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 RTAG group 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. The conversion rate was 4.92% and 8.61% in the RATG and LATG groups, respectively, with no significant difference. The ratio of splenectomy was 1.7% and 0.4% respectively. 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.

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, or cancers located at lower two-thirds of the stomach to ensure a tumor-free surgical margin[6–8]. Since Kitano[9] reported laparoscopy-assisted distal gastrectomy 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]. However, the two-dimensional visualization and limited movement of laparoscopic instruments make it difficult to perform lymphadenectomy precisely. Robotic surgical system overcomes those limitations and opens a new area of minimal invasive surgery. It has several merits including eliminating the traces of physiologic human tremor and increasing dexterity through its typical internal articulated endoscopic wrist (EndoWrist™ System) for a precise lymphadenectomy especially in the technically demanding N2 area and, more specifically, in the supra-pancreatic area around the splenic vessels with 3D high-resolution images at the console[15]. In 2002, Hashizume reported robotic-assisted gastrectomy for the first time[16]. 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[17–20]. Regretfully, most of the reported cases were early gastric cancer (EGC)[21, 22], while few literatures compared robotic-assisted total gastrectomy (RATG) with LATG alone for advanced gastric cancer (AGC) retrospectively[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 with postoperative pathological diagnoses of GC 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) Histologically confirmed adenocarcinoma by postoperative pathological diagnosis; (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. 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)*.. 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. Finally, the study cohort comprised 116 patients who underwent RATG and 116 matched LATG patients after PSM. 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[17]. 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[17]. 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 jejunojejunostomy was established both using an endoscopic linear

stapler[17]. 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 surgery (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

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 obviously 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, OR = 0.549, 95%CI: 0.218–1.384). In robotic group, two patients encountered uncontrollable bleeding, two because of tight adhesion and another two because of the left gastric artery surrounded by lymph nodes. In the laparoscopic group, twelve for tight adhesion, four for left gastric artery surrounded by lymph nodes, two for

enlarged lymph nodes, one for tumor surround artery, two for giant tumor, one for bleeding of short gastric vessel, and the last one for mechanical failure of 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, OR = 4.301, 95%CI: 0.386−47.925).

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,* the high BMI patients had longer operation time, more intraoperative blood loss and less RLNs compared to low BMI patients. Subgroup analysis of tumor size suggested that RATG had advantages in intraoperative bleeding and number of secondary lymph node dissection 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 especially in the suprapancreatic area and the splenic hilum. 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]. Coincidentally, a retrospective study in a single center, which recruited 976 patients receiving LATG, reported that LATG could gain comparable surgical outcomes and was technically feasible for AGC compared to laparoscopic-assisted distal gastrectomy (LADG)[29]. 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] In addition, it could be concluded from a stratified analysis that RATG had similar short-term outcomes except longer operation time and higher cost compared to LATG for AGC[30, 31]. 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.

As for surgical performance, the length of incision, proximal margin, distal margin, and postoperative hospital stay were not significantly different between RATG and LATG groups in both cohorts. Generally, robotic gastrectomy was known to have some advantages over laparoscopic surgery in reducing perioperative bleeding[17, 23, 31]. 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[32]. All of our surgeons had performed robotic surgery (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[33]. 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[15]. 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)[32]. 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. The RLNs of RATG after PSM was at the brink of significance compared to LATG (p = 0.062). 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[31]. 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)[30]. Therefore, it was still controversial whether robotic total gastrectomy 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 laparoscopic gastrectomy. Besides, robotic gastrectomy 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[33]. Taking all those into account, we still hold the view that robotic total gastrectomy was capable of retrieving more lymph nodes than laparoscopic gastrectomy because of its advantages. However, further studies of robotic total gastrectomy, 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, 30, 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 grade□and *□a* 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, total gastrectomy 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. We performed esophagojejunal anastomoses mostly extracorporeally and rarely intracorporeally. The extracorporeal surgical procedures had been described previously [36] 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[37]. 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. We found that the patients with tumor located at EGJ were older than those with tumor located at non-EGJ (*Table 4),* which was consistent with Liu's study[4]. 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.

Performing minimal invasive surgery in high BMI patients presents further challenges, as excessive fat in them impairs adequate exposure of the surgical field and physiologic adhesion makes it difficult to perform precise lymphadenectomy around major vessels[38]. In this study, we performed an analysis by grouping the patients into two groups (BMI<25kg/m^2 and BMI≥25kg/m^2) (*Table 5),* according to the World Health Organization definition of obesity in the Asia-Pacific region. Zhao et al. had showed in their meta-analysis that high BMI patients had longer operation time, fewer RLNs and larger amount of intraoperative blood loss than other patients[39]. Lee et al. reported that robotic distal gastrectomy was more suitable in high BMI patients in terms of blood loss and consistent quality D2 lymphadenectomy than laparoscopic surgery[38]. In the present study, our small quantity of high BMI data showed the similar results of longer operation time, fewer RLNs and larger amount of blood loss, supporting Zhao's viewpoint. Therefore, we could not conclude any benefit of robotic total gastrectomy for high

BMI patients compared with laparoscopic procedure based on this poor data and thus further studies should be conducted to clarify this.

However, this study has several limitations. First, results were based on a retrospective analysis from a single-clinic institution. Baseline and clinicopathological features were different between the two groups. Therefore, we performed a PSM analysis to minimize these differences as much as possible. 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. Although 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 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.

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: Changdong Yang and Yan Shi analyzed and interpreted the patient data and Changdong Yang was a major contributor in writing the manuscript. Shaohui Xie and Jun Chen collected and collated data. All authors read and approved the final manuscript.

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Tables

Table 1 **Clinicopathological characteristics**

Variables	All Patients			Patients after PSM		
	RATG(n=116)	LATG(n=244)	*p*	RATG(n=116)	LATG(n=116)	*p*
Age, year (mean ± SD)	60.01±9.00	58.21±10.32	0.086	60.01±9.00	60.28±9.29	0.882
Sex (male/female)	96/20	190/54	0.283	96/20	96/20	1.000
Height, cm (mean ± SD)	163.29±6.64	162.72±7.16	0.542	163.29±6.64	163.09±6.57	0.739
Weight, Kg (mean ± SD)	58.83±8.31	59.68±9.38	0.262	58.83±8.31	59.34±9.00	0.656
BMI, Kg/m^2(mean ± SD)	22.02±2.52	22.48±2.89	0.121	22.02±2.52	22.27±2.85	0.483
ASA (□/□/□)	82/31/3	176/64/4	0.742	82/31/3	81/33/2	0.923
Tumor size, cm (mean ± SD)	4.66±2.26	4.51±2.12	0.585	4.66±2.26	4.62±2.24	0.526
Tumor location			0.316			0.743
Siewert type □	25	57		25	30	
Siewert type □	27	66		27	26	
Body	64	121		64	60	
Borrmann type			0.078			1.000
□/□/□/□	3/11/91/11	11/27/196/10		3/11/91/11	3/8/97/8	
Depth of infiltration (T)			0.029			0.154
T2/T3/T4a	7/2/107	36/3/205		7/2/107	3/1/112	
Nodal status (N)			0.375			0.913
N0	28	62		28	30	
N1	27	43		27	22	
N2	26	42		26	23	
N3a	19	59		19	31	
N3b	16	38		16	10	
TNM stage			0.683			0.597
□B	3	23		3	3	
□A	6	7		6	0	
□B	23	42		23	27	
□A	49	78		49	45	
□B	19	56		19	31	
□C	16	38		16	10	
Differentiation			0.008			0.457
G1/G2/G3	0/28/88	1/92/151		0/28/88	0/33/83	
Comorbidities (0/1/2/3)	83/22/5/6	163/51/24/6	0.380	83/22/5/6	75/25/11/3	0.415
Abdominal surgery history (Y/N)	5/111	24/220	0.072	5/111	9/107	0.270

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

Variables	All Patients			Patients after PSM		
	RATG(n=116)	LATG(n=244)	*p*	RATG(n=116)	LATG(n=116)	*p*
Operation time, min (mean ± SD)	291.09±58.41	271.16±49.16	0.001	291.09±58.41	271.99±48.41	0.007
Bleeding, ml (mean ± SD)	151.98±92.83	175.53±106.58	0.007	151.98±92.83	172.59±97.01	0.032
Retrieved lymph nodes (mean ± SD)	35.09±12.93	31.73±12.33	0.014	35.09±12.93	32.34±12.05	0.062
N1 tier (mean ± SD)	25.76±10.31	24.23±10.14	0.140	25.76±10.31	24.84±10.26	0.338
N2 tier (mean ± SD)	9.33±5.46	7.50±4.50	0.001	9.33±5.46	7.50±3.86	0.018
Length of incision, cm (mean ± SD)	6.30±1.53	6.33±1.73	0.527	6.30±1.53	6.40±1.74	0.816
Proximal margin, cm (mean ± SD)	3.58±1.72	3.67±1.44	0.679	3.58±1.72	3.62±1.43	0.886
Distal margin, cm (mean ± SD)	7.16±3.78	7.63±3.84	0.101	7.16±3.78	7.17±3.67	0.862
Postoperative hospital stay, d(mean ± SD)	9.45±2.67	9.96±4.07	0.759	9.45±2.67	10.07±3.96	0.479

rison of surgical outcomes and postoperative recovery

ic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, PSM=Propensity Score Matching,
l Deviation.

Table 3 **Postoperative morbidity and mortality**

Variables	All Patients			Patients after PSM		
	RATG(n=116)	LATG(n=244)	*p*	RATG(n=116)	LATG(n=116)	*p*
Present/absent	**28/89(24.1%)**	**70/174(28.7%)**	**0.341**	**28/89(24.1%)**	**39/77(33.6%)**	**0.102**
Clavien-Dindo Classification						
Ⅰ	**3(2.6%)**	**11(4.5%)**	**0.555**	**3(2.6%)**	**9(7.8%)**	**0.138**
Wound problem	2	5		2	4	
Fever	1	5		1	3	
Cardiac dysfunction	0	2		0	2	
Diarrhea	0	2		0	2	
Chylous leakage	0	1		0	1	
Ⅱ	**19(16.4%)**	**39(16.0%)**	**0.924**	**19(16.4%)**	**19(16.4%)**	**1.000**
Fever	5	3		5	2	
Wound infection	0	1		0	0	
Intra-abdominal infection	2	7		2	4	
Intestinal obstruction	1	0		1	0	
Catheter infections	4	1		4	0	
Pulmonary infection	7	19		7	8	
Pulmonary atelectasis	0	4		0	2	
Pleural effusion	2	10		2	3	
Anastomotic leakage	1	6		1	1	
Anastomotic stenosis	2	1		2	0	
Intra-abdominal bleeding	1	0		1	0	
Duodenal stump leakage	0	2		0	2	
Cardiac dysfunction	0	2		0	1	
Ⅲa	**2(1.7%)**	**9(3.7%)**	**0.494**	**2(1.7%)**	**7(6.0%)**	**0.174**
Wound problem	0	2		0	2	
Duodenal stump leakage	1	0		1	0	
Anastomotic leakage	0	3		0	3	
Pleural effusion	1	6		1	2	
Pyothorax	0	1		0	0	
Intra-abdominal infection	0	5		0	1	
Ⅲb	**2(1.7%)**	**4(1.6%)**	**1.000**	**2(1.7%)**	**2(1.7%)**	**1.000**
Intra-abdominal bleeding	1	1		1	1	
Anastomotic bleeding	0	1		0	0	
Duodenal stump leakage	0	1		0	1	
Anastomotic leakage	1	1		1	0	
Ⅳa	**1(0.9%)**	**4(1.6%)**	**0.915**	**1(0.9%)**	**2(1.7%)**	**1.000**
Respiratory failure	1	3		1	1	
Cardiac failure	0	1		0	1	
Ⅳb	**0(0%)**	**3(1.2%)**	**0.554**	**0(0%)**	**0(0%)**	**1.000**
MODS	0	3		0	0	
Ⅴ	**1(0.9%)**	**0(0%)**	**0.322**	**1(0.9%)**	**0(0%)**	**1.000**
Clavien-Dindo grade≥IIIa	**6(5.2%)**	**20(8.2%)**	**0.300**	**6(5.2%)**	**11(9.5%)**	**0.208**
Mortality	**1(0.9%)**	**0**	**0.322**	**1(0.9%)**	**0**	**1.000**

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

arison of the 2 surgical methods between different tumor location after PSM

	Location EGJ			Location non-EGJ		
	RATG(n=52)	LATG(n=56)	p	RATG(n=64)	LATG(n=60)	p
Age	61.33±8.63	61.79±6.93	0.680	58.94±9.22	58.88±10.92	0.764
Sex(male/female)	44/8	48/8	0.872	52/12	48/12	0.860
BMI(kg/m^2)	22.84±2.43	22.43±2.89	0.416	21.36±2.41	22.13±2.82	0.103
Tumor size (cm)	3.64±1.48	4.07±1.61	0.245	5.48±2.45	5.13±2.61	0.314
TNM(IB/IIA/IIB/IIIA/IIIB/IIIC)	2/1/11/25/10/3	1/0/13/23/16/3	0.824	1/5/12/24/9/13	2/0/14/22/15/7	0.963
Comorbidities(present/absent)	16/36	11/45	0.182	17/47	28/32	0.020
Operation time(min)	283.88±50.10	270.61±44.94	0.150	296.94±64.17	273.28±51.78	0.026
Estimated blood loss(ml)	128.08±58.11	156.52±72.91	0.016	171.41±110.18	187.58±113.64	0.323
No. of N2 tier	9.13±5.00	7.36±3.90	0.105	9.48±5.85	7.63±3.84	0.097
No. of Retrieved lymph nodes	35.65±12.79	33.54±14.29	0.241	34.63±13.13	31.22±9.49	0.160
Proximal margin(cm)	2.11±1.02	2.69±1.09	0.005	4.78±1.13	4.49±1.11	0.085
Postoperative complication (%)	16(30.8)	12(22.4)	0.268	12(19.7)	27 (45.0)	0.002
Clavien-Dindo grade ≥IIIa (%)	4(7.7)	2(3.6)	0.607	2(3.1)	9(15.0)	0.045
Postoperative hospital stay (d)	9.52±2.21	9.20±2.58	0.296	9.39±3.01	10.08±4.80	0.048

ic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, BMI=body mass index, TNM=tumor-node-

GJ=esophagogastric junction

	BMI≥25 kg/m^2			BMI<25kg/m^2		
	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	0.445
Sex(male/female)	13/0	14/2	0.488	83/20	82/18	0.796
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/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	0.447
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±48.85	0.013
Estimated blood loss(ml)	186.15±112.36	193.44±94.25	0.214	147.67±89.79	169.25±97.49	0.046
No. of N2 tier	6.54±2.63	6.63±3.18	0.559	9.68±5.63	7.64±3.95	0.013
No. of Retrieved lymph nodes	29.54±12.59	33.69±14.65	0.506	35.79±12.87	32.12±11.65	0.021
Proximal margin(cm)	2.65±1.75	3.88±1.67	0.009	3.70±1.68	3.58±1.38	0.609
Postoperative complication (%)	5(38.5)	6(37.5)	1.000	23 (22.3)	33(33.0)	0.089
Clavien-Dindo grade ≥IIIa (%)	2(15.4)	4(25.0)	0.861	4(3.9)	7(7.0)	0.503
Postoperative hospital stay (d)	9.92±2.18	10.81±5.02	0.597	9.39±2.73	9.95±3.78	0.339

	BMI≥25 kg/m^2			BMI<25kg/m^2		
	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	0.445
Sex(male/female)	13/0	14/2	0.488	83/20	82/18	0.796
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/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	0.447
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±48.85	0.013
Estimated blood loss(ml)	186.15±112.36	193.44±94.25	0.214	147.67±89.79	169.25±97.49	0.046
No. of N2 tier	6.54±2.63	6.63±3.18	0.559	9.68±5.63	7.64±3.95	0.013
No. of Retrieved lymph nodes	29.54±12.59	33.69±14.65	0.506	35.79±12.87	32.12±11.65	0.021
Proximal margin(cm)	2.65±1.75	3.88±1.67	0.009	3.70±1.68	3.58±1.38	0.609
Postoperative complication (%)	5(38.5)	6(37.5)	1.000	23 (22.3)	33(33.0)	0.089
Clavien-Dindo grade ≥IIIa (%)	2(15.4)	4(25.0)	0.861	4(3.9)	7(7.0)	0.503
Postoperative hospital stay (d)	9.92±2.18	10.81±5.02	0.597	9.39±2.73	9.95±3.78	0.339

parison of the 2 surgical methods between different BMI after PSM

ic-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, BMI=body mass index, TNM=tumor-node-

GJ=esophagogastric junction

nparison of the 2 surgical methods between different tumor size after PSM

	Size≥5cm			Size<5cm		
	RATG(n=53)	LATG(n=46)	p	RATG(n=63)	LATG(n=70)	p
Age	61.58±8.38	59.48±9.94	0.435	58.68±9.36	60.81±8.87	0.268
Sex(male/female)	43/10	37/9	0.930	53/10	59/11	0.980
BMI(kg/m^2)	21.76±2.38	22.31±3.04	0.310	22.25±2.63	22.24±2.73	0.994
Tumor location(non-EGJ/EGJ)	37/16	29/17	0.476	27/36	31/35	0.639
TNM(IB/IIA/IIB/IIIA/IIIB/IIIC)	3/2/8/20/9/11	0/0/9/15/15/7	0.458	0/4/15/29/10/5	3/0/18/30/16/3	0.862
Comorbidities(present/absent)	17/36	15/31	0.955	16/47	24/46	0.264
Operation time(min)	288.26±57.17	276.15±45.02	0.270	293.46±59.78	268.93±50.60	0.012
Estimated blood loss(ml)	158.30±76.86	175.98±106.70	0.625	146.67±104.72	170.36±93.77	0.010
No. of N2 tier	8.70±4.74	8.61±4.01	0.927	9.86±5.99	6.77±3.59	0.003
No. of Retrieved lymph nodes	36.17±12.72	34.26±10.71	0.356	34.17±13.15	31.07±12.75	0.139
Proximal margin(cm)	3.98±1.63	3.97±1.34	0.774	3.25±1.72	3.39±1.44	0.510
Postoperative complication (%)	15(29.3)	17(37.0)	0.358	13(20.6)	22(31.4)	0.158
Clavien-Dindo grade ≥IIIa(%)	2(3.8)	4(8.7)	0.548	4(6.3)	3(4.3)	0.886
Postoperative hospital stay (d)	9.55±2.02	10.70±3.64	0.333	9.37±3.13	9.66±4.13	0.714

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

arison of the 2 surgical methods between different age after PSM

	Age≥65			Age<65		
	RATG(n=42)	LATG(n=41)	p	RATG(n=74)	LATG(n=75)	p
Sex(male/female)	38/4	35/6	0.706	58/16	61/14	0.653
BMI(kg/m^2)	22.53±2.80	21.70±2.62	0.168	21.74±2.32	22.58±2.93	0.060
Tumor location(non-EGJ/EGJ)	17/25	22/19	0.368	47/27	38/37	0.113
Tumor size (cm)	4.37±2.16	4.77±2.18	0.651	4.82±2.32	4.53±2.28	0.280
TNM(IB/IIA/IIB/IIIA/IIIB/IIIC)	2/3/4/17/10/6	2/0/6/16/13/4	0.834	1/3/19/32/9/10	1/0/21/29/18/6	0.618
Comorbidities(present/absent)	13/29	17/24	0.319	20/54	22/53	0.754
Operation time(min)	291.55±69.87	258.29±45.25	0.012	290.82±51.30	279.48±48.72	0.168
Estimated blood loss(ml)	160.60±99.30	167.68±97.94	0.524	147.09±89.27	175.27±97.05	0.023
No. of N2 tier	9.48±6.72	7.85±4.01	0.499	9.24±4.65	7.31±3.78	0.012
No. of Retrieved lymph nodes	34.95±14.06	34.32±12.38	0.802	35.16±12.35	31.25±11.80	0.021
Proximal margin(cm)	3.20±1.59	3.55±1.18	0.151	3.80±1.76	3.66±1.54	0.496
Postoperative complication (%)	13(31.0)	16(39.0)	0.441	15(20.7)	23 (30.7)	0.145
Clavien-Dindo grade ≥IIIa (%)	3(7.1)	4(9.8)	0.973	3(4.1)	7(9.3)	0.337
Postoperative hospital stay (d)	9.64±2.67	10.98±5.57	0.467	9.34±2.69	9.57±2.63	0.706

c-assisted total gastrectomy, LATG=Laparoscopic-assisted total gastrectomy, BMI=body mass index, TNM=tumor-node-me
ogastric junction

Figures

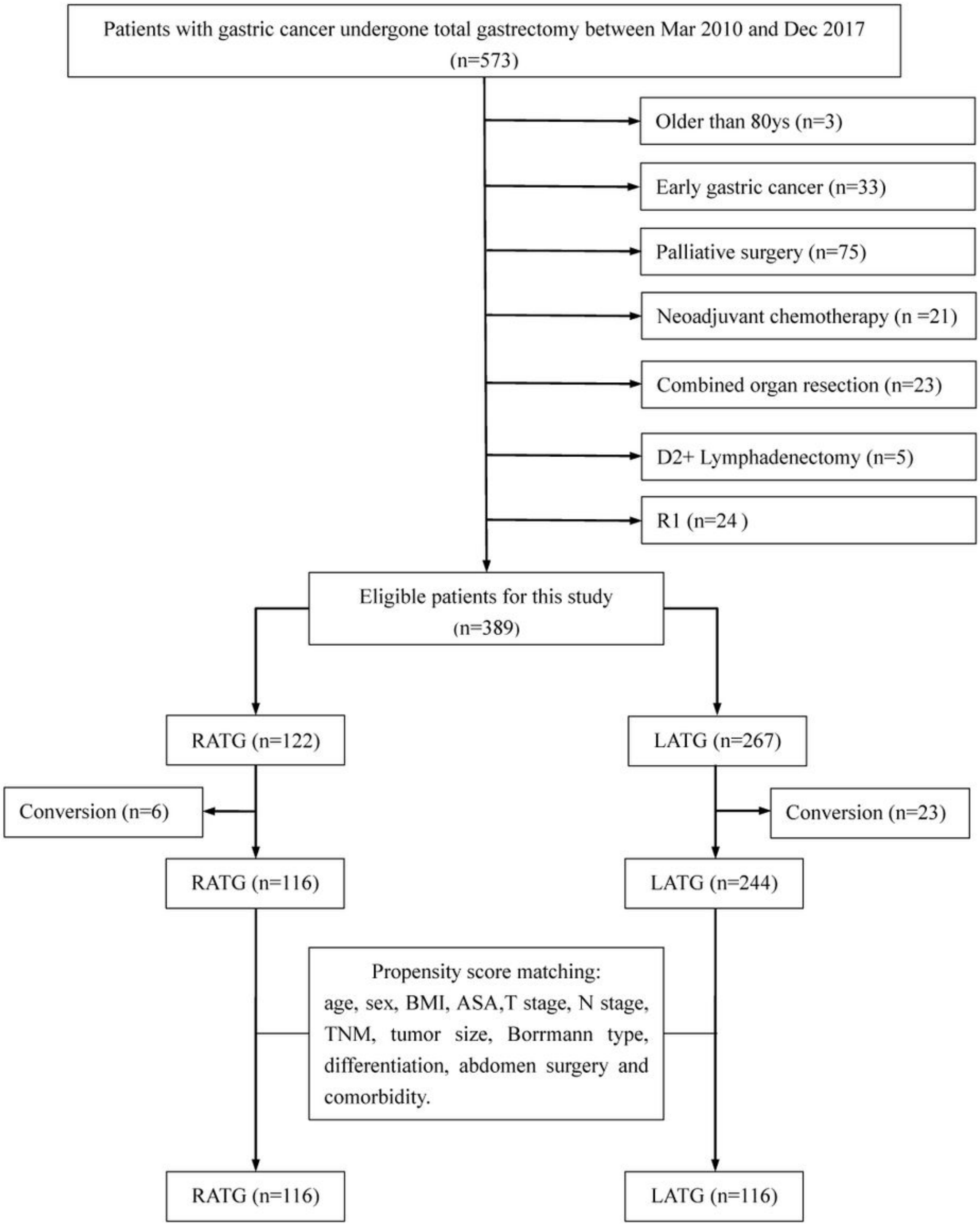

Figure 1

flow chart