

# A comparative analysis of surgical outcomes after robotic gastrectomy with conventional multiport, single-site, and single-port surgical system for gastric cancer

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**Purpose:** Technological advancements have enabled reduced-port robotic systems, enhancing the benefits of robotic surgery. This study compared the surgical outcomes of conventional multiport (5 ports), single-site (2 ports), and single-port (2 ports) robotic gastrectomy for gastric cancer.

**Methods:** A prospectively collected database was retrospectively reviewed for patients who underwent robotic distal subtotal gastrectomy between January 2010 and August 2022 at Severance Hospital, Yonsei University Health System. The initial 20 cases from each group (multiport, single-site, and SP) were analyzed, focusing on demographics, surgical procedures, pathological results, and postoperative outcomes. The “textbook outcome” metric was employed to assess surgical quality.

**Results:** The SP group showed lower visual analog pain scale compared to the multiport and single-site groups (3.5, 4.4, and 4.3, respectively,  $P = 0.017$ ), faster time to first flatus (2.0, 2.7, and 2.8 days, respectively;  $P < 0.001$ ), and shorter hospital stays (3.5, 6.2, and 5.5 days, respectively;  $P < 0.001$ ). No significant differences were observed in major complications, unplanned intensive care unit care, readmission, or mortality between the groups. The rate of patients achieving textbook outcomes were 85.0% for the multiport group, 100% for the single-site group, and 95.0% for the SP group ( $P = 0.310$ ).

**Conclusion:** Reduced-port robotic gastrectomy, including single-site and SP, has shown surgical safety with a high proportion of patients meeting textbook outcomes. The SP system demonstrated less pain and faster recovery, aligning with minimally invasive surgical goals. Therefore, the SP system could be a reliable and safe option for robotic gastrectomy, offering enhanced recovery without compromising surgical quality.

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**Key Words:** Gastrectomy, Postoperative pain, Robotic surgical procedures, Stomach neoplasms

## INTRODUCTION

Robotic surgery has gained widespread acceptance owing to its numerous advantages, including enhanced ergonomics,

3-dimensional (3D) visualization, and the use of articulating instruments [1,2]. Recent technological advancements have enabled reduced-port robotic surgery such as single-site and single-port surgical systems. In gastric cancer surgery, reduced-

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port robotic gastrectomy has become a viable alternative to the conventional 5-port approach, providing a less invasive 2-port option [3,4].

Laparoscopic reduced-port surgery offers reduced surgical trauma and cosmetic benefits [5-7]. However, this presents technical challenges, including constrained operating spaces and the potential for instrument collisions. Single-site and SP robotic systems have addressed these challenges by enabling multiple instruments to dock seamlessly within a single port, eliminating the constraints and collisions that previously hindered the procedure [3,4]. Furthermore, the enduring advantages of robotic surgery, such as articulating instruments, 3D visualization, and enhanced ergonomics, offset the potential risks associated with reduced-port approaches.

During the introduction of new technologies, the benefits associated with them come with the fear of unknown risks. Therefore, we compared conventional multiport, single-site, and SP robotic gastrectomies, including the initial learning experience, to analyze the surgical outcomes of these new technologies. To comprehensively evaluate the results, we have adopted the concept of a "textbook outcome," which serves as a pivotal metric for assessing the quality and safety of gastric cancer surgery [8-10].

This study aimed to evaluate the initial surgical outcomes associated with 3 distinct robotic approaches with a focus on the potential advantages offered by these innovative surgical approaches.

## METHODS

### Ethics statement

The Institutional Review Board of Severance Hospital, Yonsei University Health System approved this study and waived informed consent because of its retrospective nature (No. 4-2023-1358).

### Patients and data collection

This study retrospectively reviewed a prospectively collected

database of patients who underwent robotic distal subtotal gastrectomy from January 2010 to August 2022 performed by a single surgeon at Severance Hospital, Yonsei University Health System in Seoul, South Korea. Patients were divided into 3 groups based on the robotic system used: multiport, single-site, and SP. To evaluate surgical quality considering the learning curve, the initial 20 cases from each group were analyzed. Data on demographics, surgical procedures, pathological results, hospital stay, Clavien-Dindo (CD) grade, and readmissions were collected.

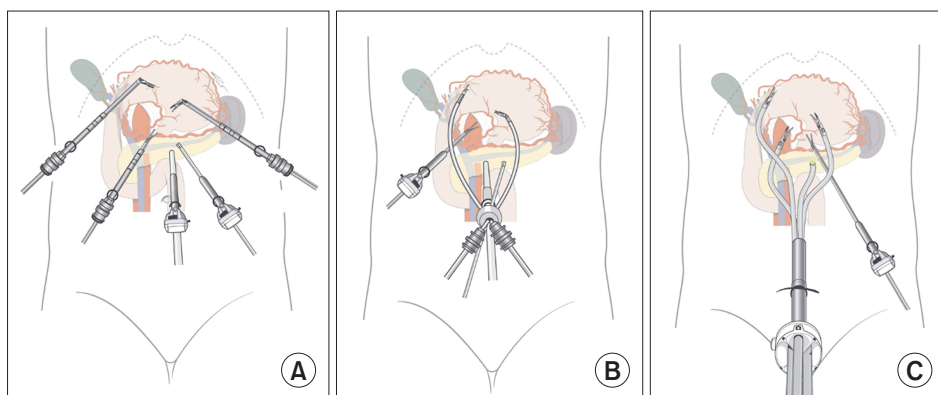
### Surgical procedure

The robotic systems used for the conventional group were the da Vinci (Intuitive Surgical) Si systems (Fig. 1A), the single-site group utilized the da Vinci Si and Xi system (Fig. 1B), and the SP group employed the da Vinci SP system (Fig. 1C). Near-infrared imaging aided fluorescent-guided lymphadenectomy during surgery through Firefly integrated into the da Vinci Xi and SP systems.

Surgical procedures were performed according to the Korean Gastric Cancer Guidelines for all robotic approaches. D1+ lymphadenectomy was performed in patients with clinically node-negative early gastric cancer, and D2 lymphadenectomy was performed in patients with clinically node-positive or advanced gastric cancer [11].

The indications for each approach changed as personnel and surgical experience increased. Recently, only patients with clinical T4b or extensive lymph node (LN) metastases were treated with conventional multiport robotic gastrectomy, whereas patients with less advanced cancer received reduced-port robotic gastrectomy as an option. The SP system represents a completely novel design compared to the existing Si or Xi systems. Therefore, to effectively compare the initial learning curve and surgical outcomes, we selected the initial cases for each system as the study cohort. This approach allows for a fair assessment of the adaptability and performance of the SP system against established platforms during the early adoption phase.

The procedures for conventional multiport [12,13] or single-



**Fig. 1.** Robotic docking systems of (A) conventional robotic gastrectomy (5 port, multiport), (B) reduced-port robotic gastrectomy (2 port, single-site), and (C) reduced-port robotic gastrectomy (2 port, single-port).

site [3,14,15] robotic gastrectomy at our institution have been previously described. Conventional or single-site robotic gastrectomy was performed in a supine position. Conventional robotic gastrectomy (Fig. 1A) involved an 8-mm camera port (Arm 3) at the umbilicus, an 8-mm port for Cadere forceps (Arm 1) in the right lateral subcostal area, an 8-mm port for Harmonic ACE curved shears (Ethicon Endo-Surgery; Arm 2) in the right lower quadrant area, a 12-mm port for the assistant in the left lower quadrant area, and an 8-mm port for Maryland bipolar forceps (Arm 4). Single-site gastrectomy (Fig. 1B) utilized a single-site port system through a 2.5-cm length incision at the umbilicus where a camera, Cadere forceps (left hand), and wristed needle driver (right hand) were installed, with the addition of a 12-mm right lower quadrant port for Harmonic ACE curved shears.

The gastrectomy procedure using the SP system has been previously described [4]. The patient was placed in a lithotomy position. The SP system was installed (Fig. 1C) through a 2.5-cm Pfannenstiel incision in the suprapubic area. Based on the reconstruction, a 12-mm assistant port was used in the right lower quadrant for gastrojejunostomy and in the left lower quadrant for gastroduodenostomy. The multichannel cannulas of the SP system were equipped with a camera and 3 wristed instruments. We used Arm 1 for monopolar curved scissors, Arm 2 for Cadere forceps, and Arm 3 for Maryland bipolar forceps. The instruments in the SP system were capable of unimpeded 360° rotation within a cannula during operation. The angulation of the multiarticulate flexible camera allowed a top-down angle, providing an optimal surgical field and enhanced visualization of deep structures. The camera was rotated from the lower to the upper position as needed, and the angulation was adjusted to facilitate the dissection of suprapancreatic LNs [16-18]. The assistant port was used for surgical assistance, including the insertion of gauze or needles, the use of laparoscopic ultrasonic devices during transection, and staplers for anastomosis.

LN dissection and reconstruction were performed in a similar manner across all 3 groups, including partial omentectomy followed by infrapyloric LN dissection, transection of the duodenum, and suprapyloric and suprapancreatic LN dissection, followed by LN dissection around the left gastric vessels. The choice of reconstruction method was based on tumor location and surgeon preference. The total omentectomy was not performed routinely in patients with advanced gastric cancer. The procedure was performed only in cases where the tumor invaded the greater curvature and showed serosal exposure. However, none of the patients with advanced gastric cancer in this study underwent total omentectomy.

### Perioperative management

From 2010 to early 2021, bowel preparation was performed with magnesium citrate solution (Magcorol solution, 250 mL; Taejoon Pharm Co.) the day before surgery and has not been

performed since then. Intravenous patient-controlled analgesia was applied to all 3 groups on the day of surgery. Thereafter, additional analgesics were provided intravenously according to the patient's request.

The postoperative diet was as follows: the conventional group started sips of water (SOW) on postoperative day 2, liquid diet (LD) on day 3, and soft diet (SD) on day 4; the single-site group started SOW on day 2, LD on the morning of day 3, and SD on the midday of day 3; the SP group started SOW on the day of surgery, LD on the morning of day 1, and SD on the afternoon of day 1. Only patients who met the following requirements were discharged: diet build-up status, patient's willingness to be discharged, and physician's confirmation of recovery for the Conventional and single-site groups. In the SP group, the decision was made based not only on previously described requirements but also on additional discharge criteria, such as pulse rate (<90/min), CRP level (110 mg/L), neutrophil count ( $6.7 \times 10^3$  cells), and body temperature (38 °C) [19].

### Textbook outcomes

Textbook outcomes were employed as a metric for short-term outcomes as described in a previous study, with a modification [9,20]. Textbook outcome satisfaction was defined as meeting all of the following criteria: radical resection determined by the surgeon at the conclusion of the surgery, absence of intraoperative complications, negative resection margins, retrieval of 16 or more LNs, absence of severe complications (CD grade III or higher), no need for intervention or reoperation, no requirement for unplanned intensive care unit (ICU) care, hospital stay of 10 days or less, no postoperative mortality, and no readmission after discharge.

### Statistical analysis

Categorical variables were analyzed using the chi-square or Fisher exact test, and the results are presented as numbers and percentages. Continuous variables were analyzed using the analysis of variance (ANOVA) test, and the results are presented as means and standard deviations. For continually measured continuous variables, repeated-measures ANOVA was used for comparison, and the Bonferroni correction was applied in the *post hoc* analysis. Linear regression was used to analyze operation time as the number of cases increased. A 2-sided P-value <0.05 was considered statistically significant. STATA software ver. 18.0 (Stata Corp.) was used for the statistical analysis.

## RESULTS

### Patient demographic characteristics and clinical features

This study included 60 patients, 20 in each group (conventional,

**Table 1.** Patients' demographics and clinical features by robotic approaches

Characteristic	Multiport group	Single-site group	SP group	P-value
No. of patients	20	20	20	
Age (yr)	52.7 ± 11.1	49.6 ± 9.8	52.7 ± 13.4	0.099
Sex				>0.999
Male	9 (45.0)	9 (45.0)	9 (45.0)	
Female	11 (55.0)	11 (55.0)	11 (55.0)	
Body mass index (kg/m <sup>2</sup> )	23.9 ± 4.2	22.6 ± 2.4	23.0 ± 2.7	0.411
Previous abdominal surgery	9 (45.0)	5 (25.0)	7 (35.0)	0.415
ASA PS classification				0.001
I	13 (65.0)	7 (35.0)	2 (10.0)	
II	7 (35.0)	13 (65.0)	18 (90.0)	
T classification				0.310
T1/2	17 (85.0)	20 (100)	19 (95.0)	
T3/4	3 (15.0)	0 (0)	1 (5.0)	
N classification				0.625
N0	16 (90.0)	19 (95.0)	18 (90.0)	
N1	2 (10.0)	1 (5.0)	1 (5.0)	
N2	2 (10.0)	0 (0)	1 (5.0)	
Stage				0.084
1	15 (75.0)	20 (100)	17 (85.0)	
2	4 (20.0)	0 (0)	3 (15.0)	
3	1 (5.0)	0 (0)	0 (0)	

Values are presented as number only, mean ± standard deviation, or number (%). ASA, American Society of Anesthesiologists; PS, physical status.

single-site, and SP groups), who underwent robotic distal subtotal gastrectomy. The SP group demonstrated a higher proportion of patients with an American Society of Anesthesiologists physical status classification of II (18/20 [90.0%],  $P = 0.001$ ) compared to the conventional (7/20 [35.0%]) and single-site (13/20 [65.0%]) groups (Table 1). No significant differences were observed among the 3 groups regarding age, sex, body mass index, history of prior abdominal surgery, T classification, N classification, and TNM stage.

### Operative findings according to robotic approach

The operative time was significantly shorter in the single-site group compared to the conventional or SP groups (multiport 248.0 ± 78.7 minutes, single-site 186.1 ± 40.2 minutes, SP 230.9 ± 42.6 minutes;  $P = 0.003$ ) (Table 2). As the number of cases increased, the surgical time decreased in the conventional and SP groups, while the single-site group showed an increase in operative time. The linear prediction of operative time was as follows: conventional group,  $y = 277.9 - 2.8x$  ( $P = 0.365$ ); single-site group,  $167.3 + 1.8x$  ( $P = 0.264$ ); SP group,  $248.1 - 1.6x$  ( $P = 0.334$ ) (Fig. 2A). Estimated blood loss was not significantly different between groups (conventional 35.5 ± 31.8 mL, single-site 28.8 ± 26.8 mL, SP 50.0 ± 37.4 mL;  $P = 0.116$ ).

The reconstruction methods were similar among the 3 groups ( $P = 0.563$ ). Gastroduodenostomy was performed in 4 patients (20.0%) in the conventional group, 7 (35.0%) in the single-site group, and 6 (30.0%) in the SP group. Gastrojejunostomy was

performed in 16 patients (80.0%) in the conventional group, 13 (65%) in the single-site group, and in 14 (70.0%) in the SP group.

There were significant differences in the proportion of patients who underwent D2 lymphadenectomy (conventional 10/20 [50.0%], single-site 0/20 [0.0%], and SP groups 6/20 [30.0%];  $P = 0.002$ ) and the proportion of patients who underwent surgery with fluorescent lymphography (conventional 0/20 [0.0%], single-site 19/20 [95.0%], and SP groups 0/20 [0.0%];  $P < 0.001$ ). The number of retrieved LNs was significantly higher in the single-site group compared to the conventional or SP groups (conventional 33.4 ± 13.3, single-site 46.8 ± 17.2, and SP groups 29.8 ± 10.5;  $P < 0.001$ ).

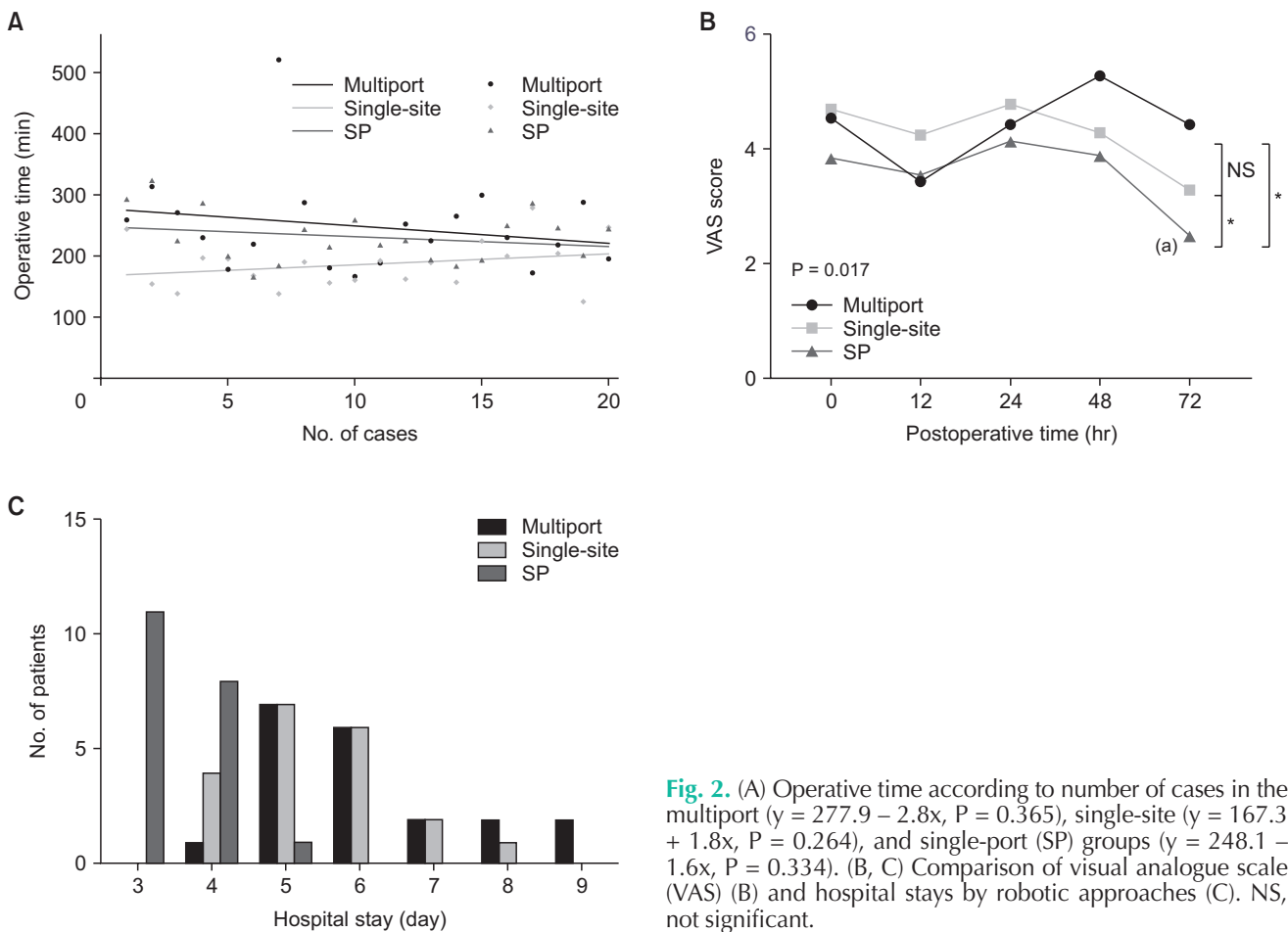
### Postoperative pain and recovery

There was a significant difference ( $P = 0.017$ ) among the 3 groups in the postoperative pain scale (visual analog scale) at 12, 24, 48, and 72 hours postoperatively. The peak postoperative pain score was 5.5 ± 1.9 at 48 hours in the multiport group, whereas it was 4.8 ± 1.6 and 4.2 ± 1.3 at 24 hours in the single-site and SP groups, respectively. In *post hoc* analysis, the SP group (estimated marginal mean, 3.5; 95% confidence interval [CI], 3.0–4.0) showed lower pain scale compared to the conventional (estimated marginal mean, 4.4; 95% CI, 3.9–4.8;  $P = 0.027$ ) and the single-site groups (estimated marginal mean, 4.3; 95% CI, 3.9–4.7;  $P = 0.048$ ). However, no significant difference was observed in pain scale scores between the conventional and single-site groups (Fig. 2B).

**Table 2.** Operative findings and short-term outcomes by robotic approaches

Variable	Multiport group (n = 20)	Single-site group (n = 20)	SP group (n = 20)	P-value
Operation time (min)	248.0 ± 78.7	186.1 ± 40.2	230.9 ± 42.6	0.003
Estimated blood loss (mL)	35.5 ± 31.8	28.8 ± 26.8	50.0 ± 37.4	0.116
Reconstruction				0.563
Gastroduodenostomy	4 (20.0)	7 (35.0)	6 (30.0)	
Gastrojejunostomy	16 (80.0)	13 (65.0)	14 (70.0)	
Lymph node dissection				0.002
D1+	10 (50.0)	20 (100)	14 (70.0)	
D2	10 (50.0)	0 (0)	6 (30.0)	
NIR-guided LND				<0.001
Yes	0 (0)	19 (95.0)	0 (0)	
No	20 (100)	1 (5.0)	20 (100)	
da Vinci version				<0.001
Si	20 (100)	12 (60.0)	0 (0)	
Xi	0 (0)	8 (40.0)	0 (0)	
SP	0 (0)	0 (0)	20 (100)	
No. of lymph nodes	33.4 ± 13.3	46.8 ± 17.2	29.8 ± 10.5	<0.001

Values are presented as mean ± standard deviation or number (%). NIR, near-infrared; LND, lymph node dissection.



**Fig. 2.** (A) Operative time according to number of cases in the multiport ( $y = 277.9 - 2.8x$ ,  $P = 0.365$ ), single-site ( $y = 167.3 + 1.8x$ ,  $P = 0.264$ ), and single-port (SP) groups ( $y = 248.1 - 1.6x$ ,  $P = 0.334$ ). (B, C) Comparison of visual analogue scale (VAS) (B) and hospital stays by robotic approaches (C). NS, not significant.

Postoperative laboratory findings showed significant differences in CRP levels, albumin levels, and lymphocyte counts between the participants ( $P = 0.012$ ,  $P = 0.025$ , and  $P = 0.017$ ,

respectively) (Supplementary Fig. 1). CRP levels were significantly lower in the SP group (estimated marginal mean, 17.7 mg/L; 95% CI, 9.8–25.5) than in the conventional group (estimated marginal

mean, 36.0 mg/L; 95% CI, 25.5–46.6; P = 0.022). No significant difference was observed between the conventional and single-site (estimated marginal mean, 24.4 mg/L, 95% CI, 19.0–29.8; P = 0.084) groups, nor between SP and single-site groups (P > 0.999). Albumin level was higher in the SP group (estimated marginal mean, 4.0 g/dL; 95% CI, 3.9–4.2) than in the conventional group (estimated marginal mean, 3.7 g/dL; 95% CI, 3.6–3.9; P = 0.021). There were no statistically significant differences between the SP and single-site groups (estimated marginal mean, 3.9 g/dL; 95% CI, 3.7–4.0; P = 0.491), nor between the single-site and the conventional groups (P = 0.493). The lymphocyte count was higher in the SP group (estimated marginal mean, 1,633; 95% CI, 1,454–1,812) than in the conventional group (estimated marginal mean, 1,270; 95% CI, 1,086–1,454; P = 0.019). There was no significant difference between the SP and single-site groups (estimated marginal mean, 1,551; 95% CI, 1,372–1,731; P = 0.097), nor between the single-site and SP groups (P > 0.999). Hemoglobin levels and neutrophil counts were not significantly different between the groups.

### Short-term outcomes with textbook outcomes according to robotic approach

Time to first flatus was significantly faster in the SP group compared to the conventional and single-site groups (conventional 2.7 ± 0.6 days, single-site 2.8 ± 0.8 days, and SP groups 2.0 ± 0.3 days; P < 0.001). Hospital stays were significantly shorter in the SP group compared to the conventional and single-site groups (conventional 6.2 ± 1.4 days, single-site 5.5 ± 1.1 days, and SP groups 3.5 ± 0.6 days; P < 0.001) (Fig. 2C). No significant differences were observed in the rates of minor or major complications (CD grade I or higher) among the groups (conventional 6/20 [30.0%], single-site 6/20 [30.0%], and SP 7/20 [35.0%]; P = 0.926). In the conventional group, there were 2 patients with wound dehiscence, 1 with fever, 1 with neutropenic septic shock, 1 with chylous ascites, 1 with diarrhea, and 1 with pancreatitis. In the single-site group, 5 patients demonstrated fever, and 1 exhibited anemia. In the SP group, there were 3 patients with fever, one patient with chylous ascites, 2 patients with urinary retention, and 1 patient with diarrhea. No anastomotic leakage or stenosis were observed in any group.

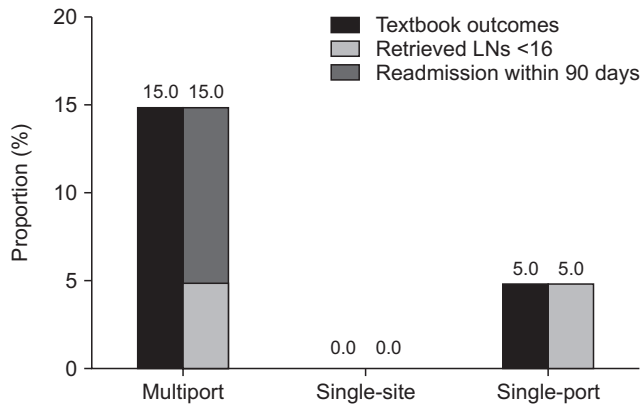
**Table 3.** Short term outcomes by robotic approaches

Variable	Multiport group (n = 20)	Single-site group (n = 20)	SP group (n = 20)	P-value
Diet build-up				
Preoperative bowel preparation	20 (100)	20 (100)	2 (10.0)	<0.001
Sips of water	2.9 ± 0.9	2.0 ± 0.0	0.8 ± 0.4	<0.001
Liquid diet	3.1 ± 0.9	3.0 ± 0.2	1.1 ± 0.5	<0.001
Soft diet	3.9 ± 0.9	3.1 ± 0.3	1.4 ± 0.6	<0.001
Hospital stay (day)	6.2 ± 1.4	5.5 ± 1.1	3.5 ± 0.6	<0.001
First flatus (day)	2.7 ± 0.6	2.8 ± 0.8	2.0 ± 0.3	<0.001
All complications (CD grade ≥1)	6 (30.0)	6 (30.0)	7 (35.0)	0.926
Wound	2 (10.0)	0 (0)	0 (0)	0.322
Fever	1 (5.0)	5 (25.0)	3 (15.0)	0.265
Neutropenic septic shock	1 (5.0)	0 (0)	0 (0)	>0.999
Anemia	0 (0)	1 (5.0)	0 (0)	>0.999
Chylous ascites	1 (5.0)	0 (0)	1 (5.0)	>0.999
Urinary retention	0 (0)	0 (0)	2 (10.0)	0.322
Diarrhea	0 (0)	0 (0)	1 (5.0)	>0.999
Pancreatitis	1 (5.0)	0 (0)	0 (0)	>0.999
Textbook outcome	17 (85.0)	20 (100)	19 (95.0)	0.310
Intraoperative complication	0 (0)	0 (0)	0 (0)	>0.999
LN retrieval <16	1 (5.0)	0 (0)	1 (5.0)	>0.999
Hospital stays >10 days	0 (0)	0 (0)	0 (0)	>0.999
Major complication (CD grade ≥III)	0 (0)	0 (0)	0 (0)	>0.999
Unplanned ICU care	0 (0)	0 (0)	0 (0)	>0.999
Resection margin	0 (0)	0 (0)	0 (0)	>0.999
Readmission	2 (10.0)	0 (0)	0 (0)	0.322
Mortality	0 (0)	0 (0)	0 (0)	>0.999

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

CD, Clavien-Dindo classification; LN, lymph node; ICU, intensive care unit.

Textbook outcome: radical resection according to the surgeon at the end of surgery, no intraoperative complication, tumor-negative resection margin, the number of retrieved LN 16 or more, no severe complication, no reintervention, no ICU care (readmit), no prolonged hospital stay (10 days or less), no postoperative mortality, no readmission after discharge.



**Fig. 3.** The proportion of patients who did not meet textbook outcomes according to robotic approaches. LN, lymph node.

The proportion of patients who met the textbook outcome was the highest in the single-site group, followed by the SP and conventional groups, although there were no statistically significant differences (conventional 17/20 [85.0%], single-site 20/20 [100%], and SP groups 19/20 [95.0%];  $P = 0.310$ ) (Table 3). In the conventional group, 1 patient (5.0%) had fewer than 16 retrieved LNs, and 2 (10.0%) were readmitted within 90 days. In the SP group, 1 patient (5.0%) had fewer than 16 retrieved LNs (Fig. 3).

## DISCUSSION

The initial cases of the reduced robotic approach, single-site, or SP demonstrated comparable surgical outcomes to the conventional multiport approach, with a high proportion of patients meeting textbook outcomes in the reduced robotic groups. The SP group showed less postoperative pain than the conventional and single-site groups. Patients in the SP group showed shorter hospital stays and a faster time to first flatus than those in the single-site or conventional groups, although these findings should be interpreted in the context of the enhanced recovery after surgery (ERAS) protocol implemented in the later SP cases. No bowel preparation and early oral nutrition may have contributed to postoperative recovery for patients in the SP group.

CRP has been recognized as an indicator of postoperative surgical stress and inflammation [21]. The variations in CRP levels likely reflect differences in surgical trauma associated with different surgical approaches. In the conventional and single-site groups, an ultrasonic device (Harmonic ACE curved shears) was utilized, whereas the SP group employed monopolar curved scissors and Maryland bipolar forceps. As previously reported, ultrasonic devices lack articulating function and often result in thermal damage on surrounding tissues, whereas bipolar devices generate less thermal injury and, through articulation, facilitate a pancreas-protective dissection [18,22,23]. These characteristics

may have contributed to the lower CRP levels observed in the SP group. However, the clinical interpretation of postoperative albumin and lymphocyte counts remains uncertain, as these are more commonly regarded as preoperative prognostic markers rather than as postoperative outcome indicators [24,25]. While these findings were statistically significant, their clinical relevance should be interpreted with caution. Textbook outcomes were used as indicators of short-term outcomes [8-10]. Patients were discharged within 5 days after gastrectomy; therefore, those staying in the hospital more than twice as long were considered outliers. Major complications in gastric cancer have been defined as CD grade III or higher in many studies, and this study also used this as a criterion. The conventional group demonstrated 3 failures in textbook outcomes, including retrieved LNs <16 and readmissions. No textbook outcomes failures were observed in the single-site group, while the SP group had one failure due to retrieved LNs <16. However, the number of retrieved LNs in the conventional group and SP group may be the result of fluorescent lymphography not being performed in this group during the early period of robotic surgery, despite the current utilization of this technique by both groups. There were no events such as major complications, unplanned ICU care, readmissions, or mortality in the single-site and SP groups, indicating safe postoperative outcomes. However, these outcomes should be interpreted with caution because accumulated surgical experience and enhanced postoperative management might affect the outcomes of each surgical approach.

The SP group demonstrated earlier recovery than did the single-site and conventional groups. The reduced robotic approach does not require an incision near the rib margin and the SP system uses a Pfannenstiel incision instead of the umbilicus [4]. The SP and single-site groups exhibited peak pain scores on postoperative day 1, whereas the conventional group demonstrated the highest pain score on postoperative day 2. This observation is consistent with findings from certain thoracoscopy or cardiac surgeries that require port placement near the rib or sternotomy [26,27]. Avoiding pain sensations around the rib margin and umbilicus may lead to a faster recovery. However, it is important to acknowledge the potential influence of the different operative years in each group, as surgeon experience accumulated and ERAS developed [28,29]. The single-site group had a shorter operative time than the other groups. As the number of cases increased, the operative time increased in the single-site group without demonstrating a clear learning effect, though the regression coefficient was not statistically significant. The single-site approach uses the same da Vinci Si or Xi system as the conventional multiport approach, making it easier to adapt, whereas the SP system uses a new da Vinci SP system, which requires more time to adapt. Moreover, the SP system was not equipped with an ultrasonic device, which resulted in longer operative times. Initially, monopolar

curved scissors were used for dissection. Although the patients included in this study underwent procedures using monopolar curved scissors, the instrument was later replaced with Maryland bipolar forceps due to insufficient hemostatic and tissue-holding capabilities, and the double-bipolar method was employed. Despite these limitations in the initial period, there were no major complications in the SP system, possibly because of the utilization of bipolar devices at Arm 3 for dissection, reducing thermal damage to the surrounding tissues [16-18].

This study had some limitations. Significant differences in operative years and surgeon experience make adequate comparison difficult. Developments in perioperative management, including a fast diet build-up, may influence postoperative recovery. The utilization of fluorescent lymphography and the extent of LN dissection affected the number of retrieved LNs [30-32]. Nonetheless, the single-site and SP groups demonstrated a remarkably high proportion of patients (95.0%–100%) meeting the textbook outcomes without any major complications, unplanned ICU care, readmissions, or mortality, confirming the safety of the reduced robotic approach. Furthermore, all procedures were performed by a single experienced surgeon in a high-volume tertiary center, which may restrict the applicability of our findings. The favorable outcomes observed with the single-site and SP system may not be reproducible in lower-volume centers or by surgeons with less experience in robotic surgery. Therefore, a multicenter randomized controlled trial is necessary to evaluate their applicability in diverse clinical settings, and to make a clear comparison between the conventional multiport robotic approach and the reduced robotic approach.

In conclusion, the reduced robotic approach using a single-site or SP system may offer a safe option with the advantages of less pain and early recovery in gastric cancer as part of the comprehensive ERAS approach without compromising surgical outcomes. However, further research is required to compare these approaches comprehensively.

## SUPPLEMENTARY MATERIALS

Supplementary Fig. 1 can be found via <https://doi.org/10.4174/astr.2026.110.4.216>.

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### Conflict of Interest

Hyung-Il Kim, serving as an Associate Editor of *Annals of Surgical Treatment and Research*, did not participate in the review process of this article. No other potential conflicts of interest pertinent to this article were reported.

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