcomes of Robotic- versus Laparoscopic-Assisted Total Gastrectomy for Advanced Gastric Cancer: A Propensity Score Matching Study

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Abstract
Background: Few studies have been designed to evaluate the short-term outcomes for advanced gastric cancer (AGC) between robotic-assisted total gastrectomy (RATG) and laparoscopy-assisted total gastrectomy (LATG) alone. The purpose of this study was to assess short-term outcomes of RATG compared with LATG for AGC. Methods: We retrospectively evaluated 116 and 244 patients who underwent RATG or LATG respectively. Besides, we performed a propensity score matching (PSM) analysis between RATG and LATG for clinicopathological characteristics to reduce bias and compared short-term surgical outcomes. Results: After PSM, the RATG group had longer operation time (291.09±58.41 vs. 271.99±48.41min, p=0.007), less intraoperative bleeding (151.98±92.83 vs. 172.59±97.01ml, p=0.032) and more N2 tier retrieved lymph nodes (RLNs) (9.33±5.46 vs. 7.50±3.86, p=0.018) than the LATG group. Besides, the total RLNs of RATG was more but not statistically significant compared to LATG (35.09±12.93 vs.32.34±12.05, p=0.062). However, no significant differences were found between the two groups in terms of length of incision, proximal resection margin, distal resection margin, postoperative hospital stay. The conversion rate was 4.92% and 8.61% in the RATG and LATG groups, respectively, with no significant difference (p=0.198). The ratio of splenectomy was 1.7% and 0.4% respectively (p=0.503). There was no significant difference in overall complication rate between RATG and LATG groups after PSM (24.1% vs. 33.6%; p=0.102)and the grade II complications accounted for most of all complications in the two cohorts. The mortality was 0.9% and 0% respectively (p=0.322). Conclusion: This study demonstrates that RATG is comparable to LATG in terms of short-term surgical outcomes.

Background
Gastric cancer (GC) is the fifth most common cancer and the third leading cause of cancer-related death worldwide[1]. Its incidence and mortality rates have been steadily declining since the middle of the 20th century all over the world [2, 3]. However, it is notable that the morbidity of esophagogastric junction cancer are increasing in the Western countries as well as in Eastern countries [2-5]. Total gastrectomy (TG) with adequate regional lymphadenectomy is the most common choice for the upper gastric cancer which included that in proximal third of the stomach and esophagogastric junction.
(EGJ) cancers (Siewert type II and III), or cancers located at lower two-thirds of the stomach to ensure a tumor-free surgical margin[6-8]. Since Kitano[9] reported laparoscopy gastrectomy (LG) in 1994 for the first time, laparoscopy-assisted gastrectomy has been widely used for gastric cancer because of its advantages over open gastrectomy, which include reduced invasiveness, less pain, faster recovery and shorter hospital stays as well as equal short-term and long-term outcomes[10-12]. Despite its technical difficulty, laparoscopy-assisted total gastrectomy (LATG) has been proved feasible technically and is superior to open total gastrectomy performed by experienced surgeons in terms of its safety and short-term outcomes[13, 14]. In 2002, Hashizume reported robotic-assisted gastrectomy for the first time[15]. Since then, robotic surgery has been demonstrated to obtain similar or even better anatomical and operative conditions compared to traditional laparoscopic approach during gastric resection[16-20]. Regrettfully, most of the reported cases were [21, 22], while few literatures compared robotic-assisted total gastrectomy (RATG) with LATG alone for advanced gastric cancer (AGC) retrospectively[20, 23]. The aim of this study is to evaluate the feasibility and safety of RATG and LATG for AGC using the PSM method.

Methods

Patients

Patients diagnosed with GC by means of gastroscopy, biopsy and histopathological assessment who underwent total gastrectomy were screened from the prospectively maintained gastric cancer database at the Department of General Surgery, Southwest Hospital, Army Medical University from March 2010 to December 2017. Data of 573 consecutive patients who underwent RATG or LATG for gastric cancer were collected. Inclusion criteria of the study were defined as follows: (1) An age between 18 to 80 years old; (2) Radical surgery; (3) No preoperative chemotherapy or radiation therapy performed before surgery; (4) Depth of invasion confined to pT2, pT3, or pT4a; (5) No distant metastasis or invasion to adjacent organs; (6) Receiving LATG or RATG with D2 lymphadenectomy; and (7) R0 resection. Patients who underwent RATG were matched to those who underwent LATG at a 1:1 ratio by using a propensity score matching (PSM) method to reduce the effect of bias due to the imbalanced clinic-pathological features of the two groups. The matched variables included age,
gender, body mass index (BMI), American Society of Anesthesiologists grade (ASA), T stage, N stage, Tumor-Node-Metastasis classification (TNM), tumor size, tumor location, Borrmann type, differentiation and comorbidity. Postoperative complications were recorded and classified according to the Clavien-Dindo classification system [24, 25]. Pathological and clinical staging was determined based on the AJCC Cancer Staging Manual (Eighth Edition)[26].

**Operation Procedures**

All patients underwent standard radical total gastrectomy with D2 lymphadenectomy according to the Guidelines of the Japanese Gastric Cancer Association[7, 27]. The da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA) was used as the robotic tool for all patients in the robotic group. During RATG five surgical ports were inserted in the upper abdomen as we previously described[16]. The detailed gastrectomy and lymph node dissections during the RATG procedures did not differ from those during the LATG procedures except for the use of the articulating robotic instruments. After finishing the lymph node (LN) dissection, the robotic arms were then undocked and withdrawn. We conducted Roux-en-Y reconstruction to rebuild the digestive tract both in the RATG and LATG surgeries mostly through a 6-8cm upper abdominal incision as we previously described[16]. When conducting the esophagojejunostomy, the esophagus was transected with an anvil in it and then the Roux-en-Y limb was brought up to complete an esophagojejunostomy, using a 25-mm circular stapler, while the jejunal stump was closed and side-to-side jeunojejunostomy was established both using an endoscopic linear stapler[16]. Whether to reinforce the anastomoses or the duodenal stump depended on the operators’ judgement during surgeries and two drainage tubes were placed under the liver and besides the spleen respectively. All patients were informed of the advantages and disadvantages of RATG and LATG and then an informed consent was signed before surgery by the patients themselves or their legal representatives. The surgeries were performed by five experienced surgeons who received robotic surgery certification and had performed robotic gastrectomy (RG) with D2 lymphadenectomy in more than 30 cases. RATG and LATG were compared by evaluating the surgical performance and postoperative short-term clinical outcomes, including the operation time, estimated blood loss, proximal resection margin, distal resection margin and numbers of retrieved
lymph nodes (RLNs), postoperative complications and length of postoperative hospital stay.

**Statistical analysis**

SPSS version 22.0 for Windows (IBM Corp., Armonk, NY) was used for statistical analysis. R version 3.5.2 for windows was used for PSM by using its MatchIt package. The independent sample t test, Mann–Whitney test and the Chi-square test were used for continuous variables or categorical variables. Data for continuous variables were presented as mean ± standard deviation (SD). A value of p<0.05 was considered statistically significant, and all p values were two-sided.

**Results**

**Clinicopathologic characteristics**

A total of 184 patients were excluded based on the following criteria: patients over 80 years old (n=3), having early gastric cancer (n=33), and receiving palliative surgery (n=75), neoadjuvant chemotherapy before surgery (n=21), combined organ resection (n=23), D3 lymphadenectomy (n=5), and R1 resection (n=24). The statistical analyses were performed in the remaining 389 patients undergoing radical total gastrectomy, of whom 122 underwent RATG, and 267 underwent LATG (Fig. 1). Finally, the study cohort comprised 116 patients who underwent RATG and 116 matched LATG patients after PSM. The patients’ clinicopathological characteristics before and after PSM are summarized in Table 1. The patients in the two groups before PSM were generally matched with no significant differences (p>0.05) in age, gender, BMI, ASA, Borrmann type, N stage, TNM stage, or medical comorbidities (such as diabetes, hypertension, heart disease and contagious disease) except T stage and tumor differentiation (p<0.05). However, those biases were reduced after PSM and the clinicopathological characteristics were well matched between the two groups.

**Short-term surgical outcomes for the cohorts**

Postoperative clinical outcomes before and after PSM are detailed in Table 2. Before PSM, the RTAG group had longer mean operation time (291.09±58.41 vs. 271.16±49.16min, p=0.001), less intraoperative bleeding (151.98±92.83 vs. 175.53±106.58ml, p=0.007), more total RLNs (35.09±12.93 vs. 31.73±12.33, p=0.014), and more N2 tier RLNs (9.33±5.46 vs. 7.50±4.50, p=0.001) than the LATG group. After PSM, the RTAG group still had longer mean operation time (291.09±58.41
vs. 271.99±48.41min, p=0.007), less intraoperative bleeding (151.98±92.83 vs. 172.59±97.01ml, p=0.032) and more N2 tier RLNs (9.33±5.46 vs. 7.50±3.86, p=0.018) than the LATG group. Besides, the total RLNs of RATG was at the brink of significance compared to LATG (35.09±12.93 vs.32.34±12.05, p=0.062). However, no significant differences were found between the two groups in terms of length of incision, proximal resection margin, distal resection margin, postoperative hospital stay.

Six patients underwent conversion to laparotomy in robotic group and 23 in laparoscopic group (4.92% vs. 8.61%; p=0.198). In robotic group, 2 patients encountered uncontrollable bleeding, 2 caused by tight adhesions and 2 encountered the left gastric artery surrounded by lymph nodes. In the laparoscopic group, 12 encountered tight adhesion, 4 encountered left gastric artery surrounded by lymph nodes, 2 caused by enlarged lymph nodes, 1 caused by tumor surround artery, 2 caused by giant tumor, 1 encountered bleeding of short gastric vessel, and the last one encountered mechanical failure of the stapler. Furthermore, two patients underwent splenectomy in robotic group and one underwent this in laparoscopic group because of the tight adhesion of spleen hilum (1.7% vs. 0.4%; p=0.503).

The postoperative complications before and after PSM were shown in Table 3. One patient in RATG died of MODS after anastomotic leakage who also received a second surgical procedure. There was no significant difference in overall complication rate between RATG and LATG groups before PSM (24.1% vs. 28.7%; p=0.341) and after PSM (24.1% vs. 33.6%; p=0.102). The grade II complications accounted for most of all complications in the two cohorts both before and after PSM. Moreover, no significant differences were noted in the major complication (Clavien-Dindo grade ≥IIIa) among all complications between the two cohorts before PSM (5.2% vs. 8.2%; p=0.300) and after PSM (5.2% vs. 9.5%; p=0.208).

**Stratified analysis of different related factors**

We evaluated the surgical outcomes of patients according to different related factors, including tumor location, BMI, tumor size and age. The surgical outcomes of subgroup analyses were summarized in Tables 4–7. Subgroup analysis of tumor location (Table 4) suggested that RATG have less blood loss
compared to LATG when tumor located at esophagogastric junction. In addition, RATG had a lower incidence of postoperative complications and shorter postoperative hospitalization days when tumor located at non esophagogastric junction. As shown in Table 5, RATG had longer operation time, more intraoperative blood loss and less RLNs compared to LATG for low BMI patients. Subgroup analysis of tumor size measured by resection specimen suggested that RATG had longer operation time, less intraoperative blood loss and numbers of N2 tier of RLNs compared with LATG in patients with tumor size smaller than 5cm, while there was no significant difference between the two groups in patients with tumor size bigger than 5cm (Table 6). While, it indicated that the postoperative complication rate of patients older than 65 year-old was higher than that of patients younger than 65 year-old (Table 7).

Discussion

It was well known that total gastrectomy combined with complete D2 lymphadenectomy and esophagojejunostomy was a technically difficult procedure compared to distal gastrectomy for more lymph node dissection [12]. Nonetheless, we have described our experience with LATG in the treatment of AGC in 2013, which indicated that LATG was a feasible and safe alternative to standard open gastric resection with similar short-term and long-term results [28]. When it comes to RATG, Yoon et al. and Son et al. both reported comparable short-term surgical and oncologic outcomes between RATG and LATG, and yet the EGC patients accounted for a large percentage in their studies[21, 22]. Current studies mostly compared RATG with LATG with the aim to present surgical outcomes of EGC or conducted a stratified analysis when compared the two surgical procedures together with distal gastrectomy. Ye’s study, a total of 205 patients of AGC who under RATG or LATG, reported that RATG had longer operation time, more RLNs, less operative blood loss and volume of abdominal drainage compared to LATG, the complication rate was also comparable (7.5% vs.9.1%, p=0.915)[23]. To the best of our acknowledge, our study firstly reported the short-term outcomes of RATG compared with LATG for AGC using the PSM method to reduce bias.

Generally, robotic gastrectomy was known to have some advantages over laparoscopic surgery in reducing perioperative bleeding[16, 23, 29]. In our study, we also concluded that robotic surgery can reduce intraoperative bleeding compared to laparoscopic surgery before PSM (151.98±92.83 vs.
175.53±106.58ml, p=0.007), and after PSM (151.98±92.83 vs. 172.59±97.01ml, p=0.032). Although we have confirmed that RATG can significantly reduce intraoperative bleeding in both cohorts, the mean difference of approximate 20mL blood loss between the two minimal invasive groups may not make much clinical benefit for every individual patient. However, the present study demonstrated that the operative time of RATG was significantly longer than that of LATG before and after PSM, which was consistent with the previous studies[21-23]. The docking time of robot arms, the time for arm change during clipping, and the lack of experience of the assistants may explain the longer operative time[21]. The docking time of robotic surgeries was between 20 and 60 min as reported in a meta-analysis[30]. Since, all of our surgeons had performed RG for more than 30 cases, which means that docking time mainly accounts for the prolonged operating time. Hence, the extra time spent in our study (approximately 20 min) for robotic surgery could be acceptable as docking time was inevitable.

D2 lymphadenectomy is an indispensable process for the application of minimally invasive surgery for AGC[31]. Or rather, the dissection of N2 area is the most crucial part of lymphadenectomy. It has been reported that robotic surgery could retrieve more dissected lymph nodes, especially in the technically demanding N2 area especially in the suprapancreatic area and the splenic vessels[32]. Besides, Son et al. found that robotic spleen-preserving total gastrectomy could retrieve more LNs around splenic vessels and hilum than laparoscopy, and they even compared each group and the metastasis of them[22]. At the same time, subgroup analysis of a meta-analysis revealed that the number of RLNs of RG was significantly higher than that of LG (p=0.03)[30]. Our study also concluded that RATG can retrieve more N2 tier (p=0.001 vs. p=0.018), compared with LATG both before and after PSM. Nevertheless, the difference of RLNs between the two methods was not much clinically significant. Moreover, the study by Shen et al. which included 23 robotic and 75 laparoscopic total gastrectomy reported that RAG and LAG groups had no significant difference in the number of harvested lymph nodes[29]. Li et al. found in their stratified analysis of 92 patients after PSM that the average number of RLNs was not significantly different between robotic and laparoscopic total gastrectomy (30.6 vs. 32.0; p=0.406)[33]. Therefore, it was still controversial whether RATG can
retrieve more lymph nodes. According to our experience, the advantage of RG was that the assistant arm could steadily pull the stomach and omentum to the opposite side of abdominal cavity to ensure a roomy operation field which made the dissection of No.2, 10, 11p, 11d more easily than LG. Besides, RG had advantages of articulated movement, elimination of physiologic tremor, a three-dimensional view and a steady image. These merits contributed to precise dissection around the vessels which could result in a large number of RLNs[31]. Taking all those into account, we still hold the view that RATG was capable of retrieving more lymph nodes than LATG because of its advantages. However, further studies of RATG, especially RCTs, should be conducted to confirm our view.

Postoperative complication was an important factor to evaluate the safety and feasibility of a surgical procedure. We evaluated the postoperative complications according the Clavien-Dindo classification system, which was applicable in most parts of the world and among different surgeons, centers, and therapies[24]. Previous studies have proved that the complication rate of laparoscopic total gastrectomy varied from 9.1% to 34.6% [14, 21-23, 33, 34]. In the current study, the complication rate of the RATG group was not significantly different from that of LATG group before PSM (24.1% vs. 28.7%; p=0.341) and after PSM (24.1% vs. 33.6%; p=0.102). The complication of gradeⅠand Ⅲa in LATG group were higher after PSM which made the complication rate up to 33.6% and verged on being significant (p=0.102). Not surprisingly, pulmonary complications obviously accounted for most of the complications in this study. Upper abdominal surgery combined with pneumoperitoneum and postoperative pain would affect the activity of diaphragm and led to micro-atelectasis which causes pulmonary dysfunction in return. More important, TG was an independent risk factor for pulmonary complications[35]. Moreover, anastomosis complications were considered to be one of the most serious complications after TG, which would result in poorer quality of life, prolonged hospital stay, and increased surgery-related costs and mortality[36]. We performed esophagojejunal anastomoses mostly extracorporeally and rarely intracorporeally. The extracorporeal surgical procedures had been described previously [37] and the intracorporeal method used liner stapler or hand-sewn to complete the anastomoses. The Japanese National Clinical Database (NCD) of digestive surgery reported that
the incidence of anastomotic leakage after total gastrectomy was 4.4% (881 of 20011) in 2011[38].

Of all the 360 patients included in the analysis, 5 patients in RATG and 10 in LATG encountered anastomosis-related complications (4.3% vs.4.1%; p=0.925, OR=1.054, 95%CI: 0.352-3.157). The anastomosis-related complications in the present study were slightly less than those in the previous studies. Besides, the severe complication (Clavien-Dindo grade ≥IIIa) rate was also comparable between the two cohorts.

Since total gastrectomy was the most common choice for the upper gastric cancer which included tumors in proximal third of the stomach and EGJ cancers [6-8], we conducted another analysis by grouping the patients according to tumor location. RATG for tumor located at EGJ has a tendency to shorter operative time, less intraoperative bleeding and more RLNs compared to the non-EGJ group. However, all those differences may be attributed to that the EGJ group has smaller tumor size which making it easier to perform surgery. As we have already mentioned above that RG can manage the fundus of stomach and esophageal hiatus easier than LG on account of its merits. In spite of not much statistical significance, RATG has an advantage dealing EGJ cancer compared with LATG in our view combining with specific surgical experience.

However, this study has several limitations. First, results were based on a retrospective analysis from a single-clinic institution. Second, the present study lacks a detailed comparative analysis of cost-effectiveness and gastrointestinal function recovery index between robotic and laparoscopic gastric surgery because this is a retrospective study. Third, although the five surgeons who perform the surgeries received robotic surgery certification and were experienced in both the two minimal invasive surgeries, different surgeons can still cause some bias and further influence the results.

Despite this study has some limitations, our findings provide evidence for minimal invasive surgery of total gastrectomy for AGC. In addition, further well designed studies, especially RCTs or prospective trials, are needed to assess the impact of RATG and LATG.

Conclusions
This retrospective study demonstrates that RATG is comparable to LATG in terms of short-term surgical outcomes. With longer operation time, less estimated blood loss, more RLNs and relatively
lower complication rate after PSM, RATG is a safe, reliable and promising approach compared with LATG for the treatment of AGC. Moreover, well-designed and randomized controlled trials are needed to further compare RATG with LATG.

List Of Abbreviations

AGC  Advanced gastric cancer

RATG  Robotic-assisted total gastrectomy

LATG  Laparoscopy-assisted total gastrectomy

PSM  Propensity score matching

RLNs  Retrieved lymph nodes

GC  Gastric cancer

TG  Total gastrectomy

LG  Laparoscopy gastrectomy

EGJ  Esophagogastric junction

EGC  Early gastric cancer

BMI  Body mass index

ASA  American Society of Anesthesiologists grade

TNM  Tumor-Node-Metastasis classification

AJCC  American Joint Committee on Cancer

LN  Lymph node

RG  Robotic gastrectomy

SD  standard deviation

NCD  National Clinical Database

Declarations

Ethics approval and consent to participate: This study was approved by the Ethics Committee of the First Affiliated Hospital of Army Medical University (Ethical number: KY201869).

Consent for publication: Not applicable.

Availability of data and materials: The datasets used and analyzed during the current study are
available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: CY and YS analyzed and interpreted the patient data and CY was a major contributor in writing the manuscript. SY and JC collected and collated data. YS, YZ, FQ, YH, and BT performed the surgeries, PY designed and been responsible for the article. All authors read and approved the final manuscript.

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Tables

*Table 1* Clinicopathological characteristics

RATG=Robotic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, PSM=Propensity Score Matching, SD=Standard Deviation, BMI=body mass index, ASA=American Society of Anesthesiologists, TNM=tumor-node-metastasis, G1/G2/G3=High/Middle/Low or Mucus differentiation, Comorbidities (0/1/2/3) = no/one/two/three comorbidities, Y=Yes, N=No.

*Table 2* Comparison of surgical outcomes and postoperative
| Variables                                      | All Patients | LATG(n=244) | $p$ | Patients after PSM | RATG(n=116) |
|------------------------------------------------|--------------|-------------|-----|--------------------|-------------|
| Age, year (mean ± SD)                          | 60.01±9.00   | 58.21±10.32 | 0.086 | 60.01±9.00         |             |
| Sex (male/female)                              | 96/20        | 190/54      | 0.283 | 96/20              |             |
| Height, cm (mean ± SD)                         | 163.29±6.64  | 162.72±7.16 | 0.542 | 163.29±6.64        |             |
| Weight, Kg (mean ± SD)                         | 58.83±8.31   | 59.68±9.38  | 0.262 | 58.83±8.31         |             |
| BMI, Kg/m$^2$ (mean ± SD)                      | 22.02±2.52   | 22.48±2.89  | 0.121 | 22.02±2.52         |             |
| ASA (Ⅰ/Ⅱ/Ⅲ)                                   | 82/31/3      | 176/64/4    | 0.742 | 82/31/3            |             |
| Tumor size, cm (mean ± SD)                     | 4.66±2.26    | 4.51±2.12   | 0.585 | 4.66±2.26          |             |
| Tumor location                                 |              |             | 0.316 |                   |             |
| Siewert type Ⅱ                                 | 25           | 57          |      | 25                 |             |
| Siewert type Ⅲ                                 | 27           | 66          |      | 27                 |             |
| Body                                           | 64           | 121         |      | 64                 |             |
| Borrmann type Ⅰ/Ⅱ/Ⅲ/Ⅳ                         | 3/11/91/11   | 11/27/196/10| 0.078 | 3/11/91/11         |             |
| Depth of infiltration (T)                      |              |             | 0.029 |                   |             |
| T2                                             | 7            | 36          |      | 7                  |             |
| T3                                             | 2            | 3           |      | 2                  |             |
| T4a                                            | 107          | 205         |      | 107                |             |
| Nodal status (N)                                |              |             | 0.375 |                   |             |
| N0                                             | 28           | 62          |      | 28                 |             |
| N1                                             | 27           | 43          |      | 27                 |             |
| N2                                             | 26           | 42          |      | 26                 |             |
| N3a                                            | 19           | 59          |      | 19                 |             |
| N3b                                            | 16           | 38          |      | 16                 |             |
| TNM stage                                      |              |             | 0.683 |                   |             |
| IB                                             | 3            | 23          |      | 3                  |             |
| ⅠA                                            | 6            | 7           |      | 6                  |             |
| ⅠB                                            | 23           | 42          |      | 23                 |             |
| ⅡA                                            | 49           | 78          |      | 49                 |             |
| ⅡB                                            | 19           | 56          |      | 19                 |             |
| ⅢC                                            | 16           | 38          |      | 16                 |             |
| Differentiation                                |              |             | 0.008 |                   |             |
| G1/G2/G3                                       | 0/28/88      | 1/92/151    |      | 0/28/88            |             |
| Comorbidities (0/1/2/3)                        | 83/22/5/6    | 163/51/24/6| 0.380 | 83/22/5/6          |             |
| Abdominal surgery history (Y/N)                | 5/111        | 24/220      | 0.072 | 5/111              |             |
| Variables                        | All Patients                                                                 | Patients after PSM |                  |                  |
|---------------------------------|-------------------------------------------------------------------------------|--------------------|------------------|------------------|
|                                 | RATG (n=116)                    | LATG (n=244)       | \( p \)          | RATG (n=116)     |                  |
| Operation time, min             | 291.09±58.41                    | 271.16±49.16       | 0.001            | 291.09±58.41     | 2                |
| (mean ± SD)                     |                                |                    |                  |                  |
| Bleeding, ml (mean ± SD)        | 151.98±92.83                    | 175.53±106.58      | 0.007            | 151.98±92.83     | 1                |
| Retrieved lymph nodes           | 35.09±12.93                     | 31.73±12.33        | 0.014            | 35.09±12.93      | 3                |
| (mean ± SD)                     |                                |                    |                  |                  |
| N1 tier (mean ± SD)             | 25.76±10.31                     | 24.23±10.14        | 0.140            | 25.76±10.31      | 2                |
| N2 tier (mean ± SD)             | 9.33±5.46                       | 7.50±4.50          | 0.001            | 9.33±5.46        | 7                |
| Length of incision, cm          | 6.30±1.53                       | 6.33±1.73          | 0.527            | 6.30±1.53        | 6                |
| (mean ± SD)                     |                                |                    |                  |                  |
| Proximal margin, cm             | 3.58±1.72                       | 3.67±1.44          | 0.679            | 3.58±1.72        | 3                |
| (mean ± SD)                     |                                |                    |                  |                  |
| Distal margin, cm               | 7.16±3.78                       | 7.63±3.84          | 0.101            | 7.16±3.78        | 7                |
| (mean ± SD)                     |                                |                    |                  |                  |
| Postoperative hospital stay, d  | 9.45±2.67                       | 9.96±4.07          | 0.759            | 9.45±2.67        | 1                |
| (mean ± SD)                     |                                |                    |                  |                  |

RATG=Robotic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy,
PSM = Propensity Score Matching, SD = Standard Deviation.

**Table 3 Postoperative morbidity and mortality**

| Variables                        | All Patients | Patients after PSM |
|----------------------------------|--------------|--------------------|
|                                  | RATG (n=116) | LATG (n=244) | p         | RATG (n=116) |
| Present/absent                   | 28/89 (24.1%) | 70/174 (28.7%) | 0.341    | 28/89 (24.1%) |

Clavien-Dindo Classification

| I                                |            |          |          |            |
|                                  | 3 (2.6%)   | 11 (4.5%) | 0.555    | 3 (2.6%)   |
| Wound problem                    | 2           | 5         |          | 2           |
| Fever                            | 1           | 5         |          | 1           |
| Cardiac dysfunction              | 0           | 2         |          | 0           |
| Diarrhea                         | 0           | 2         |          | 0           |
| Chylous leakage                  | 0           | 1         |          | 0           |

| II                               |            |          |          |            |
|                                  | 19 (16.4%)  | 39 (16.0%) | 0.924    | 19 (16.4%)  |
| Fever                            | 5           | 3         |          | 5           |
| Wound infection                  | 0           | 1         |          | 0           |
| Intra-abdominal infection        | 2           | 7         |          | 2           |
| Condition                        | Illa | Illb | Significance | Illb |
|---------------------------------|------|------|--------------|------|
| Intestinal obstruction          | 1    | 0    | 1            | 1    |
| Catheter infections             | 4    | 1    | 4            |      |
| Pulmonary infection             | 7    | 19   | 7            |      |
| Pulmonary atelectasis           | 0    | 4    | 0            |      |
| Pleural effusion                | 2    | 10   | 2            |      |
| Anastomotic leakage             | 1    | 6    | 1            |      |
| Anastomotic stenosis            | 2    | 1    | 2            |      |
| Intra-abdominal bleeding        | 1    | 0    | 1            |      |
| Duodenal stump leakage          | 0    | 2    | 0            |      |
| Cardiac dysfunction             | 0    | 2    | 0            |      |
| Wound problem                   | 0    | 2    | 0            |      |
| Duodenal stump leakage          | 1    | 0    | 1            |      |
| Anastomotic leakage             | 0    | 3    | 0            |      |
| Pleural effusion                | 1    | 6    | 1            |      |
| Pyothorax                       | 0    | 1    | 0            |      |
| Intra-abdominal infection       | 0    | 5    | 0            |      |
| **Illia**                       | **2(1.7%)** | **9(3.7%)** | **0.494** | **2(1.7%)** |
| **Illb**                        | **2(1.7%)** | **4(1.6%)** | **1.000** | **2(1.7%)** |
| Condition                              | RATG | LATG | p-value | LATG |
|---------------------------------------|------|------|---------|------|
| Intra-abdominal bleeding               | 1    | 1    |         | 1    |
| Anastomotic bleeding                   | 0    | 1    |         | 0    |
| Duodenal stump leakage                 | 0    | 1    |         | 0    |
| Anastomotic leakage                    | 1    | 1    |         | 1    |
| IVa                                    | 1(0.9%) | 4(1.6%) | 0.915 | 1(0.9%) |
| Respiratory failure                    | 1    | 3    |         | 1    |
| Cardiac failure                        | 0    | 1    |         | 0    |
| IVb                                    | 0(0%) | 3(1.2%) | 0.554 | 0(0%) |
| MODS                                   | 0    | 3    |         | 0    |
| V                                      | 1(0.9%) | 0(0%) | 0.322 | 1(0.9%) |
| Clavien-Dindo grade≥IIIa               | 6(5.2%) | 20(8.2%) | 0.300 | 6(5.2%) |
| Mortality                              | 1(0.9%) | 0    | 0.322  | 1(0.9%) |

RATG=Robotic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, PSM=Propensity Score Matching, MODS= Multiple Organ Dysfunction Syndrome

Comparison of the 2 surgical methods between different tumor location after PSM
|                                | Location EGJ | Location non-EGJ | p   | Location non-EGJ |
|--------------------------------|--------------|------------------|-----|------------------|
| Age                            | 61.33±8.63   | 61.79±6.93       | 0.680 | 58.94±9.22       |
| Sex (male/female)              | 44/8         | 48/8             | 0.872 | 52/12            |
| BMI (kg/m²)                    | 22.84±2.43   | 22.43±2.89       | 0.416 | 21.36±2.41       |
| Tumor size (cm)                | 3.64±1.48    | 4.07±1.61        | 0.245 | 5.48±2.45        |
| TNM (IB/IIA/IIB/IIBA/IIBB/IIBC) | 2/1/11/25/10/3 | 1/0/13/23/16/3  | 0.824 | 1/5/12/24/9/13 |
| Comorbidities (present/absent) | 16/36        | 11/45            | 0.182 | 17/47            |
| Operation time (min)           | 283.88±50.10 | 270.61±44.94     | 0.150 | 296.94±64.17     |
| Estimated blood loss (ml)      | 128.08±58.11 | 156.52±72.91     | 0.016 | 171.41±110.18    |
| No. of N2 tier                 | 9.13±5.00    | 7.36±3.90        | 0.105 | 9.48±5.85        |
| No. of Retrieved lymph nodes   | 35.65±12.79  | 33.54±14.29      | 0.241 | 34.63±13.13      |
| Proximal margin (cm)           | 2.11±1.02    | 2.69±1.09        | 0.005 | 4.78±1.13        |
| Postoperative complication (%)  | 16(30.8)     | 12(22.4)         | 0.268 | 12(19.7)         |
| Clavien-Dindo grade ≥IIa (%)   | 4(7.7)       | 2(3.6)           | 0.607 | 2(3.1)           |
| Postoperative hospital stay (d) | 9.52±2.21    | 9.20±2.58        | 0.296 | 9.39±3.01        |

RATG=Robotic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, BMI=body mass index, TNM=tumor-node-metastasis, EGJ=esophagogastric junction.
Comparison of the 2 surgical methods between different BMI after PSM

|                        | BMI≥25 kg/m² | BMI<25 kg/m² |
|------------------------|--------------|--------------|
|                        | RATG(n=13)   | LATG(n=16)   | p       | RATG(n=103) | LATG(n=100) | p        |
| Age                    | 65.31±4.48   | 60.94±6.03   | 0.165   | 59.34±9.22  | 60.18±9.73  | 0.105    |
| Sex(male/female)       | 13/0         | 14/2         | 0.488   | 83/20       | 82/18       | 0.013    |
| Tumor size (cm)        | 3.42±1.51    | 4.59±1.75    | 0.103   | 4.82±2.30   | 4.62±2.32   | 0.431    |
| Tumor location(non-EGj/EGj) | 4/9         | 7/9         | 0.740   | 60/43       | 53/47       | 0.451    |
| TNM(IB/IIA/IIB/IIB/IIIC) | 0/0/3/7/2/1 | 1/0/4/8/2/1 | 0.303   | 3/6/20/42/17/15 | 2/0/23/37/29/9 | 0.447 |
| Comorbidities(present/absent) | 6/7         | 8/8         | 1.000   | 27/76       | 31/69       | 0.729    |
| Operation time(min)    | 314.54±68.25 | 288.56±43.27 | 0.223   | 288.13±56.74 | 269.34±48.8 | 0.015    |
|                                | RATG (n=13) | LATG (n=16) | p   | RATG (n=103) | LATG (n=100) | p   |
|--------------------------------|-------------|-------------|-----|-------------|--------------|-----|
| BMI ≥ 25 kg/m²                 | 65.31±4.48  | 60.94±6.03  | 0.165| 59.34±9.22  | 60.18±9.73   | 0.6 |
| BMI < 25 kg/m²                 | 66.48±5.45  | 64.56±5.33  | 0.922| 63.85±4.96  | 63.85±4.96   | 1   |

- Estimated blood loss (ml): 186.15±112.36 vs. 193.44±94.25
- No. of N2 tier: 6.54±2.63 vs. 6.63±3.18
- No. of Retrieved lymph nodes: 29.54±12.59 vs. 33.69±14.65
- Proximal margin (cm): 2.65±1.75 vs. 3.88±1.67
- Postoperative complication (%): 5(38.5) vs. 6(37.5)
- Clavien-Dindo grade ≥ IIIa (%): 2(15.4) vs. 4(25.0)
- Postoperative hospital stay (d): 9.92±2.18 vs. 10.81±5.02

The table compares the results of two groups, RATG and LATG, for various parameters. The p-values indicate the statistical significance of the differences between the two groups.
|                          | Value 1 | Value 2 | p-value | Value 3 | Value 4 | p-value |
|--------------------------|---------|---------|---------|---------|---------|---------|
| Sex (male/female)        | 13/0    | 14/2    | 0.488   | 83/20   | 82/18   | 0.488   |
| Tumor size (cm)          | 3.42±1.51 | 4.59±1.75 | 0.103   | 4.82±2.30 | 4.62±2.30 | 0.796   |
| Tumor location (non-EG/EGJ) | 4/9    | 7/9    | 0.740   | 60/43   | 53/47   | 0.103   |
| TNM (IB/IIA/IIB/IIIA/IIIB/IIIC) | 0/0/3/7/2/1 | 1/0/4/8/2/1 | 0.303   | 3/6/20/42/17/15 | 2/0/23/37/29/9 | 0.431   |
| Comorbidities (present/absent) | 6/7    | 8/8    | 1.000   | 27/76   | 31/69   | 0.000   |
| Operation time (min)     | 314.54±68.25 | 288.56±43.27 | 0.223   | 288.13±56.74 | 269.34±48.8 | 0.506   |
| Estimated blood loss (ml) | 186.15±112.36 | 193.44±94.25 | 0.214   | 147.67±89.79 | 169.25±97.4 | 0.559   |
| No. of N2 tier           | 6.54±2.63 | 6.63±3.18 | 0.559   | 9.68±5.63 | 7.64±3.95 | 0.506   |
| No. of Retrieved lymph nodes | 29.54±12.59 | 33.69±14.65 | 0.506   | 35.79±12.87 | 32.12±11.6 | 0.506   |
|                          | Robotic-assisted total gastrectomy | Laparoscopic-assisted total gastrectomy | P-value |
|--------------------------|-----------------------------------|----------------------------------------|---------|
| Proximal margin (cm)     | 2.65±1.75                         | 3.88±1.67                              | 0.009   |
|                          | 3.70±1.68                         | 3.58±1.38                              |         |
| Postoperative complication | 5(38.5)                           | 6(37.5)                                | 1.000   |
|                          | 23 (22.3)                         | 33 (33.0)                              |         |
| Clavien-Dindo grade ≥IIIa (%) | 2(15.4)                           | 4(25.0)                                | 0.861   |
|                          | 4(3.9)                            | 7(7.0)                                 |         |
| Postoperative hospital stay (d) | 9.92±2.18                         | 10.81±5.02                             | 0.597   |
|                          | 9.39±2.73                         | 9.95±3.78                              |         |

RATG=Robotic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, BMI=body mass index, TNM=tumor-node-metastasis, EGJ=esophagogastric junction

**Comparison of the 2 surgical methods between different tumor size after PSM**
|                                | Size≥5cm | Size<5cm | p    |
|--------------------------------|----------|----------|------|
| **RATG (n=53)**                | LATG (n=46) | p | **RATG (n=63)** |
| **Age**                        | 61.58±8.38 | 59.48±9.94 | 0.435 | 58.68±9.36 |
| **Sex (male/female)**          | 43/10 | 37/9 | 0.930 | 53/10 |
| **BMI (kg/m²)**                | 21.76±2.38 | 22.31±3.04 | 0.310 | 22.25±2.63 |
| **Tumor location (non-EGJ/EGJ)** | 37/16 | 29/17 | 0.476 | 27/36 |
| **TNM (IB/IIA/II B/II A/II B/II C)** | 3/2/8/20/9/11 | 0/0/9/15/15/7 | 0.458 | 0/4/15/29/10/5 |
| **Comorbidities (present/absent)** | 17/36 | 15/31 | 0.955 | 16/47 |
| **Operation time (min)**       | 288.26±57.17 | 276.15±45.02 | 0.270 | 293.46±59.78 |
| **Estimated blood loss (ml)**  | 158.30±76.86 | 175.98±106.70 | 0.625 | 146.67±104.72 |
| **No. of N2 tier**             | 8.70±4.74 | 8.61±4.01 | 0.927 | 9.86±5.99 |
| **No. of Retrieved lymph nodes** | 36.17±12.72 | 34.26±10.71 | 0.356 | 34.17±13.15 |
| **Proximal margin (cm)**       | 3.98±1.63 | 3.97±1.34 | 0.774 | 3.25±1.72 |
| **Postoperative complication (%)** | 15(29.3) | 17(37.0) | 0.358 | 13(20.6) |
| **Clavien-Dindo grade ≥IIIa (%)** | 2(3.8) | 4(8.7) | 0.548 | 4(6.3) |
| **Postoperative hospital stay (d)** | 9.55±2.02 | 10.70±3.64 | 0.333 | 9.37±3.13 |

- RATG=Robotic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, BMI=body mass index, TNM=tumor-node-metastasis, EGJ=esophagogastric junction.
Comparison of the 2 surgical methods between different age after PSM
|                                | Age≥65 |       | p     | Age<65 |
|--------------------------------|--------|-------|-------|--------|
|                                | RATG(n=42) | LATG(n=41) |       | RATG(n=74) |
| Sex (male/female)              | 38/4   | 35/6  | 0.706 | 58/16  |
| BMI (kg/m$^2$)                 | 22.53±2.80 | 21.70±2.62 | 0.168 | 21.74±2.32 |
| Tumor location (non-EGJ/EGJ)   | 17/25  | 22/19 | 0.368 | 47/27  |
| Tumor size (cm)                | 4.37±2.16 | 4.77±2.18 | 0.651 | 4.82±2.32 |
| TNM (IB/IIA/IIIB/IIIA/IIIB/IIIC) | 2/3/4/17/10/6 | 2/0/6/16/13/4 | 0.834 | 1/3/19/32/9/10 |
| Comorbidities (present/absent) | 13/29  | 17/24 | 0.319 | 20/54  |
| Operation time (min)           | 291.55±69.87 | 258.29±45.25 | 0.012 | 290.82±51.30 |
| Estimated blood loss (ml)      | 160.60±99.30 | 167.68±97.94 | 0.524 | 147.09±89.27 |
| No. of N2 tier                 | 9.48±6.72 | 7.85±4.01 | 0.499 | 9.24±4.65 |
| No. of Retrieved lymph nodes   | 34.95±14.06 | 34.32±12.38 | 0.802 | 35.16±12.35 |
| Proximal margin (cm)           | 3.20±1.59 | 3.55±1.18 | 0.151 | 3.80±1.76 |
| Postoperative complication (%) | 13(31.0) | 16(39.0) | 0.441 | 15(20.7) |
| Clavien-Dindo grade ≥IIIa (%)  | 3(7.1)  | 4(9.8) | 0.973 | 3(4.1)  |
| Postoperative hospital stay (d) | 9.64±2.67 | 10.98±5.57 | 0.467 | 9.34±2.69 |

tic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, BMI=body mass index, TNM=tumor-node-metastasis, EGJ=esophagogastric junction
Patients with gastric cancer undergone total gastrectomy between Mar 2010 and Dec 2017
(n=573)

- Older than 80ys (n=3)
- Early gastric cancer (n=33)
- Palliative surgery (n=75)
- Neoadjuvant chemotherapy (n=21)
- Combined organ resection (n=23)
- D2+ Lymphadenectomy (n=5)
- R1 (n=24)

Eligible patients for this study
(n=389)

- RATG (n=122)
  - Conversion (n=6)
    - RATG (n=116)

- LATG (n=267)
  - Conversion (n=23)
    - LATG (n=244)

Propensity score matching:
age, sex, BMI, ASA, T stage, N stage,
TNM, tumor size, Location, Borrmann
type, differentiation and comorbidity.

RATG (n=116)
LATG (n=116)

Figure 1
Flow chart
