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Can female surgeons break the glass ceiling? A retrospective comparison of short-term surgical outcomes of male and female surgeons in Japan

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ABSTRACT

Objectives
To compare the short-term surgical outcomes between female and male surgeons in Japan with a large gender gap.

Design
Retrospective observational study.

Setting
Data from the Japanese National Clinical Database (2013–2017) and the Japanese Society of Gastroenterological Surgery were used.

Participants
The National Clinical Database (2013–2017) includes data pertaining to >95% of surgeries performed in Japan and data from this database were used to analyse the outcomes of distal gastrectomy (DG), total gastrectomy (TG), and low anterior resection (LAR) performed by male and female surgeons. Cases with missing data were excluded from this study.

Main outcome measures
Primary endpoints included surgical mortality, postoperative complications, pancreatic fistula (DG/TG only), and anastomotic leakage (LAR only). We examined the association of surgeons' gender with the number of years after the registration of licenced doctors, surgical complications, and surgery-related mortality using multivariable logistic regression models, adjusting for the characteristics of the patient, surgeon, and hospital.

Results
On average, female surgeons had fewer post-registration years of experience than male surgeons (9 vs. 16 years, respectively), operated on higher-risk patients, and performed fewer laparoscopic surgeries than male surgeons (DG; 52.7% vs. 35.8%, TG; 26.3% vs 13.0, LAR; 69.6% vs. 60.4%; respectively). There was no significant difference between male and female surgeons in the adjusted risk for surgical mortality, the Clavien–Dindo grade ≥3 complications in DG, TG, and LAR, pancreatic fistula in DG and TG, or anastomotic leakage in LAR.

Conclusion
There was no significant adjusted risk difference in the outcomes of surgeries performed by male vs. female surgeons. Despite disadvantages, female surgeons take on high-risk patients and strive to improve their skills. Greater access to surgical training for female physicians is warranted in Japan.

Key words
gastrointestinal surgery; surgical outcomes; surgeon; gender equality

INTRODUCTION

According to the Organization for Economic Co-operation and Development (OECD), the number of female physicians has been increasing worldwide in recent years. The percentage of female physicians was ≥40% in seven of the 27 OECD member countries in 2000, and in 21 of 26 countries in 2018.[1] Despite this increase, women remain a minority in the surgical field. Female general surgeons accounted for 27.9% (in 2019),[2] 22.0% (in 2019),[3] and 32.5% (in 2017)[4] of surgeons in Canada, the United States (US), and the United Kingdom, respectively.

In Japan, the proportion of female physicians is 21.8%, the lowest among the 27 countries listed in the Gender Gap Report,[1] and the proportion of female surgeons in general and gastrointestinal surgery is even lower, at 7.1%.[5] This suggests that the working environment in Japan poses more challenges for women looking to continue their careers and develop their skills for surgery than those posed by other listed countries. In this unique social environment, it is important to compare the outcomes of female and male surgeons to encourage women's choice of a career in surgery and/or to propose more effective training for female surgeons in Japan.

Previous studies in the US and Canada demonstrated that the proficiency of female physicians and surgeons was equal to or better than that of their male counterparts. Tsugawa et al. reported that, the mortality and readmission rates of older hospitalised patients treated by female physicians in the US were lower than those of such patients treated by male physicians.[6] In the US, no significant difference was found in postoperative mortality between female and male surgeons.[7] Moreover, there was no difference in the complication rates of surgeries performed by male vs female general surgeons in the US.[8] The postoperative mortality of patients operated on by Canadian female surgeons was slightly, but significantly, lower than that of patients operated on by male surgeons.[9]

To support the choice of surgical careers for women in Japan and to suggest more effective training for female surgeons in Japan, we compared the surgical outcomes of female and male surgeons using the Japanese National Clinical Database (NCD), which is the most extensive surgical database in Japan. We also examined the relationship between postoperative mortality and surgical complication rates and the surgeon's licencing terms.

METHODS

This study was approved by the Ethics Committee of the Japan Baptist Hospital (approval no. 19-1 Apr 2019), and written informed consent was not required because of the anonymous nature of the data. Regarding patient data registration in the NCD, each participating institution provided patients with the opportunity to opt-out of the study after their respective ethical committee review and approval. Regarding the use of data related to surgeons, members of the Japanese Society of Gastroenterological Surgery (JSGS) were provided with the opportunity to opt out via e-mail messages and through a website.

Study design and data source

We conducted a retrospective observational study using data from the NCD. We analysed data related to surgeons' gender and experience (years of clinical practice after licencing), and we classified hospitals according to the number of cases in which each procedure was performed in a year. The NCD initiated data registration in 2011.[10] By December 2019, 5,276 facilities were registered with the NCD. Approximately 1.5 million cases are registered in this database each year, equivalent to more than 95% of all surgeries in Japan.[11] The eligibility criteria for the NCD are accessible online (http://www.ncd.or.jp/). Patients with missing data were excluded from this study. Using data from the NCD, we analysed the outcomes of elective distal gastrectomy (DG), total gastrectomy (TG), and low anterior resection (LAR) performed by male and female surgeons between 2013 and 2017. These three procedures, which are commonly performed in Japan, were statistically compared. The NCD does not contain direct information on surgeons' gender or the number of years since the registration of licenced doctors, but it does contain the licence number of the surgeons. Thus, by using these licence numbers, analysis was conducted by linking the NCD information with the gender profile and the year of licencing registration for the JSGS members.

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed for this study.

Endpoints

Primary endpoints were surgical mortality, severe postoperative complications, pancreatic fistula (in DG/TG only), and anastomotic leakage (in LAR only). In this study, surgical mortality was defined as in-hospital deaths that occurred within 90 days postoperatively and any death up to 30 days postoperatively. Other primary endpoints included severe postoperative complications, which were defined as any postoperative surgical and medical complications with a Clavien–Dindo (CD) classification ≥3,[12] pancreatic fistulas (only in DG/TG),[13] and anastomotic leakage (only in LAR). The operation time and blood loss were considered intraoperative outcomes.

Adjustment variables

Surgeon's characteristics included sex and years since registration of licenced doctors in five-year increments. Patient characteristics included age (<70 vs ≥70 years), sex (male vs female), body mass index (≤18.5 vs >18.5 kg/m^2, <25 vs ≥25 kg/m^2), American Society of Anesthesiologists Physical Status classification (ASA-PS, 1–2 vs ≥3), clinical T factor (T1–2 vs T3–4) and N (0 vs 1–3) of tumours (N factor was included only for DG and TG; based on the Union for International Cancer Control–TNM classification, 7th edition), haemoglobin (male: <13.5 g/dL vs ≥13.5 g/dL, female: <11.5 g/dL vs ≥11.5 g/dL), aspartate aminotransferase (<35 IU/L vs ≥35 IU/L; included in DG and TG), albumin (<3.5 g/dL vs ≥3.5 g/dL), blood urea nitrogen (<8 mg/dL vs ≥8 mg/dL), creatinine (<1.2 mg/dL vs ≥1.2 mg/dL), absence/presence of diabetes mellitus, smoking status, habitual drinking status (only in LAR), dependence in activities of daily living (ADL), history of chronic obstructive pulmonary disease, dialysis, ischaemic heart disease, or congestive heart failure, long-term steroid use, history of cardiovascular diseases (only in LAR), weight loss, preoperative blood transfusion, preoperative chemotherapy, and preoperative radiotherapy.

We categorised hospitals into quartiles according to the number of cases of each procedure: very low (VL), low (L), high (H), and very high (VH) (VL, L, H, and VH were defined for DG as: <15, 15 to <30, 30 to <50, and ≥50; TG: <7, 7 to <13, 13 to <21, and ≥21; LAR: <8, 8 to <16, 16 to <29, and ≥29, respectively). The surgical approach (open or laparoscopic) was included as an intraoperative factor.

Statistical analysis

We used the chi-square test for categorical variables and the Mann–Whitney U test for continuous variables when comparing baseline characteristics and short-term outcomes. A multivariable logistic regression model was constructed, adjusting for patient characteristics, surgeon characteristics, and hospital characteristics, to examine the association between the surgeon's gender, surgical complications, and surgery-related mortality. We used a random-effects model to account for hospital-level characteristics. Hospital identification (ID) was used as a random intercept. Subsequently, additional analysis was conducted to examine whether an interaction effect existed between sex and years after medical licence registration. An interaction term of sex and years of experience post-medical licence registration was incorporated, instead of including them individually in the previous regression model. All p-values were two-sided, and p-values <0.05 were considered significant. Statistical analyses were performed using R software (version 3.6.3, 2020; R Foundation for Statistical Computing, Vienna, Austria).

Patient and public involvement

No patients were involved in setting the research question or the outcome measures, nor was any patient involved in developing plans for implementation of the study. No patients were asked to advise on the interpretation or writing of results. There are no plans to disseminate the results of the research to study participants or the relevant patient community. The patient data used was from an anonymized database; however, each facility requires individual patient consent in the form of opt-out for database registration.

RESULTS

Study population

This study investigated 184,238, 83,487, and 107,721 patients who underwent DG, TG, and LAR, respectively, at Japanese institutes and were registered in the Japanese NCD between 2013 and 2017. The flow diagram for surgical case selection is shown in Figure 1. Finally, 149,193 DG, 63,417 TG, and 81,593 LAR surgeries were eligible. A total of 14,0971 eligible DG surgeries were performed by male surgeons and 8,222 by female surgeons, 59,915 eligible TG surgeries were performed by male surgeons and 3,502 by female surgeons, and 77,864 eligible LAR procedures were performed by male surgeons and 3,729 by female surgeons. The numbers of male surgeons who participated in DG, TG, and LAR were 9,433, 8,238, and 8,200, respectively, and those of female surgeons were 788, 640, and 627, respectively.

Characteristics of surgeons and institutions

The surgeons' factors, institutional factors, preoperative and intraoperative factors, intraoperative outcomes, and non-risk-adjusted postoperative outcomes of DG, TG, and LAR are presented in Tables 1, 2, and 3, respectively. Female surgeons had fewer years of experience post-licence registration than male surgeons (9 vs. 16 years). Regarding DG, female surgeons were more distributed in hospitals with L (28.4%) and H (27.1%) than in those with VL (22.7%) or VH (21.8%) case numbers. Regarding TG, female surgeons were less distributed in hospitals with VH case numbers (20.7%) than in those in other categories. Regarding LAR, female surgeons were more typically distributed in hospitals with L (29.5%) numbers than in those with VL (23.3%), H (24.0%), or VH (23.2%) numbers.

Characteristics of patients

Female surgeons performed surgeries on relatively high-risk patients. Importantly, female surgeons performed surgeries on older patients (DG, 58.9% vs. 55.6%; TG, 60.4% vs. 56.4%; LAR, 45.9% vs. 43.8%) and patients with diabetes mellitus (DG, 19.2% vs. 18.1%; TG, 21.2% vs. 18.6%; LAR, 19.4% vs. 18.0%), dependence in ADL (DG, 4.9% vs. 4.2%; TG, 4.8% vs. 3.8%; LAR, 4.6% vs. 3.5%), lower haemoglobin (DG, 29.9% vs. 27.9%; TG, 37.6% vs. 35.2%; LAR, 28.7% vs. 27.0%) and serum albumin (DG, 18.5% vs. 15.0%; TG, 22.5% vs. 19.2%; LAR, 14.3% vs. 12.1%) levels, and higher T factors (DG, 35.7% vs. 30.1%; TG, 58.3% vs. 55.1%; LAR, 63.7% vs. 60.0%) in all three procedures at a higher rate than their male counterparts (Tables 1–3). Additionally, female surgeons performed DG in patients with long-term steroid use (1.3% vs. 1.0%), weight loss (4.7% vs. 3.6%), preoperative blood transfusion (3.1% vs. 2.0%), a higher N factor (37.2% vs. 31.3%), and a worse ASA-PS (12.2% vs. 11.0%); TG for patients that smoked (52.0% vs. 49.2%), under dialysis (1.0% vs. 0.6%), weight loss (6.7% vs. 5.8%), and a higher N factor (51.4% vs. 48.9%); and LAR for patients with a history of cardiovascular disease (3.9% vs. 3.1%) at a higher rate than their male counterparts. In contrast, male surgeons performed surgeries on patients who had undergone preoperative chemotherapy (DG, 2.2% vs. 1.9%; TG, 6.9% vs. 5.5%; LAR, 6.5% vs. 4.2%) in DG, TG, and LAR or radiotherapy (3.1% vs. 1.7%, in LAR) at a higher rate than their female counterparts.

Intraoperative factors and outcomes

Female surgeons performed fewer laparoscopic surgeries (DG, 35.8% vs. 52.7%; TG, 13.0% vs. 26.3%; LAR, 60.4% vs. 69.6%) than male surgeons. The operation time of surgeries performed by female surgeons was longer for DG (261 vs. 259 min) and LAR (269 vs. 265 min) than that of surgeries performed by male surgeons but not significantly different for TG (282 vs. 279 min). There was significantly more blood loss observed in all three procedures performed by female surgeons (DG, 150 vs. 100 mL; TG, 320 vs. 260 mL; LAR 80 vs. 52 mL) than by male surgeons (Tables 1–3).

Postoperative outcomes

After adjusting for patient characteristics, surgeon characteristics, and hospital characteristics, no significant difference was noted in the risk for surgical mortality in DG, TG, and LAR between male and female surgeons (DG, risk-adjusted odds ratio [OR] 0.98, 95% confidence interval [CI] 0.74–1.29; TG, risk-adjusted OR 0.83, 95% CI 0.57–1.19; LAR, risk-adjusted OR 0.56, 95% CI 0.30–1.05). The adjusted risk for surgical mortality or postoperative complication rated CD-3 or higher were similar for DG, TG, and LAR (DG, risk-adjusted OR 1.28, 95% CI 0.93–1.14; TG, risk-adjusted OR 0.92, 95% CI 0.81–1.05; LAR, risk-adjusted OR 1.02, 95% CI 0.91–1.15), pancreatic fistula for DG and TG (DG, risk-adjusted OR 1.16, 95% CI 0.97–1.38; TG, risk-adjusted OR 1.02, 95% CI 0.84–1.23), and anastomotic leakage for LAR (risk-adjusted OR 1.04, 95% CI 0.92–1.18) between male and female surgeons (Table 4).

Interaction between surgeons' gender and years since registration of medical licence

For the sub-analysis, we compared surgical outcomes between male and female surgeons in the year-since-licencing categories.

DG

The adjusted risk for surgical mortality was higher for female surgeons than for male surgeons with ≤5 years of experience after registration (risk-adjusted OR 1.64, 95% CI 1.07–2.52). However, it was lower for female surgeons with 10–15 and 15–20 years of experience after registration (risk-adjusted OR 0.43, 95% CI 0.20–0.95 and risk-adjusted OR 0.16, 95% CI 0.04–0.71, respectively). For surgery-related death or postoperative adverse events rated CD-3 or higher, female surgeons with ≤5 years of experience after registration had a higher OR (risk-adjusted OR 1.19, 95% CI 1.01–1.41), whereas those with 5–10 years of experience after registration had a lower OR (risk-adjusted OR 0.66, 95% CI 0.51–0.85) than male surgeons. The adjusted risk for pancreatic fistula showed no significant difference between male and female surgeons at any year category after registration (Table 5).

TG

The adjusted risk for surgery-related death, postoperative adverse events rated CD-3 or higher, and pancreatic fistula showed no significant differences between male and female surgeons at any year category after registration (Table 6).

LAR

The adjusted OR for surgical mortality for male surgeons with >20 years of experience after registration was lower than that for female surgeons having the same years of experience (risk-adjusted OR 11.16, 95% CI 1.05–118.24). However, there was no significant difference in adjusted ORs between male and female surgeons in the other groups. The adjusted risk for surgical mortality or postoperative adverse events rated CD-3 or higher were higher for female surgeons than for male surgeons at the 10–15 (risk-adjusted OR 1.44, 95% CI 1.01–2.07) and 15–20 years (risk-adjusted OR 1.82, 95% CI 1.24–2.68) of experience categories. The adjusted risk for anastomotic leakage were lower for female surgeons with ≤5 years (risk-adjusted OR 0.71, 95% CI 0.53–0.94) and higher with 10–15 (risk-adjusted OR 1.74, 95% CI 1.20–2.54), 15–20 (risk-adjusted OR 1.84, 95% CI 1.22–2.77), and >20 years (risk-adjusted OR 1.88, 95% CI 1.12–3.16) of experience (Table 7).

DISCUSSION

Using the NCD data for 2013–2017, we found no overall significant difference in the risk for surgical mortality in the three procedures performed by male and female surgeons. There was also no significant difference in the adjusted risk for surgical mortality or CD-3 or higher complications in DG, TG, and LAR, pancreatic fistula in DG and TG, and anastomotic leakage in LAR between male and female surgeons. More blood loss was recorded in all three procedures performed by female surgeons, probably because they performed a significantly larger proportion of open surgeries than male surgeons. Importantly, we found that female gastrointestinal surgeons were more often responsible for high-risk patients, even though, in the simple calculation, female gastrointestinal surgeons were responsible for fewer surgeries than male surgeons, as Altieri et al. has described.[14] Data from a large institution in a Western country indicated that female surgeons did not perform more complex cases than male surgeons, even after accounting for subspecialty and seniority.[15] This situation is different from that in Japan, as reported in our analysis. The number of surgeries performed per surgeon will be analysed more precisely in our subsequent report, as it is a very crucial problem in the Japanese surgical society.

As a subclass analysis, we compared the post-registration years and found differences in the risk for surgical outcomes between male and female surgeons. Regarding DG, female surgeons with >5 years post-registration experience had better surgical outcomes than male surgeons, in several categories, although the adjusted risk for surgical mortality or postoperative complications of CD-3 or higher were higher for female surgeons with ≤5 years post-registration experience. Regarding TG, there was no significant difference in the adjusted risks for "surgical mortality" and "surgical mortality with a CD-3 or higher complication" between male and female surgeons, in all categories, in terms of the years since registration. Additionally, there was no significant difference in the adjusted risk for pancreatic fistula between male and female surgeons in either DG or TG. The adjusted risk for mortality in LAR cases was significantly higher for female surgeons with ≥20 years of experience than for male surgeons. Nevertheless, there are very few female gastrointestinal surgeons in the ≥20 years category, whereas this category is the largest group of male gastrointestinal surgeons in Japan. The surgical outcomes of the minimal number of surgeries performed by female surgeons with ≥20 years of experience might have affected the results. Tsugawa et al. reported that the risk-adjusted mortality rate in surgeries performed by female surgeons aged >50 years was the lowest; however, they mentioned that it was difficult to evaluate the outcome of female surgeons aged >60 years because this group was very small.[7] These findings are consistent with ours. Wallis et al. reported a lower 30-day mortality rate for surgeries performed by female surgeons.[9] Sharoky et al. reported no difference in mortality or complication rates for surgeries performed by male and female surgeons using cardinality matching with a refined balance.[8] However, these authors did not compare surgeons by age. Further careful study is needed to examine how gender and age affect surgical outcomes, but it is necessary to note that the low volume of senior female surgeons is a particular concern.

The proportion of female gastrointestinal surgeons in Japan is small. The percentage of female gastrointestinal surgeons in Japan was 7.1% in 2021; 6.0% in 2015, the middle of the period covered by this study; and in 2011, no gender data were available from the Office of the JSGS. First, the lack of role models is often pointed out as a barrier to female surgeons' careers,[16] and female surgeons experience interprofessional conflict due to breakdowns in communication.[17] Moreover, it is difficult for female surgeons to attain leadership positions.[18] Second, previous reports have shown a bias in the number of surgical cases assigned to male vs female surgeons during their training. Foley et al.[20] reported gender differences in robotic surgery experience in colorectal surgery training programmes, with female trainees having fewer opportunities to participate in the use of consoles and to complete the procedures.[19] They also reported that male supervisors provided fewer console participation opportunities to female residents than to male residents, but female supervisors provided the same number of console-use opportunities to both female and male trainees. Female surgeons, as supervisors, may provide female residents with equitable training opportunities. Third, in the Japanese society, women are often evaluated from a biased perspective. Essentially, in 2018, gender discrimination was reported in admission tests for several medical schools. Those medical schools had manipulated the scores of female applicants to interfere with their admissions. The admissions committee of those medical schools wanted to enroll more men, since women often leave clinical practice due to marriage, pregnancy, or childcare.[21] Fourth, work-family conflict is more pronounced among female surgeons, and they may experience burn-out.[22,23]

Many aspects can impair the successful development of female surgeons. Nevertheless, in the present analysis, there was no significant difference in the mortality or complication rates of surgeries performed by female and male surgeons, suggesting that they are equally successful in developing their surgical skills. Notably, female surgeons performed a lower percentage of laparoscopic procedures in all three procedures than male surgeons did. There may have been a tendency for male surgeons to be assigned to laparoscopic procedures, which may require more time to develop experience. The percentage of women in the JSGS is gradually increasing. It is warranted that surgical teams welcome women as members and that gender equality is achieved in Japanese gastrointestinal surgery training.

The primary strength of our study is that we used the NCD, a comprehensive database, and adjusted for confounders with patient-related factors for the individual procedures selected. Many previous studies have used the Medicare claims database. By contrast, we used a clinical database such as NCD, which is highly accurate in terms of patients' preoperative condition and surgical outcomes.

This study had some limitations. First, this was an observational study, and we could not adjust for unmeasured confounders. Second, because the number of female surgeons was smaller than that of male surgeons, there may be a bias in that the outcomes of one female surgeon had a large effect on the overall outcomes. Third, the study included in this research paper lacks details about surgeons' work and personal life conditions (part-time or full-time, family structure, etc.).

CONCLUSION

Based on our study, Japanese female surgeons take on high-risk cases, and there was no significant difference in surgical mortality or CD-3 or higher complication rates between patients operated on by male or female surgeons. We found that female surgeons were successful in developing their technical skills. More appropriate and effective surgical training for female surgeons could further improve surgical outcomes.

CONTRIBUTORS AND GUARANTOR

KO, SN, EK, YF, and KH designed the study. KY, IY, YK, and YK collected the data. HE, HY, and HM analysed the data. KO wrote the first draft of the manuscript. All authors read the drafted manuscript, provided feedback, and approved the final submitted version. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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COMPETING INTERESTS

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DATA SHARING

Data on individual surgical cases and surgeons reported in this study are not publicly available. To access the aggregate data, including data reported in this study, please submit a research plan and request access to the NCD Office, usually through an NCD-related society (such as the JSGS). If the proposal is approved, the de-identified data (including participant and related data, if necessary) can be assessed by a statistics specialist affiliated with the NCD.

TRANSPARENCY STATEMENT

The corresponding author (SN) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

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Figure legends

Figure 1 Flow diagram for patient selection. DG, distal gastrectomy; TG, total gastrectomy; LAR, low anterior resection; JSGS, The Japanese Society of Gastroenterological Surgery; TX, Unknown; T, NX; Unknown N, M1, Positive for distant metastasis.

Summary boxes

What is already known on this topic:

- Women remain a minority in the surgical field, particularly in Japan
- In the United States and Canada, the proficiency of female physicians and surgeons was equal to or better than that of their male counterparts.

What this study adds:

- We found no overall significant differences in surgical mortality or CD-3 or higher complication rates associated with the three procedures (distal gastrectomy, total gastrectomy, and low anterior resection) performed by Japanese male and female surgeons.
- More opportunities and encouragement should be provided to female surgeons to address the gender-based inequity in the field of surgery.

Table 1: Preoperative and intraoperative risk factors in DG

		Male surgeons N = 9433 (92.0%)	Female surgeons N = 788 (8.0%)	p value
Total cases of operation		140971	8222	
Factor	**Category**			
Surgeon's factor				
Years since registration of licensed doctors, median [IQR]		16 [9, 22]	9 [5, 13]	<0.001
Years since registration of licensed doctors, n (%)				<0.001
	≤5	19246 (13.7)	2534 (30.8)	
	>5, ≤10	21526 (15.3)	2430 (29.6)	
	>10, ≤15	27084 (19.2)	1898 (23.1)	
	>15, ≤20	28609 (20.3)	881 (10.7)	
	>20	44506 (31.6)	479 (5.8)	
Institutional factor				
Number of surgeries per year, n (%)				<0.001
	<15	34733 (24.6)	1867 (22.7)	
	15≤, <30	35826 (25.4)	2337 (28.4)	
	30≤, <50	36092 (25.6)	2226 (27.1)	
	50≤	34320 (24.3)	1792 (21.8)	
Preoperative factor				
Age	70≤	78418 (55.6)	4840 (58.9)	<0.001
Sex	Female	46798 (33.2)	2820 (34.3)	0.041
Body mass index (kg/m^2)				<0.001
	≥18.5 <25	95141 (67.5)	5556 (67.6)	
	<18.5	17118 (12.1)	1119 (13.6)	
	≥ 25	28712 (20.4)	1547 (18.8)	
Diabetes mellitus	+	25484 (18.1)	1579 (19.2)	0.01
Smoking	+	63731 (45.2)	3777 (45.9)	0.201
Dependence in ADL	+	5965 (4.2)	401 (4.9)	0.005
COPD	+	6822 (4.8)	412 (5.0)	0.498
Dialysis	+	1062 (0.8)	77 (0.9)	0.074
History of IHD	+	5260 (3.7)	332 (4.0)	0.164
Congestive heart failure (within 30 days)	+	976 (0.7)	67 (0.8)	0.219
Long-term steroid use	+	1424 (1.0)	105 (1.3)	0.023
Weight loss	+	5046 (3.6)	386 (4.7)	<0.001
Preoperative blood transfusion	+	2859 (2.0)	251 (3.1)	<0.001
Haemoglobin (g/dL)	Male: < 13.5, Female: < 11.5	39344 (27.9)	2459 (29.9)	<0.001
Albumin (g/dL)	<3.5	21128 (15.0)	1519 (18.5)	<0.001
Blood urea nitrogen (mg/dL)	<8	19371 (13.7)	1158 (14.1)	0.389
Creatinine (mg/dL)	>1.2	9961 (7.1)	626 (7.6)	0.063
Aspartate Aminotransferase (IU/L)	> 35	9542 (6.8)	581 (7.1)	0.307
Preoperative chemotherapy		3092 (2.2)	153 (1.9)	0.049
Preoperative radiotherapy		151 (0.1)	6 (0.1)	0.451
T factor (in the TNM classification)	T3≤	42441 (30.1)	2939 (35.7)	<0.001
N factor (in the TNM classification)	N1≤	44193 (31.3)	3056 (37.2)	<0.001
ASA-PS	3, 4, 5	15563 (11.0)	1006 (12.2)	0.001

Intraoperative factor				
Surgical approach (open or laparoscopic)	Laparoscopic surgery	74282 (52.7)	2944 (35.8)	<0.001
Intraoperative outcomes				
Operating time (min) (median [IQR])		259 [205, 320]	261 [209, 322]	0.001
Estimated blood loss (mL) (median [IQR])		100 [25, 250]	150 [50, 327]	<0.001
Postoperative outcomes				
Surgical mortality	+	1030 (0.7)	61 (0.7)	0.96
Surgical mortality or complication with CD classification of 3 or higher	+	7817 (5.5)	504 (6.1)	0.026
Pancreatic fistula	+	2251 (1.6)	162 (2.0)	0.01
Postoperative hospital stay (days) (median [IQR])		13 [10, 19]	14 [10, 20]	<0.001

DG: distal gastrectomy, IQR: interquartile range, ADL: activity of daily life, COPD: chronic obstructive pulmonary disease, IHD: ischemic heart disease, ASA-PS: American Society of. Anesthesiologists Physical Status, CD: Clavien–Dindo

Table 2: Preoperative and intraoperative risk factors in TG

		Male surgeons N = 8238 (93.0%)	Female surgeons N = 640 (7.0%)	p value
Total cases of operation		59915	3502	
Factor	**Category**			
Surgeon's factor				
Years since registration of licensed doctors, median [IQR]		16 [9, 23]	9 [5, 14]	<0.001
Years since registration of licensed doctors, n (%)				<0.001
	≤5	7959 (13.3)	1115 (31.8)	
	>5, ≤10	9097 (15.2)	989 (28.2)	
	>10, ≤15	11204 (18.7)	749 (21.4)	
	>15, ≤20	11956 (20.0)	441 (12.6)	
	>20	19699 (32.9)	208 (5.9)	
Institutional factor				
Number of surgeries per year, n (%)				<0.001
	<7	15790 (26.4)	906 (25.9)	
	7≤, <13	14037 (23.4)	913 (26.1)	
	13≤, <21	14379 (24.0)	957 (27.3)	
	21≤	15709 (26.2)	726 (20.7)	
Preoperative factor				
Age	70≤	33821 (56.4)	2115 (60.4)	<0.001
Sex	Female	15127 (25.2)	906 (25.9)	0.409
Body mass index (kg/m^2)				0.081
	≥18.5 <25	40293 (67.3)	2377 (67.9)	
	<18.5	8680 (14.5)	534 (15.2)	
	≥ 25	10942 (18.3)	591 (16.9)	
Diabetes mellitus	+	11133 (18.6)	743 (21.2)	<0.001
Smoking	+	29485 (49.2)	1821 (52.0)	0.001
Dependence in ADL	+	2298 (3.8)	169 (4.8)	0.003
COPD	+	3135 (5.2)	199 (5.7)	0.246
Dialysis	+	331 (0.6)	34 (1.0)	0.001
History of IHD	+	2335 (3.9)	147 (4.2)	0.373
Congestive heart failure (within 30 days)	+	356 (0.6)	21 (0.6)	0.967
Long-term steroid use	+	512 (0.9)	33 (0.9)	0.584
Weight loss	+	3460 (5.8)	235 (6.7)	0.022
Preoperative blood transfusion	+	1552 (2.6)	92 (2.6)	0.894
Haemoglobin (g/dL)	Male: < 13.5, Female: < 11.5	21117 (35.2)	1316 (37.6)	0.005
Albumin (g/dL)	<3.5	11513 (19.2)	788 (22.5)	<0.001
Blood urea nitrogen (mg/dL)	<8	8223 (13.7)	520 (14.8)	0.061
Creatinine (mg/dL)	>1.2	4191 (7.0)	269 (7.7)	0.123
Aspartate Aminotransferase (IU/L)	> 35	4223 (7.0)	265 (7.6)	0.245
Preoperative chemotherapy		4123 (6.9)	193 (5.5)	0.002
Preoperative radiotherapy		100 (0.2)	7 (0.2)	0.644
T factor (in the TNM classification)	T3≤	33028 (55.1)	2040 (58.3)	<0.001
N factor (in the TNM classification)	N1≤	29307 (48.9)	1799 (51.4)	0.005
ASA-PS	3, 4, 5	6694 (11.2)	421 (12.0)	0.122
Intraoperative factor				

Surgical approach (open or laparoscopic)	Laparoscopic surgery	15762 (26.3)	456 (13.0)	<0.001
Intraoperative outcomes				
Operating time (min) (median [IQR])		282 [221, 354]	279 [225, 347]	0.377
Estimated blood loss (mL) (median [IQR])		260 [100, 521]	320 [150, 595]	<0.001
Postoperative outcomes				
Surgical mortality	+	667 (1.1)	35 (1.0)	0.532
Surgical mortality or complication with CD classification of 3 or higher	+	5569 (9.3)	310 (8.9)	0.38
Pancreatic fistula	+	1999 (3.3)	132 (3.8)	0.167
Postoperative hospital stay (days) (median [IQR])		16 [12, 24]	16 [12, 23]	0.175

TG: total gastrectomy, IQR: interquartile range, ADL: activity of daily life, COPD: chronic obstructive pulmonary disease, IHD: ischemic heart disease, ASA-PS: American Society of. Anesthesiologists Physical Status, CD: Clavien–Dindo

Table 3: Preoperative and intraoperative risk factors in LAR

		Male surgeons N = 8200 (92.9%)	Female surgeons N = 627 (7.1%)	p value
Total cases of operation		77864	3729	
Factor	**Category**			
Surgeon's factor				
Years since registration of licensed doctors, median [IQR]		17 [11, 23]	9 [6, 15]	<0.001
Years since registration of licensed doctors, n (%)				<0.001
	≤5	7066 (9.1)	885 (23.7)	
	>5, ≤10	10576 (13.6)	1198 (32.1)	
	>10, ≤15	15643 (20.1)	853 (22.9)	
	>15, ≤20	17698 (22.7)	562 (15.1)	
	>20	26881 (34.5)	231 (6.2)	
Institutional factor				
Number of surgeries per year, n (%)				0.012
	<8	17655 (22.7)	870 (23.3)	
	8≤, <16	21468 (27.6)	1100 (29.5)	
	16≤, <29	20112 (25.8)	895 (24.0)	
	29≤	18629 (23.9)	864 (23.2)	
Preoperative factor				
Age	70≤	34077 (43.8)	1711 (45.9)	0.011
Sex	Female	26958 (34.6)	1353 (36.3)	0.039
Body mass index (kg/m^2)				0.265
	≥18.5 <25	51808 (66.5)	2471 (66.3)	
	<18.5	8838 (11.4)	454 (12.2)	
	≥ 25	17218 (22.1)	804 (21.6)	
Diabetes mellitus	+	14049 (18.0)	722 (19.4)	0.043
Smoking	+	33997 (43.7)	1620 (43.4)	0.806
Habitual drinking	+	41677 (53.5)	1937 (51.9)	0.061
Dependence in ADL	+	2725 (3.5)	170 (4.6)	0.001
COPD	+	2800 (3.6)	104 (2.8)	0.011
Dialysis	+	391 (0.5)	23 (0.6)	0.398
History of IHD	+	2277 (2.9)	122 (3.3)	0.239
Congestive heart failure (within 30 days)	+	411 (0.5)	25 (0.7)	0.293
Long-term steroid use	+	611 (0.8)	28 (0.8)	0.894
History of CVD	+	2385 (3.1)	147 (3.9)	0.003
Weight loss	+	1805 (2.3)	102 (2.7)	0.111
Preoperative blood transfusion	+	710 (0.9)	45 (1.2)	0.08
Haemoglobin (g/dL)	Male: < 13.5, Female: < 11.5	21036 (27.0)	1072 (28.7)	0.021
Albumin (g/dL)	<3.5	9417 (12.1)	533 (14.3)	<0.001
BUN (mg/dL)	<8	9306 (12.0)	447 (12.0)	0.969
Creatinine (1.2 mg/dL)	>1.2	4350 (5.6)	221 (5.9)	0.398
Preoperative chemotherapy		5032 (6.5)	156 (4.2)	<0.001
Preoperative radiotherapy		2450 (3.1)	62 (1.7)	<0.001
T factor (in the TNM classification)	T3≤	46697 (60.0)	2375 (63.7)	<0.001
ASA-PS	3, 4, 5	7155 (9.2)	344 (9.2)	0.964
Intraoperative factor				
Surgical approach (open or laparoscopic)	Laparoscopic surgery	54199 (69.6)	2252 (60.4)	<0.001
Intraoperative outcomes				

Operating time (min) (median [IQR])		265 [204, 345]	269 [210, 343]	0.041
Estimated blood loss (mL) (median [IQR])		52 [10, 206]	80 [15, 271]	<0.001
Postoperative outcomes				
Surgical mortality	+	356 (0.5)	11 (0.3)	0.187
Surgical mortality or complication with CD classification of 3 or higher	+	7661 (9.8)	380 (10.2)	0.499
Anastomotic leakage	+	6950 (8.9)	345 (9.3)	0.514
Postoperative hospital stay (days) (median [IQR])		15 [11, 23]	15 [11, 23]	0.742

LAR: low anterior resection, IQR: interquartile range, ADL: activity of daily life, COPD: chronic obstructive pulmonary disease, IHD: ischemic heart disease, ASA-PS: American Society of. Anesthesiologists Physical Status, CVD: cardiovascular disease, BUN: Blood urea nitrogen, CD: Clavien–Dindo

Table 4: Difference in surgical mortality, complication rate, pancreatic fistula, and anastomotic leakage

	DG		TG		LAR	
Surgical mortality						
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference	
Female	0.98 (0.74 - 1.29)	0.87	0.83 (0.57-1.19)	0.30	0.56 (0.30 - 1.05)	0.07
Surgical mortality or complications with a CD classification of 3 or higher						
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference	
Female	1.28 (0.93 - 1.14)	0.59	0.92 (0.81 - 1.05)	0.21	1.02 (0.91 - 1.15)	0.69
Pancreatic fistula						
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value		
Male	Reference		Reference			
Female	1.16 (0.97 - 1.38)	0.105	1.02 (0.84 - 1.23)	0.88		
Anastomotic leakage						
Surgeon's gender					Risk-adjusted odds ratio (95% CI)	P value
Male					Reference	
Female					1.04 (0.92 - 1.18)	0.49

DG: distal gastrectomy, TG: total gastrectomy, LAR: low anterior resection, CI: confidence interval, CD: Clavien–Dindo.

Table 5: Outcomes by category of years since registration of licensed doctors in DG

Surgical mortality										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	1.64 (1.07 - 2.52)	0.02	0.59 (0.30 - 1.15)	0.12	0.43 (0.20 - 0.95)	0.04	0.16 (0.04 - 0.71)	0.02	0.41 (0.12 - 1.42)	0.16
Surgical mortality or complication with a CD classification of 3 or higher										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	1.19 (1.01 - 1.41)	0.04	0.66 (0.51 - 0.85)	0.001	0.90 (0.69 - 1.18)	0.46	0.97 (0.69 - 1.37)	0.87	0.84 (0.54 - 1.31)	0.44
Pancreatic fistula										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	1.24 (0.91 - 1.68)	0.16	0.84 (0.54 - 1.31)	0.44	0.89 (0.56 - 1.40)	0.60	1.03 (0.57 - 1.87)	0.91	1.08 (0.46 - 2.51)	0.86

DG: distal gastrectomy, CI: confidence interval, CD: Clavien–Dindo.

Table 6: Outcomes by category of years since registration of licensed doctors in TG

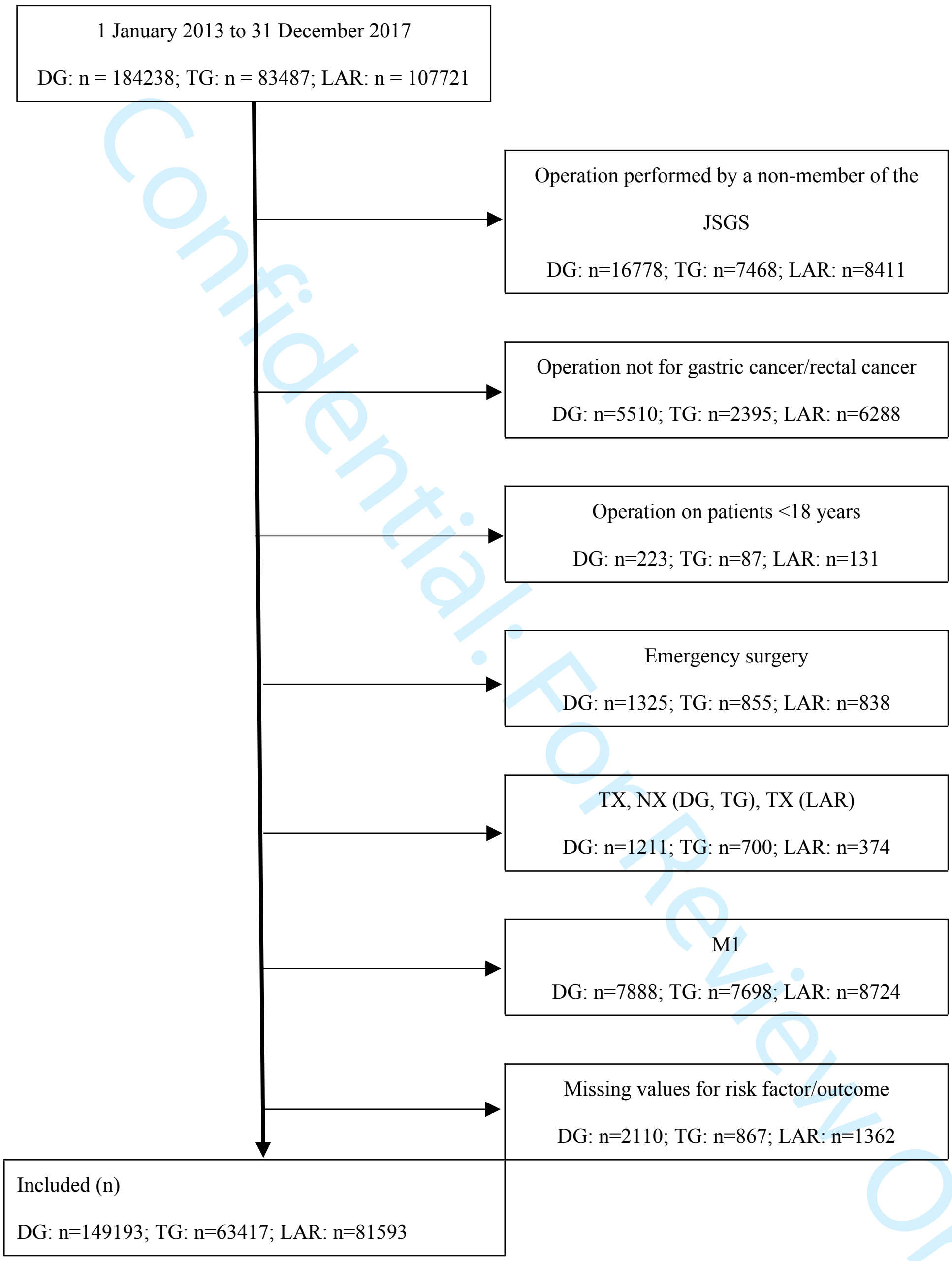
Surgical mortality										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	0.68 (0.33 - 1.37)	0.28	1.83 (0.72 - 4.61)	0.20	0.82 (0.26 - 2.65)	0.75	1.04 (0.29 - 3.67)	0.95	1.50 (0.37 - 6.08)	0.57
Surgical mortality or complication with a CD classification of 3 or higher										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	0.91 (0.72 - 1.15)	0.42	0.94 (0.67 - 1.32)	0.73	0.96 (0.67 - 1.38)	0.83	1.12 (0.74 - 1.68)	0.60	1.40 (0.84 - 2.33)	0.19
Pancreatic fistula										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	0.97 (0.70 - 1.35)	0.87	1.17 (0.72 - 1.89)	0.54	0.80 (0.46 - 1.41)	0.44	1.30 (0.71 - 2.39)	0.40	1.23 (0.49 - 3.09)	0.66

TG: total gastrectomy, CI: confidence interval, CD: Clavien–Dindo.

Table 7: Outcomes by category of years since registration of licensed doctors in LAR

Surgical mortality										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	0.18 (0.02 - 1.32)	0.09	3.75 (0.39 - 35.66)	0.25	2.58 (0.22 - 30.02)	0.45	2.07 (0.12 - 37.00)	0.62	11.16 (1.05 - 118.24)	0.045
Surgical mortality or complication with a CD classification of 3 or higher										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	0.77 (0.59 - 1.01)	0.61	1.27 (0.91 - 1.78)	0.17	1.44 (1.01 - 2.07)	0.04	1.82 (1.24 - 2.68)	0.002	1.32 (0.78 - 2.25)	0.31
Anastomotic leakage										
	Category of years since registration of licensed doctors									
	≤ 5		> 5, ≤ 10		> 10, ≤ 15		> 15, ≤ 20		> 20	
Surgeon's gender	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value	Risk-adjusted odds ratio (95% CI)	p value
Male	Reference		Reference		Reference		Reference		Reference	
Female	0.71 (0.53 - 0.94)	0.02	1.42 (0.99 - 2.04)	0.052	1.74 (1.20 - 2.54)	0.004	1.84 (1.22 - 2.77)	0.003	1.88 (1.12 - 3.16)	0.02

LAR: low anterior resection. CI: confidence interval, CD: Clavien–Dindo.


1 January 2013 to 31 December 2017
DG: n = 184238; TG: n = 83487; LAR: n = 107721
Operation performed by a non-member of the JSGS
DG: n=16778; TG: n=7468; LAR: n=8411
Operation not for gastric cancer/rectal cancer
DG: n=5510; TG: n=2395; LAR: n=6288
Operation on patients <18 years
DG: n=223; TG: n=87; LAR: n=131
Emergency surgery
DG: n=1325; TG: n=855; LAR: n=838
TX, NX (DG, TG), TX (LAR)
DG: n=1211; TG: n=700; LAR: n=374
M1
DG: n=7888; TG: n=7698; LAR: n=8724
Missing values for risk factor/outcome
DG: n=2110; TG: n=867; LAR: n=1362
Included (n)
DG: n=149193; TG: n=63417; LAR: n=81593