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Robotic-assisted gastrectomy for 700 gastric cancer patients: A comparative analysis between specialized centers in Italy and Korea☆

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A R T I C L E I N F O

Keywords:
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Survival rate

A B S T R A C T

Introduction: Robotic surgery is a safe approach for gastric cancer. Most available evidence originates from East Asia, while data from European centers remain limited. This study aims to compare surgical and oncological outcomes between different countries, focusing on the number of lymph node retrieved.

Materials and methods: We included adult patients who underwent curative-intent distal or total robotic gastrectomy for gastric cancer between 2017 and 2024 at specialized centers in Tuscany (Italy) and the Seoul National University Hospital (South Korea).

Results: A total of 700 patients were enrolled, including 232 Italian and 468 Korean patients. Western patients were older, had a higher comorbidity burden, and had more advanced disease (64.7% vs. 28.6%). Neoadjuvant chemotherapy and D2 lymphadenectomy were more frequently performed in Western centers, whereas D1+ was preferred in Eastern centers ($p < 0.001$). Median node retrieved was 34 (West 38 vs. East 33 nodes), exceeding oncological thresholds (>15) across all pathological stages. Lymph node retrieved increased with pT stage and was independent of age, while higher BMI was associated with lower nodal retrieval (31 vs. 35 nodes). Postoperative surgical complications were higher in the Western cohort (13.4% vs. 8.1%, $p = 0.029$), with an

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increased rate of anastomotic leakage ($p < 0.001$). Length of stay and perioperative mortality were comparable between centers.

Conclusion: Robotic gastrectomy ensures adequate lymphadenectomy and acceptable perioperative outcomes in both Italian and Korean centers. Observed differences in operative efficiency, morbidity, and survival mainly reflect variations in patient selection and disease stage rather than surgical quality, supporting centralization and earlier diagnosis at Western populations.

1. Introduction

Robotic surgery for gastric cancer (GC) was firstly introduced in Japan over two decades ago [1]. Despite its advantages in improved ergonomics and technical precision as well as a potential reduction in intraoperative complications, the only consistently demonstrated benefit during gastrectomy is an enhanced postoperative course [2]. As a result, the widespread adoption of robotic surgical systems for GC has remained limited for many years, particularly in Europe [3], and most of the available literature originates from East Asia [4]. These studies are primarily observational and often include a higher proportion of early stage cancers and lower prevalence of obesity.

Currently, few randomized controlled trials have investigated the effectiveness of robotic approach. These trials did not demonstrate significant differences in postoperative complication rates or lymph nodes retrieved when compared with laparoscopic surgeries performed by experienced surgeons [5]. Interestingly, these emerging results align with our previous experience in both total and subtotal gastrectomies [6].

On the other hand, the impact on oncological outcomes remains controversial. A recent randomized trial from China reported improved 3-year disease-free survival and a lower local recurrence rate in the robotic group (2.1% vs. 7.7%) [7], while other studies from the West reported higher pooled 5-year overall survival when compared with the open group (55.2% vs. 50.8%), even in advanced cases [8].

Such divergent results underscore the importance of contextualizing surgical outcomes within broader epidemiologic differences. Geographic variability in GC incidence reflects underlying differences in tumor biology and patient prognosis with South Korea exhibiting amontg the highest age-standardized rates globally (38.4 per 100,000 for males and 16.9 for females) and China alone accounting for nearly half of all global GC related deaths [9–11]. In contrast, Italy reports substantially lower rates (6.8 per 100,000; 9.0 for males and 5.0 for females), consistent with Western European trends of declining incidence [12]. These disparities highlight the need for comparative analyses across heterogeneous populations [13].

The study aims to investigate differences in robotic gastrectomy between Eastern and Western centers specialized in upper gastrointestinal surgery, providing insight into variations in surgical quality, perioperative outcomes, and survival, with a specific focus on lymph node retrieved as a surrogate for oncologic adequacy.

2. Materials and Methods

2.1. Study design

This is a retrospective multicenter study involving three Italian centers from Tuscany region (University of Siena, University of Florence and Hospital of Grosseto) and the Seoul National University Hospital (SNUH) in South Korea. All consecutive patients who underwent elective robotic (Da Vinci Robotic Surgical System, Intuitive Surgical) distal or total gastrectomy for GC between 2017 and 2024 were enrolled.

Data from Italian centers were extracted using a dedicated database, the Gastric Network DataBase [GA.N.D.]. The University of Siena serves as the coordinating center and central ethics committee (number AOUS-22846). The SNUH prospectively collected relevant data from electronic medical records and the Clinical Data Warehouse into an internally approved database (IRB number E−2512-011-1697). The study was conducted in accordance with the tenets of the Declaration of Helsinki. Patient confidentiality and data protection were ensured for all participants.

Patients with histologically confirmed gastric adenocarcinoma who underwent robotic distal or total gastrectomy with curative intent in accordance with international guidelines and for whom follow-up data (alive, deceased, or lost to follow-up) were available, were included [14,15]. Exclusion criteria were recurrent disease, previous gastrectomy (endoscopic submucosal dissection, ESD,was considered for Eastern cases), tumors involving the gastro-esophageal junction requiring oesophagectomy, evidence of metastatic tumor (peritoneal carcinomatosis, liver metastasis, distant lymph node metastasis, Krukenberg tumors, involvement of other organs), synchronous malignancies, multivisceral resections (except for cholecystectomy and omentectomy), American Society of Anesthesiology (ASA) score >3 and palliative surgery.

2.2. Surgery

Robot-assisted gastrectomy involves stepwise lymphadenectomy and vessel division, beginning with colo-epiploic detachment and progressing along the greater and lesser curvatures. In Italian centers, key lymph-node stations (3, 4sb/d, 5, 6, 7, 8a, 9, 11p, and 12) are systematically dissected, whereas the Korean approach limits lymphadenectomy in early stage cases (D1 plus 8a, 9, and 11p in total gastrectomy) [14,15]. Para-aortic nodal dissection (D2+/D3) is selectively performed in Western centers in cases with clinically detected para-aortic nodal involvement or in high-risk patients for metastasis (T3/4a tumors of Lauren diffuse type) [16].

In the Korean center, the standard robotic configuration included a fenestrated bipolar forceps or Maryland bipolar on the robotic left arm and an ultrasonic energy device (or, alternatively, advanced bipolar radiofrequency energy) on the robotic right arm, with a Cadiere forceps or tip-up fenestrated grasper mounted on the fourth robotic arm. Conversely, in Italian centers, advanced energy devices were limited to technically challenging cases or those at high risk of bleeding, with monopolar curved scissors preferentially used on the robotic right arm in standard procedures.

In the Korean hospital, linear stapling Billroth I or II was selected based on proximal stump length and duodenal involvement, and all total gastrectomies were reconstructed with antecolic Roux-en-Y using circular stapling. The Italian approach to subtotal gastrectomy ends with gastric transection and intracorporeal stapling Billroth II or Roux-en-Y reconstruction, depending on surgeon experience, while total gastrectomy includes extended lymph nodes dissection along the gastrosplenic ligament and esophageal hiatus. Reconstruction after total gastrectomy is completed with an esophagojejunal anastomosis, using either circular stapling or robotic hand-sewn methods in one center, exclusively circular stapler in one center, and linear stapler in the last. At the end of the procedure, a single perianastomotic-subhepatic drain is routinely placed in the Korean center, whereas one or two drains are positioned in Italian centers depending on the extent of surgery and lymph node dissection.

Table 1
Baseline characteristics.

	Entire (n = 700)	Western cohort (n = 232)	Eastern cohort (n = 468)	p value
Sex, n (%)				0.278
Male	448 (64.0)	142 (61.2)	306 (65.4)	
Female	252 (36.0)	90 (38.3)	162 (34.6)	
Age, years (IQR)	65 (56-75)	75 (66-79)	60 (51-68)	**<0.001**
BMI (Kg/m^2), n (%) *				**0.001**
<25	389 (55.7)	127 (56.7)	262 (56.5)	
25-30	250 (37.4)	70 (31.3)	180 (38.8)	
>30	49 (6.9)	27 (12.1)	22 (4.7)	
ASA score, n (%)				**<0.001**
1	100 (14.3)	11 (4.7)	89 (19.0)	
2	475 (67.9)	122 (52.6)	353 (75.4)	
3	125 (17.8)	99 (42.7)	26 (5.6)	
aCCI, median (IQR)	5 (4-6)	5 (4-7)	4 (3-5)	**<0.001**
Previous abdominal surgery, n (%)	117 (16.7)	101 (43.5)	16 (3.4)	**<0.001**

IQR: interquartile range; BMI: Body Mass Index; ASA: American Society of Anesthesiology score; aCCI: age-adjusted Charlson Comorbidity Index.

Frozen-section margin assessment was routinely performed in Korea and, if positive additional resection was performed [17], whereas in the Italian cohort it was reserved for selected cases, such as uncertain proximal margin, partial or complete tumor regression after neoadjuvant chemotherapy or tumors involving the esophagogastric junction. Sampling of lymph node stations was performed by surgeons at the Siena center and at SNUH.

2.3. Variables and definitions

Data on patient demographics, tumor pathology, surgery, perioperative course, and survival were collected.

Preoperative. The age-adjusted Charlson Comorbidity Index (aCCI) was used to estimate patients' mortality risk by assigning weighted scores to their comorbid conditions [18]. Previous abdominal surgery included any intra-abdominal procedure the patient had undergone. The neoadjuvant chemotherapy variable was defined as the administration of pre- or peri-operative chemotherapy following tumor board evaluation (at least 2 cycles completed).

Intraoperative. Intraoperative complications were limited to acute major bleeding requiring urgent transfusion, significant injury to major vessels or organs necessitating reconstruction or resection, and unexpected medical conditions that interrupted or altered the planned procedure.

Postoperative. Definitions of postoperative complications were previously detailed and graded according to the Clavien-Dindo classification (CDC) system. Severe complications were defined as CDC grade ≥ IIIa [19]. Delay length of stay (LOS) was defined using the 75th-percentile (75% LOS), i.e., the value below which 75% of admissions fall, calculated annually for each hospital; patients with LOS >75% were classified as delayed.

Patients underwent regular post-operative follow-ups in the surgery or oncology departments.

2.4. Endpoints

The primary aim was to compare the amount of lymph nodes retrieved between the two cohorts, stratified by pathological tumor stage.The extent of lymphadenectomy, as well as theoperation time, were adjusted for hospital volume (intended as mean annual number of procedures in the study period), surgical volume (intended as mean annual number of procedures performed by a surgeon), and analyzed [20].

Rate of postoperative complications and LOS were also compared as secondary endpoints. Subgroup analyses of the postoperative course were conducted by patients' status and tumor stage. Overall survival (OS) was detailed for pathological stage.

2.5. Statistical analysis

Categorical variables were expressed as proportions and compared using the chi-square test or 2-sided Fisher exact test, as appropriate. Continuous variables were reported as median with interquartile range (IQR). Comparisons of continuous variables were performed using Mann–Whitney *U* test, Kruskal-Wallis or van Elteren test (stratified Wilcoxon rank-sum test). The p value < 0.05 was considered statistically significant. Regression was used to estimate odds ratios (OR) and 95% confidence intervals (95% CI) of factors, including sex, age, BMI, gastrectomy, neoadjuvant and pTN stage, independently associated with the amount of lymph nodes removed and the occurrence of complications.The relationship between the volume (horizontal axis) and lymph nodes retrieved and operative time (vertical axis) were plotted. The estimated median follow-up time was calculated using the reverse Kaplan–Meier method. Survival analyses were performed using the Kaplan–Meier and compared with the log-rank test. Cox proportional hazards regression analysis was performed to evaluate the hazard ratios (HR). Due to the descriptive nature of this study, sample size calculations was not performed, and the cohort size was determined by the selected criteria. All statistical analyses were conducted using SPSS version 29.0 (SPSS Inc., USA) and GraphPad Prism version 9.5.0 (GraphPad Software, USA).

3. Results

3.1. Patients and baseline characteristics

A total of 700 patients fulfilled inclusion criteria (median age 65 years; BMI 24.5 kg/m^2), with 232 (33.1%) enrolled in Italy (75 years; 24.3 kg/m2) and 468 (66.9%) in Korea (60 years; 24.5 kg/m^2). Baseline characteristics have been reported in Table 1. Except for sex distribution, significant differences were observed between groups across most patients' features, including age, comorbidities, ASA score ($p < 0.001$), and BMI ($p = 0.001$).

3.2. Clinicopathological features and surgical management

Most patients presented with neoplasms of the lower third of the stomach, particularly 121 (52.2%) between Western patients and 335 (71.6%) between Eastern ($p < 0.001$). Treatment data have been included in Table 2.

The Western cohort included 150 (64.7%) advanced gastric cancer cases (>pT1), compared with 134 (28.6%) in the Eastern cohort ($p < 0.001$). Patients with advanced disease showed a median age of 69 (59-78) years (West 75 years versus East 61 years; $p < 0.001$). Notably, three (0.6%) Eastern patients were classified as pT0 (stage 0), corresponding to post ESD specimens, while 3 (1.3%) pTis and 2 (0.9%) cases of complete regression after neoadjuvant chemotherapy were observed in Western group.

Distal resection was the predominant procedure in both cohorts. The extent of lymphadenectomy differed, with D2 performed in 159 (37.9%) of distal and 30 (61.2%) of total gastrectomies by Eastern surgeons, while completed in 114 (67.1%) of distal and 55 (88.7%) of total cases in the West ($P < 0.001$).

Table 2
Surgical and pathological data.

	Entire (n = 700)	Western cohort (n = 232)	Eastern cohort (n = 468)	p value
Neoadjuvant chemotherapy, n (%)	85 (12.1)	80 (34.5)	5 (1.1)	**<0.001**
Tumor site, n (%)				**<0.001**
Upper	71 (10.1)	34 (14.7)	37 (7.9)	
Middle	168 (24.0)	75 (32.3)	93 (19.9)	
Lower	456 (65.1)	121 (52.2)	335 (71.6)	
2 or more sites	5 (0.7)	2 (0.9)	3 (0.6)	
Lauren type, n (%)				0.120
Intestinal	309 (44.1)	115 (49.6)	194 (41.5)	
Diffuse/Mixed	308 (44.0)	91 (39.2)	217 (46.4)	
Other/ Undetermined	83 (11.9)	26 (11.2)	57 (12.2)	
Gastrectomy, n (%)				**<0.001**
Distal	589 (84.1)	170 (73.3)	419 (89.5)	
Total	111 (15.9)	62 (26.7)	49 (10.5)	
Lymph nodes dissection, n (%)				**<0.001**
D1+	298 (42.6)	19 (8.2)	279 (59.6)	
D2	374 (53.4)	186 (80.2)	188 (40.2)	
Extended	28 (4.0)	27 (11.6)	1 (0.2)	
Reconstruction technique, n (%)				**<0.001**
Billroth I	137 (19.6)	0 (0)	137 (29.3)	
Billroth II	410 (58.6)	141 (60.8)	269 (57.5)	
Roux-en-Y	153 (21.9)	91 (39.2)	62 (13.2)	
Tumour size mm, median (IQR)	30 (19-44)	30 (20-45)	28 (17-44)	0.172
Positive margin status, n (%)	9 (1.3)	9 (3.9)	0 (0)	**<0.001**
pT/ypT, n (%)				**<0.001**
0-1	417 (59.6)	82 (35.4)	335 (71.3)	
2	95 (13.6)	37 (15.9)	59 (12.6)	
3	134 (19.1)	81 (34.9)	53 (11.3)	
4	54 (7.7)	32 (13.8)	22 (4.7)	
pN/ypN, n (%)				**<0.001**
0	487 (69.6)	124 (53.4)	363 (77.6)	
1	73 (10.4)	35 (15.1)	38 (8.2)	
2	69 (9.9)	33 (14.2)	36 (7.7)	
3a	46 (6.6)	25 (10.8)	21 (4.5)	
3b	25 (3.5)	15 (6.5)	10 (2.1)	
8th AJCC stage, n (%)				**<0.001**
0-I	426 (60.9)	105 (45.3)	321 (68.6)	
II	138 (19.7)	57 (24.6)	81 (17.3)	
III	136 (19.4)	70 (30.2)	66 (14.1)	

AJCC: American Joint Committee on Cancer; IQR: interquartile range.

3.3. Lymph node retrieval and stratification

The median lymph nodes retrieved was 34 (26-46), with 38 (26-51) in the West and 33 (26-43) in the East (p = 0.001). A correlation between the number of lymph nodes retrieved and tumor stage is showed in Fig. 1.

Overall, in older patients (>70 years) a similar number of lymph nodes were retrieved compared to younger (median 34 (25-47) versus 35 (27-44), p = 0.720). Patients who presented with higher BMI (>30 kg/m2) showed lower number of retrieved lymph nodes (median 31 (21-42) versus 35 (27-46), p = 0.023). The number of lymph nodes retrieved after total gastrectomy was the same for each group (p = 0.529). Patients' stratification has been reported in Table 3.

On regression analysis, BMI >25 was the only independent predictor of reduced lymph node retrieved in the Western cohort (P < 0.001). In the Eastern cohort, female sex (P < 0.001), tumor size >40 mm (P < 0.001), and pN+ (P = 0.033) were associated with more lypmh nodes retrieved, while older age (P < 0.001) and higher BMI (P = 0.025) with lower. Total gastrectomy and pT2–4 stage were not confirmed as independent predictors on multivariable analysis.

3.4. Complications

One intraoperative complication (0.4%) was observed in the Western cohort, whereas no complications occurred in the Eastern cohort. A total of 6 and 8 patients in the Italian and Korean cohorts, respectively, were excluded a priori from the study due to conversion to open surgery caused by extensive adhesions or technical difficulties in anatomical plane dissection.

Severe postoperative surgical complications (CDC ≥ IIIa), except for infectious, occurred in 51 (7.3%) patients, with 25 (11.2%) patients included in the Western cohort and 25 (5.3%) in the Eastern cohort (p = 0.005). Annual surgical postoperative complication rates in the Eastern cohort showed a declining trend over the study period from 18.7% to a mean of 4.2% after 2020, whereas Western rates remained stable (range 8.5–16.7%). The earlier postoperative course is detailed in Table 4.

Compared with patients undergoing distal gastrectomy, total gastrectomy was more frequently performed in older patients (median age 65 vs. 57 years) and more often preceded by neoadjuvant chemotherapy (31.5% vs. 8.5%), with similar median BMI (24 kg/m2). Anastomotic leakage after total gastrectomy occurred in 11 cases, all in the Western cohort (17.7%, p = 0.001); of these, 7 had advanced disease (63.6%) and 5 (45.5%) received neoadjuvant treatment. Total gastrectomy predicted the occurrence of anastomotic leakage in the Western cohort (OR 5.90 [95% CI of ratio, 2.08 – 16.73], P < 0.001), while older age (OR 54.09 [95% CI of ratio, 1.16 – 14.43], P = 0.029) was related in the Korean cohort. No duodenal stump leakages were observed after total gastrectomy, and two bleeding cases were reported in the Western cohort (3.2%, p = 0.502).

All cases of postoperative mortality were staged as advanced at final pathological examination.

At regression analysis, total gastrectomy (univariable OR 3.84 [95% CI of ratio, 1.66 – 8.86], p = 0.002; multivariable OR 4.33 [95% CI of ratio, 1.84 – 10.19], p < 0.001) influenced the occurrence of severe postoperative complications in the Western cohort, while no factors were isolated in the Eastern cohort (Supplementary Table).

3.5. Hospital and surgical volume

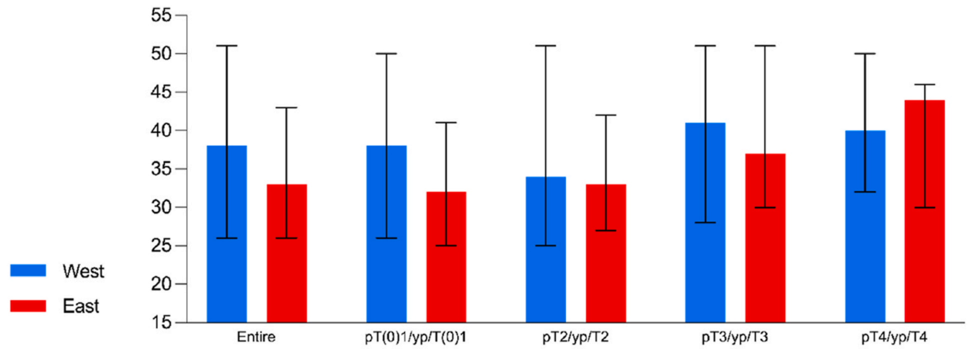
A simple correlation analysis, shown in Fig. 2, demonstrated no association between the number of lymph nodes yield and volume, whereas a strong correlation was observed between operative time (including robotic docking time) and surgical volume (ρ = −1.00).

3.6. Survival

Data of 483 patients from 2017 to 2022 were considered for survival analysis. Median follow-up time was 48 months (range 31-63); cumulative 3-year OS was 91.4% and 5-year OS was 89.5%.

Overall, 3-year OS was 80.5% vs. 96.6% and 5-year OS was 75.7% vs. 95.7% in the West and East, respectively [HR: 9.39; 95% CI of ratio, 5.11 – 17.28; P < 0.001] (Supplementary Figure a).

Patients at stage 0-I had a 5-year OS rate of 91.1% versus 99.0% in the Western and Eastern cohorts (HR: 23.1 [95% CI of ratio, 6.21 – 85.84], P < 0.001; Supplementary Figure b). Cox proportional hazards analysis showed that, among Western patients with early-stage disease, poorer survival was associated with older age (69.5%, HR 12.18 [95% CI of ratio, 1.43 – 103.48], P = 0.022) or tumor size larger than 20 (54.3%, HR 4.58 [95% CI of ratio, 1.13 – 18.52], P = 0.033), while the invasion of the muscularis propria pT2 and/or nodal metastases (stage IB 18.1%, P = 0.621) and gender (female sex 22.9%, P = 0.748) did not



Lymph nodes retrieved West (range); East (range)	Entire	pT(0)1/yp/T(0)1	pT2/yp/T2	pT3/yp/T3	pT4/yp/T4	p value
Total	38 (26-51); 33 (26-43)	38 (26-50); 32 (25-41)	34 (25-51); 33 (27-42)	41 (28-51); 38 (30-52)	40 (32-50); 43 (30-44)	**0.039**
Perigastric (1 to 7) *	22 (17-23); 25 (18-34)	24 (17-36); 25 (17-34)	24 (19-31); 25 (19-31)	20 (17-22); 27 (22-40)	23 (17-34); 34 (25-35)	0.336
Extragastric (8a to 12) *	11 (7-18); 8 (5-11)	9 (7-12); 7 (5-10)	14 (10-20); 8 (6-12)	16 (12-18); 10 (6-13)	11 (7-19); 9 (6-10)	**0.003**

Fig. 1. Number of lymph nodes retrieved in the West vs. East (median, IQR), stratified by pathological tumor stage and for lymph nodes stations. * Siena center data (posterior nodes excluded).

Table 3
Lymph nodes retrieved by age,body mass index (BMI) and type of gastrectomy.

	Median nodes in Entire cohort (IQR)	Median nodes in Western cohort (IQR)	Median nodes in Eastern cohort (IQR)	p value (West-East)
Age in years	0.704	**0.044**	**<0.001**	
<45 (n = 57)	36 (28-45)	61 (55.5-66.5)[a]	35 (28-44)	**-**
45-70 (n = 404)	34.5 (26-44)	36 (25-48)	34 (27-43)	0.680
>70 (n = 239)	34 (25-47)	40 (28-51.5)	29 (21-37.5)	**<0.001**
BMI in Kg/m^2	**<0.001**	**<0.001**	**0.003**	
<25 (n = 389)	37 (29-49)	44 (31-54.5)	35 (28-44)	**<0.001**
25-30 (n = 250)	31.5 (25-42)	32 (23.5-45.5)	31 (25-40)	0.465
>30 (n = 49)	31 (21-42)	34 (22-44)	27 (21.5-37)	0.398
Gastrectomy	**<0.001**	0.113	**0.038**	
Distal (n = 589)	33 (26-44.5)	38 (25-50)	32 (26-42)	**0.017**
Total (n = 111)	41 (30-53)	41 (31-53)	40 (25.5-49.5)	0.529

BMI: Body Mass Index; IQR: interquartile range.
[a] Three patients.

Table 4
Perioperative course.

	All (n = 700)			BMI >30 (n = 49)			Advanced (pT2-4a) (n = 284)		
	West (n = 232)	East (n = 468)	p value	West (n = 27)	East (n = 22)	p value	West (n = 150)	East (n = 134)	p value
Operation time, minutes (IQR)	320 (265-380)	240 (205-285)	**<0.001**	330 (300-380)	283 (230-305)	**0.003**	330 (277-388)	258 (221-301)	**<0.001**
Complications, n (%):	31 (13.4)	38 (8.1)	**0.029**	4 (14.8)	3 (13.6)	0.907	22 (14.7)	17 (12.7)	0.628
Bleeding	5 (2.2)	4 (0.9)	0.166	1 (3.7)	1 (4.5)	1.000	3 (2.0)	2 (1.5)	1.000
Duodenal leak	2 (0.9)	6 (1.3)	1.000	1 (3.7)	0 (0)	1.000	2 (1.3)	3 (2.2)	0.669
Anastomotic leak	15 (6.5)	4 (0.9)	**<0.001**	1 (3.7)	0 (0)	1.000	10 (6.7)	1 (0.7)	**0.012**
Pancreatic fistula	1 (0.4)	0 (0)	0.331	1 (3.7)	0 (0)	1.000	1 (0.7)	0 (0)	1.000
Obstruction	12 (5.2)	13 (2.8)	0.130	1 (3.7)	2 (9.1)	0.581	9 (6.0)	5 (3.7)	0.423
Higher CDC, n (%):			**<0.001**			0.701			**0.002**
Grade IIIa	5 (2.2)	23 (4.9)		1 (3.7)	2 (9.1)		3 (2.0)	11 (8.2)	
Grade IIIb	17 (7.3)	0 (0)		1 (3.7)	0 (0)		11 (7.3)	0 (0)	
Grade IV	2 (0.9)	1 (0.4)		2 (7.4)	0 (0)		2 (1.3)	0 (0)	
Grade V	2 (0.9)	0 (0)		0 (0)	0 (0)		2 (1.3)	0 (0)	
Escalation in level of care, n (%)	5 (2.2)	2 (0.4)	**0.043**	0 (0)	0 (0)	-	4 (2.7)	0 (0)	0.125
LOS, days (IQR)	8 (6-10)	7 (6-8)	0.112	8 (7-11)	7 (6.5-9.5)	0.299	8 (7-11)	7 (7-10)	0.298
Delayed 75th LOS, n (%)	55 (23.7)	107 (22.9)	0.803	11 (40.7)	8 (36.4)	0.777	43 (28.7)	43 (32.1)	0.531
30-day Mortality, n (%)	2 (0.9)	0 (0)	0.110	0 (0)	0 (0)	-	2 (1.3)	0 (0)	0.500
90-day Mortality, n (%)	2 (0.9)	0 (0)	0.110	0 (0)	0 (0)		2 (1.3)	0 (0)	0.500

BMI: Body Mass Index; CDC: Clavien-Dindo classification; IQR: interquartile range; LOS: lenght of stay.
Bleeding: intra- and extraluminal bleeding (more than 150 mL) requiring urgent transfusions and/or other invasive treatment (endovascular or endoscopic or surgical); Duodenal leak: leak of the duodenal stump regardless of clinical consequences and treatment; Anastomotic leak: full thickness defect involving esophagus, anastomosis, staple line, gastric or jejunal stump or the presence of an abscess close to the anastomoses; Pancreatic fistula: fluid amylase greater than three times the serum amylase level without duodenal or anastomotic leaks; Obstruction: clinical and/or radiological signs of mechanical stenosis or paralytic ileus, with a patient's inability to enteral feed; Escalation in level of care: unplanned intensive care unit (ICU).

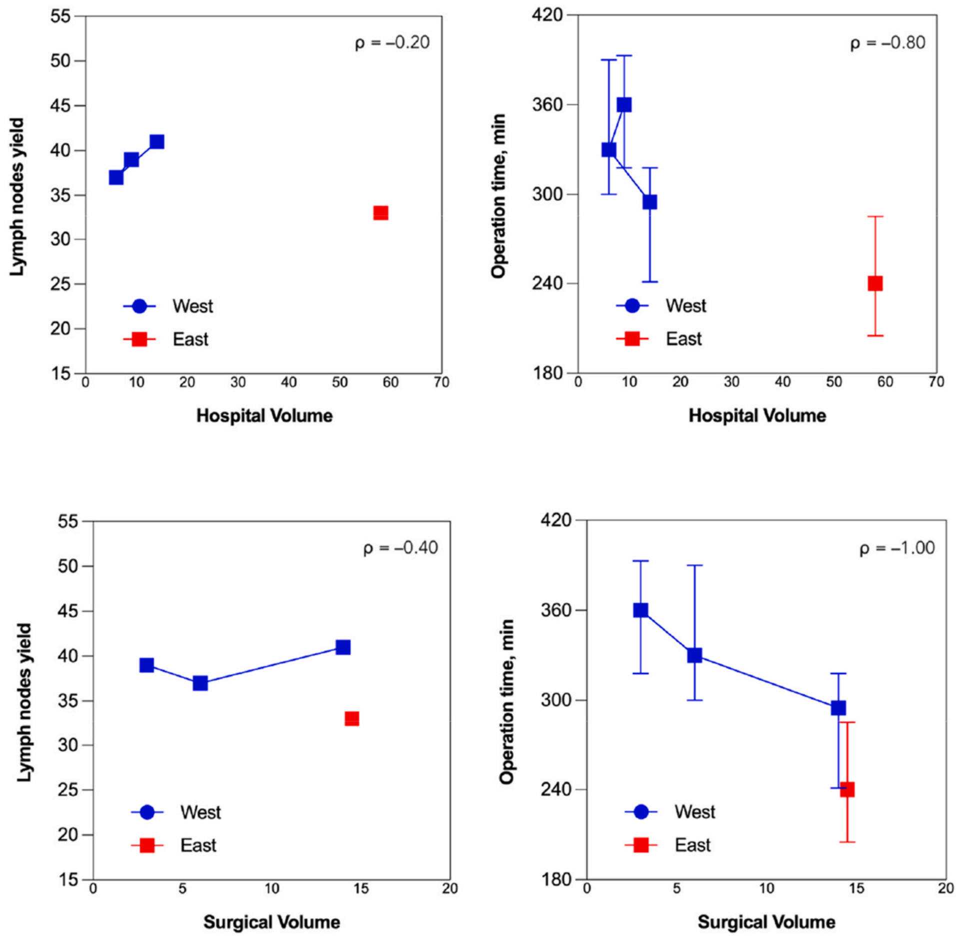


Fig. 2. Variation in the number of lymph nodes yield and operation time according to surgical volume (average yearly procedures per surgeon) and hospital volume (average yearly procedures per hospital).

significantly affect survival. In the Eastern cohort, none of these factors were associated with reduced survival: older age (23.7%, P = 0.109), tumor size >20 mm (56.4%, p = 0.461), pT2 and/or pN (3.7%, P = 0.992), or female sex (34.9%, P = 0.882).

Patients with stage II disease had a 5-year OS rate of 81.2% versus 97.1% (HR: 7.42 [95% CI of ratio, 2.23 – 24.74], P = 0.003; Supplementary Figure c). Patients with stage III disease had a 5-year OS rate of 36.8% versus 77.0% (HR: 3.00 [95% CI of ratio, 1.37 – 6.52], P = 0.013; Supplementary Figure d). Furthermore, we investigated differences in OS between advanced gastric cancer cases with different number of lymph nodes retrieved: median 5-year OS for patients with a median of <15, 16-30, >30 lymph nodes retrieved was 65.5%, 81.3%, and 76.2%, respectively (Supplementary Figure e).

Notably, cases with positive resection margins at final pathological examination in the Western cohort had lower survival: 3-year OS rate of 57.1% versus 77.2% (HR: 1.92 [95% CI of ratio, 0.69 – 5.34], p = 0.057), and no survivors at 5 years versus 74.2%.

4. Discussion

The use of robotic platforms for GC has increased exponentially, despite trial evidence failing to demonstrate a clear superiority over the laparoscopic approach [5,7]. Patient referral to robotic surgery often depends on tumor stage, surgeon preferences, and national health systems or insurance coverage, limiting data comparability across countries [21,22]. To our knowledge, this is the first dedicated East–West comparison of robotic gastrectomy performed in specialized centers. Our results showed that robotic approach may enable consistently adequate lymphadenectomy in both Italian and Korean cohorts, even with markedly different patient populations. Variations in perioperative morbidity diminished after adjustment for clinicopathological characteristics. The Western cohort achieved a slightly higher number of lymph nodes retrieved, but this did not translate into improved survival, suggesting that oncologic outcomes are probably driven by intrinsic factors and tumor biology beyond nodal dissection alone.

The first key finding is that the median number of retrieved lymph nodes exceeded twice the recommended minimum in both cohorts across all pathological stages, with 34 (26–46) nodes overall, 32 (25–42) in early-stage disease, 38 (28–50) in advanced-stage disease [23,24]. Eastern data support harvesting ≥30 lymph nodes for optimal survival [25]. However, lower thresholds suit frail patients, early lesions, or lower-volume centers, and the Italian Research Group on Gastric Cancer (GIRCG) proposed to remove 20 lymph nodes for subtotal and 25 for total gastrectomy [26]. The progressive increase in lymph nodes harvested with advancing tumor stage in the Eastern cohort suggests a stage-adapted surgical strategy to tumor burden, whereas the Western cohort showed consistent D2 per national guidelines [14]. Nevertheless, patient-related factors may influence nodal removing, as obesity was associated with a lower number of retrieved lymph nodes (median 31 in BMI >30 kg/m^2 vs. 35 in <30 kg/m^2), likely due to technical challenges in dissection and/or pathology processing. Yet, the number of nodes removed remained oncologically adequate across BMI levels, confirming robotic feasibility in obese patients [24]. Notably, the absence of a clear relationship between nodal retrieved and hospital and surgical volume, together with the strong association with the operative time, suggests that experience mainly improves efficiency, while oncologic adequacy can be consistently achieved once the procedure is implemented in specialized centers [20].

Second, perioperative outcomes revealed a substantially higher burden of severe complications in the Western cohort, particularly anastomotic leakage. The identification of total gastrectomy as an independent predictor of major complications in the Western cohort indicates that reconstruction after total gastrectomy remains the main target for quality improvement [27]. A slight difference in bleeding occurrence may probably follow a more frequent complete omentectomy per guidelines, non-routine use of advanced energy devices, and predominance of advanced cases in Western centers [28,29]. In a 2024 analysis of the Upper Gastrointestinal International Robotic Association (UGIRA) Gastric Registry, the overall anastomotic leakage rate was 5.5% (vs. 6.5% in our Western series) and 10% after total gastrectomy, while bleeding rates were 2.3% overall (vs. 2.2%) [30]. Other surgical complications were relatively infrequent in our series, resulting in an overall reintervention rate of 7.8% compared with 10.7% in the UGIRA registry. At the same time, the similar length of stay and very low perioperative mortality suggest acceptable postoperative management and complication rescue capacity in both settings.

Third, survival analysis confirmed a substantial advantage for the Eastern cohort, both overall (5-y OS 95.7% vs. 75.7%) and when stratified by stage. This disparity likely reflects earlier diagnosis, a higher proportion of node-negative disease, and broader use of screening programs in Eastern countries [31,32]. Western patients were older, with higher comorbidities and advanced disease. Pooled LOGICA/STOMACH trials, including a higher proportion of patients from Northern Europe, reported lower 1-y survival (83.8%) than our Western cohort [33,34], and data from the European Network of Cancer Registries (ENCR) show highest 5-y GC survival in Southern Europe vs. Eastern/Northern regions, mainly attributable to stage at diagnosis, tumor subsite/morphology, and treatment variations [35]. Similarly, the survival difference observed in our patients with early-stage disease (HR 23.1) should be interpreted with caution. Even within this subgroup, Western patients showed different tumor burden and greater nodal involvement (stage IB 18.1% vs 3.7%).

A final implication of our study is the need for centralization supported by multidisciplinary decision-making and standardized clinical pathways [36,37]. Differences in case volume and screening infrastructure, with Korea offering biennial endoscopic surveillance to all young adults, directly shape disease stage at presentation, and ultimately long-term outcomes. However, the optimal strategy for implementing centralization remains controversial especially in Western countries. Of the 4537 gastrectomies registered in Italy in 2024, only 15.7% of hospitals performed more than 15 cases per year, accounting for 54.2% of all procedures. Overall 30-day mortality was 4.9% (95% CI 4.2–5.6), ranging from 7.7% in lower-volume centers to 4.7% in higher-volume centers [38]. On the other hand, high rate of GC in East Asia facilitates faster completion of robotic learning curves, leading to a substantial decrease in operative time and complication rates, though reported learning curves are generally longer than in the West (approximately 65 vs. 25–30 cases) [39,40].

This study has several limitations, including its retrospective design, baseline imbalances between cohorts, differences in perioperative treatment and reconstruction strategies, and the inclusion of only expert institutions, which may limit generalizability and not fully reflect real-world practice. Furthermore, despite the use of multivariable models to adjust for key confounders, residual confounding cannot be excluded as statistical techniques sensitive to the positivity assumption were not applied, and caution is warranted when interpreting comparisons between cohorts derived from markedly different epidemiological and clinical settings.

5. Conclusions

Robotic gastrectomy may be associated with oncologically adequate lymphadenectomy and acceptable perioperative outcomes. The observed differences in morbidity and survival between centers could be most likely attributable to discrepancies in patient selection, disease stage, and potential different tumor behaviour, although causal inference cannot be established. Efforts should focus on earlier detection in Western populations and improved perioperative management, especially for total gastrectomy.

Author contributions

Ludovico Carbone and Yo-Seok Cho: Conceptualization, Methodology, Formal analysis, Writing - Original draft preparation; Min Kyu Kang, Kyoyoung Park, Laura Fortuna, Giuseppe Giuliani, Eleonora Andreucci: Validation, Investigation, Writing - Review & Editing, Visualization; Sen Wang and Aurora Visani: Methodology, Validation, Writing - Review & Editing, Visualization; Chungyoon Kim, Sa-Hong Kim, Jeesun Kim, Francesco Coratti, Francesco Guerra: Validation, Data Curation, Writing - Review & Editing, Visualization; Yoonjin Kwak, Hye Seung Lee, Yun-Suhk Suh: Data Curation, Writing - Review & Editing, Visualization; Seong-Ho Kong, Han-Kwang Yang, Fabio Cianchi, Andrea Coratti, Franco Roviello, Hyuk-Joon Lee: Writing - Review & Editing, Visualization, Supervision; Daniele Marrelli and Do Joong Park: Conceptualization, Writing - Original draft preparation, Project administration.

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Declaration of competing interest

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Appendix A. Supplementary data

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References

[1] Hashizume M, Shimada M, Tomikawa M, Ikeda Y, Takahashi I, Abe R, et al. Early experiences of endoscopic procedures in general surgery assisted by a computer-enhanced surgical system. Surg Endosc Intervent Tech 2002;16:1187–91. https://doi.org/10.1007/s004640080154.

[2] Baral S, Arawker MH, Sun Q, Jiang M, Wang L, Wang Y, et al. Robotic versus laparoscopic gastrectomy for gastric cancer: a mega meta-analysis. Front Surg 2022;9. https://doi.org/10.3389/fsurg.2022.895976.

[3] van Boxel GI, Ruurda JP, van Hillegersberg R. Robotic-assisted gastrectomy for gastric cancer: a European perspective. Gastric Cancer 2019;22:909–19. https://doi.org/10.1007/s10120-019-00979-z.

[4] Yamamoto M, Rashid OM, Wong J. Surgical management of gastric cancer: the east vs. west perspective. J Gastrointest Oncol 2015;6:79–88. https://doi.org/10.3978/j.issn.2078-6891.2014.097.

[5] Marrelli D, Carbone L, Poto GE, Fusario D, Gjoka M, Andreucci E, et al. Minimally invasive lymphadenectomy for gastric cancer: could the robotic approach provide any benefits than laparoscopy? World J Gastrointest Oncol 2025;17. https://doi.org/10.4251/wjgo.v17.i6.104015.

[6] Cho Y-S, Berlth F, Kim J, Suh Y-S, Kong S-H, Park DJ, et al. Clinical outcomes of robotic and laparoscopic gastrectomy using propensity score matching method: data of 5-year period in a Korean high-volume gastric cancer center. Eur J Surg Oncol 2025;51:110014. https://doi.org/10.1016/j.ejso.2025.110014.

[7] Lu J, Xu B, Zheng H-L, Li P, Xie J, Wang J, et al. Robotic versus laparoscopic distal gastrectomy for resectable gastric cancer: a randomized phase 2 trial. Nat Commun 2024;15:4668. https://doi.org/10.1038/s41467-024-49013-6.

[8] Solaini L, Avanzolini A, Pacilio CA, Cucchetti A, Cavaliere D, Ercolani G. Robotic surgery for gastric cancer in the west: a systematic review and meta-analyses of short-and long-term outcomes. Int J Surg 2020;83:170–5. https://doi.org/10.1016/j.ijsu.2020.08.055.

[9] Thrift AP, Wenker TN, El-Serag HB. Global burden of gastric cancer: epidemiological trends, risk factors, screening and prevention. Nat Rev Clin Oncol 2023;20:338–49. https://doi.org/10.1038/s41571-023-00747-0.

[10] Carbone L, Incognito GG, Incognito D, Nibid L, Caruso G, Berretta M, et al. Clinical implications of epithelial-to-mesenchymal transition in cancers which potentially spread to peritoneum. Clin Transl Oncol 2025;27:2838–51. https://doi.org/10.1007/s12094-024-03837-2.

[11] Sundar R, Nakayama I, Markar SR, Shitara K, van Laarhoven HWM, Janjigian YY, et al. Gastric cancer. Lancet 2025;405:2087–102. https://doi.org/10.1016/S0140-6736(25)00052-2.

[12] McLean MH, El-Omar EM. Genetics of gastric cancer. Nat Rev Gastroenterol Hepatol 2014;11:664–74. https://doi.org/10.1038/nrgastro.2014.143.

[13] Yamaoka Y, Kato M, Asaka M. Geographic differences in gastric cancer incidence can be explained by differences between Helicobacter pylori strains. Intern Med 2008;47:1077–83. https://doi.org/10.2169/internalmedicine.47.0975.

[14] De Manzoni G, Marrelli D, Baiocchi GL, Morgagni P, Saragoni L, Degiuli M, et al. The Italian research group for gastric cancer (GIRCG) guidelines for gastric cancer staging and treatment: 2015. Gastric Cancer 2017;20:20–30. https://doi.org/10.1007/s10120-016-0615-3.

[15] Kim I-H, Kang SJ, Choi W, Seo AN, Eom BW, Kang B, et al. Korean practice guidelines for gastric cancer 2024: an evidence-based, multidisciplinary approach (update of 2022 guideline). J Gastric Cancer 2025;25:5. https://doi.org/10.5230/jgc.2025.25.e11.

[16] Marrelli D, Piccioni SA, Carbone L, Petrioli R, Costantini M, Malagnino V, et al. Posterior and para-aortic (D2plus) lymphadenectomy after neoadjuvant/conversion therapy for locally advanced/oligometastatic gastric cancer. Cancers (Basel) 2024;16:1376. https://doi.org/10.3390/cancers16071376.

[17] Whei KJ, Jane CK, Hyun-Jae L, Kyo-Young P, Sa-Hong K, Jeesun K, et al. Impact of resection margin status on survival in gastric cancer: a retrospective cohort study. Chin J Cancer Res 2025;37:821–36. https://doi.org/10.21147/j.issn.1000-9604.2025.05.12.

[18] Quan H, Li B, Couris CM, Fushimi K, Graham P, Hider P, et al. Updating and validating the charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. Am J Epidemiol 2011;173:676–82. https://doi.org/10.1093/aje/kwq433.

[19] Baiocchi GL, Giacopuzzi S, Marrelli D, Bencivenga M, Morgagni P, Rosa F, et al. Complications after gastrectomy for cancer: italian perspective. Updates Surg 2017;69:285–8. https://doi.org/10.1007/s13304-017-0478-0.

[20] Marano L, Verre L, Carbone L, Poto GE, Fusario D, Venezia DF, et al. Current trends in volume and surgical outcomes in gastric cancer. J Clin Med 2023;12:2708. https://doi.org/10.3390/jcm12072708.

[21] Childers CP, Uppal A, Tillman M, Chang GJ, Tran Cao HS. Insurance disparities in access to robotic surgery for colorectal cancer. Ann Surg Oncol 2023;30:3560–8. https://doi.org/10.1245/s10434-023-13354-1.

[22] Coco D, Leanza S. Global utilization and clinical outcomes of robotic abdominal surgery in Western vs eastern countries: an expanded systematic review and meta-analysis. J Robot Surg 2025;19:601. https://doi.org/10.1007/s11701-025-02769-5.

[23] Nagata H, Kinoshita T, Komatsu M, Habu T, Yoshida M, Yura M. Comparison of robotic versus laparoscopic total gastrectomy for gastric cancer: a single-center retrospective cohort study in a Japanese high-volume center. Eur J Surg Oncol 2024;50:108706. https://doi.org/10.1016/j.ejso.2024.108706.

[24] Yang L-W, Bai X-Y, Jing G-M. Systematic review and meta-analysis of short-term outcomes: robot-assisted versus laparoscopic surgery for gastric cancer patients with visceral obesity. J Robot Surg 2024;18:238. https://doi.org/10.1007/s11701-024-02002-9.

[25] Cho Y-S, Kim S, Kim J, Kwak Y, Suh Y-S, Kong S-H, et al. Textbook outcome of gastric cancer surgery and lymph node evaluation as its parameter to improve long-term survival. Sci Rep 2025;15:34159. https://doi.org/10.1038/s41598-025-14971-4.

[26] Marrelli D, Carbone L, Piccioni SA, Torroni L, Treppiedi E, Ministrini S, et al. Textbook outcome in gastric cancer surgery: a multicenter cohort study and proposal for a new specific index (TOGS). Gastric Cancer 2026;29:452–64. https://doi.org/10.1007/s10120-025-01710-x.

[27] Li SS, Costantino CL, Mullen JT. Morbidity and mortality of total gastrectomy: a comprehensive analysis of 90-Day outcomes. J Gastrointest Surg 2019;23:1340–8. https://doi.org/10.1007/s11605-019-04228-7.

[28] Lin H-W, Loh E-W, Shen S-C, Tam K-W. Gastrectomy with or without omentectomy for gastric cancer: a systematic review and meta-analysis. Surgery 2022;171:1281–9. https://doi.org/10.1016/j.surg.2021.10.052.

[29] Marano L, Carbone L, Poto GE, Restaino V, Piccioni SA, Verre L, et al. Extended lymphadenectomy for gastric cancer in the neoadjuvant era: current status, clinical implications and contentious issues. Curr Oncol 2023;30:875–96. https://doi.org/10.3390/curroncol30010067.

[30] de Jongh C, Cianchi F, Kinoshita T, Kingma F, Piccoli M, Dubecz A, et al. Surgical techniques and related perioperative outcomes after robot-assisted minimally invasive gastrectomy (RAMIG). Ann Surg 2024;280:98–107. https://doi.org/10.1097/SLA.0000000000006147.

[31] Oh S-Y, Lee J-H, Lee H-J, Kim TH, Huh Y-J, Ahn H-S, et al. Natural history of gastric cancer: observational study of gastric cancer patients not treated during Follow-Up. Ann Surg Oncol 2019;26:2905–11. https://doi.org/10.1245/s10434-019-07455-z.

[32] Kim JW, Hong H, Park S-H, Choi J-H, Suh Y-S, Kong S-H, et al. Lymph node metastasis prediction model for each lymph node station in gastric cancer patients. Eur J Surg Oncol 2025;51:109590. https://doi.org/10.1016/j.ejso.2025.109590.

[33] Haverkamp L, Brenkman HJ, Seesing MF, Gisbertz SS, van Berge Henegouwen MI, Luyer MD, et al. Laparoscopic versus open gastrectomy for gastric cancer, a multicenter prospectively randomized controlled trial (LOGICA-trial). BMC Cancer 2015;15:556. https://doi.org/10.1186/s12885-015-1551-z.

[34] van der Wielen N, Straatman J, Daams F, Rosati R, Parise P, Weitz J, et al. Open versus minimally invasive total gastrectomy after neoadjuvant chemotherapy: results of a European randomized trial. Gastric Cancer 2021;24:258–71. https://doi.org/10.1007/s10120-020-01109-w.

[35] Anderson LA, Tavilla A, Brenner H, Luttmann S, Navarro C, Gavin AT, et al. Survival for oesophageal, stomach and small intestine cancers in Europe 1999–2007: results from EUROCARE-5. Eur J Cancer 2015;51:2144–57. https://doi.org/10.1016/j.ejca.2015.07.026.

[36] Busweiler LAD, Dikken JL, Henneman D, van Berge Henegouwen MI, Ho VKY, Tollenaar RAEM, et al. The influence of a composite hospital volume on outcomes for gastric cancer surgery: a Dutch population-based study. J Surg Oncol 2017;115:738–45. https://doi.org/10.1002/jso.24562.

[37] Chowdhury MM, Dagash H, Pierro A. A systematic review of the impact of volume of surgery and specialization on patient outcome. Br J Surg 2007;94:145–61. https://doi.org/10.1002/bjs.5714.

[38] Lorenzon L, Biondi A, Agnes A, Scrima O, Persiani R, D'Ugo D. Quality over volume: modeling centralization of gastric cancer resections in Italy. J Gastric Cancer 2022;22:35. https://doi.org/10.5230/jgc.2022.22.e4.

[39] Kim MS, Kim WJ, Hyung WJ, Kim H-I, Han S-U, Kim Y-W, et al. Comprehensive learning curve of robotic surgery. Ann Surg 2021;273:949–56. https://doi.org/10.1097/SLA.0000000000003583.

[40] Solaini L, D'Ignazio A, Marrelli D, Marano L, Avanzolini A, Morgagni P, et al. The effect of learning curve on perioperative outcomes of robotic gastrectomy in two Western high-volume centers. Int J Med Robot Comput Assist Surg 2021;17. https://doi.org/10.1002/rcs.2212.