Robotic Versus Laparoscopic Gastrectomy for Locally Advanced Gastric Cancer

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Abstract: Robotic gastrectomy (RG) has progressed rapidly in the last decade, overcoming many obstacles in laparoscopic technology. We compared surgical performance and short-term clinical outcomes between RG and laparoscopic gastrectomy (LG). In total, 163 patients with gastric cancer were randomly treated with RG (n = 102) or LG (n = 61). D2 lymphadenectomy was achieved in all patients. Digestive tract reconstruction in the RG group was performed by intracorporeal hand sewing, but extracorporeal anastomosis in the LG group was performed with a 25-mm circular stapler or linear stapler. Compared with the LG group, the RG group had less intraoperative blood loss ($P = 0.005$) and more lymph nodes retrieved ($P = 0.000$). Postoperative complications between the 2 groups were not significantly different during the 11-month follow-up ($P = 0.063$). Compared with LG, RG is a feasible and safe approach with minimally invasive, satisfactory intracorporeal digestive tract reconstruction, and fast recovery. Multicenter randomized controlled studies of larger numbers of patients are needed.

Key Words: gastric cancer, robotic gastrectomy, laparoscopic gastrectomy

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Gastric cancer is the fourth leading cause of cancer-related mortality and is responsible for 8.8% of all cancer-related deaths worldwide.[1] Gastrectomy with extensive lymphadenectomy is currently the only curative-intent treatment for gastric cancer.[2] Since the first laparoscopy-assisted distal gastrectomy was reported by Kitano et al[3] in 1994, this minimally invasive technique has gained acceptance among surgeons. Moreover, the long-term outcomes of laparoscopic gastrectomy (LG), such as morbidity and mortality, were comparable with those of open gastrectomy in several prospective and randomized controlled studies.[4,5] However, the 2-dimensional visualization and limited range of movement of laparoscopic instruments make performance of precise lymphadenectomy difficult. In addition, an incision is needed to perform extracorporeal anastomosis, which increases the risk of surgical wound complications and postoperative pain.

Robotic gastrectomy (RG) was developed as an alternative minimally invasive approach that may overcome the disadvantages of LG. Because of its ergonomic and technical advantages, RG allows for the performance of precise and safe lymphadenectomy, including the nodes at the left gastric artery (station no. 7), common hepatic artery (station no. 8), celiac trunk (station no. 9), and splenic artery (station no. 11d). In addition, RG can be used to perform all types of intracorporeal digestive tract reconstruction, including Billroth I, Billroth II, and Roux-en-Y anastomosis, which are beneficial because they induce less injury and faster recovery. However, data comparing RG and LG are lacking. In the present study, we performed an equivalent comparison of the short-term surgical outcomes of RG and LG with evaluate the safety and feasibility of RG.

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MATERIALS AND METHODS

Study Population

From January 2015 to August 2016, 163 patients were treated with curative intent, and all lymphadenectomies performed were D2 in accordance with the Japanese gastric cancer treatment guidelines.[6] All patients provided written agreement to participate in this prospective study after being informed of all study details. The patients were randomly assigned to either the RG group (n = 102) or LG group (n = 61).

The inclusion criteria were endoscopy-considered and biopsy-proven gastric cancer; clinical stage of I, II, or III based on the seventh version of the pathologic classification of the International Union Against Cancer[7]; an American Society of Anesthesiologists score of ≤ 2; and informed consent obtained from each patient.

The exclusion criteria were serious cardiovascular or respiratory disorders, hepatic or renal failure, distant metastases, Krukenberg tumors, remnant gastric cancer, synchronous malignancy in other organs, surgical failure (defined as conversion to open surgery), and D1/D3/D4 lymphadenectomy.

All surgeries were performed by a surgical team led by Dr Z.-W.J., who had experience with > 550 cases of RG.

The following data were collected: patient and tumor characteristics, type of gastrectomy (total, distal, or proximal), incision length, operating time (from pneumoperitoneum induction to portsite closure), intraoperative blood loss, number of retrieved lymph nodes (LNs), visual analog pain scale (VAS) score, time to beginning liquid diet, time to walking, time to first flatus, duration of hospital stay (from day of surgery to discharge), and postoperative complications during the 11-month follow-up.

Perioperative Management

Perioperative management was performed by adopting the following measures of fast-track surgery.[8,9] Oral laxatives were administered or an enema was performed. The patients drank a 10% glucose solution on the eve of surgery (1000 mL) and 2 hours before surgery (500 mL). General anesthesia combined with epidural anesthesia of the chest region was performed. A nasogastric tube and abdominal drainage tube were not usually placed. A specific cyclooxygenase-2 inhibitor, such as celecoxib, was regularly offered to patients to relieve postoperative pain. The patients were allowed to drink water and a liquid diet as soon as they awoke. They were discharged when they had no obvious pain, were able to ingest a semi-liquid diet, had no need for IV fluids, and could walk freely.

Surgical Technique

Patient and Robot Position

There are 3 types of gastrectomy: total, distal, and proximal. Total gastrectomy is the most complicated technique as well as the representative type in all gastrectomies performed in this study; therefore, it is herein described in detail.

After general anesthesia combined with epidural anesthesia of the chest region, the patient was placed in the reverse Trendelenburg position at ~20 degrees with both legs in abduction. The patient cart was placed above the patient's head with the video cart on the left of the patient. The assistant surgeon stood on the left of the patient.

Port Placement

After performance of a 10-mm incision under the umbilicus, 2 surgeons lifted the skin on either side of the navel with 2 towel clamps and a 12-mm trocar (Fig. 1, ①) for camera insertion and establishment of pneumoperitoneum (12 to 15 mm Hg according to the body mass index). With the aid of camera visualization, two 8-mm trocars were placed under direct visualization 3 fingerbreadths below the costal margin at the right and left anterior axillary line, respectively (Fig. 1, ④ and Fig. 1, ⑤). The third 8-mm trocar (Fig. 1, ③) was placed in the right area about 1 handbreadth away from the umbilicus. The last 12-mm trocar (Fig. 1, ②) was placed in a symmetrical position with the third 8-mm trocar (Fig. 1, ③) and was used by the assistant surgeon to introduce the clips, endoscopic linear stapler, aspirator, medical gauze, scissors, and stitches in the various surgical phases.

Surgical Procedures

The gastrectomy began with downward traction of the transverse colon, and the gastrocolic ligament was dissected close to the stomach in the direction of the cardia. The left gastroepiploic vessels were dissected by dividing them with titanium clips and removing the LNs (LN station no. 4sb) (Fig. 2). The rest of the gastrocolic ligament was dissected in the direction of the pylorus. After confirmation of the pylorus ring, the gastroduodenal artery was successfully divided, and the right gastroepiploic vessels were easily found along this artery and divided (Fig. 3). The nearby LNs were then removed (LN station nos. 4d and 6). The superior mesenteric vein was confirmed along the right gastroepiploic vein, and LN dissection was performed (LN station no. 14v).

The ligamentum hepatogastricum along the distal stomach was dissected, and the right gastric artery was ligated (Fig. 4). The LNs were then easily removed (LN station no. 5). The assistant transected the duodenum 3 cm under the pyloric ring using a 60-mm endoscopic linear stapler. With upward traction of the stomach, the arteriae gastricae breves and splenic hilum were dissected, and lymphadenectomy was performed (LN station nos. 4sa and 10). The dissection continued to the gastropancreatic ligament, and lymphadenectomy was performed along the celiac artery (LN station no. 9), common hepatic artery (LN station no. 8), hepatic artery (LN station no. 12a), left gastric vessels (ligated and divided) (LN station no. 7), and splenic artery (LN station nos. 11p and 11d) (Fig. 5). With downward traction of the stomach again, the rest of the ligamentum hepatogastricum was dissected in the direction of the cardia (LN station no. 1). Importantly, before

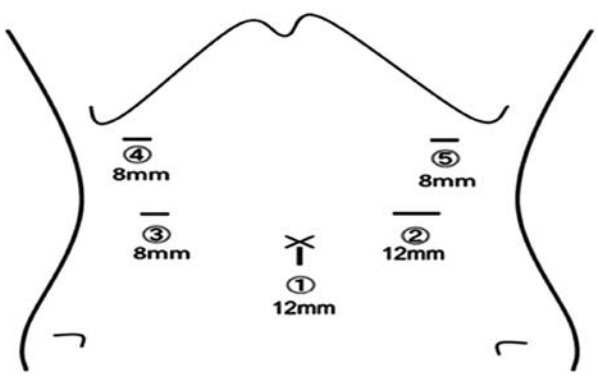

FIGURE 1. Schematic diagram of port placement.

FIGURE 2. Dissection of lymph node station no. 4sb.

FIGURE 3. Division of right gastroepiploic vessels with titanium clips.

FIGURE 4. Dissection of right gastric artery.

esophageal transection, the proximal esophagus was sewn to the surrounding diaphragm muscle about 1.5 cm away from the proposed incisal edge to prevent esophageal retraction and facilitate the anastomosis. The esophagus was then transected using the same technique as for the duodenum. The specimen was placed into the specimen bag and removed from the enlarged incision under the umbilicus after the surgery.

The jejunum, 15 to 20 cm away from the ligament of Treitz, was placed below the esophageal stump for antecolic end-to-side anastomosis. Continuous suturing was performed between the posterior esophageal muscle layer and seromuscular layer of the jejunum with a 15- to 20-cm-long barbed suture (we call this technique "strengthening suturing"). The esophageal stump, which contained some metal studs from the linear stapler in the cut edge, was gradually dissected from the posterior wall with an ultrasonic scalpel, and a 2- to 3-cm incision was made in the jejunum. Continuous knotless suturing was then started from the posterior esophageal wall and jejunal wall (Fig. 6). When the anterior wall was accomplished, continuous strengthening suturing of the anastomosis wall was performed. The jejunum, 20 to 25 cm away from the ligament of Treitz, was ligated with silk or transected with a 45-mm endoscopic linear stapler without separating the mesentery. The side-to-side jejunojejunostomy was achieved using the same technique as for the esophagojejunal anastomosis (Fig. 7).

The port placement and surgical procedures of LG are similar to those of RG, but reconstruction is performed by open access with an incision of about 8.67 ± 0.93 cm.

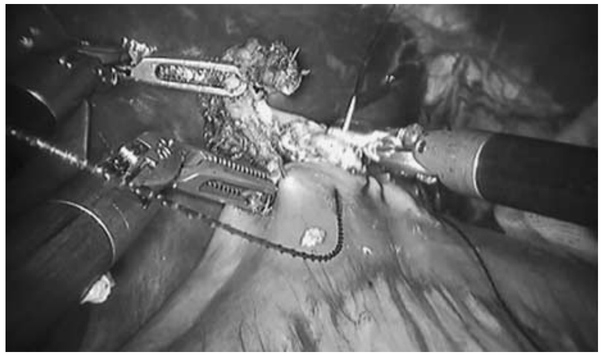

FIGURE 6. Traction of esophageal stump dissected by an ultrasonic scalpel, with continuous knotless suturing starting between the esophageal wall and jejunal wall.

Statistical Analysis

All data were analyzed with the statistical software SPSS 19.0 (IBM Corp., Armonk, NY). Continuous variables are expressed as mean ± SD and were compared with Student *t* test or the analysis of variance *F* test. Categorical variables were compared using the χ^2 test. A *P* value of <0.05 based on 2-sided statistical tests was considered statistically significant.

RESULTS

Clinicopathologic Characteristics

Table 1 summarizes the demographics and clinicopathologic characteristics of patients. There were no significant differences in age, sex, body mass index, American Society of Anesthesiologists score, tumor location, tumor diameter, histologic type, or tumor, nodes, metastasis-classification stage between the RG and LG groups ($P > 0.05$).

Intraoperative Data and Early Outcomes

Table 2 shows the surgical performance and postoperative evaluation findings. All surgeries were successfully performed with no conversion, organ damage, large volume of blood loss, or death. There were no significant differences in the types of gastrectomy performed ($P = 0.479$). Patients in the LG group had a longer incision that those in the RG group (8.67 ± 0.93 vs. 4.07 ± 0.68 cm, respectively; $P = 0.000$). The operation time was similar between the RG and LG groups (153.11 ± 16.44 vs. 151.97 ± 23.58 min,

FIGURE 5. Dissection of celiac artery, common hepatic artery, left gastric vessels (ligated), and splenic artery.

FIGURE 7. The jejunum, 20 to 25 cm away from the ligament of Treitz, was ligated with silk without separating the mesentery, and side-to-side jejunojejunostomy anastomosis was performed.

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TABLE 1. Summary of Patients' Clinicopathologic Characteristics

Clinicopathologic Characteristics	RG (N = 102)	LG (N = 61)	P
Sex (M/F)	65/37	45/16	0.185
Age(y)	65.13 ± 11.81	65.67 ± 13.58	0.788
BMI	24.12 ± 1.73	23.90 ± 1.63	0.432
ASA (I/II)	79/23	47/14	0.953
Tumor location [n (%)]			0.106
Cardia	32 (31)	14 (23)	
Fundus	15 (15)	11 (18)	
Body	9 (9)	13 (21)	
Pylorus	46 (45)	23 (38)	
Tumor diameter (cm) [n (%)]			0.119
< 1	13 (13)	2 (3)	
1-3	45 (44)	29 (48)	
4-8	34 (33)	24 (39)	
> 8	10 (10)	6 (10)	
Histology [n (%)]			0.107
Well-differentiated tubular	24 (23.5)	16 (26.2)	
Moderately differentiated tubular	22 (21.6)	19 (31.1)	
Poorly differentiated	23 (22.5)	7 (11.5)	
Mucinous	21 (20.6)	6 (9.8)	
Signet ring cell	8 (7.8)	8 (13.1)	
Undifferentiated	4 (3.9)	5 (8.2)	
TNM stage [n (%)]			0.072
I	22 (22)	7 (11)	
II	47 (46)	39 (64)	
III	33 (32)	15 (25)	

ASA indicates American Society of Anesthesiologists; BMI, body mass index; F, female; LG, laparoscopic gastrectomy; M, male; RG, robotic gastrectomy; TNM, tumor, nodes, metastasis-classification.

TABLE 2. Surgical Performance and Postoperative Evaluation

Variables	RG (N = 102)	LG (N = 61)	P
Type of gastrectomy [n (%)]			0.479
Total	58(57)	40(66)	
Distal	36(35)	16(26)	
Proximal	8(8)	5(8)	
The length of the incision (cm)	4.07 ± 0.68	8.67 ± 0.93	0.000
Operation time (min)	153.11 ± 16.44	151.97 ± 23.58	0.717
Evaluated blood loss (mL)	41.27 ± 20.23	83.69 ± 32.81	0.000
No. retrieved lymph nodes	36.06 ± 6.21	30.03 ± 5.27	0.000
VAS			
The first postoperative day	2.61 ± 0.73	7.48 ± 1.18	0.000
The second postoperative day	0.79 ± 0.79	3.52 ± 1.30	0.000
The third postoperative day	0.11 ± 0.31	0.95 ± 1.02	0.000
Days of eating liquid diet	1.06 ± 0.28	1.30 ± 0.58	0.001
Days of walking	1.25 ± 0.45	1.23 ± 0.42	0.828
Days of first flatus	2.05 ± 0.68	2.51 ± 0.79	0.000
Days of hospital stay	3.75 ± 0.74	5.36 ± 1.24	0.000
Postoperative complications [n (%)]			0.063
No complications	97(95.0)	49(80.3)	
Ileus	0	1(1.6)	
Wound infection	2(2.0)	4(6.6)	
Pneumonia	2(2)	4(6.6)	
Oesophago-jejunal anastomosis leak	0	2(3.3)	
Duodenal stump leak	1(1.0)	1(1.6)	

LG indicates laparoscopic gastrectomy; RG, robotic gastrectomy; VAS, visual analog pain scale.

respectively; $P = 0.717$). The intraoperative blood loss volume was smaller in the RG than LG group (41.27 ± 20.23 vs. 83.69 ± 32.81 mL, respectively; $P = 0.000$). The number of LNs retrieved was higher in RG than LG group (36.06 ± 6.21 vs. 30.03 ± 5.27, respectively; $P = 0.000$). The VAS score, which was the index of postoperative pain, was significantly lower in the RG than LG group for the first 3 days after surgery ($P = 0.000$). Patients in the RG group ingested a liquid diet earlier than those in the LG group (1.06 ± 0.28 vs. 1.30 ± 0.58 d, $P = 0.001$). There was no significant difference in the time to first walking between the RG and LG groups (1.25 ± 0.45 vs. 1.23 ± 0.42 d, respectively; $P = 0.828$). Bowel function recovery, evaluated by the number of days to first flatus, was faster in the RG than LG group (2.05 ± 0.68 vs. 2.51 ± 0.79 d, respectively; $P = 0.000$). The postoperative hospital stay was also significantly shorter in the RG than LG group (3.75 ± 0.74 vs. 5.36 ± 1.24 d, respectively; $P = 0.000$).

During the 11-month follow-up, 1 patient in the LG group who underwent total gastrectomy required Braun anastomosis on postoperative day 10 because of jejunal afferent loop obstruction. Two patients in the RG group and 4 patients in the LG group developed an infection of their enlarged incision, but the infection resolved with dressing changes. Two patients in the RG group and 4 patients in the LG group developed postoperative pneumonia and recovered with antibacterial drug treatment according to the bacterial culture results. Four tiny leakages occurred: 1 patient in the RG group developed a duodenal stump leakage, whereas 2 patients in the LG group developed esophagojejunal anastomosis leakage and another patient in the LG group developed duodenal stump leakage. All patients recovered by enteral nutrition therapy with gastroscopic placement of a nasointestinal tube. There were no significant differences between the 2 groups in terms of postoperative complications.

DISCUSSION

Treatment of gastric cancer requires multidisciplinary teamwork, and surgical resection plays an important role. With the increasing interest in minimally invasive surgery and rapid development of technology, LG quickly spread worldwide during the past 2 decades. Its advantages include less blood loss, faster gastrointestinal function recovery, a shorter hospital stay, and a lower postoperative complication rate compared with open gastrectomy.[10,11] However, the vast majority of LG procedures should actually be called laparoscopy-assisted gastrectomy because reconstruction is often performed by open access with a midline incision, which increases postoperative pain, and the manual handling of organs is an important contributor to the postoperative inflammatory response.[12] Some surgeons perform intracorporeal anastomosis by a double stapling method using EEA OrVil (Covidien, Dublin, Ireland), which also results in the formation of dog ears and a higher rate of leakage.[13] Our team successfully performed intracorporeal reconstruction by hand sewing for 11 patients but at the cost of greater physical effort and the intrinsic drawbacks of the procedure, such as the 2-dimensional view, poor flexibility of instruments, difficult exposure of some of the surgical field, and other disadvantages.

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With the development of robotic surgery, all of the above-mentioned drawbacks of laparoscopic surgery were greatly improved because of the 3-dimensional view, wristed instruments with 7 *df*, independent regulation of the camera and instruments to achieve good exposure, tremor filtering, and other advantages. These developments ensure that complicated and delicate surgeries are performed successfully.

Since Hashizume and Sugimachi[14] first used the robotic approach for gastrectomy in 2003, increasingly more interest in and expectations of robotic surgery have developed. RG is reportedly beneficial for patients because it induces less injury and has short-term oncological outcomes comparable with those of open gastrectomy or LG.[15,16] The present study produced many encouraging results of RG compared with LG. The intraoperative blood loss volume was lower in the RG group, which might help to prevent tumor cell dissemination into the peritoneal cavity during the operation[17]; theoretically, therefore, patients might have a better prognosis. The number of retrieved LNs was also higher in the RG group; in particular, the LN stations that are conventionally difficult to retrieve (Nos. 7, 8a, 9, and 11p) could be dissected more thoroughly, which would increase staging accuracy and help to formulate an individualized chemotherapy regimen. Compared with patients who underwent LG, those who underwent RG had a smaller incision, and this was directly correlated with a lower VAS score; their postoperative stress reaction was weaker and recovery was faster. No esophagojejunal anastomosis leakage occurred in the RG group, which might have been because of the satisfactory exposure of the surgical field and extremely flexible wristed instruments. In addition, we were accustomed to sewing the esophageal stump to the surrounding diaphragm muscle to prevent esophageal retraction and facilitate the anastomosis, which could avoid tissue trauma caused by continued pulling by pliers. Although no significant difference in the total postoperative complications was found between the 2 groups, we firmly believe that these encouraging results will produce increasing numbers of cases and studies of RG with subgroup analyses.

In terms of intracorporeal reconstruction, RG demonstrated an extremely superior hand sewing performance. Although many studies have evaluated various extracorporeal or mechanical stapler methods with which to conduct reconstruction,[15,16,18–31] our team is the first to perform 2 studies of complete robot-sewn anastomosis.[32,33] With intracorporeal reconstruction, we no longer need an assisted incision, and hand sewing technology avoids the leakage that results from dog ears with the double stapling method. Therefore, we consider that this may be a minimally invasive surgery in its true sense. There was a progress in details that we performed the construction of the Roux limb without separating the mesentery, but just transected the jejunum between the esophagojejunal anastomosis and jejunojejunal anastomosis, which was first reported by Parisi et al[34]; they called this the double-loop method. We also believe that this technique should be promoted for its simplification of the traditional technique as well as the obvious reduction of internal hernia formation.

In conclusion, our data indicate that RG for gastric cancer is safe and feasible and can be superior to LG. This may be explained by the better visualization and precise tissue handling. We have confidence that RG will be recommended as the preferred surgical procedure for gastric cancer in the future. However, because all data were collected from a single institution (Department of General Surgery, Jinling Hospital, School of Medicine, Nanjing University, Nanjing, Jiangsu Province, China), large-scale, multicenter, prospective, randomized controlled studies are necessary for a more precise assessment.

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