

Original Article



Comparison of Reduced Port Gastrectomy and Multiport Gastrectomy in Korea: Ad Hoc Analysis and Nationwide Survey on Gastric Cancer 2019

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OPEN ACCESS

Received: Aug 4, 2024
Revised: Oct 21, 2024
Accepted: Nov 20, 2024
Published online: Feb 10, 2025

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ABSTRACT

Purpose: This study aimed to evaluate the outcomes and current status of reduced-port laparoscopic distal gastrectomy (RLDG) compared with multiport laparoscopic distal gastrectomy (MLDG) based on a 2019 nationwide survey of surgical gastric cancer treatments by the Korean Gastric Cancer Association (KGCA).

Materials and Methods: The study was conducted retrospectively from March to December 2020 using data from the 2019 KGCA nationwide survey database. To compare RLDG and MLDG based on age, sex, body mass index, American Society of Anesthesiologists score, histological type, tumor invasion, and lymph node metastasis, propensity score matching was performed.

Results: Of the 14,076 registered patients with gastric cancer, the five-port approach was the most favored for multiport gastrectomy, accounting for 6,396 (70.9%) cases, followed by the four-port approach, with 1,462 (16.2%) cases. The single-port approach was used in 303 (3.4%) cases, the two-port approach in 95 (1.1%) cases, and the three-port approach in 731 (8.1%) cases. RLDG was performed in 805 patients (6.4%), MLDG was conducted in 4,831 patients (34.3%), and 804 patients were 1:1 matched in each group. The average operation time was shorter in the RLDG (168.2±49.1 min vs. 179.5±61.5 min, $P<0.001$). No significant difference was found in blood loss (84.8±115.9 cc vs. 75.5±119.6 cc, $P=0.152$), overall complication rates (11.3% vs. 13.1%, $P=0.254$), or complications $\geq$ to grade IIIa (3.2% vs. 4.4%, $P=0.240$).

Conclusions: This study revealed that RLDG is a safe and effective surgical option for gastric cancer with the potential to offer shorter operation times without increasing the risk of complications.

Keywords: Stomach cancer; Laparoscopic surgery; Minimally invasive surgical procedures

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Funding

This research was supported by the nationwide survey project of the Information Committee of the Korean Gastric Cancer Association (study number: KGCA2022IC11).

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

Conceptualization: H.D., S.Y.S.; Data curation: H.D., S.Y.S.; Formal analysis: H.D., S.Y.S.; Investigation: H.D., Y.M., M.G.H., L.E., S.Y.S.; Methodology: H.D., S.Y.S.; Project administration: H.D., K.S.H., P.Y.S., A.S.H., K.H.H., S.Y.S.; Resources: Information Committee of the Korean Gastric Cancer Association; Writing - original draft: H.D.; Writing - review & editing: S.Y.S.

INTRODUCTION

Gastric cancer continues to be a predominant cancer worldwide and poses significant health challenges [1]. Minimally invasive surgical techniques, particularly laparoscopic gastrectomy, have been introduced and have revolutionized surgical approaches, offering reduced postoperative pain, faster recovery, and better cosmetic outcomes than open surgery [2]. Following this trend, reduced-port laparoscopic gastrectomy has been developed to further reduce surgical trauma while retaining the laparoscopic advantages [3,4].

Interest in reduced-port gastrectomy is increasing, particularly because of its potential to minimize surgical trauma and postoperative pain [5]. Such techniques have been increasingly applied in various procedures including distal gastrectomy, total gastrectomy, and pylorus-preserving gastrectomy [6,7]. However, the limited working space in reduced port gastrectomy poses significant challenges in the adoption and standardization of this technique. The requirement for advanced laparoscopic skills, which entails a steep learning curve, adds complexity to the standardization of procedures for reduced-port surgery [8-10].

Previous studies have assessed the surgical outcomes and complication rates of reduced-port gastrectomy [11], and several have demonstrated its feasibility and benefits [5,12,13]. However, these studies were limited by their single-institution cohort design, which presents constraints in definitively proving their efficacy [13,14]. However, a multicenter assessment of the current status and surgical outcomes of reduced-port gastrectomy has not been conducted. Thus, a large-scale multicenter study is required to evaluate the efficacy of reduced-port gastrectomy in diverse populations.

However, research on institutional surgical outcomes and complications based on large-scale data is lacking. This study aimed to evaluate the safety and effectiveness of reduced-port gastrectomy in Korean patients with gastric cancer and is the first to assess the efficacy of reduced-port gastrectomy using nationwide data. Propensity score matching (PSM) was used to compare reduced port gastrectomy with multiport laparoscopic gastrectomy to evaluate their performance in a real-world clinical setting. These findings provide robust evidence of the comparative efficacy of the surgical techniques, thereby informing clinical practice and guiding future research in this field.

MATERIALS AND METHODS

Study design and patient selection

This study was conducted retrospectively from March to December 2020, utilizing data from the 2019 Korean Gastric Cancer Association (KGCA) nationwide survey, to assess the current status, metrics, and complication rates of reduced-port gastrectomy. A standardized case report form was used by the KGCA institutions, enabling the collection of comprehensive and uniform data on patient demographics, clinical characteristics, surgical procedures, and outcomes. Of the initial 14,076 patients included in the KGCA survey, those who underwent open gastrectomy or robot-assisted gastrectomy, had inaccurate information, or underwent atypical surgeries were excluded based on predefined exclusion criteria. This study primarily focused on reduced-port laparoscopic distal gastrectomy (RLDG) and multiport laparoscopic distal gastrectomy (MLDG) procedures. RLDG included single-, two-, and three-port surgeries. MLDG procedures were categorized into five-port and six-port

surgeries. Four-port cases were excluded as they fell on the boundary between the reduced port and multiport and were therefore excluded from both categories. Proximal gastrectomy and pylorus-preserving gastrectomy were excluded from the comparison groups because of an insufficient number of cases, and patients in the M1 stage were also excluded given the therapeutic purpose of the study. Finally, the reduced port and multiport gastrectomy groups were allocated. A flow diagram of the surgery type and port number is illustrated in this study (**Fig. 1, Supplementary Table 1**). PSM was used to mitigate potential confounding factors [15]. The variables used for matching included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, histological type, tumor invasion, and lymph node metastasis (**Fig. 1, Supplementary Table 1**). Matching was conducted at a 1:1 ratio using the nearest-neighbor method with a caliper of 0.05. For a detailed comparison, PSM was used to compare the MLDG with the single-port and three-port groups. Furthermore, PSM was conducted to compare the surgical outcomes and complications of RLDG in early gastric cancer (EGC) and advanced gastric cancer (AGC), as well as reduced port total gastrectomy

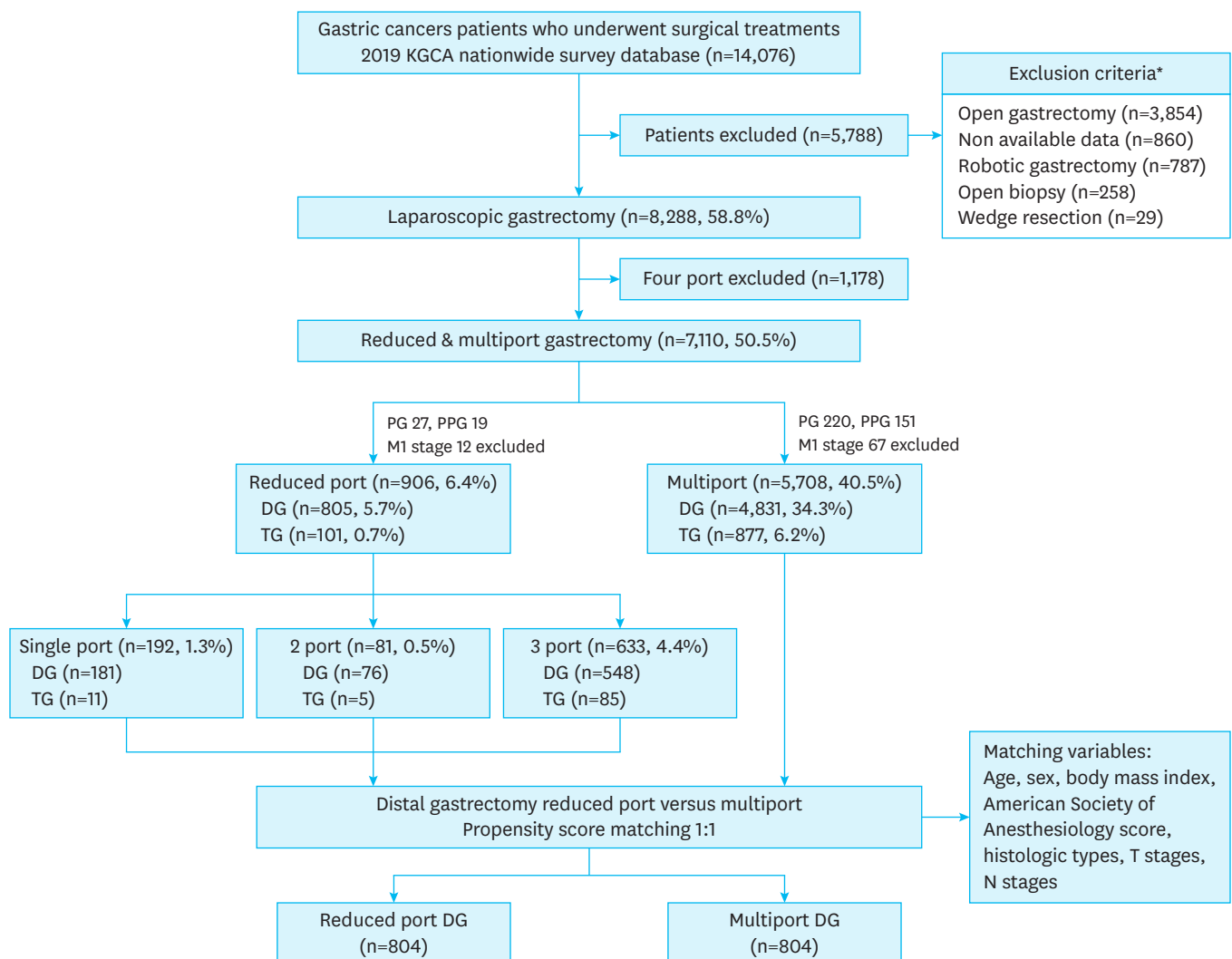


Fig. 1. Flow diagram of study.

KGCA = Korean Gastric Cancer Association; PG = proximal gastrectomy; PPG = pylorus preserving gastrectomy; DG = distal gastrectomy; TG = total gastrectomy.

*Exclusion criteria details are provided in the **Supplementary Table 1**.

with multiport gastrectomy. In this study, PSM was performed using the same variables for all comparisons.

Surgical outcome measures and pathologic results

Various indicators, such as operative time, intraoperative blood loss, complication rate, rate of complications above grade IIIa, Clavien–Dindo classification of complications [16], mortality, and detailed complication descriptions, were utilized to compare surgical outcomes between the reduced-port gastrectomy and multiport gastrectomy groups. The complications included anastomotic leakage, anastomotic stricture, duodenal stump leakage, intra-abdominal bleeding, luminal bleeding, pancreatic fistula, intra-abdominal abscess, fluid collection, wound complications, mechanical ileus, pulmonary complications, cerebrovascular accidents, and cardiac problems.

The following parameters were utilized in the analysis of the pathological data: T stage, pN stage, pM stage, and histological type. According to the histological classification, papillary carcinoma, well-differentiated adenocarcinoma, and moderately differentiated adenocarcinoma were categorized as differentiated carcinomas. Undifferentiated carcinomas include poorly differentiated adenocarcinoma, poorly cohesive carcinoma, signet ring cell carcinoma, mucinous carcinoma, and mixed-type tubular adenocarcinoma. Other types include gastric lymphomas and neuroendocrine tumors.

Continuous variables between the two groups were analyzed using the t-test, and chi-square tests were used to compare categorical variables. The SPSS software (version 26.0; IBM Corp., Armonk, NY, USA) was used to compare the two groups. Statistical significance was set at $P < 0.05$ in all tests.

Ethical considerations

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. The research protocol was reviewed and approved by the Institutional Review Board or Ethics Committee of the participating institutions and informed consent was obtained from all study participants. This retrospective study was approved by the Institutional Review Board (IRB) of Seoul National University Bundang Hospital (IRB No. X-2302-809-902).

RESULTS

Nationwide status of reduced port gastrectomy

According to the 2019 KGCA nationwide survey data, there was substantial institutional variability in the proportion of patients who underwent reduced-port laparoscopic gastrectomy (**Fig. 2**). Among the 65 institutions surveyed, five (7.6%) institutions performed over 500 laparoscopic gastrectomies annually, whereas 42 (64.6%) conducted fewer than 100 gastrectomies annually. Differences in preferences for reduced-port surgery techniques were also observed. Reduced-port gastrectomies were performed in 27 (41.5%) of the 65 institutions, accounting for 1,129 (12.5%) of the total 9,020 laparoscopic gastrectomies. Nine institutions conducted single-port gastrectomies, five performed two-port gastrectomies, and 18 performed three-port gastrectomies. For multiport gastrectomy, the five-port approach was the most favored, with 6,396 (70.9%) cases, followed by the four-port approach with 1,462 (16.2%) cases. In reduced-port laparoscopic gastrectomy, the single-port approach

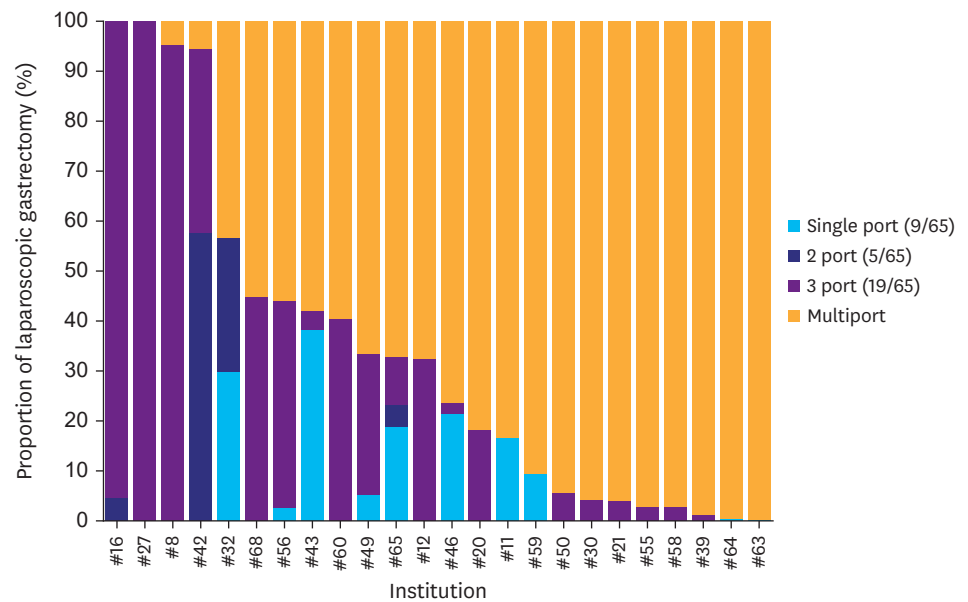


Fig. 2. The institutional proportion of reduced port laparoscopic gastrectomy across Korea in 2019.

was used in 303 (3.3%) cases, the two-port approach in 95 (1.1%) cases, and the three-port approach in 731 (8.1%) cases, with the three-port approach being the most preferred among the reduced-port gastrectomy techniques (**Fig. 2**).

Baseline patient characteristics

The clinicopathological characteristics of patients who underwent laparoscopic distal gastrectomy were compared between those who underwent RLDG and MLDG using PSM to balance the groups. Prior to PSM, the reduced port group consisted of 805 patients, whereas the multiport group included 4,831 patients (**Table 1**). No significant differences were observed in most clinicopathological characteristics between patients who underwent RLDG and those who underwent MLDG. However, BMI values were a significantly different between the RLDG and MLDG groups (24.0 ± 3.3 kg/m² vs. 24.2 ± 3.3 kg/m², $P=0.011$, standardized difference=0.097). However, this discrepancy was resolved by using a matching process. After PSM, 804 patients were included. BMI values were not significantly different in each group (24.0 ± 3.3 kg/m² vs. 24.2 ± 3.3 kg/m², $P=0.487$, standardized difference=0.034). The standardized differences for all variables were <0.1 before and after PSM, indicating a reduction in differences between the cohorts.

Surgical outcomes and postoperative complications

Table 2 shows the differences in surgical outcomes and complications between patients who underwent RLDG and those who underwent MLDG. After PSM, the operation time was significantly shorter for RLDG than for MLDG (168.28 ± 49.15 min vs. 179.56 ± 61.54 min, $P<0.001$). There was no statistically significant difference in blood loss after PSM ($P=0.152$). The overall complication rates were not significantly different between the two groups before (11.3% vs. 10.6%, $P=0.573$) and after PSM (11.3% vs. 9.5%, $P=0.254$). In addition, no significant difference in grade IIIa complications was observed between the two groups before (RLDG: 3.2% vs. MLDG: 3.1%, $P=0.801$) or after PSM (RLDG: 3.2% vs. MLDG: 4.4%, $P=0.240$), and there was no mortality in the reduced port group. In the analysis of specific complications, anastomosis leakage rates were higher in the multiport group before

Table 1. Clinicopathological characteristics of patients between reduced port and multiport approaches in laparoscopic distal gastrectomy before and after propensity score matching

Variables	Before propensity score matching				After propensity score matching			
	Reduced port (n=805)	Multiport (n=4,831)	P-value	Standardized difference	Reduced port (n=804)	Multiport (n=804)	P-value	Standardized difference
Age	62.8±12.3	63.0±11.9	0.565	0.022	62.8±12.3	63.0±12.1	0.726	0.018
Sex, male	500 (62.1)	3,073 (63.6)	0.437	-0.031	499 (62.1)	501 (62.3)	0.959	-0.005
Body mass index (kg/m ²)	24.0±3.3	24.2±3.3	0.011	0.097	23.9±3.2	24.1±3.3	0.487	0.034
American Society for Anesthesiology			0.152				0.192	
1	202 (25.1)	1,187 (24.6)		0.063	202 (25.1)	187 (23.3)		0.072
2	496 (61.6)	2,863 (59.3)		0.050	495 (61.6)	485 (60.3)		-0.016
≥3	107 (13.3)	773 (16.0)		-0.006	107 (13.3)	132 (16.4)		0.018
Histology			0.084				0.903	
Differentiated carcinoma	374 (46.5)	2,250 (46.6)			374 (46.5)	383 (47.6)		
Undifferentiated carcinoma	424 (52.7)	2,478 (51.3)			423 (52.6)	414 (51.5)		
Others	7 (0.9)	84 (1.7)			7 (0.9)	7 (0.9)		
T stage*			0.558				0.657	
T1	636 (79.0)	3,794 (78.5)			635 (79.0)	630 (78.3)		
T2	68 (8.4)	433 (9.0)			68 (8.5)	63 (7.8)		
T3	59 (7.3)	395 (8.2)			59 (7.3)	72 (9.0)		
T4	42 (5.2)	209 (4.3)			42 (5.2)	39 (4.9)		
N stage*			0.313				0.732	
N0	658 (81.7)	3,900 (80.7)			657 (81.7)	648 (80.6)		
N1	61 (7.6)	425 (8.8)			61 (7.6)	68 (8.4)		
N2	41 (5.1)	285 (5.9)			41 (5.1)	48 (6.0)		
N3	45 (5.6)	221 (4.6)			45 (5.6)	40 (5.0)		
TNM stage*			0.171				0.736	
IA	587 (72.9)	3,450 (71.4)			586 (72.9)	574 (71.4)		
IB	71 (8.8)	463 (9.6)			71 (8.8)	67 (8.3)		
IIA	52 (6.5)	331 (6.9)			52 (6.5)	63 (7.8)		
IIB	28 (3.5)	241 (5.0)			28 (3.5)	35 (4.4)		
IIIA	26 (3.2)	173 (3.6)			26 (3.2)	32 (4.0)		
IIIB	27 (3.4)	123 (2.5)			27 (3.4)	22 (2.7)		
IIIC	14 (1.7)	50 (1.0)			14 (1.7)	11 (1.4)		
Comorbidity	537 (66.7)	3,317 (68.7)	0.270		536 (66.7)	545 (67.8)	0.633	
Diabetes mellitus	146 (18.1)	930 (19.3)	0.457		146 (18.2)	143 (17.8)	0.846	
Hypertension	297 (36.9)	1,758 (36.4)	0.783		297 (36.9)	292 (36.3)	0.796	
Liver disease	23 (2.9)	197 (4.1)	0.098		23 (2.9)	30 (3.7)	0.328	
Tuberculosis	12 (1.5)	152 (3.1)	0.010		12 (1.5)	23 (2.9)	0.060	
Heart disease	48 (6.0)	343 (7.1)	0.240		48 (6.0)	63 (7.8)	0.140	
Chronic renal disease	9 (1.1)	53 (1.1)	0.958		9 (1.1)	10 (1.2)	0.817	
Chronic obstructive pulmonary disease	17 (2.1)	161 (3.3)	0.067		17 (2.1)	34 (4.2)	0.016	
Cerebral vascular accident	31 (3.9)	155 (3.2)	0.345		31 (3.9)	20 (2.5)	0.118	
Other	181 (22.5)	959 (19.9)	0.085		180 (22.4)	145 (18.0)	0.030	

Values are presented as mean ± standard deviation or number (%).

TNM = tumor-node-metastasis.

*The American Joint Committee on Cancer TNM classification, 8th edition.

matching (1.4% vs. 0.6%, P=0.027) but were not significantly different after PSM (1.4% vs. 1.1%, P=0.653). Similarly, the pancreatic fistula rates were higher in the reduced port group before PSM (P=0.043). However, this difference was not significant after PSM (P=0.125). Other complications, including pulmonary and cerebrovascular accidents, did not differ significantly after PSM.

Surgical outcomes based on the number of ports and tumor stage

The surgical outcomes of patients who underwent RLDG and MLDG based on the surgical type and tumor stage are shown in **Table 3**. PSM was performed to determine the clinicopathological characteristics of each group (**Supplementary Table 2**). In EGC, no significant difference

Table 2. Surgical outcomes and postoperative complications of patients between reduced port and multiport approaches in laparoscopic distal gastrectomy before and after propensity score matching

Variables	Before propensity score matching			After propensity score matching		
	Reduced port (n=805)	Multiport (n=4,831)	P-value	Reduced port (n=804)	Multiport (n=804)	P-value
Op time (minutes)	168.3±49.1 (n=803)	178.8±63.4 (n=4,496)	<0.001	168.2±49.1 (n=802)	179.5±61.5 (n=752)	<0.001
Blood loss (mL)	84.7±115.8 (n=793)	71.7±95.0 (n=3,320)	0.004	84.8±115.9 (n=792)	75.5±119.6 (n=554)	0.152
Overall complication	91 (11.3)	514 (10.6)	0.573	91 (11.3)	106 (13.1)	0.254
Complication ≥ Gr. IIIa	26 (3.2)	148 (3.1)	0.801	26 (3.2)	35 (4.4)	0.240
Clavien–Dindo classification			0.212			0.147
I	13 (1.6)	95 (2.0)		13 (1.6)	28 (3.5)	
II	49 (6.1)	246 (5.1)		49 (6.1)	42 (5.2)	
IIIa	10 (1.2)	85 (1.8)		10 (1.2)	18 (2.2)	
IIIb	14 (1.7)	44 (0.9)		14 (1.7)	14 (1.7)	
IV	2 (0.2)	14 (0.3)		2 (0.2)	2 (0.2)	
V	0 (0.0)	5 (0.1)		0 (0.0)	1 (0.1)	
Complications						
Anastomosis leakage	11 (1.4)	31 (0.6)	0.027	11 (1.4)	9 (1.1)	0.653
Anastomosis stricture	12 (1.5)	40 (0.8)	0.069	12 (1.5)	9 (1.1)	0.510
Duodenal stump leakage	8 (1.0)	31 (0.6)	0.265	8 (1.0)	9 (1.1)	0.807
Intraabdominal bleeding	4 (0.5)	25 (0.5)	1.000	4 (0.5)	8 (1.0)	0.246
Luminal bleeding	3 (0.4)	19 (0.4)	1.000	3 (0.4)	3 (0.4)	1.000
Pancreatic fistula	4 (0.5)	6 (0.1)	0.043	4 (0.5)	0 (0.0)	0.125
Intraabdominal abscess	8 (1.0)	31 (0.6)	0.265	8 (1.0)	4 (0.5)	0.386
Fluid collection	9 (1.1)	58 (1.2)	0.841	9 (1.1)	10 (1.2)	0.817
Wound complication	10 (1.2)	37 (0.8)	0.169	10 (1.2)	9 (1.1)	0.817
Mechanical ileus	12 (1.5)	47 (1.0)	0.181	12 (1.5)	15 (1.9)	0.560
Pulmonary complication	20 (2.5)	67 (1.4)	0.019	20 (2.5)	13 (1.6)	0.218
Cerebral vascular accident	0 (0.0)	5 (0.1)	1.000	0 (0.0)	0 (0.0)	
Cardiac problem	2 (0.2)	10 (0.2)	0.685	2 (0.2)	2 (0.2)	1.000
Other	15 (1.9)	171 (3.5)	0.014	15 (1.9)	31 (3.9)	0.017

Values are presented as mean ± standard deviation or number (%).

was observed in age between the RLDG and MLDG groups after PSM (62.0±12.0 vs. 62.3±11.3 years). Likewise, in AGC, no significant difference was observed between the RLDG and MLDG groups after PSM (66.4±13.3 vs. 66.5±12.5 years), although the average age was higher than that of the EGC group. No significant differences were found in the clinicopathological characteristics between RLDG and MLDG for total gastrectomy and both three-port and single-port laparoscopic distal gastrectomy (SLDG). In terms of surgical outcomes, when comparing RLDG vs. MLDG for EGC, RLDG showed a significantly shorter operation time after matching (165.27±48.32 min vs. 176.50±67.45 min, $P<0.001$). However, no significant differences were found in the overall complication rates and rates of grade IIIa complications. When comparing RLDG vs. MLDG for AGC, reduced port surgery also showed a significantly shorter operation time after PSM (181.9±50.6 min vs. 197.9±61.0 min, $P=0.019$). No significant differences were observed in the overall complications and rates of grade IIIa complications in AGC. For three-port distal gastrectomy vs. MLDG, operation times were significantly shorter in the three-port group compared to the MLDG group, both before (163.54±47.48 min vs. 178.82±63.44 min, $P<0.001$) and after matching (163.54±47.48 min vs. 181.52±54.71 min, $P<0.001$). No significant differences were found in the complication rates between the three-port groups before and after matching. In the comparison of single-port versus MLDG, no significant difference was noted in operation time or blood loss before and after matching. However, after PSM, the overall complication rate (16.8% vs. 8.9%, $P=0.027$) and the rate of grade IIIa complications (5.6% vs. 1.7%, $P=0.048$) were significantly higher in the single-port group than in the MLDG group (**Supplementary Table 3**). No significant differences in the postoperative complication rates were observed between the groups (**Supplementary Table 4**).

Table 3. Surgical outcomes based on the number of ports and tumor stage in laparoscopic distal or total gastrectomy before and after propensity score matching

Variables	Before propensity score matching			After propensity score matching		
	Reduced port	Multiport	P-value	Reduced port	Multiport	P-value
Reduced port vs. multiport in distal gastrectomy for early gastric cancer	n=658	n=3,913		n=658	n=658	
Op time (minutes)	165.2±48.3 (n=656)	175.3±62.1 (n=3,658)	<0.001	165.2±48.3 (n=656)	176.5±67.4 (n=615)	<0.001
Blood loss (mL)	81.0±115.0 (n=648)	70.4±96.4 (n=2,681)	0.015	81.0±115.0 (n=648)	68.2±109.8 (n=456)	0.141
Overall complication	70 (10.6)	399 (10.2)	0.730	70 (10.6)	63 (9.6)	0.522
Complication ≥ Gr. IIIA	18 (2.7)	102 (2.6)	0.848	18 (2.7)	13 (2.0)	0.363
Reduced port vs. multiport in distal gastrectomy for advanced gastric cancer	n=147	n=918		n=147	n=147	
Op time (minutes)	181.9±50.6 (n=147)	193.8±66.9 (n=838)	0.013	181.9±50.6 (n=147)	197.8±61.0 (n=134)	0.019
Blood loss (mL)	101.1±118.7 (n=145)	77.4±88.9 (n=639)	0.025	101.1±118.7 (n=145)	80.5±108.1 (n=101)	0.166
Overall complication	21 (14.3)	115 (12.5)	0.553	21 (14.3)	25 (17.0)	0.521
Complication ≥ Gr. IIIA	8 (5.4)	46 (5.0)	0.825	8 (5.4)	12 (8.2)	0.354
Reduced port vs. multiport in total gastrectomy	n=101	n=877		n=97	n=97	
Op time (minutes)	215.0±60.2 (n=101)	228.2±87.9 (n=826)	0.051	214.0±60.4 (n=97)	226.9±82.1 (n=93)	0.220
Blood loss (mL)	130.8±133.7 (n=98)	120.2±164.6 (n=577)	0.485	132.3±136.0 (n=94)	97.4±121.3 (n=61)	0.106
Overall complication	26 (25.7)	168 (19.2)	0.116	25 (25.8)	23 (23.7)	0.739
Complication ≥ Gr. IIIA	13 (12.9)	52 (5.9)	0.008	13 (13.4)	7 (7.2)	0.157

Values are presented as mean ± standard deviation or number (%).

Institutional surgical outcomes

Fig. 3 demonstrated a decreasing trend in the total, ≥IIIA complications, and pulmonary complications with an increase in institutional surgical volume. Institutions performing more than 50 procedures had a complication rate of <14%. **Fig. 4** shows the institutional differences in complication rates among patients who underwent laparoscopic distal gastrectomy after PSM. The Y-axis represents the difference (RLDG minus MLDG) in the complication rates between RLDG and MLDG at each institution. A positive value indicates a higher complication rate for RLDG, whereas a negative value indicates a higher complication rate for MLDG. **Fig. 4A, B, and C** depict the differences in the complication rates between RLDG and MLDG. When compared using the Mann–Whitney U non-parametric test, institutions performing 90 or fewer RLDG procedures annually showed a significant

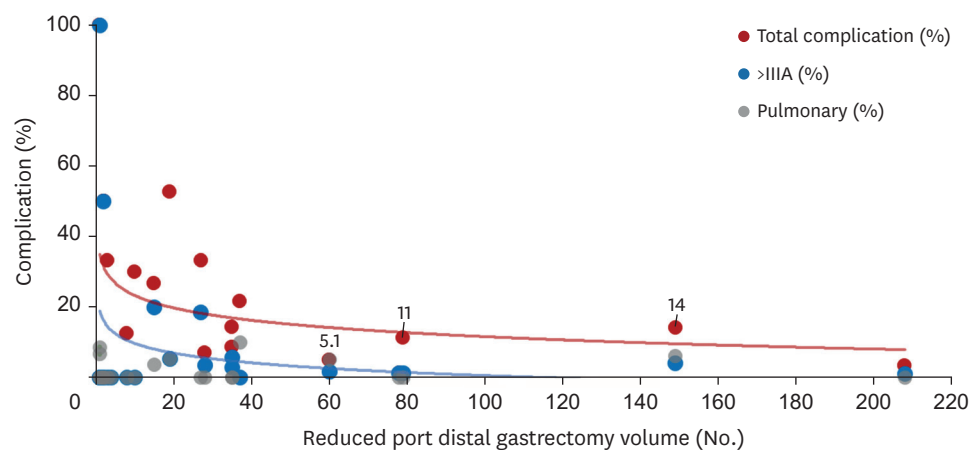


Fig. 3. Complication rates by reduced port distal gastrectomy volume in Korea, 2019.

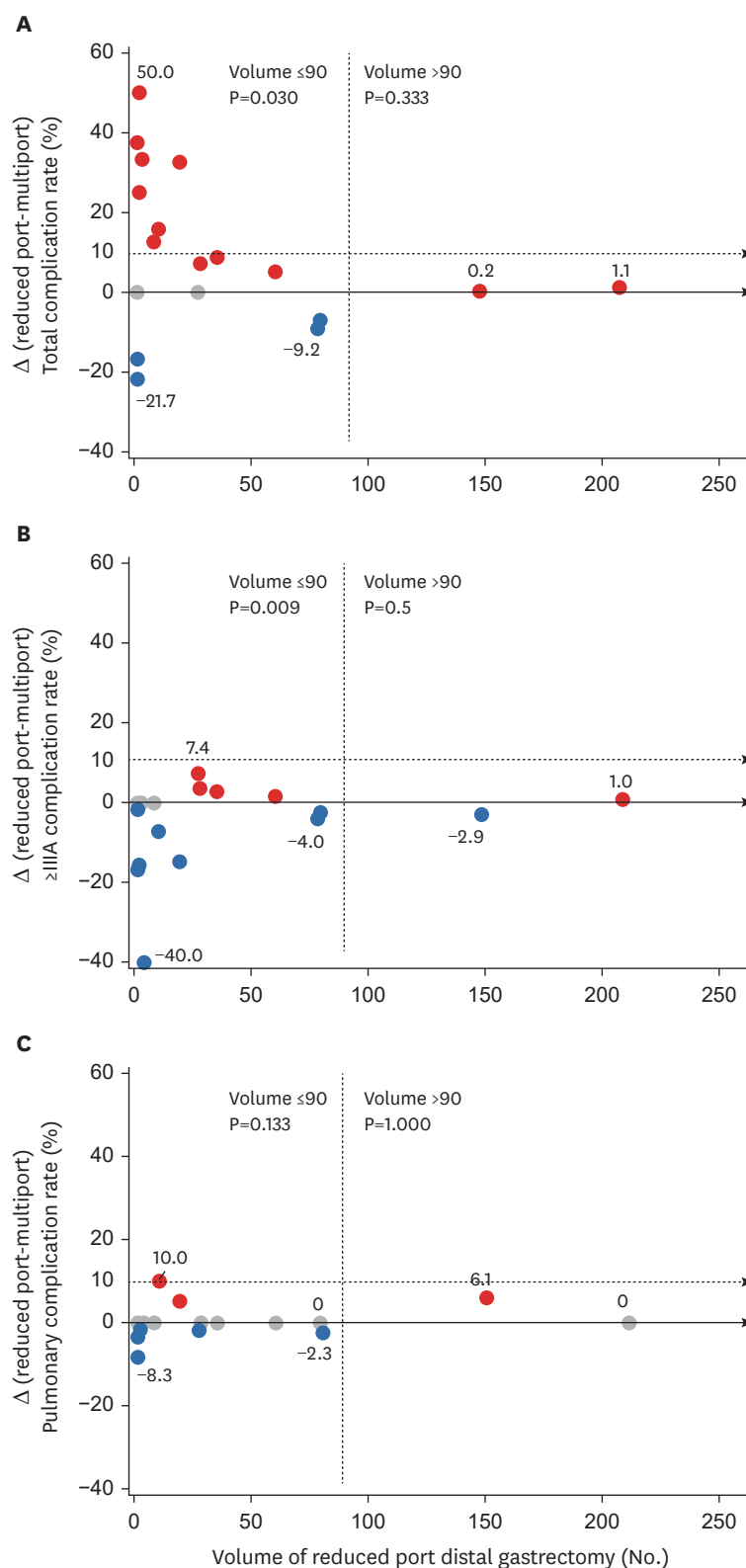


Fig. 4. Institutional differences in complication rates for reduced port laparoscopic distal gastrectomy after propensity score matching.

difference in the total complication rates compared to MLDG ($P=0.030$). A significant difference in the rates of $\geq$ IIIa grade complications was observed ($P=0.009$). Conversely, no significant difference in the total complication rates between RLDG and MLDG ($P=0.333$) was observed in institutions performing more than 90 RLDG procedures annually.

DISCUSSION

This study is the first to compare the safety of RLDG and MLDG using the KGCA nationwide, multicenter, retrospective database involving 65 institutions in Korea in 2019. By utilizing big data with well-matched PSM, this study revealed that RLDG shortened operative time without increasing complication rates. In this study, the current practice and surgical outcomes of reduced port gastrectomy in a nationwide multicenter setting were analyzed, and the safety of RLDG was presented. According to the 5th Gastric Cancer Adequacy Evaluation by the Health Insurance Review and Assessment Service in 2019, 13,597 patients diagnosed with gastric cancer underwent surgery at 182 institutions [17]. In this study, 13,553 of 14,097 patients underwent gastric cancer surgery, indicating that the KGCA nationwide survey reflected real-world data from South Korea [18]. In this study, 12.5% of the laparoscopic gastrectomies were performed using reduced-port techniques, and differences in the number of ports adopted by different institutions were observed. Of the institutions that performed laparoscopic surgery, 41.5% performed reduced-port gastrectomy. Our results indicate that RLDG is a viable surgical option for gastric cancer, demonstrating shorter operation times than MLDG without a significant increase in complication rates.

Previous retrospective studies revealed mixed results regarding RLDG operation times, with some groups demonstrating significantly shorter operation times [19-22], while others reported longer operation times, indicating inconsistent outcomes [23,24]. Furthermore, the variation in the surgical methods used across groups renders consistent comparisons challenging. The inconsistency in the number of ports used in each study, ranging from one port to two or three ports, further complicates the derivation of generalizable results. Significantly fewer prospective randomized controlled trials have been conducted than retrospective studies and their findings vary. Additionally, the studies included in these analyses often involved very small patient groups, which limits the evidence available to generalize the benefits of RLDG. These results highlight the need for further research on reduced-port gastrectomies.

This study used a nationwide database to assess the current status and surgical outcomes of reduced-port gastrectomy and to overcome the limitations of previous studies. In this study, the large cohort included very even clinicopathological characteristics, suggesting minimal potential confounding factors even before PSM matching. Although not statistically significant, reduced port gastrectomy was performed more frequently in younger female patients and was significantly more common in patients with a lower BMI ($P=0.011$). Conversely, estimated blood loss was significantly different between the groups before PSM and showed a similar tendency after PSM, although the difference was after PSM. Although PSM was employed to minimize preoperative biases and enhance the accuracy of the results, real-world data before PSM should be carefully interpreted.

The findings indicate that RLDG could reduce operation time without increasing the risk of complications (168.28 ± 49.15 min vs. 179.56 ± 61.54 min, $P < 0.001$). **Table 3** shows that

there were no significant differences in operation time or complications between the SLDG and MLDG groups. However, the three-port approach demonstrated a significant reduction in operative time, consistent with previous retrospective studies [19-22]. While a few studies have suggested that RLDG for EGC reduces operation time without increasing complications [19,25], Studies that compare RLDG for AGC with a sufficient number of patients are lacking. **Table 3** shows that RLDG in patients with AGC had shorter operation times and no significant differences in complications. This suggests that reduced-port gastrectomy techniques, such as the three-port approach, may have a shorter learning curve, making it easier to achieve the necessary surgical skills and expertise compared to multiport gastrectomy because of the less drastic reduction in the number of ports. In SLDG, the study revealed the impact of surgical volume on complication rates. Institutions performing high-volume RLDG had lower complication rates than those with fewer RLDG. Additionally, institutions performing >90 RLDG surgeries annually showed smaller differences in complication rates between RLDG and MLDG (**Fig. 4**). Compared with MLDG at other institutions, SLDG showed a significantly lower overall complication rate after PSM (12.5% vs. 24.0%, $P=0.040$) (**Fig. 4**). This trend suggests that surgical proficiency and institutional experience play pivotal roles in optimizing the outcomes of reduced-port surgeries.

Despite our results, many challenges remain in standardizing reduced-port surgeries. Owing to the collection of data from various institutions, a significant amount of data was excluded because of quality issues. In addition, differences in data quality must be considered because of the varying contributions from each institution. Information on previous abdominal surgeries can be an important factor in determining the indications for laparoscopic and open surgeries, as well as for reduced port gastrectomy and multiport gastrectomy. Owing to the lack of detailed data on prior surgeries in a nationwide survey, caution is needed when interpreting and selecting appropriate indications for laparoscopic surgery. In this study, no significant difference was observed in the history of previous abdominal surgeries between the reduced-port and multiport distal gastrectomy groups after PSM (16.8% [135/802] vs. 15.6% [117/752]; $P=0.536$). However, this was the first study to analyze the current status of reduced-port gastrectomies using big data, providing valuable insights into the implementation and surgical outcomes of reduced-port gastrectomies across different institutions. Nevertheless, similar to previous studies, it is difficult to find clear advantages other than the reduced operative time. While some studies have reported cosmetic satisfaction and postoperative pain, definitive evidence is lacking.

Reduced-port surgery requires advanced laparoscopic skills and has a steep learning curve, which can be a barrier to its widespread adoption. Training programs and standardized guidelines are essential for helping surgeons develop the necessary skills. The significant variability in outcomes across institutions suggests that factors such as surgical volume, institutional protocols, and team experience play critical roles in the success of reduced-port gastrectomies. Institutions with low surgical volumes may benefit from targeted interventions to improve patient outcomes. Although this study provided valuable data on short-term outcomes, long-term follow-up is necessary to fully understand the benefits and potential drawbacks of reduced-port gastrectomy. Developing standardized protocols and best practices for reduced-port gastrectomy can help minimize variability in surgical outcomes and facilitate wider adoption. Conducting randomized controlled trials comparing reduced port and multi-port gastrectomies in diverse patient populations can provide more robust evidence on the efficacy and safety of reduced port techniques. Currently, the KCLASS-12 multicenter randomized controlled trial is underway to prospectively verify the

safety of reduced port gastrectomy compared with multiport gastrectomy. These large-scale prospective studies will help to establish the safety of reduced-port techniques.

This was the first study to compare the safety of RLDG and MLDG using a nationwide multicenter retrospective database. Our results indicate that RLDG is an effective surgical option for gastric cancer, capable of reducing operative time without significantly increasing complication rates. However, challenges in standardizing reduced-port gastrectomy remain due to lacking research evidence, the learning curve, non-standardized surgical protocols, and technical difficulties. Large-scale prospective randomized controlled trials such as the ongoing KLASS-12 study are essential to provide robust evidence of the efficacy and safety of reduced-port techniques. Further research is warranted to establish the long-term benefits of reduced port gastrectomy and to develop standardized protocols to ensure consistent outcomes.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Exclusion criteria

Supplementary Table 2

Clinicopathological characteristics of patients undergoing laparoscopic gastrectomy according to tumor stage and surgical method before and after propensity score matching

Supplementary Table 3

Surgical outcomes based on the number of ports in laparoscopic distal gastrectomy before and after propensity score matching

Supplementary Table 4

Postoperative complication rates based on the number of ports and disease stage in laparoscopic distal and total gastrectomies before and after propensity score matching

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