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Eleven-year experience with 3000 cases of laparoscopic gastric cancer surgery in a single institution: analysis of postoperative morbidities and long-term oncologic outcomes

Young Suk Park[1] · Sang-Yong Son[1] · Aung Myint Oo[1,3] · Do Hyun Jung[1] · Dong Joon Shin[1] · Sang-Hoon Ahn[1] · Do Joong Park[1,2] · Hyung-Ho Kim[1,2]

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Abstract

Background The present study summarizes the 11-year laparoscopic gastric cancer surgery experience of a single institution in South Korea and evaluates the current trends of laparoscopic gastric cancer surgery through our experience.

Methods A total of 3000 minimally invasive gastric cancer surgeries were performed at Seoul National University Bundang Hospital between May 2003 and January 2014. The types of laparoscopic gastrectomy used, surgical techniques, postoperative morbidities, and long-term oncologic outcomes were analyzed.

Results The proportion of challenging procedures such as laparoscopic total gastrectomy and laparoscopic gastrectomy for patients with advanced gastric cancer increased during the study period. The frequency of laparoscopic function-preserving gastrectomy for patients with early-stage cancer also increased. The overall rate of complications was 16.7 %; surgical and systemic complication rates were 11.8 and 6.2 %, respectively. There was one case of postoperative mortality due to delayed bleeding after discharge. Male gender, high BMI, long operating times, combined resection of other organs, and total and proximal gastrectomies were independent predictors of surgical morbidities; however, pathologic T-stage was not a predictable factor. Accumulated experience in laparoscopic surgery decreased the surgical complication rates of total and proximal gastrectomies more than it did in distal gastrectomy over time. The 5-year overall survival rates of patients in advanced stages and those who underwent laparoscopic total gastrectomy were comparable to those reported previously.

Conclusions Our results indicate the trends toward the expansion of laparoscopic approaches to technically demanding procedures and an increased use of laparoscopic function-preserving surgeries for patients with EGC with acceptable outcomes.

Keywords Laparoscopy · Gastric cancer · Morbidity · Survival

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✉ Hyung-Ho Kim
hhkim@snubh.org

[1] Department of Surgery, Seoul National University Bundang Hospital, 166 Gumi-ro, Bundang-gu, Seongnam-shi, Kyeonggi-do 463-707, South Korea

[2] Department of Surgery, College of Medicine, Seoul National University, Seoul, South Korea

[3] Department of General Surgery, Tan Tock Seng Hospital, Novena, Singapore

Since Kitano et al. [1] first reported the use of laparoscopy-assisted gastrectomy for patients with early gastric cancer (EGC) in 1994, the laparoscopic procedure has gained widespread international acceptance as one of the general modalities for the management of EGC. In Korea, 3783 laparoscopic gastrectomies were performed in 2009, accounting for 25.8 % of gastric cancer surgeries [2].

Accumulating experience and technical advances resulted in the emergence of two major trends in laparoscopic gastrectomy [3]. First, laparoscopic procedures are increasingly applied in technically demanding operations, such as laparoscopic gastrectomy for patients with

advanced gastric cancer (AGC) or laparoscopic total gastrectomy (TG). Recent studies analyzing morbidities and long-term oncologic outcomes support the use of laparoscopic gastrectomy in patients with AGC [4–6] and laparoscopic TG [7–9]. Second, laparoscopic function-preserving gastrectomy is increasingly being used for the treatment for patients with EGC. Because of recent developments in screening programs in Korea and Japan, the proportion of EGC exceeds 50 % [2, 10], and the low incidence of lymph node metastasis and the favorable prognosis of EGC make it suitable for laparoscopic function-preserving surgery.

Our experience with laparoscopic gastric cancer surgery reflects these current trends in laparoscopic gastrectomy. The aims of the present study were to summarize our experience with laparoscopic surgery for gastric cancer in a single center in Korea over a period of 11 years and evaluate postoperative complication rates, how they have changed, and the long-term outcomes of patients.

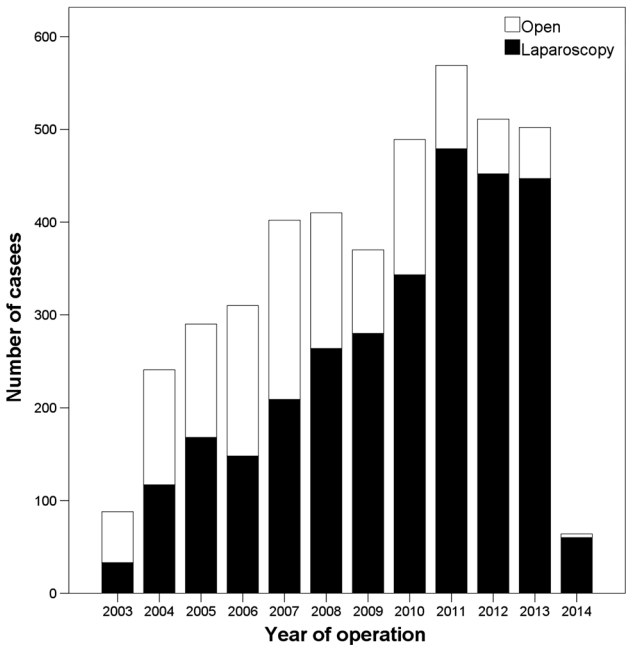

Fig. 1 Number of patients who underwent operations for gastric cancer

Materials and methods

Types of laparoscopic procedures

Between May 2003 and January 2014, 3000 laparoscopic operations for gastric cancer were performed by four surgeons at the Department of Surgery at Seoul National University of Bundang Hospital (Table 1). Although the proportion of laparoscopic operation was 37.5 % of the total cases in 2003, the proportion increased to 89.0 % in 2013 (Fig. 1). Among laparoscopic operations, 2749 (91.7 %) were laparoscopic curative resections, and 98 (3.2 %) were sentinel node navigation surgeries, which were performed after 2010. A total of 147 (4.2 %) operations were performed as non-curative surgeries, of which 67 were laparoscopic peritoneal seeding nodule biopsies, 28 were palliative gastrojejunostomies, 11 were metastatic mass excisions (small bowel metastasis in four, port-site metastasis in one, locoregional lymph node metastasis in three, and distant lymph node metastasis in three), four were jejunostomy or ileostomy formation for seeding ileus, and 37 were palliative gastric resections (21 cases of R1 resection and 16 cases of R2 resection).

Table 1 Types of laparoscopic gastric cancer surgery ($n = 3000$)

Laparoscopic operations for gastric adenocarcinoma	*n* (%)
Curative gastric resections	2749 (91.6)
Sentinel lymph node navigation surgeries	98 (3.2)
Gastric wedge resections	6 (0.1)
Palliative operations	147 (4.2)
R1 resections	21 (0.7)
R2 resections	16 (0.5)
Palliative gastrojejunostomy	28 (0.9)
Metastatic mass excision	11 (0.4)
Jejunostomy/ileostomy formation	4 (0.1)
Peritoneal seeding nodule biopsy	67 (2.2)

All cases were restaged retrospectively according to the 7th American Joint Committee on Cancer/International Union Against Cancer Tumor Node Metastasis staging, and the study protocol was approved by the institutional review board of SNUBH (IRB No. B-1508-312-110).

Operative criteria and strategy for laparoscopic gastrectomy

During the initial 5-year period, the indication for laparoscopic gastrectomy was confined to clinical T1–T2 stage without suspected lymph node metastasis. However, accumulating laparoscopic experience and the building of a competent laparoscopic surgical team resulted in the expansion of the criteria to locally advanced cancer. A prospective phase II clinical trial of our institution (NCT01441336) was initiated in 2008 to evaluate the technical and oncological safety of laparoscopic gastrectomy for patients with AGC, and thereafter, we gradually extended the indications of laparoscopic gastrectomy to clinical T4a (serosa invasion) stage and/or suspected node metastasis. A prospective phase II clinical trial was

Table 2 Clinicopathologic features of patients who underwent laparoscopic curative gastrectomy for gastric cancer ($n = 2749$)

Variable	*n* (%)
Age (year)	59.9 (range 20–92)
Sex (M/F)	1816 (66.1):933 (33.9)
Type of gastrectomy	
Distal	2231 (81.2)
Total	327 (11.9)
Proximal	150 (5.5)
Pylorus-preserving	28 (1.0)
Completion total	13 (0.5)
Reconstruction	
Billroth I	1340 (48.7)
Billroth II	283 (10.3)
Roux-en-Y gastrojejunostomy	73 (2.7)
Uncut Roux-en-Y gastrojejunostomy	535 (19.4)
Roux-en-Y esophagojejunostomy	340 (12.4)
Double tract anastomosis (in PG)	81 (2.9)
Esophagogastrostomy	69 (2.5)
Gastrogastrostomy	28 (1.0)
Intracorporeal anastomosis	
Distal ($n = 2231$)	520 (23.3)
Total (including completion total) ($n = 340$)	238 (71.9)
Proximal ($n = 150$)	116 (77.3)
Pylorus-preserving ($n = 28$)	6 (21.4)
Simultaneous organ resection	280 (10.2)
Combined resection	88 (3.3)
Concomitant resection	192 (6.9)
LN dissection (except for completion total gastrectomy, $n = 2736$)	
D1	7 (0.3)
D1+	1306 (47.5)
D2	1410 (51.3)
D2+	13 (0.5)
Retrieved lymph nodes	47.7 (range 4–221)
Histologic type	
Papillary adenoca.	21 (0.8)
Tubular adenoca. w/d	464 (16.9)
Tubular adenoca. m/d	954 (34.7)
Tubular adenoca. p/d	576 (21.0)
Mucinous adenoca.	32 (1.2)
Poorly cohesive ca.	628 (22.8)
Others	74 (2.7)
Tumor invasion	
T1a/T1b	1071 (39.0)/954 (34.7)
T2	296 (10.8)
T3	258 (9.4)
T4a/T4b	161 (5.9)/6 (0.2)
Lymph node metastasis	
N0	2059 (74.9)
N1/N2/N3	307 (11.2)/178 (6.5)/205 (7.4)
TNM stage	
IA	1791 (65.2)
IB	333 (12.1)
IIA	196 (7.1)
IIB	132 (4.8)
IIIA	106 (3.9)
IIIB	96 (3.5)
IIIC	90 (3.3)
IV	5 (0.2)

initiated in 2008 to evaluate the technical and oncological safety of laparoscopic gastrectomy for patients with AGC (NCT01441336). Lymph node dissection was performed as described in the Japanese gastric cancer treatment guidelines [11, 12]. The data on the extent of lymphadenectomy were revised retrospectively according to a recently published version of those guidelines [11]. Patients with gastric cancer clinically limited to the submucosa without evidence of lymph node metastasis underwent D1+ lymph node dissection, while D2 lymph node dissection was routinely performed when the clinical stage of the tumor was advanced (beyond the submucosa) or lymph node metastasis was suspected despite the diagnosis of EGC. D1 dissections were limited to decrease postoperative complications in high-risk patients. Partial omentectomy was performed routinely except in cases of AGC with serosa exposure under laparoscopic view, in which total omentectomy was performed.

Changes in anastomosis techniques

During the initial period, reconstructions (gastroduodenostomy and gastrojejunostomy) after laparoscopic distal gastrectomy (DG) were extracorporeally completed with direct visualization through mini-laparotomies (transverse incisions from 5 to 7 cm in the epigastric area). Intracorporeal gastroduodenostomy (delta-shaped anastomosis using linear stapler) was performed after 2010, and the first intracorporeal gastrojejunostomy was performed in 2011. In totally laparoscopic DG with intracorporeal reconstruction, all anastomoses were performed in the laparoscopic view, and specimens were extracted through vertically extended umbilical trocar sites (3–4 cm).

End-to-side esophagojejunostomy (E–J stomy) using a circular stapler after TG was performed intracorporeally

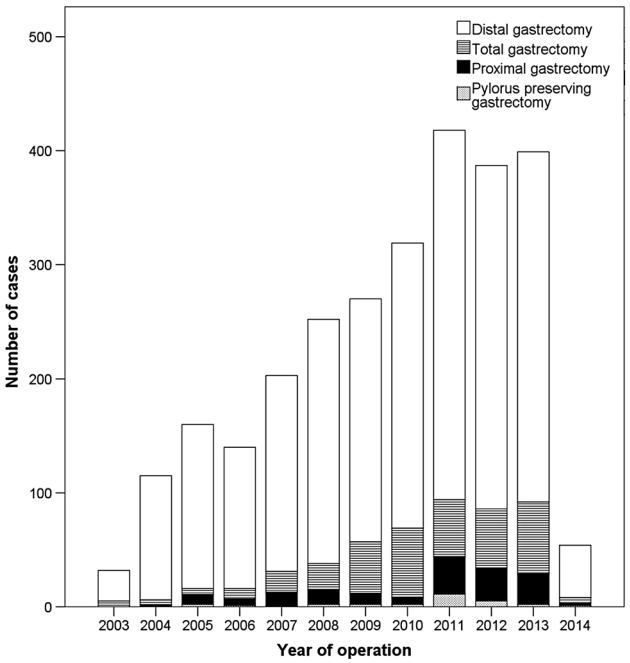

Fig. 2 Changes in laparoscopic gastrectomy procedures over time ($n = 2749$)

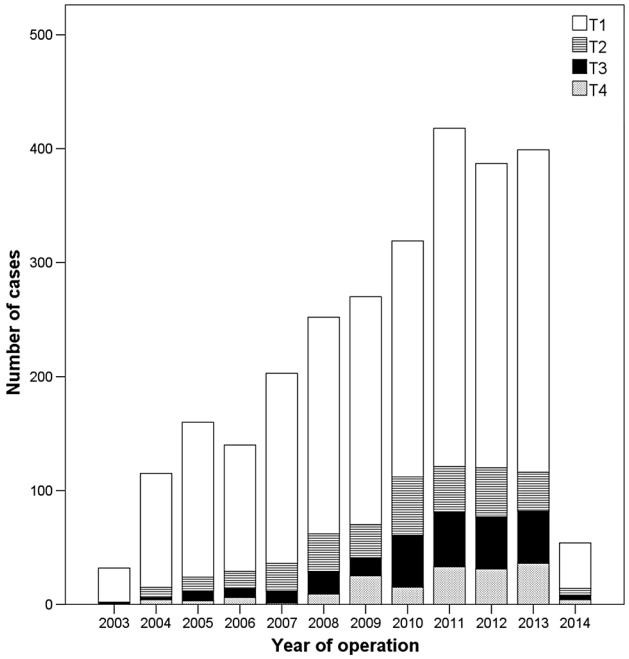

Fig. 3 Changes in pathologic results according to T-stage ($n = 2749$)

using a laparoscopic purse-string clamp (Lap-Jack, Greenmate Biotech Corp., Seoul, Korea, and Endo-PSI, Hope Electronics, Chiba, Japan) after 2008. Before the use of the laparoscopic purse-string clamp, extracorporeal E–J stomy was performed through a vertical incision in the epigastric area or intracorporeal side-to-side E–J stomy using a linear stapler was performed [13]. End-to-side jejunojejunostomy (J–J stomy), 40 cm below the E–J stomy, was performed using an extracorporeal hand-sewing suture or linear staplers through a minilaparotomy (5–6 cm) with extension of the left 12-mm trocar site.

The first laparoscopic proximal gastrectomy (PG) for upper-third EGC was performed in 2004. Esophagogastrostomy (E–G stomy) was used initially; however, in 2009, the reconstruction method was changed to double tract reconstruction (DTR) because of its lower incidence of late complications such as gastroesophageal reflux and anastomotic stenosis [14]. DTR consists of conventional Roux-en Y E–J stomy and side-to-side gastrojejunostomy between the E–J stomy and J–J stomy. Currently, all reconstructions after PG are performed by DTR.

Patient selection for the analysis of changes in postoperative complication rates

To analyze changes in the rate of complications over time, 192 cases of gastrectomy with concomitant resections were excluded from the 2749 cases of laparoscopic curative gastrectomy. Other organ resections performed

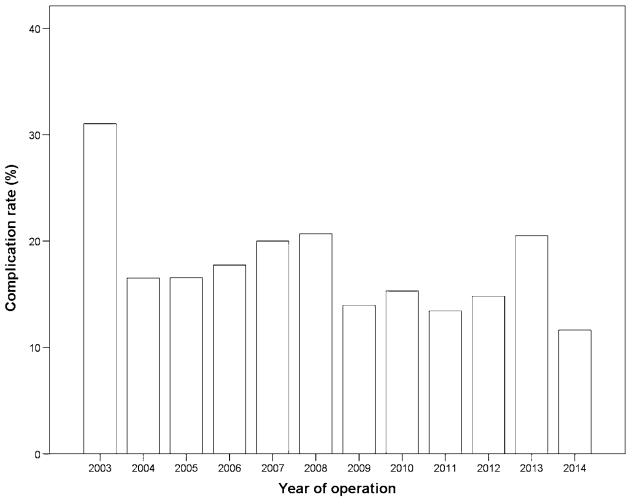

Fig. 4 Overall complication rates over time ($n = 2409$)

simultaneously were classified into two groups: concomitant resections for other pathological conditions (such as cholecystectomy for gallstone, colectomy for synchronous colon cancer, or hepatectomy for hemangioma), and combined resection for cancer invasion or for extended lymphadenectomy (such as distal pancreatectomy for the removal of a directly invaded tumor or splenectomy for resection of lymph node #10) [15]. Most concomitant resections except cholecystectomies were performed by surgeons from other divisions; attributing the postoperative complications to gastrectomy in such cases may be

Table 3 Postoperative morbidity ($n = 2409$)

	n (%)
Overall complications	402 (16.7)
Surgical complications	284 (11.8)
Wound	50 (2.1)
Leakage	39 (1.6)
Bleeding	32 (1.3)
Stricture	38 (1.6)
Intra-abdominal abscess	42 (1.7)
Pancreatic fistula	53 (2.2)
Intestinal obstructive morbidity	46 (1.9)
Other surgical complications	20 (0.8)
Systemic complications	150 (6.2)
Lung morbidity	53 (2.2)
Urinary tract morbidity	81 (3.4)
Other systemic complications	21 (0.9)

difficult. Therefore, only cases of combined resection were included out of all simultaneous other organ resections.

In addition, 148 operations performed by two surgeons were also excluded because these surgeons performed a small number of surgeries during a short period of time. These cases could be a confounder when analyzing the trend of complication rates over time. Finally, 2409 cases of laparoscopic curative gastrectomy were included in the analysis; postoperative surgical and systemic complications of grade II or higher in the Clavien–Dindo classification [16] were investigated. Complications associated with the surgical technique or the operation field were considered surgical complications. Surgical complications included wound morbidity, leakage (anastomosis and duodenal stump), anastomotic stricture, bleeding (anastomosis site or intra-abdominal), intra-abdominal abscess, pancreatic fistula (drain amylase content greater than 1000 U/L after postoperative days 3–5), pancreatitis (elevated serum amylase >150 U/L with symptoms such as back pain and fever), splenic arterial aneurysm, lymphorrhea, remnant stomach infarction, delayed gastric emptying, reflux esophagitis, and intestinal obstructive morbidity (paralytic ileus during the immediate postoperative period and adhesive ileus occurring after 1 month postoperatively). Systemic complications were defined as complications not associated with the operation field, such as lung morbidity, urinary tract morbidity, cardiovascular morbidity, renal failure, and uncontrolled ascites in patients with liver cirrhosis.

Patient selection for the analysis of 5-year overall survival

The long-term oncologic outcomes of patients who underwent laparoscopic curative distal or total gastrectomy were evaluated. A total of 2308 cases were selected from 2749 cases of laparoscopic curative gastrectomy, and the inclusion criteria were as follows: (1) pathologically proven gastric adenocarcinoma; (2) patients who underwent curative distal or total gastrectomy with D1+/D2 lymphadenectomy as described in the third Japanese gastric cancer treatment guidelines [11]; (3) no history of other therapies for gastric cancer; and (4) no history of other organ malignancy.

Statistical analysis

Continuous values are expressed as the mean and standard deviation. Statistical analyses were performed using the Chi-square test or Fisher's exact test for categorical variables and a *t* test for continuous variables when appropriate. To identify the risk factors for morbidity, univariable and multivariable analyses were performed using Chi-square tests and binary logistic regression models. The interactions between surgical complication rates and the operation year were investigated. Kaplan–Meier curves were used to determine the prognosis of each staging system, and survival probabilities were compared using the log-rank test.

Statistical analyses were performed using SPSS version 20.0 software (IBM SPSS Inc., Chicago, IL, USA) and R version 3.1.1 (R Foundation for Statistical Computing, Vienna, Austria). A P value of ≤ 0.05 was considered statistically significant for all analyses.

Results

Clinicopathological features of patients who underwent laparoscopic curative gastric resection

The clinical and pathologic features of patients who underwent laparoscopic curative gastrectomy for gastric cancer are listed in Table 2. DG (81.2 %) was the most commonly performed procedure, followed by TG (11.9 %), PG (5.5 %), and pylorus-preserving gastrectomy (PPG, 1.0 %). The most common method of reconstruction after DG was Billroth I anastomosis (1340/2231, 60.1 %), followed by uncut Roux-en Y gastrojejunostomy (535/2231, 24.0 %). Simultaneous organ resection was performed in 280 cases; the most commonly resected organ in concomitant resections was the gallbladder (102/192, 53.1 %), whereas that in combined resections was the spleen (71/88, 80.7 %). Most patients underwent D1+ (47.5 %) and D2 (51.3 %) lymph node resection; laparoscopic D2+ lymph node dissection including the para-aortic lymph nodes (PAN) was performed in patients with suspected isolated

Table 4 Univariable analysis factors predictive of postoperative complications

Variables	*n*	Local complications		Systemic complications	
		n (%)	*P* value[a]	*n* (%)	*P* value[a]
Age			0.343		<0.001
<60	1203	134 (11.1 %)		38 (3.2 %)	
≥60	1206	150 (12.4 %)		112 (9.3 %)	
Gender			0.001		0.001
Male	1589	212 (13.3 %)		118 (7.4 %)	
Female	820	72 (8.8 %)		32 (3.9 %)	
Body mass index (kg/m^2)			0.02		0.102
<23.0	1009	110 (10.9 %)		75 (7.4 %)	
≥23.0, <27.5	1149	131 (11.4 %)		60 (5.2 %)	
≥27.5	251	43 (17.1 %)		15 (6.0 %)	
ASA score			0.04		<0.001
1	1211	126 (10.4 %)		51 (4.2 %)	
2	1034	131 (12.7 %)		76 (7.4 %)	
≥3	164	27 (16.5 %)		23 (14.0 %)	
Operating time (min)			<0.001		0.048
<180	1442	125 (8.7 %)		78 (5.4 %)	
≥180	967	159 (16.4 %)		72 (7.4 %)	
Combined resection			<0.001		0.001
None	2328	256 (11.0 %)		137 (5.9 %)	
Yes	81	28 (34.6 %)		13 (16.0 %)	
Type of gastrectomy			<0.001		0.001
Distal gastrectomy	1952	186 (9.5 %)		103 (5.3 %)	
Total gastrectomy	294	68 (23.1 %)		34 (11.6 %)	
Proximal gastrectomy	137	27 (19.7 %)		9 (6.6 %)	
Pylorus-preserving gastrectomy	26	3 (11.5 %)		4 (15.4 %)	
Extent of lymphadenectomy ($n = 2399$[c])			0.359		0.516
≤D1+	1169	148 (12.7 %)		66 (5.6 %)	
D2	1219	132 (10.8 %)		81 (6.6 %)	
D2+	11	1 (9.1 %)		1 (9.1 %)	
Tumor size			0.021		0.001
<5 cm	2083	233 (11.2 %)		115 (5.5 %)	
≥5 cm	326	51 (15.6 %)		35 (10.7 %)	
T staging			0.001		<0.001
T1	1783	189 (10.6 %)		89 (5.0 %)	
T2	263	33 (12.5 %)		17 (6.5 %)	
T3	217	31 (14.3 %)		22 (10.1 %)	
T4	146	31 (21.2 %)		22 (15.1 %)	
N staging			0.001		0.001
N0	1812	191 (10.5 %)		103 (5.7 %)	
N1	270	41 (15.2 %)		13 (4.8 %)	
N2	154	18 (11.7 %)		11 (7.1 %)	
N3	173	34 (19.7 %)		23 (13.3 %)	
Year of operation[b]		OR 0.96 (95 % CI 0.91–0.99)	0.041	OR 1.03 (95 % CI 0.97–1.10)	0.396

[a] Chi-square test was used except for "Year of operation"

[b] Univariable binary logistic regression model

[c] Except for 10 cases of laparoscopic remnant gastrectomy

PAN metastasis after palliative chemotherapy. Of 13 patients who underwent D2+ lymph node dissection, five had pathologically proven stage IV gastric cancer (pathologically positive PAN). The ratio of EGC to AGC diagnosed pathologically was 2025 (73.7 %):721 (26.3 %), and the most common histologic type was moderately differentiated tubular adenocarcinoma (34.7 %) followed by poorly cohesive carcinoma (22.8 %).

Changes in the type of laparoscopic gastrectomy for gastric cancer

The frequency of laparoscopic total gastrectomy has increased at an accelerated pace since 2009 after the establishment of the end-to-side E–J stomy method using a laparoscopic purse-string clamp (Fig. 2). The proportion of function-preserving gastrectomies (PG, PPG, and sentinel lymph node navigation surgery) increased from 0 % (0/29 total EGC cases) in 2003 to 13.8 % (40/250) in 2013, reaching a peak in 2011 at 21.4 % (69/254). The proportion of patients with AGC among those undergoing laparoscopic curative gastrectomy increased gradually after 2003 (Fig. 3). In 2013, 28.8 % of patients who underwent laparoscopic curative gastrectomy for gastric cancer were pathologically diagnosed with AGC, whereas only 6.2 % of all patients had advanced disease in 2003.

Postoperative morbidity and mortality

Postoperative morbidities were evaluated in 2409 cases selected according to the above-described criteria. The rate of complications changed over time; of 29 patients who underwent laparoscopic curative gastrectomy during the first year, nine (31.0 %) had complications, whereas the rate of complications stabilized to approximately 10–20 % after 2003 (Fig. 4). Grade II or higher complications according to the Clavien–Dindo classification are listed in Table 3. The overall complication rate was 16.7 %; the surgical and systemic complications occurred at a rate of 11.8 and 6.2 %, respectively. The most frequent surgical morbidity was pancreatic fistula (2.2 %), followed by wound morbidity (2.1 %). In 33 cases (1.4 %), reoperation was required because of postoperative complications, and the most common cause of repeat surgery was bleeding (8/33, 24.2 %), followed by stricture (7/33, 21.2 %) and internal herniation (2/33, 6.0 %). There was one case of postoperative mortality because of delayed bleeding after discharge in a patient who underwent laparoscopic DG.

Risk factors associated with postoperative morbidity

Risk factors associated with postoperative morbidity were evaluated in the selected 2409 cases. Variables associated with the occurrence of surgical complications in the univariable analysis were as follows: male gender, high BMI, high American Society of Anesthesiology (ASA) score, long operating time, combined resection, type of gastrectomy, large tumor size, and advanced T and N stages; a recent year of operation was a negative predictive factor (Table 4). In the multivariate analysis, male gender, BMI $\geq$ 27.5 kg/m^2, operating time $\geq$180 min, combined resection of other organs, and total and proximal gastrectomies were independent risk factors for the occurrence of surgical complications, whereas a recent year of operation was an independent negative predictive factor (Table 5).

Table 5 Multivariable analysis of predictive factors associated with surgical complications

Variables	*P* value	OR	95 % CI
Gender	0.004		
Male		1	
Female		0.65	0.49–0.87
Body mass index (kg/m^2)	0.029		
<23.0		1	
≥23.0, <27.5		1.05	0.80–1.40
≥27.5		1.70	1.13–2.54
Operating time (min)	0.001		
<180		1	
≥180		1.58	1.20–2.08
Combined resection	0.001		
None		1	
Yes		2.62	1.45–4.75
Type of gastrectomy	<0.001		
Distal gastrectomy		1	
Total gastrectomy		1.96	1.34–2.87
Proximal gastrectomy		2.33	1.47–3.70
Pylorus-preserving gastrectomy		1.53	0.45–5.24
Year of operation	<0.001	0.91	0.86–0.95

Table 6 Multivariable analysis of predictive factors associated with systemic complications

Variables	*P* value	OR	95 % CI
Age	<0.001		
<60		1	
≥60		2.65	1.77–3.98
Gender	0.004		
Male		1	
Female		0.55	0.36–0.83
ASA score	0.023		
1		1	
2		1.3	0.88–1.92
≥3		2.19	1.25–3.84

Old age, male gender, high ASA score, long operation time, combined resection, type of gastrectomy, large tumor size, and advanced T and N stages were factors associated with systemic complications in the univariable analysis (Table 4). Among them, age ≥60 years, male gender, and ASA score ≥3 were identified as independent risk factors associated with systemic complications in the multivariable analysis (Table 6).

Changes in the surgical complication rate over time according to each predictive factor

In the subgroup analysis, we investigated whether the rate of surgical complications changed over time according to each predictive factor. For this purpose, the study period was subdivided into three periods (first period: 2003–2007, second period: 2008–2010, and third period: 2011–2014.1), and the surgical complication rates in each period were analyzed according to each independent predictive factor (Supplementary Table 1). The reduction in the rate of surgical complications from the first to the third period was greater in patients undergoing PG than in those undergoing DG (first to third period: 46.2–11.9 % in PG vs. 10.8–8.9 % in DG, $P = 0.009$), and in TG compared with DG (from 43.6 to 21.6 % in TG, $P = 0.057$). When we dichotomize the whole period by merging the second and third periods, the introduction of intracorporeal end-to-side E–J stomy in 2008 resulted in a significant decrease in TG complication rate from 43.6 % in the first period (2003–2007) to 20.0 % in the second and third periods (2008–2014.1) ($P = 0.001$) (Supplementary Table 2). In particular, anastomosis-related complications, such as leakage (10.3 vs. 2.0 %, $P = 0.020$) and stenosis (5.1 vs. 0.4 %, $P = 0.047$), decreased significantly between the two periods.

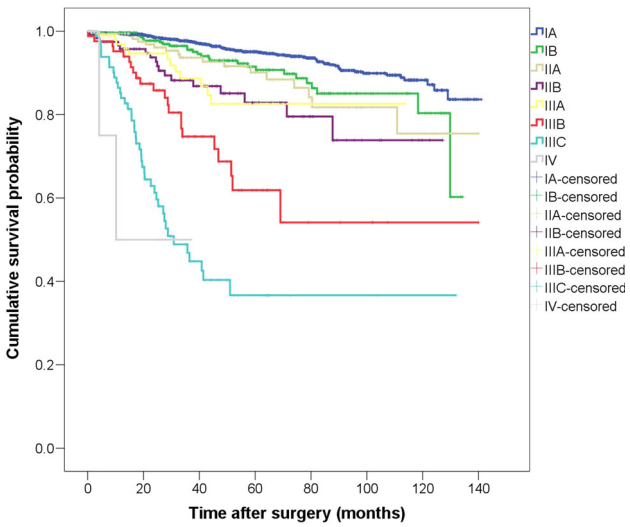

Fig. 5 Overall survival rates of patients who underwent laparoscopic curative gastrectomy according to tumor stage ($n = 2308$)

Long-term oncologic outcomes

The median follow-up period for the 2308 cases was 49.6 months (range 2.0–141.1 months). The overall 5-year survival rate was 90.2 %. The 5-year overall survival rates according to TNM stage were 95.1 % for stage IA ($n = 1476$), 91.5 % for stage IB ($n = 284$), 90.1 % for stage IIA ($n = 167$), 82.8 % for stage IIB ($n = 117$), 82.6 % for stage IIIA ($n = 96$), 61.9 % for stage IIIB ($n = 83$), and 36.7 % for stage IIIC patients ($n = 81$) (Fig. 5). The 5-year overall survival of stage IV patients ($n = 4$) could not be estimated because of two patient deaths at 4 and 10 months from aggravated alcoholic liver cirrhosis and cancer recurrence, respectively; the remaining patients were referred to other hospitals 2 and 3 years postoperatively. In the subgroup analysis of the DG and TG groups, there were no differences in the 5-year overall survival rates according to tumor stage [stage IA: 95.2 % ($n = 1346$) vs. 93.4 % ($n = 130$), $P = 0.066$; stage IB: 91.4 % ($n = 261$) vs. 92.3 % ($n = 23$), $P = 0.564$; stage IIA: 90.6 % ($n = 140$) vs. 87.5 % ($n = 27$), $P = 0.306$; stage IIB: 82.2 % ($n = 100$) vs. 86.3 % ($n = 17$), $P = 0.926$; stage IIIA: 81.2 % ($n = 67$) vs. 85.7 % ($n = 29$), $P = 0.580$; stage IIIB: 62.4 % ($n = 51$) vs. 59.3 % ($n = 32$), $P = 0.529$; and stage IIIC: 37.5 % ($n = 40$) vs. 35.1 % ($n = 41$), $P = 0.712$].

Discussion

One of the interesting findings of the present study was that the accumulated laparoscopic experience of the hospital was associated with a reduction in the rate of surgical complications. Although surgical complication rates remained stable after the second year of the study, the year of operation was found to be a protective factor for the prevalence of surgical complications in the multivariate analysis because the proportion of TG and combined resection, which were independent predictive factors of surgical complications, increased steadily during the same period. There are several studies in the literature addressing the learning curves of laparoscopic gastrectomy. These studies show that 40–90 cases of laparoscopic DG and 100 cases of laparoscopic TG are required for initial completion of learning [17–20]. Our study showed that the sustained accumulation of experience contributes to the decrease in surgical complications after overcoming the learning curve. The improved surgical outcomes could be attributed to the use of standardized laparoscopic procedures and the establishment of a laparoscopic gastrectomy team that includes experienced scopists

and nurses, as well as an increase in the surgeons' personal laparoscopic techniques and the advance of laparoscopic equipment such as high definition or three-dimensional laparoscopic cameras and more reliable energy devices [21]. Although our hospital is responsible for the education of residents and fellowship trainees as a national tertiary hospital and a large proportion of the operations are performed under supervision, standardized procedures that can be reproduced easily and an experienced supporting staff may have improved the surgical outcomes [22].

During the course of the present study, one of the major trends in laparoscopic gastrectomy in our hospital was an increase in the application of laparoscopic methods to technically demanding operations, such as laparoscopic gastrectomy for patients with AGC and laparoscopic TG. The results regarding morbidity and survival showed the technical feasibility and long-term oncologic safety of laparoscopic gastrectomy for AGC patients. Our data showed that the extent of lymphadenectomy did not affect the occurrence of postoperative complications, whereas a high pathologic (p) T-stage was associated with an increased rate of surgical complications in the univariate analysis. However, the proportion of combined resections of other organs was also significantly higher in patients with pT3 and pT4 stage than in those with pT1 and pT2 stage disease (T1: 0.8 %, T2: 3.4 %, T3: 7.8 %, and T4: 27.4 %, $P < 0.001$). Consequently, the independent predictive factor for surgical complications was not pT-stage, but rather combined resections in the multivariate analysis. Previous studies reported similar complication rates of laparoscopic gastrectomy in patients with EGC and AGC [6, 7, 23–26], with rates of 10.5–25.4 % for EGC [23–25], and 8.0–24.2 % for AGC [6, 7, 26]. These figures did not differ from those of open gastrectomy for AGC (8.0–28.5 %) [7, 26, 27]. The overall 5-year survival rate in the present study was also acceptable compared with that reported previously [5, 28, 29]. These survival data could provide preliminary evidence supporting the use of laparoscopic gastrectomy in patients with AGC before the results of randomized controlled clinical trials investigating the efficacy of the laparoscopic approach for the treatment for AGC become available.

Although TG was a predictive factor for surgical morbidity in the present study, the mean surgical complication rate of laparoscopic TG during the study period (23.1 %) was comparable to that reported previously [7, 30, 31]. The rate of surgical complications including anastomotic leakage and stenosis after TG decreased sharply between the early (2003–2007) and late (2008–2014.1) periods. The anastomosis technique of intracorporeal end-to-side E–J stomy using the laparoscopic purse-string clamp was introduced in 2008, and accumulated experience in this technique could reduce the rate of anastomosis-related surgical complications. Furthermore, the long-term outcomes did not differ between laparoscopic TG and laparoscopic DG in all tumor stages and were comparable with those reported previously [7, 30, 32].

According to the Nationwide Registries of Gastric Cancer of Korea and Japan [2, 10], the rates of incidence of pathological T1 (mucosal and submucosal) cancer in 2009 and 2008 were 57.6 and 51.2 %, respectively, and quality of life after surgery became an increasingly important factor because of the excellent long-term survival of patients with EGC. Therefore, function-preserving surgery such as PG has become increasingly popular as a patient-specific operation. Proximal gastrectomy for upper EGC is unpopular in Korea because of its well-established late complications such as reflux esophagitis, which occurs regardless of improved nutrition [33, 34]. At our institution, the number of PGs performed has increased steeply since 2011. This increase can be attributed to two factors, namely the establishment of the E–J anastomosis technique and the introduction of DTR as a new reconstruction method after PG. DTR consists of conventional Roux-en-Y reconstruction after TG and additional gastrojejunostomy. Therefore, reduced anastomosis-related complications after laparoscopic TG could reduce the burden of DTR after laparoscopic PG. DTR after PG has been performed since 2009, and the incidence of reflux esophagitis decreased to a level similar to that associated with TG [14]. In the present study, laparoscopic PG was associated with a significantly higher mean rate of surgical complications (19.7 %) than laparoscopic DG (9.5 %); however, this rate decreased from 46.2 % in the first period to 11.9 % in the third period. This drop was significantly greater than that of DG. The two technical factors mentioned above could have contributed to this sharp decrease in the surgical morbidities of PG.

In conclusion, the sustained accumulation of laparoscopic gastrectomy experience may contribute to a continuous decrease in the rate of surgical complications. Challenging laparoscopic procedures, such as laparoscopic TG and laparoscopic surgery for patients with AGC, showed acceptable short-term and long-term outcomes. With the advancement in laparoscopic techniques, laparoscopic PG can be performed safely. The present results indicate the trends toward the expansion of laparoscopic approaches to technically demanding procedures and an increased use of laparoscopic function-preserving surgeries for patients with EGC with acceptable outcomes.

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Compliance with ethical standards

Disclosures Young Suk Park, Sang-Yong Son, Aung Myint Oo, Do Hyun Jung, Dong Joon Shin, Sang-Hoon Ahn, Do Joong Park, and Hyung-Ho Kim have no conflicts of interest.

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