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Original Article

Emerging Role of Robot-assisted Gastrectomy: Analysis of Consecutive 200 Cases

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Purpose: Robotic surgery for gastric cancer is a promising alternative to laparoscopic surgery, but the data are limited. We aimed to evaluate whether gaining experience in robotic gastrectomy could improve surgical outcomes in the treatment of gastric cancer.

Materials and Methods: Two hundred and seven consecutive cases of patients with clinical stage I gastric cancer who underwent robotic surgery at the National Cancer Center of Korea between February 2009 and February 2012 were retrospectively reviewed. Surgical outcomes were analyzed and compared between the initial 100 and later 100 cases.

Results: Seven patients required conversion to open surgery and were excluded from further analysis. The mean operating time for all patients was 248.8 minutes, and mean length of hospitalization was 8.0 days. Twenty patients developed postoperative complications. Thirteen were managed conservatively, while 6 had major complications requiring invasive procedures. One mortality occurred owing to myocardial infarction. Operating time was significantly shorter in the latter 100 cases than in the initial 100 cases (269.9 versus 233.5 minutes, P<0.001). The number of retrieved lymph nodes was significantly greater in the latter cases (35.9 versus 39.9, P=0.032). The hospital stay of patients with complications was significantly longer in the initial cases than in the latter cases (16 versus 7 days, P=0.005).

Conclusions: Increased experience with the robotic procedure for gastric cancer was associated with improved outcomes, especially in operating time, lymph node retrieval, and shortened hospital stay of complicated patients. Further development of surgical techniques and technology might enhance the role of robotic surgery for gastric cancer.

Key Words: Stomach neoplasms; Minimally invasive surgical procedures; Robotics; Laparoscopy

Introduction

Robotic technology is one of the latest developments in minimally invasive surgery. Adoption of robotic surgery has come into the spotlight in various fields of surgery as a solution to the shortcomings of conventional laparoscopic surgery and is expected to play a role in advanced laparoscopic surgery. A robotic system was first applied to gastric cancer surgery in 1997, but reports on robotic gastrectomy are sparse owing to its slow adoption in many countries. After Song et al.[1] reported on a large series of robotic surgeries for gastric cancer in 2005, the procedure gradually increased in popularity among several tertiary hospitals in Korea.

The most important clinical question regarding use of a robotic system vs. conventional open or laparoscopic surgery for gastric cancer is whether there is an objective benefit to compensate for its high expense. Laparoscopic gastrectomy has long been promoted for feasibility and efficacy for gastric cancer[2-4] and ultimately has proven to be superior to open surgery in terms of postoperative quality of life, shortened hospital stay, and improved postoperative pain.[5] Several studies have demonstrated that robotic gastrectomy is

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comparable to laparoscopic gastrectomy in terms of feasibility and safety, but few have shown a definite benefit of robotics over the laparoscopic approach, and most studies included their initial learning experience in the analysis.[1,6-8] It would be easy to justify adopting robotic gastrectomy, in spite of its high cost, if there were any specific value. Considering the time it takes to master the standard operative technique with newly adopted instruments, an unbiased assessment of robotic gastrectomy after the initial learning experience is necessary.

This study investigated 200 consecutive cases of robotic gastrectomy in a single institution and compared the surgical outcomes between the initial 100 and later 100 cases. We aimed to evaluate the improvement in surgical outcomes associated with the learning experience of robot-assisted gastrectomy and to investigate the possible benefit of robotic assistance in gastric cancer surgery after sufficient experience.

Materials and Methods

1. Study design and inclusion criteria

A robotic system was first used for gastric cancer surgery at the National Cancer Center of Korea in February 2009. Between February 2009 and February 2012, 207 consecutive patients who were clinically diagnosed with stage I gastric cancer according to the American Joint Committee on Cancer (AJCC) 7th edition and underwent robot-assisted gastrectomy were enrolled in a retrospective analysis. Clinical diagnosis was obtained by esophagogastroduodenoscopy, endoscopic ultrasonography, and computed tomography. The prospectively established database and medical records of these patients were retrospectively reviewed.

2. Operative procedures

The da Vinci® Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) was used for all robotic procedures. The procedures were performed by 3 surgeons who were all highly experienced in conventional laparoscopic gastrectomy. These surgeons all completed at least 200 laparoscopic gastrectomies prior to performing robotic surgery. The operation was performed according to the institutionally standardized operative rules: (1) partial omentectomy, (2) resection margin more than 2 cm from the primary tumor, and (3) D1+ or more lymphadenectomy based on Japanese Research Society for Gastric Cancer guidelines.

Patients were placed under general anesthesia and positioned in reverse Trendelenburg with slight leg elevation. The camera port was inserted through the umbilicus with a 12-mm trocar after establishing the pneumoperitoneum through a Veress needle. Three additional trocars (8 mm in diameter) for robotic arms were placed under camera visualization, and 1 assistant port was placed in the left umbilical level port using a 12-mm trocar. After docking the robotic arms with a surgical cart placed above the patient's head, a modified liver lift was performed, enabling full exposure of the operative field by transfixing the left lateral segment of the liver to the abdominal wall with a straight needle. Four robotic arms were used during the operation: a central one for a dual-channel endoscope, and the others for Cadiere forceps, bipolar Maryland forceps, and unipolar electrocautery or ultrasonic shears, depending on the surgeon's preference. The procedure itself was similar to conventional laparoscopic procedures described previously.[8,9] After dissection and full mobilization of the stomach, the robotic arms were undocked from the patient. All anastomoses were performed extracorporeally via a 4 to 6 cm mini-laparotomy incision in the epigastrium.

3. Surgical and oncologic outcomes

Electronic medical records and prospectively collected data from the Gastric Cancer Center database were reviewed for surgical outcomes. Intraoperative parameters such as operating time and blood loss were assessed. Operating time was defined as time from skin incision to wound closure. Postoperative complications were graded according to the Accordion Severity Grading System.[10] Pathologic results were also reviewed in terms of Lauren's classification, histology, tumor location, size, and resection margin. Final pathologic stage was assessed according to the AJCC 7th edition.[11]

4. Statistics

Statistical analysis was performed using the SAS program (SAS Institute Inc., Cary, NC, USA). Means and standard deviations were calculated. The chi-square test or Fisher's exact test was applied to analyze categorical variables, and the Student's t-test was used for continuous variables. Linear regression was applied to evaluate change in operating time according to the accumulated cases. A P-value less than 0.05 was considered statistically significant.

Results

1. Patient characteristics and their surgical outcomes

Seven patients required conversion to open surgery due to severe adhesion, bleeding during operation, or inadequate resection margin, and these patients were excluded from further analysis. The demographics of the 200 enrolled patients are shown in Table 1. The study patients consisted of 110 men and 90 women, and mean age of the patients was 53.4 years. Of the 200 total patients, 154 underwent subtotal gastrectomy, and 46 underwent total gastrectomy with more than D1+ lymph node dissection. The mean operating time for all patients was 248.8 minutes, and mean length of hospitalization was 8.0 days. Mean number of retrieved lymph nodes was 37.9. The final pathologic report revealed that 22 patients had cancers beyond stage II, and 31 patients showed lymph node metastasis. Resection margins were tumor-free in all patients (Table 2).

2. Postoperative complications

Twenty patients (10%) developed postoperative complications (Table 3). Half of them developed mild complications, such

Table 1. Demographics of the patients (n=200)

Characteristic	Value
Age (yr)	53.4±11.7
Sex	
Male	110 (55.0)
Female	90 (45.0)
Body mass index (kg/m^2)	24.0±3.3
Co-morbidity	
No	123 (61.5)
Yes	77 (38.5)
History of previous abdominal surgery	20 (10.0)
History of previous endoscopic resection	10 (5.0)

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

Table 2. Surgical and pathologic outcomes

Variable	Value	Variable	Value
Open conversion		Depth of invasion (pT)	
No	200 (96.6)	Mucosa	105 (52.5)
Yes	7 (3.4)	Submucosa	68 (34.0)
Operator		Proper muscle	24 (12.0)
A	130 (65.0)	Subserosa	3 (1.5)
B	59 (29.5)	Number of retrieved lymph nodes	37.9±13.3
C	11 (5.5)	Nodal metastasis (pN)	
Surgical extent		N0	169 (84.5)
Subtotal	154 (77.0)	N1	19 (9.5)
Total	46 (23.0)	N2	8 (4.0)
Reconstruction		N3	4 (2.0)
Billroth I	94 (47.0)	Histological classification*	
Billroth II	59 (29.5)	Tubular well differentiated	39 (19.5)
Roux-en-Y	47 (23.5)	Tubular moderate differentiated	31 (15.5)
Combined operation	10 (5.0)	Poorly differentiated	50 (25.0)
Cholecystectomy	8 (4.0)	Signet ring cell	69 (34.5)
Splenectomy	1 (0.5)	Others	7 (3.5)
Salphingo-oophorectomy	1 (0.5)	Lauren classification	
Operating time (min)	248.8±55.6	Intestinal	66 (33.0)
Estimated blood loss (ml)	146.1±130.3	Diffuse	106 (53.0)
Length of hospital stay (d)	8.0±3.7	Mixed	24 (12.0)
Tumor size (cm)	3.0±1.8	Others	4 (2.0)
Tumor location			
Upper	32 (16.0)		
Middle	87 (43.5)		
Lower	81 (40.5)		

Values are presented as number (%) or mean±standard deviation. *Histological classification of World Health Organization.

as wound problems, adhesive ileus, or delayed emptying, and 3 developed complications of moderate severity. All were successfully managed conservatively. Six patients had severe complications requiring invasive procedures, including 3 cases of reoperation: one duodenal stump repair, one hernia repair, and one open drainage for pancreatitis that did not respond to medical treatment. One mortality due to myocardial infarction occurred on postoperative day 2. No specific intraoperative events, such as bleeding or traumatic injury to normal organs, occurred.

Table 3. Postoperative complications graded according to the Accordion severity classification (n=20)

Variable	Value
Mild	10 (5.0)
Ileus	4
Delayed gastric emptying	2
Wound infection	4
Moderate	3 (1.5)
Bleeding	1
Abdominal abscess	2
Severe	6 (3.0)
Leakage	2
Anastomotic stenosis	1
Pancreatic leak	1
Incisional hernia	1
Splenic infarct	1
Death	1 (0.5)
Postoperative myocardial infarction	1
Total	20 (10.0)

Values are presented as number (%) or number only.

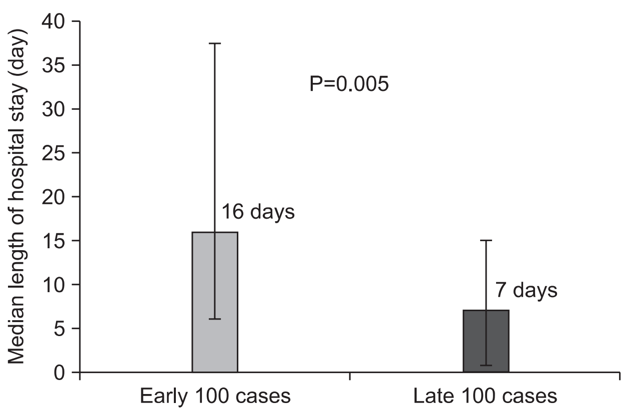

Fig. 1. Comparison of length of hospital stay between the initial and latter experience in complicated cases. Error bar depicts interquartile ranges (Mann-Whitney U test applied).

3. Comparison of surgical outcomes between initial 100 and later 100 cases

Surgical outcomes of the initial 100 and later 100 cases were reviewed and compared (Table 4). Operating time was significantly shorter in the late surgery group as compared to that in the early cases (269.9±54.8 vs. 233.5±51.3 minutes, $P<0.001$). The number of retrieved lymph nodes was greater in the latter 100 cases, and this difference was statistically significant (35.9±13.0 vs. 39.9±13.4, $P=0.032$). Blood loss during surgery and the incidence of

Table 4. Comparison between early and late surgical experiences

Variable	Early 100 cases	Late 100 cases	P-value
Age (yr)	52.8±12.0	53.9±11.4	0.478‡
Sex			
Male	53	57	0.670†
Female	47	43	
Body mass index	24.0±3.4	23.8±3.1	0.755‡
Open conversion	2/102 (2.0)	5/105 (4.8)	0.445*
Surgical extent			
Subtotal	81	73	0.239†
Total	19	27	
Reconstruction			
Billroth I	47	47	0.222†
Billroth II	34	25	
Roux-en-Y	19	28	
Operating time (min)	269.9±54.8	233.5±51.3	<0.001‡
Estimated blood loss (ml)	208.4±156.9	228.2±137.4	0.345‡
Retrieved LNs (n)	35.9±13.0	39.9±13.4	0.032‡
pStage§			
IA or IB	92	86	0.258†
II or more advanced	8	14	
Postoperative complications			
No	92	88	0.346†
Yes	8	12	
Mild	3	7	0.588*
Moderate	2	1	
Severe	3	3	
Death	0	1	
Length of hospital stay (d)	8.1±5.0	7.2±1.6	0.092‡

Values are presented as mean±standard deviation, number only, or number (%). LN = lymph node. *Fisher's exact test, †chi-square test, ‡Student's t-test, §UICC 7th classification.

postoperative complications did not differ between the 2 groups. Duration of hospital stay was shorter in the latter than in the earlier 100 cases, but the difference was not statistically significant (P=0.092). Mean length of hospital stay after surgery in complicated cases was compared between the 2 groups (Fig. 1). Although the incidence and severity distribution were not different between the 2 groups, the median length of stay of 8 patients with complications in the initial 100 cases was significantly longer than that of 12 patients in the latter 100 cases (16 vs. 7 days, P=0.005, Mann-Whitney U test). Subgroup analysis according to surgical extent showed similar results (Table 5). Operating time was significantly decreased in the latter 100 cases, both in subtotal and total gastrectomy (P<0.001 and =0.003, respectively). The number of retrieved lymph nodes was greater in the latter 100 cases, both in subtotal and total gastrectomy, but the difference was not statistically significant (P=0.243 and 0.091, respectively).

Table 5. Comparison of surgical outcomes according to the surgical extent

Variable	Early 100 cases	Late 100 cases	P-value
Subtotal gastrectomy			
Number of patients	81	73	
Operating time (min)	255.6±44.8	223±42.1	<0.001*
Estimated blood loss (ml)	186.5±137.8	227.6±136.9	0.066*
Retrieved LNs (n)	34.7±12.9	37.2±12.7	0.236*
Length of hospital stay (d)	7.8±5.1	7.1±1.8	0.243*
Total gastrectomy			
Number of patients	19	27	
Operating time (min)	324.0±56.9	261.7±63.2	0.003*
Estimated blood loss (ml)	301.6±199.0	229.6±141.3	0.158*
Retrieved LNs (n)	41.0±12.4	47.4±12.7	0.096*
Length of hospital stay (d)	9.5±4.3	7.7±1.1	0.091*

Values are presented as only number or mean±standard deviation. LN = lymph node. *Student's t-test.

4. Relationship between operating time and accumulation of experience

Operating time gradually decreased along with the accumulation of surgical experience in 2 participating surgeons (Fig. 2). For one surgeon who only performed robotic surgery in 11 cases, no significant correlation to improved operating time could be demonstrated. Operating time during subtotal gastrectomy was inversely related to the number of robotic surgeries performed and revealed statistical significance in both surgeon I and II (P<0.001 and P=0.037, respectively). Likewise, a decreasing trend in operating time was seen during total gastrectomy, but the relationship was

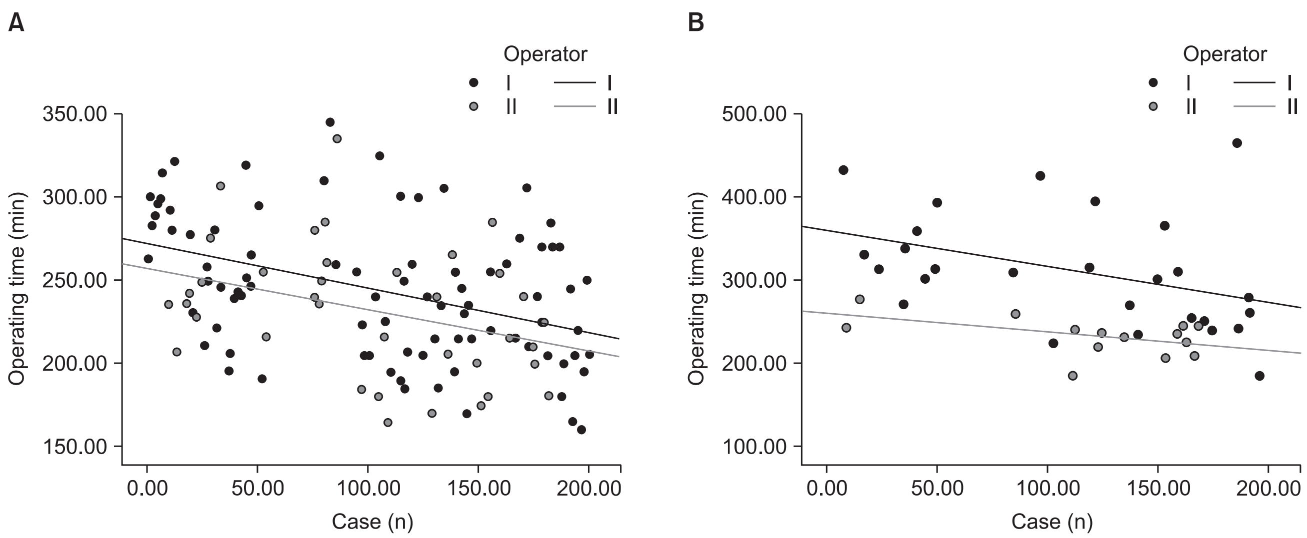

Fig. 2. Change in operating time. Operating time gradually decreased along with the accumulation of surgical experience. (A) Robot-assisted distal gastrectomy, (B) Robot-assisted total gastrectomy.

(A)

Operator	Equation of linear regression	R2	P-value
I	Op time=-0.268×case no.+272.1	0.169	<0.001
II	Op time=-0.248×case no.+256.9	0.119	0.037

(B)

Operator	Equation of linear regression	R2	P-value
I	Op time=-0.435×case no.+359.0	0.160	0.039
II	Op time=-0.217×case no.+258.9	0.240	0.076

statistically significant only in surgeon I (P=0.039).

Discussion

Robotic gastrectomy is reported to be increasingly performed in Korea over the last 7 years.[12] Nonetheless, evidence for the effectiveness of robotic surgery for gastric cancer is limited. Only several case series have been published so far, mostly by Eastern Asian centers,[1,13-16] and prospectively randomized controlled trials (RCTs) reporting on safety and feasibility have not yet been published.[12] By contrast, the value, safety, and feasibility of laparoscopic surgery for early gastric cancer has been proven in several RCTs.[2,3,5,17] Robotic surgery is assumed to improve short-term patient outcomes such as length of postoperative hospital stay, frequency of postoperative complications, and quality of life.[12] However, all previous studies have failed to demonstrate the superiority of robotic surgery as compared to the laparoscopic approach. Our previous study revealed that surgical trauma in terms of cytokine response was not reduced in robotic surgery patients as compared with laparoscopically resected patients.[18]

The main focus of our analysis was to see whether increasing experience with robotic gastrectomy could improve the quality of surgery after the known learning curve of 20 initial cases.[19] We found that gaining experience with the robotic procedure translated into improved outcomes, especially in terms of operating time and number of dissected lymph nodes.

Mean operating time in our cohort was approximately 250 minutes, with a statistically significant decrease of operating time within the analyzed period. The first 100 cases had a mean operating time of around 270 minutes compared to approximately 230 minutes for the second 100 cases. Operating times in previously published series range from 150 to 700 minutes, depending on the type of resection.[1,6-8,13-17,20-24] Interestingly, there appears to be a relationship between caseload and operating time. Institutions with low caseloads seem to take longer for the robotic procedure compared to the time taken by those with high caseloads where surgeons presumably have more experience with minimally invasive laparoscopic surgery. Compared to various published studies, our study cohort was among those with the shortest operative time, especially after the first 100 cases. It remains elusive if shorter operative time results in a lower postoperative complication rate. The prevailing mode of reconstruction in our analysis was Billroth I, followed by Billroth II and Roux-en-Y anastomosis, according to the surgeon's preference. We did not notice any difference in operating time related to reconstruction methods as all anastomoses were performed extracorporeally. Nonetheless, intra-abdominal robot-sewn anastomosis has been demonstrated to be safe and feasible[14] and might contribute to reduction of postoperative trauma in the future.

Blood loss within our cohort lies within the range of other published series.[1,6-8,13-17,20-24] We also found a marked reduction in blood loss within our cohort after the first 100 cases of surgical experience, but it was not statistically significant. Reviewing published data, blood loss was almost always reduced for robotic surgery patients as compared to laparoscopic or open surgery patients.[1,6-8,20] It may be debatable if application of robotic surgery really influences operative trauma, and consequently blood loss, or if due to the retrospective aspect of the studies, a selection bias of patients prevailed. A selection bias may have been that only patients with clinical stage IA cancer were selected for robotic surgery and limited lymphadenectomy was performed. Nonetheless, blood loss improved as patient numbers increased, so a learning curve is likely.[25]

We report a postoperative complication rate of 10%, which compared to previously published studies, is acceptable. European studies reported postoperative complication rates of up to 46%[20,21,23] whereas Asian studies demonstrate postoperative complication rates of 10% to 15%.[1,6-8,13-15,22,24] The high complication rates from European publications may be explained by the relatively lower caseload due to reduced gastric cancer incidence. It is also conceivable that less experience in minimally invasive (laparoscopic) surgery for gastric cancer may explain the higher European complication rates. The classification of complication might have been different as well, especially when the Accordion Severity Grading System was applied.[10] Nonetheless, postoperative stay in the present study is among the shortest compared to other published studies. This might be, in part, due to the low postoperative morbidity rate of 10%. Furthermore, the median length of hospital stay for complicated patients was markedly decreased in the later 100 cases. This suggests that surgical outcomes regarding the severity of postoperative complications improve with the accumulation of experience in robotic gastrectomy.

A crucial aspect of curative resection for gastric cancer patients is adequate lymphadenectomy. We found an increased number of dissected lymph nodes in the second 100 patients. Therefore, we believe that lymph node retrieval improves with increasing experience with the robotic procedure. Although the benefit of lymph node dissection in gastric cancer treatment is still controversial in Europe,[26,27] improved lymph node retrieval could be an advantage of robot-assisted surgery. The 3-dimensional and other enhanced imaging techniques used in robotic surgery to identify lymph nodes may contribute to an improved oncologic outcome for patients.[15] Within our patient cohort, a mean number of 38 lymph nodes were dissected, indicating appropriate lymphadenectomy as compared to previously published papers.[1,6-8,13-17,20-24] Interestingly, European case series reveal lower numbers of resected nodes compared to Asian reports, suggesting that traditional experience with D2 dissection translates into successful application of the robotic procedure. When robot-assisted resection was compared to laparoscopic resection in previous reports, there was no inferiority of lymph node retrieval for the robotic procedure, indicating that adequate lymphadenectomy is safe and feasible in robotic gastrectomy.[6-8,24]

The present study has several limitations. It was based on a retrospective analysis, which could have led to a selection bias. One of the participating surgeons contributed only 11 cases out of 200, and his experience gained might be questionable. The surgical outcomes were not properly stratified according to the additional combined surgical procedures, such as cholecystectomy or splenectomy.

In conclusion, we found that increased experience with the robotic procedure for gastric cancer surgery translated into improved outcomes, especially in operating time and number of dissected lymph nodes. Prospective trials will have to focus on patient benefit and outcome. Improvements in lymphadenectomy may be conceivable due to the technical advantages of the robotic device compared to laparoscopic procedures.

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