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ORIGINAL ARTICLE

Identification of the factor affecting learning curves of laparoscopic gastrectomy through the experience at a Japanese high-volume center over the last decade

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Abstract

Background: Though laparoscopic gastrectomy (LG) has become the gold standard for gastric cancer treatment according to the Japanese treatment guidelines, its learning curve remains steep. Decreasing numbers of surgeons and transitions in the work environment have changed LG training recently. We analyzed LG training over the last decade to identify factors affecting the learning curve.

Study Design: Laparoscopic distal and pylorus-preserving gastrectomies conducted between 2010 and 2020 were included. We assessed learning curves based on the standard operation time (SOT) defined by analysis of covariance. Then we divided the trainees into two groups based on the length of the learning curve and examined the factors affecting the learning curve with linear regression analysis.

Results: Among 2335 LGs, 960 cases treated by 27 trainees and 1301 cases treated by six attending surgeons were analyzed. The operation time was prolonged ($p = 0.009$) and postoperative morbidity rates were lower ($p = 0.0003$) for cases treated by trainees. Trainees experienced 38 (range, 9–81) cases as scopists and nine (range, 0–41) cases as first assistants to the first operator. The learning curve was approximately 30 cases. The SOT was calculated based on gender, body mass index, tumor location, reconstruction, and lymph node dissection. Trainees who had shorter learning curves had more experience (51–100 cases) with any laparoscopic surgery before LG training than the others (11–50 cases, $p = 0.017$).

Conclusion: Sufficient experience with laparoscopic surgery before starting LG training might contribute to the efficiency of LG training and shorten the learning curve.

KEYWORDS
education, gastric cancer, high-volume center, laparoscopic gastrectomy, learning curve

1 | INTRODUCTION

Laparoscopic gastrectomy (LG) has become the gold standard for the surgical treatment of gastric cancer according to the Japanese treatment guidelines.[1] Several studies have shown the safety, efficacy, and feasibility of LG.[2] However, the learning curve of LG is still not short enough, and an optimal education system for LG has not been established to date, mainly due to the complexity of the procedure.[3–5]

Though we have previously reported that education in LG is based on the trainee's understanding of each standardized step of the procedure,[6,7] many transitions have led to changes in LG training over the last decade. The number of general surgeons has been decreasing due to lifestyle issues, such as long hours, being on call, and family considerations,[8,9] which has resulted in decreased manpower in surgical departments. In addition, implementation of duty hour restrictions has become the standard working style in many countries.[10–12] Both labor issues and time restrictions result in insufficient time for education. Together with the recent decrease in the incidence of gastric cancer,[13] establishing efficient LG training to be matched with the clinical environment in this new era is an urgent challenge to be solved.

In the present study, we evaluated more than 2000 cases of LG in a Japanese high-volume center over the last decade, and we identified factors affecting the learning curve of LG training.

2 | PATIENTS AND METHODS

2.1 | Patients

We reviewed the clinical records of patients with gastric cancer who underwent R0 laparoscopic distal or pylorus-preserving gastrectomy (LDG/LPPG) at the Cancer Institute Hospital (CIH) of the Japanese Foundation for Cancer Research in Tokyo, Japan between April 2010 and March 2020. Among them, the cases operated on by trainees who learned for 2 years or more or by attending surgeons who worked for 2 years or more were included in this retrospective case–control study. The study was approved by an Institutional Review Board. All enrolled patients provided written informed consent.

All tumors were diagnosed histologically as adenocarcinomas. LDG was indicated if the cancer was located in the lower third of the stomach, and LPPG was the procedure of choice if the lesion was in the middle third of the stomach. We evaluated tumor location and depth of tumor invasion based on the results of endoscopy, an upper gastrointestinal series, and endoscopic ultrasonography. Lymph node metastases and distant metastases were evaluated by abdominal ultrasonography and computed tomography. Patients with gastric cancer not suitable for endoscopic resection were treated laparoscopically. Both LDG and LPPG were performed by experienced attending surgeons and some trainees using standardized procedures, as previously described.[7]

2.2 | Trainees and training system

Surgical fellows were recruited from all over Japan and assigned as trainees in the gastric surgery department for 3 months to 3 years. Trainees usually have 7–13 years of experience as surgeons after graduation. Our training system focused on understanding the laparoscopy-specific anatomy for gastrectomy and the standardization of LG procedures, including the role of the scopist and the assistant. Each trainee participated in LG procedures as a scopist and an assistant in some cases, and then performed the first case of LAG as an operator, as previously reported.[7]

2.3 | Study design

We first compared surgical outcomes between trainees and attending surgeons. Then we defined the standard operation time (SOT) using the characteristics of patients who underwent surgery by attending surgeons by analysis of covariance (ANCOVA). We examined how trainees achieved the SOT and divided the trainees into two groups by learning curve. We finally investigated factors affecting the learning curve by logistic regression analysis.

2.4 | Statistical analysis

Statistical calculations were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan). Patient characteristics were compared with Pearson's chi-square test or the Mann–Whitney U test, as appropriate. Survival was calculated with the Kaplan–Meier method. A log-rank test was used to compare survival between groups. The SOT was calculated by ANCOVA.

TABLE 1 Characteristics of training for laparoscopic gastrectomy.

Characteristic	
Number of times as a scopist before a first operator	38 (9–81)
Number of times as an assistant before a first operator	9 (0–41)
Period from training start to first operator, days	361 (101–692)
Total times as an operator	34 (10–59)
Yearly times as an operator	13 (5.0–25.5)

Note: Values are represented as median (range).

Univariate analysis for investigating factors affecting the learning curve was conducted with Pearson's chi-square test, the Kruskal–Wallis rank sum test, or the Mann–Whitney *U*-test, as appropriate. Statistical significance was set at a *p* value of <0.05.

3 | RESULTS

3.1 | Characteristics of trainees and LG training

Over 11 years, 35 trainees received LG training in our department. Among them, 27 trainees who learned for 2 years or more were enrolled in this study. Table 1 shows the characteristics of LG training. The median number of times a trainee served as a scopist and an assistant before becoming a first operator were 38 (range, 9–81) and nine (range, 0–41), respectively. The period from the start of training to serving as a first operator was 361 (range, 101–692) days. Total times and yearly times that individuals served as operators during LG training were 34 (range, 10–59) and 13 (range, 5.0–25.5), respectively.

3.2 | Patient characteristics

Among 2335 patients with gastric cancer who underwent R0 LDG/LPPG between April 2010 and March 2021, 2261 patients whose surgeries were performed by 27 trainees and six attending surgeons who belonged to the CIH for 2 years or more were enrolled in this study. Of these, 960 patients (42.5%) were operated on by trainees (trainee group), and 1301 patients (57.5%) were operated on by attending surgeons (attending group, Figure 1). Table 2 shows the clinical characteristics of the enrolled patients. Regarding clinical background, the proportion of females was higher in the trainee group ($p < 0.0001$). Body mass index (BMI) and ratio of Roux-en Y reconstruction were higher in the attending group ($p < 0.0001$ and $p < 0.0001$, respectively). There was no difference in the proportions of substages and type of resection. In terms of surgical outcomes, operation time was longer ($p = 0.0086$), and blood loss was less ($p = 0.002$) in the trainee group. Though there was no significant difference in morbidity defined by Clavien–Dindo classification of grade III or more (CD ≧ III), the morbidity of CD ≧ II was higher in the attending group (16.4%) than in the trainee group (10.8%, $p = 0.0003$). In terms of oncological safety, Kaplan–Meier analysis showed that there was no difference in the 5-year survival rate between the two groups (trainee, 97.3%; attending, 96.1%; Figure 2).

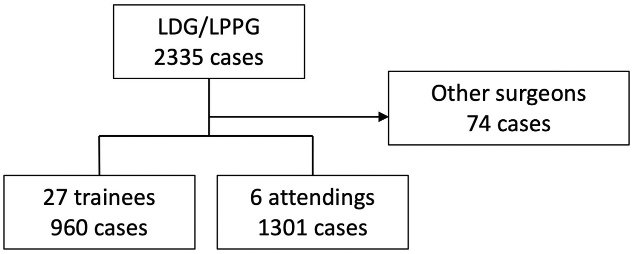

FIGURE 1 Patient flow diagram.

3.3 | SOT and trainees' learning curves of laparoscopic gastrectomy

To analyze the learning curve of the trainees, we first plotted the operation time of each trainee (Figure S1). Then we compared the gross operation time between trainees and attending surgeons. The trainees' average operation time seemed to converge with that of attending surgeons at around 30 times of serving as an operator (Figure 3).

To further examine the learning curve of LG training, we conducted ANCOVA to identify factors affecting the SOT. We analyzed the operation time with co-factors including age, gender, BMI, tumor location, surgical method, reconstruction method, and lymph node dissection level, which resulted in the following formula:

$$SOT = 174 + 17.3 \times A + 3.42 \times B + 21.5 \times C + 10.0 \times D + 14.7 \times E.$$

*A, gender (male,1; female, 0). B, BMI. C, tumor location (upper stomach, 1; middle or lower, 0). D, reconstruction, (Roux-en Y, 2; Billroth I, 1; gastro-gastro, 0). E, lymph node dissection (D2, 1; D1+, 0).

We applied the formula to the trainees' patients and calculated the SOT and assessed how many times trainees required to achieve the SOT. The average number of times required for trainees was 15 (range, 3–39), and the achievement ratio was 52.5% (range, 16.1% – 85.3%). The average number of times required to serve as an operator until first achievement was two (range, 1–11), and the average frequency of two and three consecutive achievements was four (range, 2–29) and nine (range, 3–46), respectively (Table 3).

3.4 | Identification of a factor affecting the learning curve of LG

To identify the factors affecting the learning curve of LG, we next divided the trainees into two groups according to length of the learning curve. Among 27 trainees, five were excluded due to their more extensive experience, which was more than 20 cases of LG as an operator before they started LG training in the CIH. The trainees who required more than nine times as an operator until three consecutive achievements were defined as the longer group, and the others were assigned to the shorter group. We compared the background and experience before and during LG training between those two groups. By univariate analysis, the trainees in the shorter group had more experience (median, 51–100 cases) with any kind of laparoscopic surgery than those in the longer group (median, 11–50 cases, $p = 0.017$, Table 4). No significant difference was observed regarding other factors, including number of times serving as an assistant before serving as the first operator, pre-training period, and board certifications.

TABLE 2 Clinical characteristics.

Clinical factors	Trainees	Attending surgeons	*p*-Value
Patient background			
Gender male/female	491/469	842/459	<0.0001
BMI (kg/m^2/m^2)	22.1 (20.2–24.1)	23.0 (20.8–25.3)	<0.0001
cStage I / cStage II or more	935/25	1248/53	0.063
Resection DG / PPG	664/296	942/359	0.10
Reconstruction BI / RY / GG	276/385/296	267/666/359	<0.0001
Outcomes			
Operation time, min	279 (248–315)	236 (236–313)	0.0086
Blood loss, mg	20 (10–35)	20 (10–46)	0.0020
Clavien–Dindo classification Grade <II/≧II	856/104 (10.8%)	1091/210 (16.1%)	0.0003
Clavien–Dindo classification Grade <III/≧III	924/32 (3.33%)	1239/62 (4.77%)	0.11

Note: Continuous values are represented as median (interquartile range).

Abbreviations: BI, Billroth I; BMI, body mass index; DG, distal gastrectomy; GG, gastro-gastro anastomosis; PPG, pylorus preserving gastrectomy; RY, Roux-en Y.

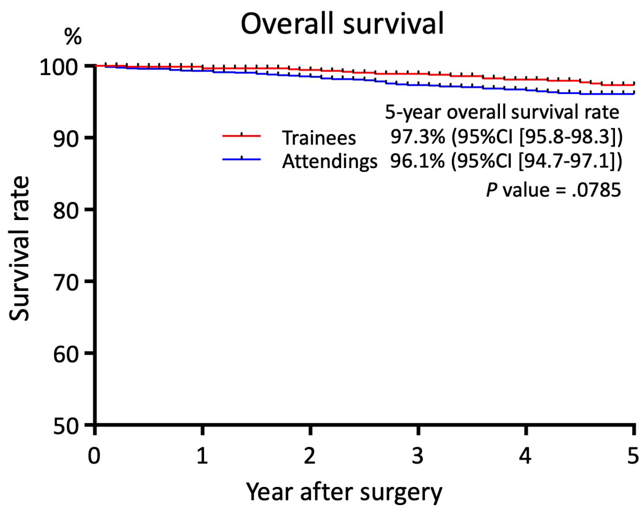

FIGURE 2 Five-year overall survival rate. Kaplan–Meier analyses of overall survival comparing patients operated on by trainees and attending surgeons.

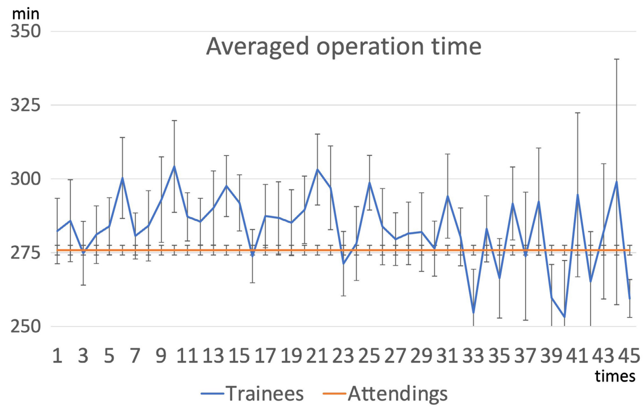

FIGURE 3 Average operation time between trainees and attending surgeons. Compared with the averaged operation time of attending surgeons, that of trainees seemed to converge at around 30 times of serving as an operator. Red line represents the averaged operation time of attending surgeons. Blue line represents the averaged operation time of trainees. Error bars shows standard error.

TABLE 3 Achievement of standard operation time.

Achievement	
Total times of achievement	15 (3–39)
Achievement ratio (%)	52.5 (16.1–85.3)
Number of times as an operator until three consecutive achievements	9 (3–46)[a]

Note: Data represented as median (range).

[a]Four trainees did not achieve.

4 | DISCUSSION

The trend toward reductions in resident work hours constitutes one of the greatest challenges in recent surgical training.[14] Many surgical educators have predicted a negative impact on surgical education, continuity of care, and resident operative volume experience.[15] In addition, the proportion of young physicians in the population of surgeons is decreasing.[16,17] Decreasing numbers of young surgeons may increase the amount of work, which includes pre- and postoperative patient care, for each young surgeon, which could

TABLE 4 Factors affecting the learning curve of laparoscopic gastrectomy.

Factors	Shorter	Longer	All	*p*-Value
Pre-training period				
Post graduate year at the time LG training started	9 (7–12)	7.5 (7–8)	8 (7–9)	0.14
Period of clinical practice before LG training, years	6 (6–9)	6 (5–7)	6 (6–7.5)	0.23
Pre-training experience				
Experienced times of any laparoscopic surgeries before LG training	—	—	—	0.017
1–10/11–50/51–100/>101 times	0/3/5/3	1/8/1/1	1/11/6/4	—
Experienced times of laparoscopic surgeries for cancer before LG training	—	—	—	0.82
0/1–10/11–30/>31 times	3/5/2/1	1/8/2/0	4/13/4/1	—
Experienced times of gastric surgeries before LG training	—	—	—	0.053
0/1–10/11–30/>31 times	0/2/5/4	0/6/4/1	0/8/9/5	—
Experienced times of laparoscopic surgeries for GC before LG training	—	—	—	0.46
0/1–5/6–10/>11 times	7/3/1/0	5/5/1/0	12/8/2/0	—
Qualification at the time LG training started				
Board-certified surgeon (obtained/not obtained)	10/1	9/2	19/3	0.53
Board-certified gastroenterological surgeon (obtained/not obtained)	2/9	3/8	5/17	0.61
PhD (obtained/not obtained)	8/3	6/5	14/8	0.37
Experience after LG training started				
Number of times as a scopist before a first operator	31 (24–53)	44 (34–67)	41 (28–61)	0.18
Number of times as an assistant before a first operator	7 (3–23)	12 (6–14)	9 (4–20)	0.45
Total times as a scopist and an assistant before a first operator	37 (28–73)	65 (44–81)	59 (35–76)	0.29
Period from time training started to first operator, days	383 (203–441)	368 (342–395)	369 (274–426)	0.87

Abbreviations: GC, gastric cancer; LG, laparoscopic gastrectomy; PhD, Doctor of Philosophy.

result in a decrease in the time available for learning experience on surgical procedures. Together with the recent decrease in the incidence of gastric cancer,[13] establishing efficient LG training to be matched with the clinical environment in this new era is an urgent challenge to be solved.

The learning curves of various procedures have been analyzed in many ways, including the moving average method and cumulative sum.[18–20] When the learning curve is simply evaluated by operation time, various factors, including patient background, can become biases. In this study, we firstly examined the gross operation time to compare this study with our previous study using the same method. Then, to pursue a more un-biased result, we identified factors that affected the learning curve of LG by setting a SOT based on the surgical results of attending surgeons skilled in the technique and adjusting the bias of each patient to evaluate the learning curve.

In this study, we examined LG training with more than 2000 cases of gastric cancer in a Japanese high-volume center over the last decade. Our findings demonstrate that more experience with any kind of laparoscopic surgery may contribute to more efficient LG training (Table 4). Because there was no difference in experience with laparoscopic surgeries for cancer between groups, the majority of any kind of laparoscopic surgery was for benign diseases or relatively minor surgeries, including cholecystectomy, appendectomy and hernia repair. This result suggested basic laparoscopic skills, such as hand-eye coordination and intracorporeal suturing, can shorten the learning curve of LG.[21,22] Our results showed that more experience with gastrectomy including open gastrectomy which is often assigned to young surgeons before starting LG training tended to contribute to a shortening of the LG learning curve (Table 4), which suggests that a deeper anatomical understanding of the stomach might be needed for more efficient learning.

Recently, LG has been widely performed worldwide for both early and advanced gastric cancer.[2] However, the procedure is technically complicated, with many difficult steps to master, and each institution performs only a limited number of surgeries due to the decreased incidence of gastric cancer. Previous reports showed that surgeons who had performed 40 to 60 LGs were more likely to have satisfactory outcomes than lesser-trained surgeons.[3,4,23] Even in high-volume centers, it is difficult for young surgeons to perform 40 to 60 LGs. We previously reported that with an average of 34 cases as a scopist and 35 as an assistant, only six cases as an operator were required for the trainees to achieve optimum proficiency.[7] In this study, the averaged operation time of residents converged to that of the attending surgeons at around 30 cases as an operator, 38 as a scopist, and nine as an assistant. Though required times as an operator were increased in this study, the total numbers of times as an operator, scopist, and assistant were similar to those in our previous report. To participate the operations as assistant is absolutely important to learn the procedure. However, in the current clinical environment of decreased numbers of young surgeons, increasing their opportunities to serve as an operator might maintain their motivation as surgeons. In this study, the result suggests that increasing times of an operator has the possibility to compensate for the decreased experience of assistants even if in the recent situation of surgical education. On the other hand, the decreased numbers of patients make it difficult to obtain more experience as an operator. In this study, the median experience of laparoscopic surgeries in the shorter group was 51 to 100 cases. For more efficient LG training, it may be necessary to have more experience with laparoscopic surgery before LG training.

Regardless of training nature, both perioperative and oncological safety must be secured in LG training. According to the National Clinical Database (NCD), a public database of Japan, the morbidity of postoperative complications classified as CD $\geqq$ III was 7.1%.[24] In this study, morbidity rates in the trainee group and the attending group were 3.33% and 4.77%, respectively, which was lower than that of the NCD. In terms of CD $\geqq$ II, the morbidity rate in the trainee group (10.8%) was lower than that in the attending group (16.4%). Survival outcomes also tended to be better in the trainee group in this study. Even though the fact that attending surgeons had to be assigned to high-risk patients might influence these differences, this study may reflect the safety of our LG training.

This study has several limitations. The surgical outcomes of LG performed by trainees were only assessed in the presence of attending surgeons who were assisting as leading assistants. Therefore, the surgical outcomes in this study were influenced by an experienced assistant. In addition, due to its retrospective nature, biases may exist relative to the background of the patients and trainees. Thus, we must validate the results of this study in a prospective study for further improvement of LG training.

In conclusion, in an analysis of more than 2000 cases of LG over the last decade examining the learning curve of LG training with the SOT, we identified a factor affecting the learning curve. Sufficient experience with laparoscopic surgery before starting LG training may contribute to the efficiency of LG training and shorten the learning curve.

AUTHOR CONTRIBUTIONS

Study concept and design: DI, SN; Acquisition of clinical data: DI, SN, MH, RM, MO, MW, TS; Analysis and interpretation of data and statistical analysis: DI, SN; Drafting of the manuscript: DI, SN, MH, RM, MO, MW, and TS.

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The authors have no financial relationships to disclose.

CONFLICT OF INTEREST STATEMENT

Dr. Daisuke Izumi, Dr. Souya Nunobe, Dr. Naoki Ishizuka, Dr. Taisuke Yagi, Dr. Masaru Hayami, Dr. Rie Makuuchi, Dr. Manabu Ohashi, Dr. Masayuki Watanabe, and Dr. Takeshi Sano have no conflict of interest to disclose.

ETHICS STATEMENT

Approval of the research protocol: The Institutional Review Boards approved this study (2021-GB-060).
Informed Consent: N/A.
Registry and the Registration No. of the study/trial: N/A.
Animal Studies: N/A.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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