Circular stapling anastomosis with indocyanine green fluorescence imaging for cervical esophagogastric anastomosis after thoracoscopic esophagectomy: A propensity score-matched analysis

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Abstract

Background: Thoracoscopic esophagectomy has been widely used worldwide as a curative surgery for esophageal cancer, but complications, such as anastomotic leakage and stenosis remain a major concern. Therefore, this study aimed to evaluate the efficacy of circular stapling anastomosis with indocyanine green (ICG) fluorescence imaging, which was standardized for cervical esophagogastric anastomosis after thoracoscopic esophagectomy.

Methods: In total, 121 patients with esophageal cancer who underwent thoracoscopic esophagectomy with radical lymph node dissection and cervical esophagogastric anastomosis between November 2009 and December 2020 at Tottori University Hospital were enrolled in this study. Patients who underwent surgery before the anastomotic method was standardized were included in the classical group ($n = 82$), and patients who underwent surgery after standardization were included in the ICG circular group ($n = 39$). We compared the short-term postoperative outcomes, including anastomotic complications, between the two groups using propensity matched analysis, and evaluated the risk factors for anastomotic leakage using logistic regression analyses.

Results: Of 121 patients, 33 were respectively included in each group after propensity score matching. The clinicopathological characteristics of patients between the two groups did not differ after matching. In perioperative outcomes, a significantly higher proportion of patients who underwent surgery using the laparoscopic approach ($P < 0.001$) and narrow gastric tube ($P = 0.003$), as well as those who had a lower volume of blood loss ($P = 0.009$) in the ICG circular group were seen after matching. Moreover, the ICG circular group had a significantly lower incidence of anastomotic leakage (39% vs. 9%, $P = 0.004$) and anastomotic stenosis (46% vs. 21%, $P = 0.037$) and a shorter postoperative hospital stay (30 vs. 20 days, $P < 0.001$) than the classical group. In the multivariate analysis, anastomotic method was an independent risk factor for anastomotic leakage after thoracoscopic esophagectomy ($P = 0.013$).

Conclusions: Circular stapling anastomosis with ICG fluorescence imaging is effective in reducing complications including anastomotic leakage and stenosis.

Background

Esophageal cancer is the ninth most commonly diagnosed cancer worldwide and the sixth most common cause of cancer-related mortality [1]. Esophagectomy is the mainstay of treatment for resectable esophageal cancer. Thoracoscopic esophagectomy was first reported by Cuschieri et al. in 1992 [2]. However, thoracoscopic esophagectomy has been widely used worldwide as a curative surgery for esophageal cancer. Moreover, it reduces respiratory complications compared with open esophagectomy in a randomized controlled trial [3]. However, complications such as anastomotic leakage and stenosis remain a major concern. At our institution, thoracoscopic esophagectomy was initially performed in November 2009. Different anastomotic methods such as hand-sewing, triangulating [4], circular stapling,

and Collard anastomosis [5] have been applied. However, the anastomotic complication rate was not reduced.

A systematic review has reported that indocyanine green (ICG) fluorescence imaging can be an important adjunct tool for reducing anastomotic leakage after esophagectomy [6]. ICG is a water-soluble near-infrared phosphor that has immediate and long-term safety [7, 8]. ICG fluorescence imaging is a simple evaluation method. In recent robot-assisted surgery, high-resolution near-infrared images can be obtained using the Firefly system with the da Vinci Xi surgical robot (Intuitive Surgical Inc., Sunnyvale, California). Therefore, to assess gastric tube blood flow during esophagectomy reconstruction, we have standardized the use of ICG fluorescence imaging at our institution in July 2018. In addition, the anastomotic method was standardized to circular stapling anastomosis because it is simple and applicable to almost all cases, including those with short remnant esophagus.

The current study aimed to evaluate the efficacy of circular stapling anastomosis with ICG fluorescence imaging for cervical esophagogastric anastomosis after thoracoscopic esophagectomy by comparing the short-term outcomes before and after the anastomotic method was standardized via propensity matched analysis.

Methods

Patients

We included 145 patients with esophageal cancer who underwent thoracoscopic esophagectomy with radical lymph node dissection between November 2009 and December 2020 at Tottori University Hospital. Among them, 19, 2, and 3 who underwent reconstruction using the jejunum or colon, pharyngeal gastric tube anastomosis due to the simultaneous duplication of hypopharyngeal cancer, and two-stage reconstruction, respectively, were excluded. Finally, 121 patients were enrolled in the current study (Fig. 1). Patients who underwent surgery until June 2018, which was before the anastomotic method was standardized, were included in the classical group, and those who underwent surgery starting July 2018, which was after the standardization, in the ICG circular group. The clinicopathological findings were determined according to the Japanese Classification of Esophageal Cancer (11th edition) [9] [10]. This study was approved by the institutional review board (20A234), and the need for informed consent was waived.

Surgical procedure

All patients underwent thoracoscopic subtotal esophagectomy with mediastinal lymph node dissection in the prone position under right pneumothorax, and robot-assisted esophagectomy has been used since February 2020. After completion of the thoracic procedure, patients were subsequently repositioned in the supine position, and cervical and abdominal procedures were started simultaneously. Cervical lymph node dissection was not performed on patients with lower thoracic or abdominal esophageal cancer

without cervical or upper mediastinal lymph node metastasis. Abdominal procedures such as laparotomy, hand-assisted laparoscopic surgery, and complete laparoscopy for abdominal lymph node dissection were performed. In patients who require complete laparoscopy, 8-cm laparotomy was performed on the upper abdomen after completing abdominal lymph node dissection. The gastric tube was created under direct visualization in all cases. Then, it was pulled up to the neck via the retrosternal or posterior mediastinal route, and esophagogastric anastomosis was performed on the left side of the neck.

ICG circular anastomosis method

The ICG circular anastomosis was performed as follows: After the gastric tube was created, ICG at a dose of 10 mg/body was administered intravenously, and ICG fluorescence imaging of the blood flow in the gastric tube was assessed using PhotoDynamic Eye (Hamamatsu Photonics, Hamamatsu, Japan) or the Firefly system, which was integrated with the da Vinci Xi surgical robot (Intuitive Surgical Inc., Sunnyvale, California). The reconstructed gastric tube was used until the site where the wall of the gastric tube had a uniform contrast within 20 s after the right gastroepiploic artery was contrasted with ICG, as reported by Noma et al. [11] (Figs. 2a, b). After the gastric tube was pulled up to the neck, end-to-side esophagogastric anastomosis was performed on the posterior wall of the gastric tube using the 25-mm DST Series EEA circular stapler (Medtronic, Minneapolis, Minnesota) (Fig. 2c). The stump of the gastric tube was sectioned and closed using the Signia stapling system with a 60-mm purple cartridge (Medtronic, Minneapolis, Minnesota) (Fig. 2d). Finally, the staple line was buried.

Definition of perioperative complications

Anastomotic leakage was defined as saliva leakage from the cervical wound, contrast leakage outside the gastrointestinal tract on gastrointestinal series, and abnormal air or fluid accumulation around the anastomosis on CT scan. Anastomotic stenosis was defined as cases in which a 9.0-mm-diameter endoscope could not pass through the anastomosis and balloon dilation was required during endoscopy for postoperative dysphagia. Pneumonia was defined as the appearance of consolidation on chest radiography or CT scan and the detection of bacteria on sputum culture. Recurrent nerve paralysis was assessed by an otolaryngologist on postoperative day 6 or 7 via laryngoscopy.

Statistical analysis

Continuous data were presented as mean $\pm$ standard deviation or median with range, as indicated. The Mann–Whitney U test and the χ^2 test were used to evaluate differences in continuous and categorical variables, respectively. Propensity matched analysis was conducted using the logistic regression model and covariates such as age, sex, histological type, tumor location, clinical stage, and presence or absence of neoadjuvant chemotherapy. Univariate and multivariate logistic regression analyses were used to identify risk factors for anastomotic leakage. Variables that were considered statistically significant in the univariate analysis were used in the multivariate analysis. *P* values of <0.05 indicated statistically significant differences, and the Statistical Package for the Social Sciences software version 25 (IBM SPSS Inc., Chicago, Illinois) was used for statistical analyses.

Results

Characteristics of patients

Of 121 patients, 82 were included in the classical group and 39 in the ICG circular group before matching. Then, 33 patients were respectively included in each group (Fig. 1). Table 1 shows the clinicopathological characteristics of patients before and after matching. Before matching, there were significant differences in terms of the American Society of Anesthesiologists physical status (ASA-PS) score ($P = 0.021$) and histological type ($P = 0.009$). However, after matching, the background characteristics did not significantly differ between the two groups.

Table 1
Characteristics of patients

	Before matching			After matching		
	Classical group	ICG circular group	<i>P</i> value	Classical group	ICG circular group	<i>P</i> value
	(n = 82)	(n = 39)		(n = 33)	(n = 33)	
Age (years)			0.892			0.872
Median (range)	66 (49–81)	66 (41–79)		65 (49–79)	67 (41–79)	
Sex			0.914			0.282
Male	70 (85%)	33 (85%)		30 (90%)	27 (82%)	
Female	12 (15%)	6 (15%)		3 (9%)	6 (18%)	
Body mass index (kg/m ²)	21.2 ± 3.1	22.2 ± 3.3	0.083	21.8 ± 3.1	21.9 ± 3.3	0.677
Serum albumin level (g/dL)	4.2 ± 0.4	4.1 ± 0.4	0.494	4.1 ± 0.4	4.1 ± 0.4	0.985
Brinkman index			0.733			0.278
Median (range)	800 (0–2600)	860 (0–1250)		820 (0–2600)	840 (0–1250)	
Performance status			0.586			0.601
0	68 (83%)	34 (87%)		27 (82%)	28 (85%)	
1	12 (15%)	5 (13%)		5 (15%)	5 (15%)	
2	2 (2%)	0 (0%)		1 (3%)	0 (0%)	
Comorbidity						
Diabetes	15 (18%)	4 (10%)	0.256	10 (30%)	4 (12%)	0.071
Cardiovascular disease	10 (12%)	6 (15%)	0.628	2 (6%)	5 (15%)	0.230
Obstructive ventilation failure	27 (33%)	13 (33%)	0.965	10 (30%)	11 (33%)	0.792
ASA-PS score			0.021			0.115
1	11 (13%)	1 (3%)		3 (9%)	1 (3%)	
2	63 (77%)	28 (72%)		27 (82%)	23 (70%)	

ASA-PS, American Society of Anesthesiologists physical status

	Before matching		After matching	
3	8 (10%)	10 (26%)	3 (9%)	9 (27%)
Histological type		0.009		1.000
Squamous cell carcinoma	78 (95%)	30 (77%)	30 (91%)	30 (91%)
Adenocarcinoma	2 (2%)	6 (15%)	2 (6%)	2 (6%)
Others	2 (2%)	3 (8%)	1 (3%)	1 (3%)
Tumor location		0.229		0.642
Upper thoracic	11 (13%)	6 (15%)	5 (15%)	6 (18%)
Middle thoracic	43 (52%)	16 (41%)	15 (46%)	16 (49%)
Lower thoracic	24 (29%)	11 (28%)	11 (33%)	7 (21%)
Abdominal	4 (5%)	6 (15%)	2 (6%)	4 (12%)
cT		0.405		0.667
1	36 (44%)	16 (41%)	16 (49%)	14 (42%)
2	14 (17%)	11 (28%)	5 (15%)	9 (27%)
3	31 (38%)	11 (28%)	11 (33%)	9 (27%)
4a	1 (1%)	1 (3%)	1 (3%)	1 (3%)
cN		0.224		0.420
0	44 (54%)	28 (72%)	19 (58%)	24 (73%)
1	17 (21%)	5 (13%)	7 (21%)	4 (12%)
2	20 (24%)	5 (13%)	7 (21%)	5 (15%)
3	1 (1%)	1 (3%)	0 (0%)	0 (0%)
cStage		0.296		0.393
1	32 (39%)	14 (36%)	16 (49%)	13 (39%)
2	19 (23%)	14 (36%)	5 (15%)	10 (30%)
3	31 (38%)	11 (28%)	12 (36%)	10 (30%)
Neoadjuvant chemotherapy		0.974		1.000
Absent	36 (44%)	17 (44%)	16 (49%)	16 (49%)
ASA-PS, American Society of Anesthesiologists physical status				

	Before matching		After matching	
Present	46 (56%)	22 (56%)	17 (52%)	17 (52%)
ASA-PS, American Society of Anesthesiologists physical status				

Changes in anastomotic methods and perioperative outcomes

Figure 3 presents changes in anastomotic methods for cervical esophagogastric anastomosis after thoracoscopic esophagectomy, and Table 2 depicts the perioperative outcomes in both groups. As shown in Table 2, before matching, there was a significantly higher proportion of patients who underwent surgery using the laparoscopic approach ($P < 0.001$) and narrow gastric tube ($P = 0.001$) and those who had a lower volume of blood loss ($P = 0.038$) in the ICG circular group. After matching, the same factor indicated a significant difference. In terms of postoperative outcomes, the ICG circular group had a significantly lower proportion of patients with anastomotic leakage (34% vs. 8%, $P = 0.002$) and shorter postoperative hospital stay (29 vs. 20 days, $P < 0.001$) before matching. After matching, there was a significantly lower proportion of patients with anastomotic leakage (39% vs. 9%, $P = 0.004$) and stenosis (46% vs. 21%, $P = 0.037$) and a shorter postoperative hospital stay (30 vs. 20 days, $P < 0.001$) in the ICG circular group.

Table 2
Perioperative outcomes of patients with esophageal cancer after thoracoscopic esophagectomy

	Before matching			After matching		
	Classical group	ICG circular group	<i>P</i> value	Classical group	ICG circular group	<i>P</i> value
	(n = 82)	(n = 39)		(n = 33)	(n = 33)	
Abdominal approach			<0.001			< 0.001
Open	34 (42%)	0 (0%)		15 (46%)	0 (0%)	
Laparoscopic	48 (59%)	39 (100%)		18 (55%)	33 (100%)	
Lymph node dissection			0.180			1.000
Two-field	18 (22%)	13 (33%)		10 (30%)	10 (30%)	
Three-field	64 (78%)	26 (67%)		23 (70%)	23 (70%)	
Route of reconstruction			0.070			0.131
Retrosternal	68 (83%)	37 (95%)		27 (82%)	31 (94%)	
Posterior mediastinal	14 (17%)	2 (5%)		6 (18%)	2 (6%)	
Shape of the gastric tube			0.001			0.003
Subtotal	21 (26%)	0 (0%)		8 (24%)	0 (0%)	
Narrow	61 (74%)	39 (100%)		25 (76%)	33 (100%)	
Total operative time (min)	634 ± 89	617 ± 53	0.573	638 ± 100	616 ± 51	0.753
Volume of blood loss (mL)	186 ± 219	103 ± 97	0.038	251 ± 298	93 ± 89	0.009
Postoperative complications						
Anastomotic leakage	28 (34%)	3 (8%)	0.002	13 (39%)	3 (9%)	0.004
Anastomotic stenosis	29 (35%)	8 (21%)	0.097	15 (46%)	7 (21%)	0.037
Pneumonia	18 (22%)	11 (28%)	0.451	8 (24%)	9 (27%)	0.778

	Before matching			After matching		
Recurrent nerve paralysis	14 (17%)	2 (5%)	0.070	7 (21%)	2 (6%)	0.073
Postoperative hospital stay	29 (10–128)	20 (14–53)	<0.001	30 (10–128)	20 (14–53)	<0.001

Risk factor analyses of anastomotic leakage

Finally, we evaluated the risk factors for anastomotic leakage via propensity score matching in 66 patients. The univariate analysis indicated that Brinkman index ($P = 0.048$) and anastomotic method ($P = 0.008$) were significantly associated with anastomotic leakage (Table 3). In the multivariate analysis, anastomotic method was an independent risk factor for anastomotic leakage after thoracoscopic esophagectomy (odds ratio: 5.983, 95% confidence interval [CI]: 1.469–24.359, $P = 0.013$) (Table 4).

Table 3
Univariate logistic regression analyses of anastomotic leakage

Anastomotic leakage					
	Absent (n = 50)	Present (n = 16)	OR	95% CI	<i>P</i> value
Age (years)					
<65	20 (40%)	8 (50%)	1.500	0.484–4.651	0.483
≥65	30 (60%)	8 (50%)	1		
Sex					
Male	42 (84%)	15 (94%)	2.857	0.329–24.795	0.341
Female	8 (16%)	1 (6%)	1		
Body mass index (kg/m ²)					
<22	24 (48%)	10 (63%)	1.806	0.569–5.726	0.316
≥22	26 (52%)	6 (38%)	1		
Serum albumin level (g/dL)					
<4	20 (40%)	5 (31%)	0.682	0.206–2.261	0.531
≥4	30 (60%)	11 (69%)	1		
Brinkman index					
<800	24 (48%)	3 (19%)	0.250	0.063–0.986	0.048
≥800	26 (52%)	13 (81%)	1		
Performance status					
0	42 (84%)	13 (81%)	0.825	0.191–3.574	0.797
1, 2	8 (16%)	3 (19%)	1		
Diabetes					
Absent	39 (78%)	13 (81%)	1.222	0.295–5.069	0.782
Present	11 (22%)	3 (19%)	1		
Cardiovascular disease					
Absent	46 (92%)	13 (81%)	0.377	0.075–1.901	0.237

OR, odds ratio; CI, confidence interval; ASA-PS, American Society of Anesthesiologists physical status

Anastomotic leakage					
Present	4 (8%)	3 (19%)			
Obstructive ventilation failure					
Absent	36 (72%)	9 (56%)	0.500	0.156–1.603	0.243
Present	14 (28%)	7 (44%)	1		
ASA-PS score					
1	3 (6%)	1 (6%)	1.044	0.101–10.806	0.971
2, 3	47 (94%)	15 (94%)	1		
Histological type					
Squamous cell carcinoma	45 (90%)	15 (94%)	1.667	0.180–15.425	0.653
Others	5 (10%)	1 (6%)	1		
Tumor location					
Ut, Mt	31 (62%)	11 (69%)	1.348	0.406–4.484	0.626
Lt, Ae	19 (38%)	5 (31%)	1		
cT					
1	21 (42%)	9 (56%)	1.776	0.570–5.531	0.322
2, 3, 4a	29 (58%)	7 (44%)	1		
cN					
Absent	33 (66%)	10 (63%)	0.859	0.267–2.764	0.798
Present	17 (34%)	6 (38%)	1		
cStage					
1	20 (40%)	9 (56%)	1.929	0.618–6.020	0.258
2, 3	30 (60%)	7 (44%)	1		
Neoadjuvant chemotherapy					
Absent	22 (44%)	10 (63%)	2.121	0.668–6.739	0.202
Present	28 (56%)	6 (38%)	1		

OR, odds ratio; CI, confidence interval; ASA-PS, American Society of Anesthesiologists physical status

Anastomotic leakage					
Abdominal approach					
Open	11 (22%)	4 (25%)	1.182	0.317–4.400	0.803
Laparoscopic	39 (78%)	12 (75%)	1		
Lymph node dissection					
Two-field	15 (30%)	5 (31%)	1.061	0.314–3.585	0.925
Three-field	35 (70%)	11 (69%)	1		
Route of reconstruction					
Retrosternal	43 (86%)	15 (94%)	2.442	0.277–21.519	0.421
Posterior mediastinal	7 (14%)	1 (6%)	1		
Shape of gastric tube					
Subtotal	5 (10%)	3 (19%)	2.077	0.437–9.871	0.358
Narrow	45 (90%)	13 (81%)	1		
Total operative time (min)					
<600	20 (40%)	6 (38%)	0.900	0.282–2.870	0.859
≥600	30 (60%)	10 (63%)	1		
Blood loss (mL)					
<100	26 (52%)	7 (44%)	0.718	0.231–2.229	0.566
≥100	24 (48%)	9 (56%)	1		
Anastomotic method					
ICG circular group	30 (60%)	3 (19%)	0.154	0.039–0.610	0.008
Classical group	20 (40%)	13 (81%)	1		
OR, odds ratio; CI, confidence interval; ASA-PS, American Society of Anesthesiologists physical status					

Table 4
Multivariate logistic regression analyses of anastomotic leakage

	OR	95% CI	<i>P</i> value
Brinkman index (≥ 800)	3.538	0.842–14.860	0.084
Anastomotic method (classical group)	5.983	1.469–24.359	0.013
OR, odds ratio; CI, confidence interval			

Discussion

The current study aimed to evaluate the efficacy of circular stapling anastomosis with ICG fluorescence imaging for cervical esophagogastric anastomosis after thoracoscopic esophagectomy by comparing the short-term outcomes before and after the anastomotic method was standardized via propensity matched analysis. The ICG circular group had a significantly lower rate of complications, including anastomotic leakage and stenosis, and a shorter postoperative hospital stay. Furthermore, anastomotic method was an independent risk factor for anastomotic leakage after thoracoscopic esophagectomy.

The incidence of anastomotic leakage was significantly lower in the ICG circular group than in the classical group, and anastomotic method was an independent risk factor for postoperative anastomotic leakage. According to a systematic review of ICG fluorescence imaging after esophageal cancer surgery, the overall anastomotic leakage rate of patients who underwent surgery with ICG fluorescence imaging was lower than that of controls (13.5% [118/873] vs. 18.5% [86/466]) [6]. Furthermore, when anastomosis was performed on the area with good ICG perfusion, the incidence of anastomotic leakage was 9.0% (67/746). In our current study, anastomosis was performed on the area of good ICG perfusion in all patients in the ICG circular group. Thus, the outcomes of anastomotic leakage were comparable. Honda et al. performed a systematic review comparing anastomosis after esophagectomy between hand-sewn and mechanical anastomosis with a circular stapler [12]. Results showed that the anastomotic leakage rate with circular stapling anastomosis (6.1%, 41/668) was similar to that with hand-sewn anastomosis (6.1%, 39/640) (risk ratio [RR]: 1.02, 95% CI: 0.66–1.59, $P = 0.43$). Moreover, both anastomotic methods had a significantly lower rate. However, this review included studies performing intrathoracic anastomosis. Hence, the outcomes were not completely comparable to those of cervical esophagogastric anastomosis, and our results are considered acceptable. In addition, Honda et al. showed that mechanical circular stapling anastomosis significantly reduced the operative time by 15.3 min compared with hand-sewn anastomosis. In our study, total operative time tended to be shorter in the ICG circular group than in the classical group; however, it was not significant. Therefore, circular stapling anastomosis with ICG fluorescence imaging is a simple and safe method that can reduce anastomotic leakage after thoracoscopic esophagectomy.

The current study showed that the incidence of anastomotic stenosis was significantly lower in the ICG circular group than in the classical group after propensity score matching. However, the anastomotic

stenosis rate in the classical group after matching was extremely high at 46%, which might had a significant impact. Honda et al. showed that the stenosis rate of circular stapling anastomosis was significantly higher than that of hand-sewn anastomosis (16.9% [106/626] and 9.9% [62/629]) (RR: 1.67, 95% CI: 1.16–2.42, $P = 0.006$). The subgroup and meta-regression analysis showed no significant differences in the anastomotic site, diameter of the circular stapler, layer, and configuration [12]. A randomized controlled trial by Hayata et al. comparing cervical esophagogastric circular stapling and triangulating stapling anastomosis after esophagectomy showed no significant difference in terms of anastomotic stenosis rate between the circular stapling group (17%, 8/47) and the triangulating stapling group (19%, 9/51) ($P = 0.935$) [13]. In the current study, the stenosis rate of circular stapling anastomosis was 21%, which is similar to that of previous reports but not satisfactory. Therefore, although the incidence rate of anastomotic stenosis is improving due to the standardization of anastomotic methods, it should still be further reduced.

The current study had several limitations. First, this was a retrospective study with a small sample size. Reconstruction-related perioperative outcomes, such as abdominal approach and shape of gastric tube were not consistent between the two groups. Therefore, the outcomes of ICG circular anastomosis after standardization must be prospectively evaluated. Second, various anastomotic methods were included in the classical group. Therefore, propensity matched analysis was performed to eliminate differences in patient characteristics and to prevent bias as much as possible.

Conclusions

Circular stapling anastomosis with ICG fluorescence imaging is effective in reducing anastomotic complications for cervical esophagogastric anastomosis after thoracoscopic esophagectomy. However, the incidence rate of anastomotic stenosis can still be improved, and this is an issue that should be addressed in the future.

List Of Abbreviations

ICG: indocyanine green

ASA-PS: American Society of Anesthesiologists physical status

CI: confidence interval

RR: risk ratio

Declarations

Ethics approval and consent to participate:

This study was approved by the ethical review board, Tottori University School of Medicine (20A234), waived the informed consent, and performed in accordance with the Declaration of Helsinki.

Consent for publication:

Not applicable.

Availability of data and materials:

The datasets generated during and analyzed during the current study are not publicly available due to difficulty in obtaining approval from all patients for the release of detailed personal data, but are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

Study conception: YS; Study design: YS and TM; Data acquisition: YS, TM, MM, WM, SS and KM; Quality control of data and algorithms: CU, MM, YM, TH and KK; Data analysis and interpretation: MY, NT, ST and TS; Statistical analysis: YS; Manuscript preparation: YS; Manuscript editing: HS and TH; Manuscript review: TM and YF; Final approval of the article: all authors.

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Figures

Figure 1

Patient selection for the evaluation of cervical esophagogastric anastomosis after thoracoscopic esophagectomy

Figure 2

Procedures in ICG circular anastomosis

- (a) The right gastroepiploic artery was contrasted with ICG.
- (b) The site where the wall of the gastric tube had a uniform contrast with ICG.
- (c) End-to-side esophagogastric anastomosis was performed on the posterior wall of the gastric tube using the 25-mm DST Series EEA circular stapler.
- (d) The stump of the gastric tube was sectioned and closed using the Signia stapling system with a 60-mm purple cartridge.

Figure 3

Changes in anastomotic methods for cervical esophagogastric anastomosis after thoracoscopic esophagectomy

Changes in the classical and ICG circular groups, and the annual incidence rates of anastomotic leakage and stenosis in anastomotic methods for cervical esophagogastric anastomosis after thoracoscopic esophagectomy are shown.