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Robot-Assisted *versus* Totally Laparoscopic Distal Gastrectomy for Gastric Cancer: A Retrospective Propensity Score-Matched Analysis

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Abstract

Background: Robot-assisted gastrectomy is increasingly performed, but rarely reported for delta-shaped anastomosis. This study compared surgical outcomes of Robot-Assisted Laparoscopic Distal Gastrectomy with Delta-Shaped Anastomosis (RALG-d) with totally Laparoscopic Distal Gastrectomy with the Same Anastomosis (LAG-d) by a Propensity Score Matching (PSM).

Methods: From March 2012 to April 2019, 31 patients underwent RALG-d, and 468 patients underwent LAG-d for gastric cancer by a single surgeon. Surgical outcomes were compared by PSM.

Results: After PSM, 30 patients were included into the RALG-d group, and 118 patients into the LAG-d group. All of the covariates were balanced, except TNM stage. Mean operation times were longer in the RALG-d group than the LAG-d group (P<0.001). The number of retrieved lymph nodes and length of hospital stay were not significantly different (P=0.110 and P=0.939, respectively). The flatus passage was faster in the RALG-d group (P=0.002). The Numeric Rating Scale for pain (NRS) on postoperative day 3 in the RALG-d group was higher than that of the LAG-d group (P=0.051), while those on postoperative days 1 and 5 were similar between the two groups. Overall, postoperative complications were experienced by 1 patient (3.2%) in the RALG-d group and 28 (6.0%) in the LAG-d group (P=0.811). There was no operation-related mortality and no open conversion in both groups.

Conclusion: Our study shows comparable surgical outcomes of RALG-d, especially rapid recovery of intestinal function. RALG-d can be a safe and feasible treatment option for gastric cancer.

Keywords: Gastric cancer; Robot-assisted gastrectomy; Delta-shaped anastomosis; Propensity score matching

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Introduction

Gastric cancer is one of the most common malignancies and has a crude mortality rate of 16.3% in Korea [1]. Since the first laparoscopic gastrectomy performed by Kitano in 1994, minimally invasive gastrectomy has gained worldwide acceptance as a surgical mainstay for early gastric cancers and has become a standard treatment option for gastric cancers [2,3]. Although laparoscopic surgery could provide benefits, such as reduced postoperative pain, better cosmesis, and shorter hospital stay compared with open surgery [4], it has some drawbacks including limited degrees of motion and ergonomic discomfort [5,6]. On the other hand, robot-assisted surgery has advantages, including freedom of motion, dexterity, tremor elimination, ergonomic position, and improved operative field by 3-dimensional view [7]. Recent studies have reported that Robot-Assisted Gastrectomy (RAG) has a shorter learning curve than Laparoscopy-Assisted One (LAG) [8] and makes suprapancreatic nodal dissection easier [9]. Although several studies demonstrated noninferior surgical and oncologic outcomes of RAG with such potential advantages, it is still controversial because there is no published prospective randomized trial.

Gastroduodenostomy, known as delta-shaped anastomosis in totally laparoscopic procedures, is the most frequently performed reconstruction method after distal gastrectomy in East Asia but poses still higher technical challenges than Billroth 2 and Roux-en-Y gastrojejunostomy during laparoscopic gastrectomy. In robotic surgery, higher cost but a restricted range of available staplers makes it more reluctant to conduct Billroth 1 anastomosis. There have been a few studies investigating delta-shaped anastomosis in RAG [10-12], but most of these have been small-scale or

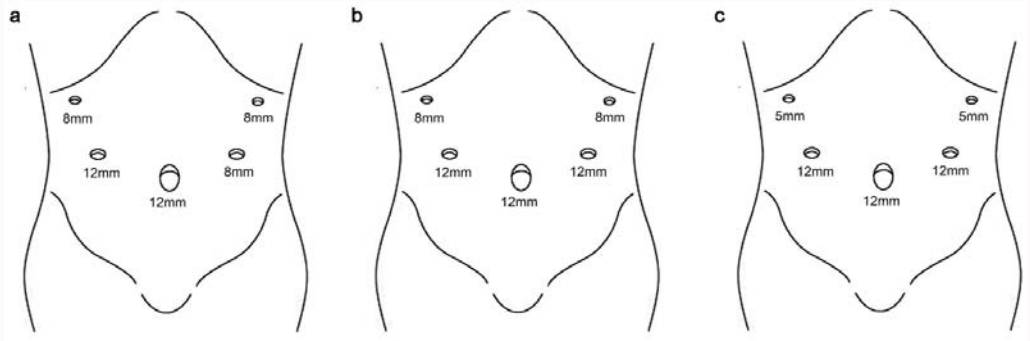

Figure 1: (a) Trocar size and placement in robot-assisted gastrectomy. **(b)** Trocar change after lymph node dissection. **(c)** Trocar size and placement in laparoscopic gastrectomy.

non-comparative studies.

This study aimed to compare surgical outcomes of Robot-Assisted Laparoscopic Distal Gastrectomy with Delta-Shaped Anastomosis (RALG-d) with Totally Laparoscopic Distal Gastrectomy with the Same Reconstruction Method (LAG-d) by a Propensity Score Matched (PSM) analysis.

Materials and Methods

From March 2012 to April 2019, 468 cases of LAG-d were performed by a single surgeon, and 31 patients received RALG-d for gastric cancer between July 2017 and April 2019. RALG-d was conducted using the da Vinci Xi® system (Intuitive Surgical Inc., Sunnyvale, CA, USA). We retrospectively reviewed clinicopathologic data, including age at operation, sex, Body Mass Index (BMI), TNM stage, American Society of Anesthesiologists (ASA) score, the presence of diabetes, the number of retrieved lymph nodes, operation time, the date of flatus, length of postoperative hospital stay, Numeric Rating Scale for pain (NRS), complications within 30 days following surgery, and mortality within 60 postoperative days. Pathologic staging was based on the American Joint Committee on Cancer (AJCC) Staging Manual 7th edition [13] and complication was classified according to Clavien-Dindo classification [14].

This study was reviewed and approved by the Institutional Review Board of Asan Medical Center, Seoul, Korea.

Surgical Procedures of Robot-Assisted Distal Gastrectomy

In all RALG cases, five trocars were used. Two 12 mm trocars were inserted below the umbilicus for scope entry and right lower site for assistance, respectively. Three 8 mm cannulas were placed on both upper quadrants and left lower site (Figure 1a). After the patient was placed in the reverse Trendelenburg position, three cannulas and the camera port were docked. Cardier forceps (Intuitive Surgical Inc., Sunnyvale, CA, USA) were introduced through the right upper 8 mm trocar. On the patient's left side, ultrasonic shears (Harmonic scalpel®, Ethicon Endo-Surgery Inc., Cincinnati, OH, USA) and Maryland bipolar forceps (Intuitive Surgical Inc., Sunnyvale, CA, USA) were docked in the lower and upper 8 mm trocar, respectively. A triangle method was used to retract the liver [15]. Regarding nodal clearance, D1+ lymph node dissection was performed for clinical stage T1N0 patients, and D2 dissection was conducted in the other patients. After lymph node dissection, we introduced a 12 mm trocar instead of the 8 mm trocar in the left lower abdomen and converted to the laparoscopic system to resect the stomach and duodenum and construct delta-shaped anastomosis with an endoscopic linear stapler (Figure 1b). Finally, the type and location of trocars became identical to LAG except two cannulas in both upper quadrants (Figure 1c).

Postoperative Course

Before mid-2016, patients started to drink water 24 h following the operation, and a liquid diet was permitted on postoperative day 3. A soft diet was introduced after passing flatus. Since mid-2016, patients receiving minimally invasive gastrectomy have begun to sip water from the morning of the day following surgery, while a liquid diet and soft diet is now permitted on the evening of postoperative days 1 and 2, respectively, according to the introduction of the Enhanced Recovery after Surgery program. Postoperative care and medication were the same between the two groups.

Statistical Analysis

Propensity score matching was conducted using the following covariates: age, sex, BMI, TNM stage, the presence of diabetes, and ASA score. The matching process was based on the caliper matching method, under a 0.2 caliper to perform 1:4 matching. Linear regression model using robust estimators to allow for the clustering effect within matched stratum was used for continuous variables. Logistic regression model with Firth correction to allow for rare events was used for categorical variables. P values less than 0.05 were considered statistically significant. All statistical analyses were performed using R software version 3.2.1 (R Core Team, Vienna, Austria).

Results

There were 18 men and 13 women in the RALG-d group. Their mean age at operation and BMI were 53.9 years and 24.0, respectively. About 90% of patients had stage I tumors. Five patients had underlying diabetes mellitus. Regarding ASA score, patients with score of 2 were the most common followed by score of 1 and 3 (Table 1). Compared to the LAG-d group, the RALG-d group was younger, but there were no between-group differences in sex, BMI, stage, diabetes, and ASA score. Most of the covariates were balanced after PSM (Standardized Mean Difference <0.1 except TNM stage only).

PSM analysis included 30 patients in the RALG-d group and 118 in LAG-d group. No cases required conversion from RALG-d to LAG-d or open surgery and LAG-d to open surgery. No operation-related mortality was identified in either group. There was no difference in number of retrieved lymph nodes, length of hospital stays, or morbidity (Table 2). Longer operation time (180.6 *vs.* 108.5 min, P<0.001) and rapid flatus passage after surgery (3.3 *vs.* 3.8 days,

Table 1: Comparison of clinicopathologic characteristics of patients receiving RALG-d and LAG-d and those after 1:4 propensity score-matching.

Variables	Initial Data			Propensity score-matched Data		
	RALG-d (n=31)	LAG-d (n=468)	P value	RALG-d (n=30)	LAG-d (n=118)	SMD
Age at operation (years) (mean ± SD)	53.9 (± 10.8)	59.2 (± 11.1)	0.012	54.1 (± 10.9)	53.7 (± 10.5)	0.038
Sex			0.753			0.071
Male	18 (58.1)	293 (62.6)		17 (56.7)	71 (60.2)	
Female	13 (41.9)	175 (37.4)		13 (43.3)	47 (39.8)	
BMI (kg/m^2) (mean ± SD)	24.0 (±2.6)	24.2 (± 2.9)	0.721	24.0 (± 2.6)	24.1 (± 2.7)	0.037
TNM Stage[a]			0.342			0.123
Ia	27 (87.1)	387 (83.6)		26 (86.7)	105 (89.0)	
Ib	1 (3.2)	48 (10.4)		1 (3.3)	5 (4.2)	
≥ II	3 (9.7)	28 (6.0)		3 (10.0)	8 (6.8)	
Diabetes			>0.999			0.015
Yes	5 (16.1)	71 (15.2)		5 (16.7)	19 (16.1)	
No	26 (83.9)	397 (84.8)		25 (83.3)	99 (83.9)	
ASA score			0.469			0.07
1	9 (29.0)	107 (22.9)		9 (30.0)	35 (29.7)	
2	19 (61.3)	333 (71.2)		19 (63.3)	77 (65.3)	
3	3 (9.7)	28 (6.0)		2 (6.7)	6 (5.1)	

[a]TNM stage was based on the American Joint Committee on Cancer Staging Manual, 7th edition.
Data shown are number (%) unless otherwise specified.
RALG-d: Robot-Assisted Laparoscopic Distal Gastrectomy with Delta-shaped Anastomosis; LAG-d: Totally Laparoscopic Distal Gastrectomy with Delta-shaped Anastomosis; SMD: Standardized Mean Difference; SD: Standard Deviation; BMI: Body Mass Index; ASA: American Society of Anesthesiologists

Table 2: Comparison of surgical outcomes of patients receiving RALG-d with LAG-d.

Variables	Initial Data			Propensity score-matched Data		
	RALG-d (n=31)	LAG-d (n=468)	P value	RALG-d (n=30)	LAG-d (n=118)	P value
No. of retrieved LNs	32.0 (± 8.6)	33.5 (± 12.7)	0.515	31.7 (± 8.6)	34.6 (± 11.7)	0.11
Operation time (min)	182.3 (± 40.8)	114.3 (± 23.9)	<0.001	180.6 (± 40.3)	108.5 (± 21.2)	<0.001
Flatus passage (POD)	3.3 (± 0.7)	3.9 (± 0.9)	<0.001	3.3 (± 0.7)	3.8 (± 0.8)	0.002
Postoperative hospital stays (days)	8.7 (± 19.2)	6.2 (± 1.8)	0.006	8.8 (± 19.5)	6.0 (± 1.6)	0.939
NRS for pain						
POD 1	3.8 (± 1.5)	3.6 (± 1.5)	0.331	3.9 (± 1.5)	3.6 (± 1.4)	0.379
POD 3	3.6 (± 1.8)	2.8 (± 1.3)	0.002	3.5 (± 1.8)	2.7 (± 1.3)	0.051
POD 5	1.6 (± 1.3)	1.7 (± 1.2)	0.66	1.6 (± 1.3)	1.8 (± 1.3)	0.557
Open conversion	0	0		0	0	
Complication	1 (3.2%)	28 (6.0%)	0.811	1 (3.3%)	5 (4.2%)	0.834
Mortality	0 (0.0%)	9 (1.9%)	0.933	0 (0.0%)	1 (0.8%)	NA

± Values are the standard deviations.
RALG-d: Robot-Assisted Laparoscopic Distal Gastrectomy with Delta-Shaped Anastomosis; LAG-d: Totally Laparoscopic Distal Gastrectomy with Delta-Shaped Anastomosis; LN: Lymph Node; POD: Postoperative Days; NRS: Numeric Rating Scale; NA: Not Available

P=0.002) was observed in the RALG-d group. Regarding pain, the mean NRS score on postoperative day 3 in the RALG-d group was much higher than in the LAG-d group (3.5 *vs.* 2.7, P=0.051), while those on postoperative days 1 and 5 showed no difference between the two groups (Figure 2).

There was no difference in overall incidence of postoperative morbidity. In the RALG-d group, there was one major complication of anastomosis leakage requiring a revisional surgery. In the LAG-d group, there were 28 cases with complications occurring, of which pneumonia was the most common followed by fluid collection not requiring intervention, and wound infection. There were two cases each of anastomosis-related and bleeding-associated complications. Grade 2 was the most commonly observed Clavien-Dindo classification (Table 3).

Discussion

Robot-assisted gastrectomy can provide similar benefits of laparoscopic surgery as a minimally invasive approach. With the help of endowristed instrumentation, a stable platform, and better magnified and multidimensional vision, RAG is expected to produce better surgical and oncologic outcomes compared with LAG. However, there are still no published prospective randomized studies to confirm the superiority of RAG.

In Korea, the surgical fee for LAG is mostly covered by the national

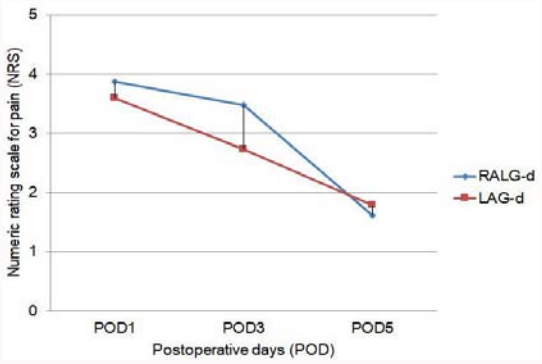

Figure 2: Numeric rating scale for postoperative pain.

Table 3: Comparison of postoperative complications.

Variables	RALG-d (n=31)	LAG-d (n=468)	P value
Complications: n (%)	1 (3.2)	28 (6.0)	0.811
Anastomosis leakage	1	1	
Anastomosis stricture	0	1	
Mechanical ileus	0	1	
Intraluminal bleeding	0	1	
Intra-abdominal bleeding	0	1	
Intra-abdominal abscess	0	1	
Fluid collection	0	5	
Wound infection	0	3	
Pneumonia	0	6	
Cerebral vascular accident	0	1	
Others	0	7	
Clavien-Dindo classification			
I	0	6	
II	0	17	
IIIa	0	2	
IIIb	1	1	
IVa	0	2	
IVb	0	0	

RALG-d: Robot-Assisted Laparoscopic Distal Gastrectomy with Delta-shaped Anastomosis; LAG-d: Totally Laparoscopic Distal Gastrectomy with Delta-shaped Anastomosis

health insurance system. However, the cost of RAG is usually fixed by each institution, and the full amount is paid by patients. A Korean study reported that the total surgical cost of RAG is significantly higher than that of LAG, with a difference of about €3,800 [16], and it can be an economic burden to patients. Five to six staplers are usually used in conventional LAG-d. To reduce the overall costs, after the dissection phase is completed, we undock all robotic devices and convert to the laparoscopic setting for the gastric/duodenal resection and anastomosis phase to use less expensive laparoscopic endolinear staplers instead of an EndoWrist® stapler 45 (Intuitive Surgical, Sunnyvale, CA, USA).

Several studies have reported that RAG has similar complication rates, hospital stay durations, and the number of harvested lymph nodes but longer operation times compared with LAG [17-19]. This study demonstrated that RAG is associated with earlier flatus passage and longer surgical times, but no differences were observed in number of harvested nodes, morbidity, and mortality, which is similar to previous studies. Because of introduction of the Enhanced Recovery after Surgery program in mid-2016, a significant number of patients in the LAG-d group were not included in the process. As this might affect the flatus passage and hospital stay findings, we reconducted 1:2 PSM analysis only for patients undergoing surgery after July 2016, and the difference in flatus passage was maintained (3.0 *vs.* 4.0 days, P=0.012). However, there was still no difference in duration of hospital stay. Among 31 patients receiving RAG, there was an elderly patient who had several underlying diseases, including severe atherosclerosis obliterans and aortic arch aneurysm that could compromise blood supply after surgery. He did not experience any extraordinary event during surgery but was diagnosed with anastomosis leakage caused by infarction of the remnant stomach by endoscopy. Eventually, he underwent laparoscopic revisional surgery. Under the assumption that this complication was not specific to robotic surgery, if we exclude this case from the results, there was no morbidity in RALG-d group. Additionally, the mean hospital stay in the robotic group was shorter, but the difference did not reach statistical significance (5.3 *vs.* 5.6 days, P=0.332). Therefore, this study also demonstrated that RALG-d could be a safe treatment option for gastric cancer.

Interestingly, the present study showed that pain levels on the third postoperative day were higher in RALG-d group. Some studies focusing on robotic pelvic surgery also reported more pain and a slower return to normal activities was seen in robotic groups compared with laparoscopic groups [20,21]. This consistency suggests that the robotic approach to treating gastric cancer may be associated with higher postoperative pain. There are some reasons to be considered. First, the length of incision is different. The diameter of incision on the umbilicus and two 12 mm trocar sites are identical but for two additional trocars, 5 mm and 8 mm incisions are needed for LAG-d and RALG-d, respectively. Second, continuous pressure and accumulation of stress on docking sites during longer surgery might enhance pain. As increments of pain ratings were observed temporarily, and there was no follow-up data after discharge, the clinical implications of the pain findings are questionable and more follow-up data are required. However, efforts to reduce pain in the first few days after surgery should be considered.

This study had several limitations. First, despite the use of PSM analysis, this was a retrospective study based on data generated by a single surgeon at a high-volume center. Second, as our RALG-d is not an entirely robotic procedure, we could not compare the results of anastomosis between the two groups.

Conclusion

The present study is valuable because it raises awareness of the necessity to reduce postoperative pain after RALG-d and confirmed that RALG-d could be a safe treatment option for gastric cancer and enhance rapid recovery of intestinal function.

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Authors' Contribution

All the above-mentioned authors met all the criteria for authorship contribution of the International Committee of Medical Journal Editors (ICMJE).

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