J Gastric Cancer. 2019 Jun;19(2):165-172
https://doi.org/10.5230/jgc.2019.19.e13
pISSN 2093-582X·eISSN 2093-5641

Journal of Gastric Cancer

Original Article

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Similar Operative Outcomes between the da Vinci Xi® and da Vinci Si® Systems in Robotic Gastrectomy for Gastric Cancer

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Received: Oct 17, 2018
Revised: Mar 24, 2019
Accepted: Mar 25, 2019

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ABSTRACT

Purpose: The robotic system for surgery was introduced to gastric cancer surgery in the early 2000s to overcome the shortcomings of laparoscopic surgery. The more recently introduced da Vinci Xi® system offers benefits allowing four-quadrant access, greater range of motion, and easier docking through an overhead boom rotation with laser targeting. We aimed to identify whether the Xi® system provides actual advantages over the Si® system in gastrectomy for gastric cancer by comparing the operative outcomes.
Materials and Methods: We retrospectively reviewed all patients who underwent robotic gastrectomy as treatment for gastric cancer from March 2016 to March 2017. Patients' demographic data, perioperative information, and operative and pathological outcomes were collected and analyzed.
Results: A total of 109 patients were included in the Xi® group and 179 in the Si® group. Demographic characteristics were similar in both groups. The mean operative time was 229.9 minutes in the Xi® group and 223.7 minutes in the Si® group. The mean estimated blood loss was 72.7 mL in the Xi® group and 62.1 mL in the Si® group. No patient in the Xi® group was converted to open or laparoscopy, while 3 patients in the Si® group were converted, 2 to open surgery and 1 to laparoscopy, this difference was not statistically significant. Bowel function was resumed 3 days after surgery, while soft diet was initiated 4 days after surgery.
Conclusions: We found no difference in surgical outcomes after robotic gastrectomy for gastric cancer between the da Vinci Xi® and da Vinci Si® procedures.

Keywords: Robot; Gastrectomy; Gastric cancer

INTRODUCTION

Since the introduction of robotic systems, the minimally invasive approach was further revolutionized. Robotic application facilitates technically challenging procedures, such as suturing, to be performed easily and in comfort [1,2]. Robotic gastrectomy has also been increasingly performed and has demonstrated satisfactory initial surgical outcomes, which are comparable to the laparoscopic approach [3-6].

Conflict of Interest
Dr. Woo Jin Hyung has stock in Hutom, received a research grant from Medtronic and GC Pharma, and was a consultant for Ethicon and Verb Surgical. The other authors declare that they have no conflicts of interest.

The da Vinci Xi® system (Intuitive Surgical, Sunnyvale, CA, USA), a new generation robotic surgery system, was introduced to overcome the limitations of the previous platform, the da Vinci Si® system. It offers better anatomical access for multi-quadrant surgical procedures because of the overhead boom rotation without axis limitation with a laser precision targeting that allows optimum boom positioning [7]. Moreover, it is equipped with an 8-mm endoscope that does not require draping, autofocuses and white balances, and can be used through all arms [8]. In addition, the da Vinci Xi® system has narrower arms and a longer instrument shaft, which gives the surgeon a better reach [9].

Whether these benefits influence outcomes after gastrectomy need to be investigated to justify the higher cost of the da Vinci Xi® system, although a few comparative studies comparing the da Vinci Xi® and da Vinci Si® systems when performing rectal and prostate surgery have been reported [1,7,9-13]. Our study aimed to evaluate the clinical efficiency of the da Vinci Xi® system by comparing operative outcomes in robotic gastrectomy using the da Vinci Xi® and da Vinci Si® systems.

MATERIALS AND METHODS

Patients

We started using the da Vinci Xi® system in March 2016. We identified 286 patients who underwent robotic gastrectomy from March 2016 to March 2017, 107 patients with da Vinci Xi® system (Xi® group) and 179 with da Vinci Si® system (Si® group). Data were acquired from the prospective database of gastric cancer in our institute. We obtained data regarding the patients' preoperative status, operative outcomes, pathological features, and immediate postoperative recovery results. The diagnosis of gastric adenocarcinoma was confirmed by preoperative endoscopy and biopsy. Abdominopelvic computed tomography was performed for all patients for clinical staging. Patients who were found eligible for the procedure provided written informed consent after the surgical approaches, costs, and risks associated with the surgery were clearly explained to them. Postoperative complications were graded using the Clavien-Dindo classification of surgical complications [14]. We classified fever, urinary retention, and wound complications as grade I complications. Fever was defined as temperature of 38.0°C or higher or the use of antipyretics, regardless of the temperature. Pancreatitis, pleural effusion, and transfusion were classified as grade II complications. Grade III complications were defined as complications requiring surgical, endoscopic, or radiological procedures, such as anastomosis site leakage, pulmonary thromboembolism, pleural effusion, and atrial fibrillation. Grade IV complications were defined as life-threatening complications, which in our study population were new-onset left bundle branch block and anastomosis leakage due to a peripancreatic abscess. Grade V complication was patient death [14]. This retrospective study was approved by the Institutional Review Board (IRB) of Severance Hospital, Yonsei University College of Medicine, Seoul, Republic of Korea (IRB No. 4-2018-0048).

Surgical procedure

Our robotic gastrectomy procedures, both conventional and reduced port procedures, have been described previously [5,6,15-21]. Three surgeons with experience in robotic gastrectomy performed all the operations included in our study. These 3 surgeons performed 839, 268, and 12 robotic gastrectomy procedures using da Vinci Si®. The gastrectomy procedures using the da Vinci Xi® and da Vinci Si® systems were performed using the same approach. The Xi®

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robotic gastrectomy procedures have been performed with the same port placement, with the exception of using an 8-mm port for the camera and using the laser targeting feature prior to docking. Conventional robotic gastrectomy was defined as a robotic gastrectomy with 5 ports, namely, a camera port and 4 ports for robotic instruments and assistant port [5,6]. Reduced port surgery was defined as robotic gastrectomy using the Single-Site™ system with 1 or 2 additional ports [15,17]. Anastomosis was performed intracorporeally in all patients.

Statistical analysis

IBM SPSS (version 23 for Mac; IBM Corp., Armonk, NY, USA) software package was used to perform the statistical analyses. Continuous variables were analyzed with independent sample t-tests and were expressed as the mean±standard deviation, while categorical variables were compared using χ^2 tests. A P-value of <0.05 was considered significant.

RESULTS

Patients' demographic characteristics are shown in **Table 1**. Both groups had equal age distributions; age and preoperative body mass index were similar as well as past medical and surgical histories.

Resection extent was similar in both groups, with over 70% of patients undergoing distal gastrectomy, as shown in **Table 2**. Operative variables were not statistically different between the groups in terms of total operation time, docking, and console time. Total operation time was 196 minutes in the Xi® group and 192 minutes in the Si® group. The mean docking time was 4.8 minutes in the Xi® group and 4.5 minutes in the Si® group. In addition, the console time was 121.4 minutes in the Xi® group and 116.0 minutes in the Si® group.

The conversion rate was not statistically different, although there were 3 conversions in the Si® group and none in the Xi® group. Of the 3 converted patients in the Si® group, 2 converted to open surgery because of severe adhesions in 1 patient and gastrocolic vein bleeding in the other, and 1 converted to laparoscopic secondary due to a trocar-related mechanical problem.

Table 1. Patients' demographic data

Variables	All (n=286)			Conventional (n=169)			Reduced port (n=117)		
	Xi® (n=107)	Si® (n=179)	P-value	Xi® (n=61)	Si® (n=108)	P-value	Xi® (n=46)	Si® (n=71)	P-value
Age (yr)	55.8±13.7	56.8±11.8	0.509	57.6±14.6	57.6±11.8	0.968	53.4±12.2	55.7±11.8	0.305
Sex			0.491			0.789			0.162
Male	66 (61.7)	103 (57.5)		36 (59.0)	66 (61.1)		30 (65.2)	37 (52.1)	
Female	41 (38.3)	76 (42.5)		25 (41.0)	42 (38.9)		16 (34.8)	34 (47.9)	
BMI (kg/m²)	23.7±3.1	23.7±3.3	0.746	24.0±3.3	24.0±3.6	0.966	23.6±2.9	23.3±2.9	0.554
Comorbidity			0.191			0.713			0.024
No	28 (26.2)	35 (19.6)		11 (18.0)	22 (20.4)		17 (37.0)	13 (18.3)	
Yes	79 (73.8)	144 (80.4)		50 (82.0)	86 (79.6)		29 (63.0)	58 (81.7)	
Previous abdominal surgery			0.065			0.240			0.150
No	89 (83.2)	132 (73.7)		48 (78.7)	76 (70.4)		41 (89.1)	56 (78.9)	
Yes	18 (16.8)	47 (26.3)		13 (21.3)	32 (29.6)		5 (10.9)	15 (21.1)	
Surgeons			0.281			0.711			0.129
A	43 (40.2)	79 (44.1)		43 (70.5)	79 (73.1)		0	0	
B	42 (39.3)	76 (42.5)		18 (29.5)	29 (26.9)		24 (52.2)	47 (66.2)	
C	22 (20.6)	24 (13.4)		0	0		22 (47.8)	24 (33.8)	

Data are shown as mean±standard deviation or number (%).
Xi = the da Vinci Xi® system; Si = the da Vinci Si® system; BMI = body mass index.

Table 2. Perioperative details

Variables	All (n=286)			Conventional (n=169)			Reduced port (n=117)		
	Xi® (n=107)	Si® (n=179)	P-value	Xi® (n=61)	Si® (n=108)	P-value	Xi® (n=46)	Si® (n=71)	P-value
Operations performed			0.397			0.447			0.350
Distal gastrectomy	78 (72.9)	141 (78.8)		40 (65.6)	80 (74.1)		38 (82.6)	61 (85.9)	
Total gastrectomy	21 (19.6)	23 (12.8)		13 (21.3)	15 (13.9)		8 (17.4)	8 (11.3)	
Proximal gastrectomy	7 (6.5)	11 (6.1)		7 (11.5)	9 (8.3)		0 (0.0)	2 (2.8)	
Completion total gastrectomy	1 (0.9)	4 (2.2)		1 (1.6)	4 (3.7)		-	-	
Total operation time (min)	196.3±55.6	192.5±63.1	0.610	203.5±53.1	192.0±66.3	0.247	186.7±57.9	193.3±58.3	0.552
Operative preparation (min)	12.5±9.0	13.8±17.4	0.502	12.5±5.3	16.1±21.1	0.199	12.7±12.3	10.3±8.5	0.236
Docking time (min)	4.8±1.8	4.5±2.4	0.162	4.8±1.8	3.9±1.6	<0.001	4.9±1.8	5.3±3.1	0.329
Console time (min)	121.4±50.3	116.0±49.4	0.379	120.7±41.9	110.9±42.9	0.154	122.3±60.1	123.8±57.3	0.893
Specimen retrieval and closure (min)	53.9±28.9	54.1±32.7	0.969	60.3±25.6	55.1±36.3	0.329	45.6±31.3	52.5±26.6	0.202
Estimated blood loss (mL)	72.8±135.0	62.1±133.0	0.511	81.2±133.2	71.2±165.4	0.686	61.8±138.0	48.3±53.5	0.459
Conversion	0 (0.0)	3 (1.7)	0.178	0 (0.0)	2 (1.9)	0.285	0 (0.0)	1 (1.4)	0.419
Days to first flatus (days)	3.3±1.4	3.1±0.9	0.319	3.2±0.8	3.2±0.8	0.958	3.4±1.9	3.1±0.9	0.216
Days to sips of water (days)	2.1±1.1	2.3±0.8	0.128	2.1±0.4	2.3±0.9	0.055	2.1±1.7	2.2±0.7	0.651
Days to liquid diet (days)	3.3±2.2	3.2±0.9	0.443	3.1±0.6	3.2±0.8	0.591	3.5±3.2	3.1±0.9	0.318
Days to first soft diet (days)	4.2±2.8	4.0±2.3	0.571	3.9±0.8	4.2±2.8	0.273	4.6±4.1	3.6±1.2	0.059
Hospital length of stay (days)	7.2±11.2	6.01±3.4	0.195	7.6±14.4	6.0±3.7	0.283	6.6±4.4	5.9±2.9	0.352

Data are shown as mean±standard deviation or number (%).
Xi = the da Vinci Xi® system; Si = the da Vinci Si® system.

Table 3. Complications noted in the patients in the Xi® and Si® groups Complications

Complications	All (n=286)			Conventional (n=169)			Reduced port (n=117)		
	Xi® (n=107)	Si® (n=179)	P-value	Xi® (n=61)	Si® (n=108)	P-value	Xi® (n=46)	Si® (n=71)	P-value
Presence of complications			0.187			0.142			0.761
No	39 (36.4%)	80 (44.7%)		19 (31.1%)	46 (42.6%)		20 (43.5%)	34 (47.9%)	
Yes	68 (63.6%)	99 (55.3%)		42 (68.9%)	62 (57.4%)		26 (56.5%)	37 (52.1%)	
Complications grade			0.269			0.039			0.751
I	49 (70.8%)	74 (74.7%)		29 (69.0%)	46 (74.2%)		20 (76.9%)	28 (80%)	
II	14 (21.5%)	19 (19.2%)		10 (23.8%)	12 (19.4%)		4 (15.4%)	7 (20%)	
III	2 (3.1%)	6 (6.1%)		0 (0.0%)	4 (6.5%)		2 (7.7%)	2 (5.7%)	
IV	2 (3.1%)	0 (0.0%)		2 (4.8%)	0 (0.0%)		-	-	
V	1 (1.6%)	0 (0.0%)		1 (2.3%)	0 (0.0%)		-	-	

Values are presented as number (%).
Xi = the da Vinci Xi® system; Si = the da Vinci Si® system.

Complications were documented in 65 (60.7%) patients in the Xi® group and 99 (55.3%) in the Si® group (**Table 3**). Most complications were grade I, which occurred in 46 (42.9%) patients from the Xi® group and 74 (41.34%) from the Si® group. Major complications, grade III or higher, occurred in 5 (4.6%) patients in the Xi® group and in 6 (3.3%) patients in the Si® group (**Table 3**). Grade III or higher complications in the Xi® group included 2 anastomosis leakages at the esophagojejunostomy site, a pulmonary thromboembolism, and a new-onset left bundle branch block. One patient in the Xi® group had anastomosis bleeding, which was controlled by endoscopy but complicated by cardiac arrest and death. Grade III or higher complications that occurred in the Si® group included a pleural effusion, a pulmonary thromboembolism, a trocar site herniation, a bile duct injury, and an intra-abdominal fluid collection.

The pathological analyses in **Table 4** show comparable tumor size, depth of invasion, and histological types of tumors. The majority of patients had stage I, with 68% in the Xi® group and 67.4% in the Si® group. The mean number of retrieved lymph nodes was also similar, with 58 lymph nodes in the Xi® group and 57.4 in the Si® group.

We further divided our patients into the conventional and reduced port groups; then, we compared the 2 approaches using the da Vinci Xi® and the da Vinci Si® systems. In the

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Table 4. Pathological findings of the patients in the Xi® and Si® groups Pathology

Variables	All patients (n=286)			Conventional (n=169)			Reduced port (n=117)		
	Xi® (n=107)	Si® (n=179)	P-value	Xi® (n=61)	Si® (n=108)	P-value	Xi® (n=46)	Si® (n=71)	P-value
EGC	73 (68.2)	121 (67.5)	0.828	39 (63.9)	67 (62.0)	0.806	34 (73.9)	54 (76.1)	0.774
AGC	34 (31.7)	58 (32.4)	-	22 (36.1)	41 (38.0)	-	12 (26.1)	17 (23.9)	-
Histological type			0.973			0.346			0.817
Well differentiated	6 (5.6)	11 (6.1)		2 (3.3)	7 (6.5)		4 (8.7)	4 (5.6)	
Moderately differentiated	34 (31.8)	54 (30.2)		22 (36.1)	39 (36.1)		12 (26.1)	15 (21.1)	
Poorly differentiated	38 (35.5)	65 (36.3)		19 (31.1)	35 (32.4)		19 (41.3)	30 (42.3)	
Mucinous	2 (1.9)	2 (1.1)		2 (3.3)	0 (0.0)		0 (0.0)	2 (2.8)	
Signet ring carcinoma	24 (22.4)	39 (21.8)		15 (24.6)	22 (20.4)		9 (19.6)	17 (23.9)	
Others	3 (2.8)	8 (4.5)		1 (1.6)	5 (4.6)		2 (4.3)	3 (4.2)	
Tumor size (mm)	32.7±24.4	32.5±20.3	0.946	33.8±21.5	32.6±21.8	0.743	31.3±27.9	32.3±17.9	0.804
Depth of invasion			0.075			0.085			0.781
Mucosa	45 (42.1)	58 (32.4)		23 (37.7)	29 (26.9)		22 (47.8)	29 (41.4)	
Submucosa	28 (26.2)	63 (35.2)		16 (26.2)	38 (35.2)		12 (26.0)	25 (34.3)	
Proper muscle	11 (10.4)	15 (8.4)		7 (11.5)	8 (7.4)		4 (8.7)	7 (10.0)	
Subserosal	7 (6.6)	26 (14.5)		4 (6.6)	21 (19.4)		3 (6.5)	5 (7.1)	
Serosal exposure	15 (14.2)	16 (8.9)		10 (16.4)	11 (10.2)		5 (10.8)	5 (7.1)	
Adjacent organ invasion*	1 (0.9)	0 (0.0)		1 (1.6)	0 (0.0)		-	-	
No residual cancer†	0 (0.0)	1 (0.6)		0 (0.0)	1 (0.9)		-	-	
N stage			0.721			0.415			0.449
N0	79 (73.8)	127 (70.9)		46 (75.4)	71 (65.7)		33 (71.7)	56 (78.8)	
N1	21 (19.6)	38 (21.2)		11 (18)	24 (22.2)		10 (21.7)	14 (19.7)	
N2	4 (3.7)	11 (6.1)		2 (3.3)	10 (9.3)		2 (4.3)	1 (1.4)	
N3	3 (2.8)	3 (1.7)		2 (3.3)	3 (2.8)		1 (2.2)	0 (0.0)	
Lymphovascular invasion			0.688			0.668			0.199
No	75 (70.1)	130 (72.3)		43 (70.5)	73 (67.3)		32 (69.6)	57 (80.0)	
Yes	32 (29.9)	49 (27.7)		18 (29.5)	35 (32.7)		14 (30.4)	14 (20.0)	
Perineural invasion			0.542			0.668			0.431
No	84 (78.5)	144 (80.4)		46 (75.4)	85 (78.7)		38 (82.6)	59 (82.9)	
Yes	23 (21.4)	35 (19.6)		15 (24.6)	23 (21.3)		8 (17.4)	12 (17.1)	
Retrieved LNs	58.0±23.2	57.4±24.2	0.827	60.6±24.2	59.5±26.6	0.802	54.7±21.45	54.1±19.5	0.882
Metastatic LNs	1.5±4.1	1.8±5.9	0.728	1.6±4.6	2.4±7.5	0.446	3.43±0.51	1.7±0.21	0.159

Data are shown as mean±standard deviation or number (%).
EGC = early gastric cancer; AGC = advanced gastric cancer; Xi = the da Vinci Xi® system; Si = the da Vinci Si® system; LN = lymph node.
*Invasion to distal pancreas; †Post chemotherapy after cycles of docetaxel, oxaliplatin, and S-1 regimen.

conventional group, demographic characteristics, postoperative outcomes, and pathological results were comparable. The Si® group had significantly shorter docking time than the Xi® group, 3.9 minutes and 4.8 minutes, respectively, (P<0.001).

Additionally, in the reduced port group, the Xi® and Si® groups showed similar demographic characteristics, as well as operative, pathological, and postoperative outcomes.

DISCUSSION

When comparing the da Vinci Xi® and da Vinci Si® systems in robotic gastrectomy for gastric cancer in our institution, both showed similar perioperative outcomes. We further divided the patients into conventional and reduced port groups, comparing the Xi® and Si® in both groups. The Si® group with the conventional approach had a shorter docking time than the Xi® group. Additionally, dividing performed procedures into distal and total gastrectomy and comparing the Xi® and Si® in both groups showed no significant difference, except that the docking time in total gastrectomy was shorter in the Si® group.

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With the continuing evolution of robotic technology, new platforms must be proven to be safe and to have better or comparable outcomes than the previous platforms. Furthermore, proving that the new platforms have more benefits justifies their higher costs in comparison to the other platforms. Although the advances in the da Vinci Xi® system, such as facilitating docking and improving access, were expected to shorten the operative time in the Xi® group, neither total operative nor docking times were different compared to those in the Si® group during gastrectomy for gastric cancer. This could be because before we started using the da Vinci Xi® platform, a large number of procedures were performed using the da Vinci Si® platform. This could eventually lead to more experience with the system and, therefore, shorter docking time. There is an additional step of targeting the endoscope during the docking process using the da Vinci Xi® system, which is not required during the docking process of the da Vinci Si® system; therefore, the operating team must accordingly adapt. Moreover, the actual difference in docking time was less than 1 minute between the 2 groups, although it was statistically significant.

Although no similar study has been published for gastric cancer surgery comparing the da Vinci Xi® and da Vinci Si® platforms, previously published studies for colorectal and urology surgery showed similar results, with comparable outcomes. A previous study on colorectal surgery where a modified port placement and approach was used reported shorter total operative times (318±57 minutes in the Si® group vs. 285±49 minutes in the Xi® group; $P<0.05$) and docking times (23.5±2.7 minutes in the Si® group vs. 17.5±3.4 minutes in the Xi® group; $P<0.001$) in the Xi® group [11]. The study described modified trocar insertion and docking procedures in both groups, while we used the same approach in the Xi® and Si® groups, which was probably why we had similar operative times, and theirs were shortened. Another study comparing the da Vinci Xi® and da Vinci Si® systems during robotic nephroureterectomy also showed significantly shorter operative times as well as a decrease in anesthesia cost because of reduced duration [7]. However, other surgical outcomes were comparable in both groups. In our comparison study, the total operative time was slightly shorter in the Si® group, especially using the conventional method, but was not statistically significant.

To the best of our knowledge, this was the first study to compare the da Vinci Xi® and da Vinci Si® systems in the field of gastric surgery; however, there were some limitations of our study. We conducted this study retrospectively; therefore, there is potential for selection bias, although the data were extracted from our prospective database. Additionally, in our study, the only procedure included in the comparison was gastrectomy for gastric cancer. As gastrectomy is a two-quadrant surgery, the advantage of having a multi-quadrant access could not be fully utilized, unlike other abdominal procedures, such as colorectal surgery.

Comparisons between the da Vinci Xi® and da Vinci Si® in other different types of surgery requiring multi-quadrant procedures would be necessary to evaluate the advantages of having better anatomical access for multi-quadrant surgical procedures because of the overhead boom rotation without axis limitation in the da Vinci Xi® system. Another possible drawback was the use of the same port placement and operative approach when performing our procedures using both da Vinci Xi® and da Vinci Si® systems. Some modifications to take advantage of the features offered by the da Vinci Xi® system might produce different results. Furthermore, performing the same procedures on a different population may show some benefit because Asian patients have a relatively smaller stature, which negates the use of longer robotic arms for better reach.

Our results have revealed no difference in surgical outcomes between the da Vinci Xi® and da Vinci Si® platforms for robotic gastrectomy. As our approach was not changed between the 2 systems, no significant change in outcomes was shown in our results. Therefore, we cannot justify that the use of the da Vinci Xi® system when performing gastrectomy for gastric cancer improved the surgical outcomes.

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