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Totally Robotic Distal Gastrectomy: A Safe and Feasible Minimally Invasive Technique for Gastric Cancer Patients Who Undergo Distal Gastrectomy

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Keywords
Gastric cancer · Distal gastrectomy · Totally robotic distal gastrectomy · Robotic-assisted distal gastrectomy · Safe

Abstract
Purposes: To explore the safety and feasibility of totally robotic distal gastrectomy (TRDG) for gastric cancer patients who undergo distal gastrectomy. ***Methods:*** Consecutive patients with gastric cancer who underwent TRDG (TRDG group) and robotic-assisted distal gastrectomy (RADG) (RADG group) were systematically reviewed at the Second Xiangya Hospital of Central South University from October 2015 to August 2018. Data were collected and statistically analyzed. ***Results:*** A total of 161 consecutive patients were included in this study: 84 cases in the TRDG group and 77 in the RADG group. Clinical characteristics and pathological results were mostly similar in both groups. The TRDG group had a significantly longer anastomotic time (20.6 ± 3.3 vs. 17.5 ± 4.0 min, $p < 0.001$) but showed no difference in total operating time (167.0 ± 18.0 vs. 162.9 ± 17.6 min, $p = 0.159$). The postoperative hospitalization in the TRDG group was shorter than that in the RADG group (6.7 ± 1.2 vs. 7.2 ± 1.7 days, $p = 0.019$). Conversion rate, estimated blood loss, and postoperative complications were similar in both groups. There were no statistical differences in the estimated 2-year disease-free survival and overall survival rate between both groups. ***Conclusions:*** Although our current results need to be verified in further studies, TRDG represents a safe and feasible approach to distal gastrectomy and embodies the theory of minimally invasive surgery.

Introduction

Gastric cancer is the second-most common malignancy after lung cancer in China [1]; accordingly, it has high incidence worldwide [2, 3]. Surgery is the main treatment method for gastric cancer. At present, laparoscopic-assisted surgery has replaced open surgery as the main method for patients who undergo gastrectomy, and its superiority has been proven in multiple studies [4–6]. Although intracorporeal anastomosis (IA) in totally laparoscopic distal gastrectomy (TLDG) is more difficult to perform than totally laparoscopic colectomy, several clinical studies have demonstrated the safety and feasibility of TLDG [7–9].

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With improvement in surgical instruments and technology, robotic-assisted distal gastrectomy (RADG) has also been reported on by experienced surgeons all over the world [10–12]. However, the safety and feasibility of totally robotic distal gastrectomy (TRDG) is not fully clear. From October 2015, TRDG and RADG were performed at the Second Xiangya Hospital of Central South University. Herein, we explore the safety and feasibility of TRDG for gastric cancer patients who underwent distal gastrectomy at our medical center.

Methods

Patients and Clinical Protocol

The study conformed to the ethical standards of the World Medical Association Declaration of Helsinki and was approved by the ethics committee at our institution. From October 2015 to August 2018, consecutive patients who were all pathologically diagnosed with gastric adenocarcinoma by biopsy and underwent TRDG and RADG were systematically reviewed. However, patients with distal metastasis and pyloric obstruction and those who underwent combined multiple organ resection were excluded from this study. All included patients accepted similar preoperative examinations such as routine blood tests; serum carcinoembryonic antigen (CEA); electrocardiograms; and pectoral, abdominal, and pelvic computed tomography scans. Before operation, detailed explanations of the pros and cons of both approaches were conveyed to patients and their families; then, one approach was chosen and consent forms were signed.

All surgeons in this study performed both types of surgery, and all of them had more than 100 cases of surgical experience with gastric cancer. Two pathologists who specialized in gastric cancer examined the surgical specimens. Tumor staging was based on the criteria from the 7th edition of the American Joint Committee on Cancer (AJCC) guidelines. Postoperative pain was evaluated by the standard clinical visual analog scale (VAS) of 0–10, with 0 representing no pain and 10 representing the worst pain imaginable. Hemoglobin <120 g/L for men and <110 g/L for women were defined as anemia. The anastomotic leakage and duodenal stump leakage were diagnosed by digestive tract radiography. General information, operative outcomes, pathological outcomes, postoperative complications, and follow-up information of all included patients were recorded in our database.

Surgical Procedure

All operations were performed under general anesthesia with endotracheal intubation. The posture and equipment arrangement of all patients were the same as those of traditional robot surgery, with high head, low feet, and supine position. We adopted these 5 points: the 3 cm under the umbilicus to place a 12-mm trocar as the observation hole; the 3 cm under the costal margin of the left anterior axillary line is implanted with an 8-mm trocar as Robot Arm R1; the McBurney point is placed with an 8-mm trocar as Robot Arm R2; the 2 cm under the costal margin of the right anterior axillary line is implanted with an 8-mm trocar as Robot Arm R3; the 2 cm under the left midclavicular line is implanted with a 12-mm trocar as an assistant hole (Fig. 1). D2 lymph node dissection of distal gastric cancer was performed according to preoperative staging (Fig. 2–6). Through the assistant hole, the duodenum was cut off by 2 cm below the pylorus and the stomach was cut off by 4~5 cm at the proximal end of the tumor (Fig. 7, 8). After the specimen was collected in the self-made specimen bag, the bag was tightened and placed in the right lower abdomen. After the TRDG tract reconstruction was completed, the specimen was taken out through a small incision. The specimen can also be taken out by a small incision to check whether the cutting edge is sufficient, and then TRDG tract reconstruction can be performed. During digestive tract reconstruction, make a hole at the anti-mesenteric border of the jejunum about 15 cm from the Treitz ligament, and another hole at the junction of the gastric stump and the greater curvature of the stomach. Side-to-side gastrojejunostomy of lesser curvature of the stomach and afferent loop was performed by an endovascular gastrointestinal anastomosis stapler (ENDO-GIA) in front of the colon (Fig. 9). The common opening was closed according to the principle of delta-shaped anastomosis by using an ENDO-GIA. The completion of the whole Billroth II anastomosis is shown in Figure 10. Through the lens observation, the specimen may be taken out through a small incision.

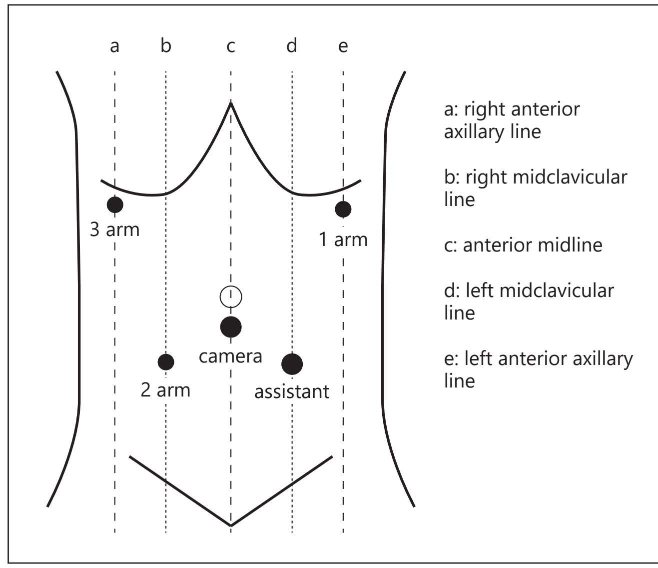

Fig. 1. Location of the trocar and incision.

Follow-Up

The first day after surgery was defined as the beginning of the follow-up time. After discharge, patients were advised to visit their doctors every 3 months for the first 2 years and every 6 months for the next 3 years and then have yearly visits after 5 years. The follow-up ended on September 20, 2018.

Statistical Analysis

Patients who required conversion were included in their intended groups because the data were analyzed based on an intention-to-treat basis. Data were analyzed by the Statistical Package for the Social Sciences (SPSS) version 24.0. Normally distributed quantitative data are presented as means ± SD and were analyzed by Student's t test; otherwise, they are expressed as median and

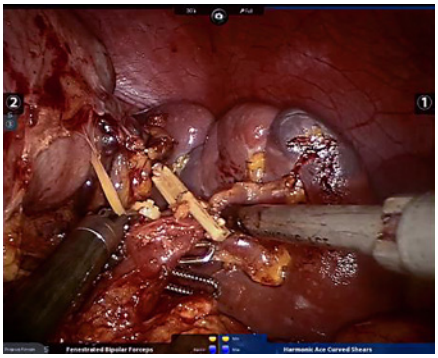

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Fig. 2. Transecting gastric omental left blood vessels. Dissection of the 10, 4sb LNs.

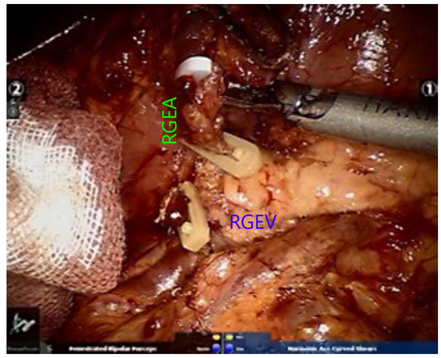

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Fig. 3. Separating along the middle colon vein and its branches. Separating the adhesions of the gastric antrum and colon transverse. Dissection of the 6, 4d, 14v LNs.

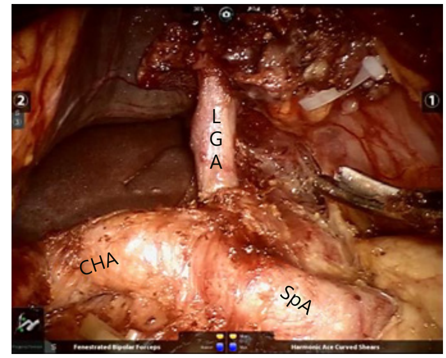

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Fig. 4. Closing to the upper edge of the pancreas. Separating and exposing the splenic artery, the celiac trunk, the left gastric artery, and the common hepatic artery. Dissection of the 7, 8a, 9, 11p LNs.

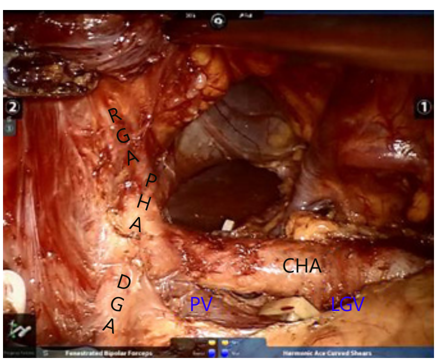

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Fig. 5. Cutting the hepatogastric ligaments to expose the right gastric artery, the hepatic proper artery, the portal vein, and the common bile duct. Dissection of the 12a, 5 LNs.

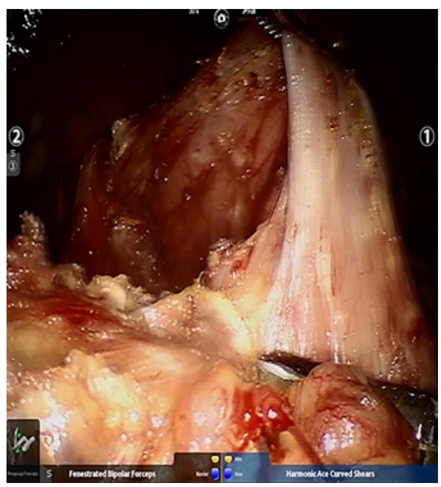

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Fig. 6. Dissection of the 3, 1 LNs along the lesser curvature.

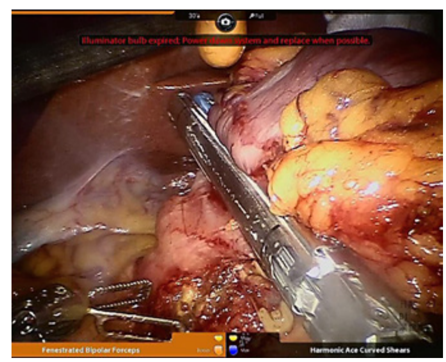

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Fig. 7. Cutting off by 2 cm below the pylorus.

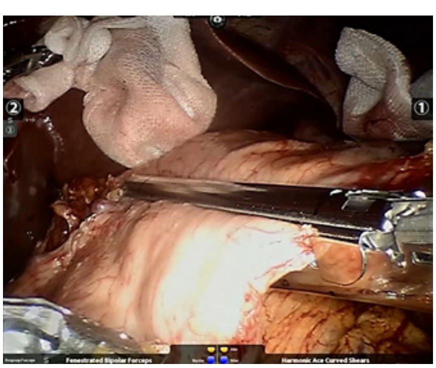

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Fig. 8. The stomach was cut off by 4~5 cm at the proximal end of the tumor.

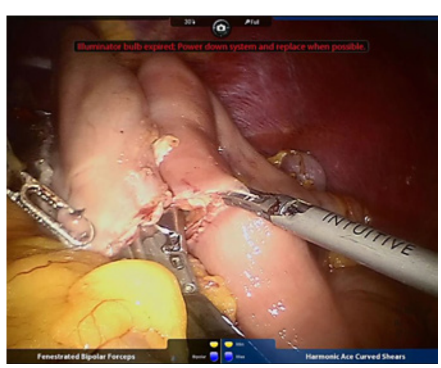

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Fig. 9. Side-to-side anastomosis of the lesser curvature gastrojejunal with anterior colonic input loop.

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Fig. 10. The completion of the whole Billroth II anastomosis.

Table 1. Clinical characteristics

Parameters	TRDG group (n = 84)	RADG group (n = 77)	p value
Sex, n (%)			0.875
Male	48 (57.1)	45 (58.4)	
Female	36 (42.9)	32 (41.6)	
Age, years	53.3±8.9 (32–69)	55.5±8.4 (39–72)	0.105
BMI, kg/m^2	23.9±2.2 (20.4–31.6)	23.6±2.0 (19.8–30.2)	0.375
ASA score, n (%)			0.921
1	38 (45.2)	35 (45.5)	
2	41 (48.8)	36 (46.8)	
3	5 (6.0)	6 (7.7)	
CEA level, ng/mL			0.678
<5, n (%)	71 (84.5)	63 (81.8)	
≥5, n (%)	13 (15.5)	14 (18.2)	
Preoperative chemotherapy, n (%)	14 (16.7)	15 (19.5)	0.685
Preoperative anemia, n (%)	15 (17.9)	10 (13.0)	0.514
Previous abdomen surgery, n (%)	10 (11.9)	10 (13.0)	1.000

TRDG, totally robotic distal gastrectomy; RADG, robotic-assisted distal gastrectomy; ASA, American Society of Anesthesiologists; CEA, carcinoembryonic antigen.

were analyzed by the Mann-Whitney *U* test. Categorical data are presented as a number and percentage and were analyzed by the χ^2 test or Fisher's exact test, and ranked data were analyzed by the Mann-Whitney *U* test. Survival analysis was calculated by the Kaplan-Meier method and analyzed using the log-rank test. A *p* value of less than 0.05 was used as the threshold for statistical significance.

Results

General Information of the TRDG Group

A total of 84 consecutive patients (48 male and 36 female; mean age, 54.1 ± 9.1 years) were included in the TRDG group. Among them, CEA level ≥5 g/mL was found in 13 (15.2%) patients, 4 (16.7%) patients underwent preoperative chemotherapy, 15 (17.9%) patients had preoperative anemia, and 10 (11.9%) had previous abdominal surgery (Table 1). All 84 patients underwent TRDG surgery successfully without any subsequent laparotomy. The average anastomotic time was 20.6 ± 3.3 min, and time to first flatus was 2.0 ± 1.7 days. The postoperative hospitalization was 7.0 ± 1.6 days. The postoperative pain was slight (Table 2). All patients received R0 resection with no positive margins. Three (3.6%) patients who underwent preoperative chemotherapy had <15 lymph nodes harvested. Twenty-two (26.2%), 31 (36.9%), and 31 (36.9%) patients were classified as stage I, stage II, and stage III, respectively, based on the 7th edition of the NCCN guidelines (Table 3). The digestive tract radiography showed that anastomotic leakage and duodenal stump leakage occurred in 2 (2.4%) patients and 1 (1.2%) patient, respectively. Two (2.4%) patients underwent anastomotic stenosis, and 1 patient suffered from anastomotic bleeding. One patient with anastomotic bleeding underwent unintended secondary surgery. No patients died during the perioperative period (Table 4).

Comparisons between Two Groups

Table 1 shows that both groups had similar clinical characteristics including age, sex, BMI, ASA (American Society of Anesthesiologists) score, CEA level, preoperative chemotherapy, preoperative anemia, and previous abdominal surgery. Surgical outcomes showed that the anastomotic time was longer in the TRDG group than in the RADG groups (20.6 ± 3.3 vs. 17.5 ± 4.0 min, $p < 0.001$), while the overall operating time was similar between the 2 groups (167.0 ± 18.0 vs. 162.9 ± 17.6 min, $p = 0.159$). There were no significant differences in estimated blood loss ($p = 0.459$), time to first flatus ($p = 0.482$), time to first oral intake ($p = 0.695$), postoperative hospitalization ($p = 0.880$), and postoperative pain score. The incision length for the TRDG group was significantly shorter than that for the RADG group (6.0 ± 1.8 vs. 7.4 ± 1.9, $p < 0.001$) (Table 2). The pathological results were similar with respect to the number of lymph nodes harvested ($p = 0.333$)

Table 2. Surgical results

Parameters	TRDG group (*n* = 84)	RADG group (*n* = 77)	*p* value
Operating time, min (range)	167.0±18.6 (135–205)	162.9±17.6 (135–225)	0.159
Anastomotic time, min (range)	20.6±3.3 (16–30)	17.5±4.0 (12–34)	<0.001
Estimated blood loss, mL (range)	73.8±26.2 (40–180)	77.0±28.6 (40–180)	0.459
Open conversion, *n* (%)	4 (4.8)	3 (3.9)	1.000
Time to first flatus, days (range)	2.0±1.2 (1.0–13)	2.3±2.0 (1.0–13)	0.322
Time to first oral intake, days (range)	1.9±1.3 (1.0–13)	2.0±2.1 (1.1–15)	0.523
Postoperative hospitalization, days (range)	6.7±1.2 (5–15)	7.2±1.7 (5–17)	0.019
Postoperative pain score			
First day (range)	3.5±1.0 (2–5)	3.6±1.1 (2–5)	0.494
Second day (range)	2.1±0.7 (1–3)	2.2±0.7 (1–3)	0.264
Third day (range)	0.7±0.5 (0–2)	0.7±0.5 (0–1)	0.750
Incision length, cm (range)	6.0±1.8 (5.3–15.2)	7.4±1.9 (5.8–17.5)	<0.001

TRDG, totally robotic distal gastrectomy; RADG, robotic-assisted distal gastrectomy.

Table 3. Pathological results

Parameters	TRDG group (*n* = 84)	RADG group (*n* = 77)	*p* value
Tumor size, cm (range)	4.5±1.0 (2.8–6.9)	4.5±1.0 (3.1–7.0)	0.803
Proximal resection margin, cm (range)	10.0±1.6 (8.5–12.0)	9.9±1.6 (7.6–13.5)	0.713
Distal resection margin, cm (range)	7.2±1.3 (5.4–9.6)	6.9±1.6 (4.8–10.2)	0.130
Lymph nodes harvested, *n* (range)	23.3±4.7 (12–33)	22.4±4.9 (11–34)	0.260
Lymph nodes harvested <15, *n* (%)	3 (3.6)	3 (3.9)	1.000
pTNM stage, *n* (%)			0.785
I	22 (26.2)	18 (23.4)	
II	31 (36.9)	30 (39.0)	
III	31 (36.9)	29 (37.6)	

TRDG, totally robotic distal gastrectomy; RADG, robotic-assisted distal gastrectomy; pTNM, pathological tumor node metastasis.

Table 4. Postoperative complications

Parameters	TRDG group (*n* = 84)	RADG group (*n* = 77)	*p* value
Anastomotic leakage, *n* (%)	2 (2.4)	3 (3.9)	0.671
Duodenal stump leakage, *n* (%)	1 (1.2)	2 (2.6)	0.607
Anastomotic stenosis, *n* (%)	2 (2.4)	1 (1.3)	1.000
Anastomotic bleeding, *n* (%)	1 (1.2)	1 (1.3)	1.000
Abdominal infection, *n* (%)	2 (2.4)	1 (1.3)	1.000
Gastric paralysis syndrome, *n* (%)	1 (1.2)	2 (2.6)	0.607
Intestinal obstruction, *n* (%)	1 (1.2)	1 (1.3)	1.000
Wound infection, *n* (%)	2 (2.1)	5 (6.5)	0.261
Reoperation, *n* (%)	1 (1.2)	3 (3.9)	0.350

TRDG, totally robotic distal gastrectomy; RADG, robotic-assisted distal gastrectomy.

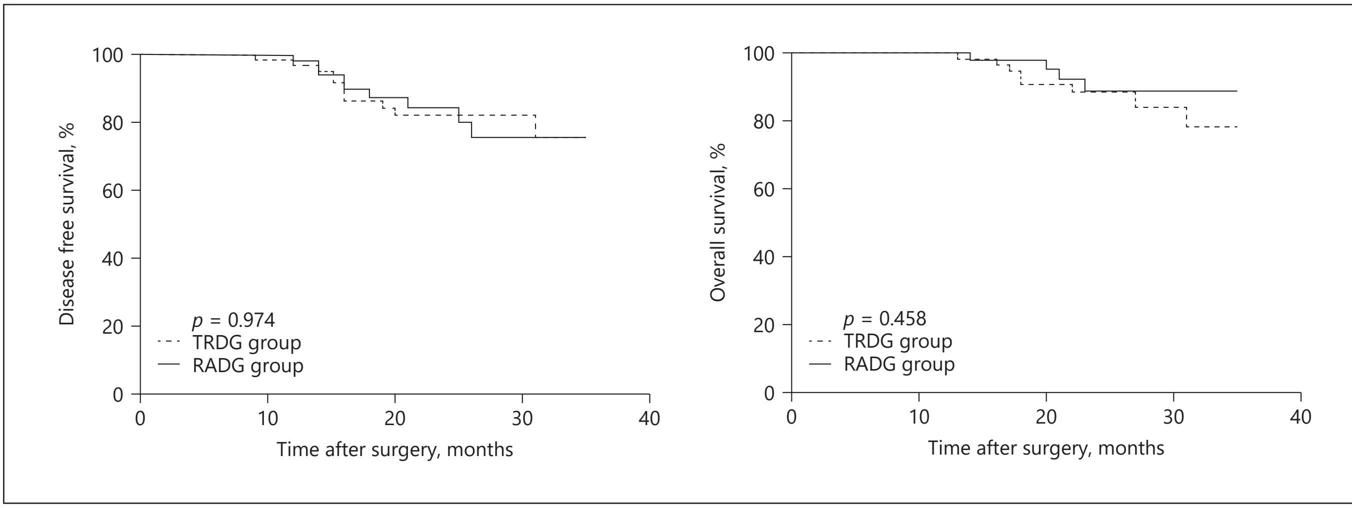

Fig. 11. Disease-free survival and overall survival of patients in the TRDG and RADG groups. TRDG, totally robotic distal gastrectomy; RADG, robotic-assisted distal gastrectomy.

and pathological tumor node metastasis (pTNM) (p = 0.785) (Table 3). Although some patients underwent postoperative complications, including anastomotic leakage, duodenal stump leakage, anastomotic stenosis, anastomotic bleeding, abdominal infection, gastric paralysis syndrome, intestinal obstruction, and wound infection in both groups, they were not statistically significant ($p > 0.05$). Only 1 patient in the TRDG group and 3 patients in the RADG group underwent unintended secondary surgery ($p = 0.350$) (Table 4).

Survival Analysis

The mean follow-up period was 20 months (range: 1–35 months) in the TRDG group and 18 months (range: 1–35 months) in the RADG group ($Z = -0.448$, $p = 0.654$). No patients suffered from local recurrence in the specimen extraction sites in both groups. The estimated 2-year disease-free survival rate was 82.1% in the TRDG group and 84.3% in the RADG group ($p = 0.974$). The estimated 2-year overall survival rate was 88.5% in the TRDG group and 88.8% in the RADG group ($p = 0.458$) (Fig. 11).

Discussion

The current state of gastric cancer is characterized by low rates of early diagnosis and high rates of incidence and mortality [1]. Gastric cancer is reportedly the most common malignancy of the digestive system in China [1]. Gastric antrum is the most common site of gastric cancer, accounting for 90% of all cases, so distal gastrectomy is the most effective treatment [13].

Laparoscopic-assisted distal gastrectomy (LADG) has the advantages of minor trauma, rapid recovery, and fewer complications than traditional open surgery, and studies have shown that for patients who underwent LADG more lymph nodes could be harvested with accompanying survival benefits [4–6]. Thus, LADG has been increasingly chosen by surgeons and patients during the past 3 decades.

Given the unceasing advances in surgical devices and gradual improvements in surgical performance, Da Vinci's surgery was tried and reported on by experienced surgeons, and its safety and feasibility were also proved [10–12]. Suda et al. [14] showed that morbidity (2.3 vs. 11.4%, $p = 0.009$) and hospital stay (4 [2–31] vs. 15 [8–136] days, $p = 0.021$) were significantly improved in the robotic group than in the laparoscopic group. In particular, local complication rates (1.1 vs. 9.8%, $p = 0.007$) were decreased. Gao et al. [15] reported that although RADG was associated with a longer mean operating time (249.46 ± 63.26 vs. 232.17 ± 65.39 min, $p = 0.008$) than LADG, both RADG and LADG were similar with respect to short-term recovery and long-term oncological outcomes. Hikage et al. [16] also reported that patients in the TRDG group experienced longer operating times than the LADG group (323 vs. 285 min; $p < 0.001$), and the incidence of all complications was similar.

However, totally robotic IA is a technically demanding procedure, making it the most important reason for

TRDG being rarely performed. However, the IA technique has been explored by surgeons. Parisi et al. [17] adopted the "Parisi Technique" to complete reconstruction for 55 patients during totally robotic gastrectomy. The results showed that no conversions to open surgery occurred and R0 resections were obtained in all cases. In addition, the hospital stay was 5 (3–17) days, and no anastomotic leakage occurred. However, the anastomotic time was not mentioned.

In 2002, the delta-shaped anastomosis applied to TLDG was first reported by the Japanese experts Kanaya et al. [18]. They reported that all 9 patients recovered smoothly without severe complications. This new method of intracorporeal Billroth I anastomosis using only endoscopic linear staplers was proved to be simple, easy, and safe by their initial study. In 2011, he summarized that on average, only 13 min were needed to complete the intracorporeal anastomosis based on 100 cases of delta-shaped anastomosis carried out by 8 surgeons; all surgeons experienced a short learning curve. In addition, he also reported that time to first oral intake was short [19]. Subsequently, an increasing number of studies confirmed the safety and feasibility of this procedure during TLDG [7–9].

In our medical center, we innovatively applied delta-shaped anastomosis to TRDG in October 2015. In this study, we included 161 patients: 84 cases in the TRDG group and 77 in the RADG group. Our study showed no significant difference in total operating time, estimated blood loss, return of bowel function, and postoperative pain. For most patients in the TRDG group, the specimen was extracted via the bikini incision, which may be less conspicuous, as the incision length was significantly shortened and therefore less invasive. In addition, pathological outcomes were not compromised, with no significant difference in the number of lymph nodes harvested and the number of lymph nodes <15. Postoperative complications such as anastomotic leak, duodenal stump leakage, anastomotic stenosis, anastomotic bleeding, and abdominal infection occurred in both groups, but the difference was not statistically significant, and the incidence rate was similar to the reported results [14–16]. Most importantly, there were no significant differences in 2-year disease-free survival ($p = 0.974$) and overall survival rate ($p = 0.458$) between both groups.

A limitation of our study is its retrospective nature that may have led to a bias. However, we recruited patients based on unique inclusion and exclusion criteria, and the follow-up data were complete, so we believe that our results are reliable. At present, our results represent the largest consecutive examples comparing TRDG and RADG. Randomized controlled studies in the future can verify these results.

Conclusion

Although our current results need to be verified in further studies, TRDG represents a safe and feasible approach to distal gastrectomy and embodies the theory of minimally invasive surgery.

Statement of Ethics

The study conformed to the ethical standards of the World Medical Association Declaration of Helsinki and was approved by the ethics committee at our institution. All the patients signed the operation consent and had given their written informed consent to publish the paper.

Disclosure Statement

There are no conflicts of interest to declare.

Funding Sources

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