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ORIGINAL ARTICLE – THORACIC ONCOLOGY

Novel "Modified Bascule Method" for Lymphadenectomy Along the Left Recurrent Laryngeal Nerve During Robot-Assisted Minimally Invasive Esophagectomy

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ABSTRACT

Background. Given the worldwide popularization of conventional minimally invasive esophagectomy (C-MIE), robot-assisted MIE (RAMIE) can be expected to provide a finer procedure. However, controversy remains regarding whether RAMIE is superior to C-MIE in preventing recurrent laryngeal nerve (RLN) palsy. Considering the shallow learning curve for RAMIE, a novel procedure for lymphadenectomy along the RLN during RAMIE is needed.

Methods. Based on a logical and simple understanding of the left upper mediastinum anatomy, the authors developed a novel "modified bascule method" for RAMIE that could simplify lymphadenectomy along the left RLN and prevent it from being touched and stretched. Between 2018 and 2020, 46 patients with esophageal carcinoma underwent RAMIE using this method at Kobe University.

Results. The modified bascule method was used to perform RAMIE for 29 men and 17 women with a median age of 67 years (range, 49–82 years). The median thoracoscopic procedure time was 438 min (range, 344–625 min), and the median console time was 351 min (range 273–518 min). The study harvested a median of 24 (range, 8–34) lymph nodes from the thoracic portion and 4 (range, 0–10) lymph nodes from along the left RLN. The mortality rate was 0%. Postoperative left RLN palsy classified as Clavien–Dindo (C–D) grade 1 or higher was observed for 9 patients (19%), whereas grade 2 or higher was not seen (0%). Pneumonia and anastomotic leakage rates higher than C–D grade 2 were respectively 13% and 19%.

Conclusions. The novel modified bascule method for RAMIE can promote feasible lymphadenectomy along the left RLN even when performed during the learning period.

Studies have shown that for nearly 20% to 40% of patients with esophageal squamous cell carcinoma (ESCC) who undergo esophagectomy, lymph node (LN) metastasis develops along the recurrent laryngeal nerve (RLN).[1–3] Another study has shown that not only ESCC but also esophageal adenocarcinoma with long esophageal involvement has a high rate of LN metastasis along the RLN.[4] Thus, LN dissection along the RLN can be expected to improve clinical outcomes in both ESCC and esophageal adenocarcinoma.[2,4,5]

During the past 15 years, minimally invasive esophagectomy (MIE) with thoracoscopy performed with the patient in the prone position has received worldwide consideration, with expectations of decreased invasiveness.[6,7] Accordingly, a few novel techniques for

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lymphadenectomy along the RLN for MIE have been developed and are reported to reduce RLN palsy.[8–11] Studies have shown that RLN palsy is strongly associated with pneumonia, which is an independent prognostic factor after esophagectomy for esophageal carcinoma.[12,13] Thus, prevention of RLN palsy is quite important.

As a next step for MIE, robot-assisted MIE (RAMIE) is expected to provide a finer procedure due to its articulated arms than conventional MIE (C-MIE). Indeed, results from the multicenter international registry indicate a high-quality RAMIE. However, more optimal approach should be defined.[14] Considering the shallow learning curve for RAMIE, a novel procedure for lymphadenectomy along the RLN during RAMIE is needed to decrease RLN palsy rates.[15,16]

This study aimed to determine a new concept and procedure for RAMIE. Based on a logical and simple understanding of the left upper mediastinum anatomy, we developed a novel "modified bascule method" for RAMIE that could simplify lymphadenectomy along the left RLN, leading to lower palsy rates.

PATIENTS AND METHODS

Patient Population

This study retrospectively analyzed a cohort of patients with esophageal carcinoma who underwent robot-assisted minimally invasive McKeown esophagectomy at Kobe University between 2018 and 2020.[17] At our institution, as a common practice, all surgical candidates with esophageal carcinoma undergo C-MIE or RAMIE in the prone position.

In this study, the diagnosis of esophageal carcinoma was based on the eighth edition of the Union for International Cancer Control (UICC) tumor-node-metastasis cancer staging system.[18] Preoperative chemoradiotherapy was not provided. The inclusion criteria specified patients 18 to 85 years old with cT1–3 or cN0–3 disease[18] who had undergone upper mediastinal lymphadenectomy, simultaneous esophagectomy, and reconstruction.

A neck procedure around the trachea and left RLN via the cervical wound had been performed in both two- and three-field lymphadenectomies. Three-field lymphadenectomy included the additional dissection of clinically positive supraclavicular LNs.

All data were extracted from a prospectively registered database. This study was approved by the Institutional Review Board and the Ethics Committee of Kobe University.

Thoracic Procedure Criteria

Since 2011, all patients with esophageal carcinoma have undergone C-MIE in the prone position. Meanwhile, RAMIE was introduced in 2018 after approval by the Japanese insurance system in the same year. Therefore, RAMIE had been performed since 2018 by two surgeons who had experience with more than 200 C-MIEs. Since 2018, RAMIE has been performed for all surgical patients except those undergoing surgery when the robot was in use by other departments that shared its use.

Thoracic Procedure

All the patients underwent RAMIE (using the da Vinci Xi surgical system, Intuitive Surgical, Inc., Sunnyvale, CA) with radical mediastinal lymphadenectomy in the prone position. With the patient under single-lumen tracheal tube intubation, a blocker was inserted into the right bronchus for one-lung ventilation anesthesia. All the patients were placed in the prone position, after which five ports were inserted into the intercostal space (ICS). Four 8- or 12-mm ports were inserted respectively into the third, fifth, seventh, and ninth ICSs along the middle axillary line. A da Vinci stapler was inserted into the thoracic cavity through 12-mm ports, and an assistant port was inserted into the fifth ICS on the anterior axillary line (Fig. 1A). The chest cavity was inflated using carbon dioxide insufflation at a pressure of 8 mmHg.

Traditional and Novel Lymphadenectomy Along the Left RLN

Concept of the Traditional Bascule Method Since 2015, the bascule method had been adopted for lymphadenectomy along the left RLN during C-MIE.[8,9] Specifically, the fundamental concept behind the bascule method involves drawing the proximal portion of the divided esophagus and two-dimensional membrane, which includes the left RLN and LNs. This technique simplifies recognition of the two-dimensional membrane, identification and reliable cutting of the tracheoesophageal artery, and distinction of the left RLN from the LNs.[8,9]

Procedures of the Traditional Bascule Method First, pleura alone is cut behind the upper esophagus. To mobilize the upper esophagus from the trachea, arteries flowing into the longitudinal anastomosis of the trachea (vascular plexus on the tracheal wall) should be cut. The esophagus then is divided at the level of the aortic arch using linear stapling to obtain flexibility in the proximal portion of the divided esophagus. Drawing the divided

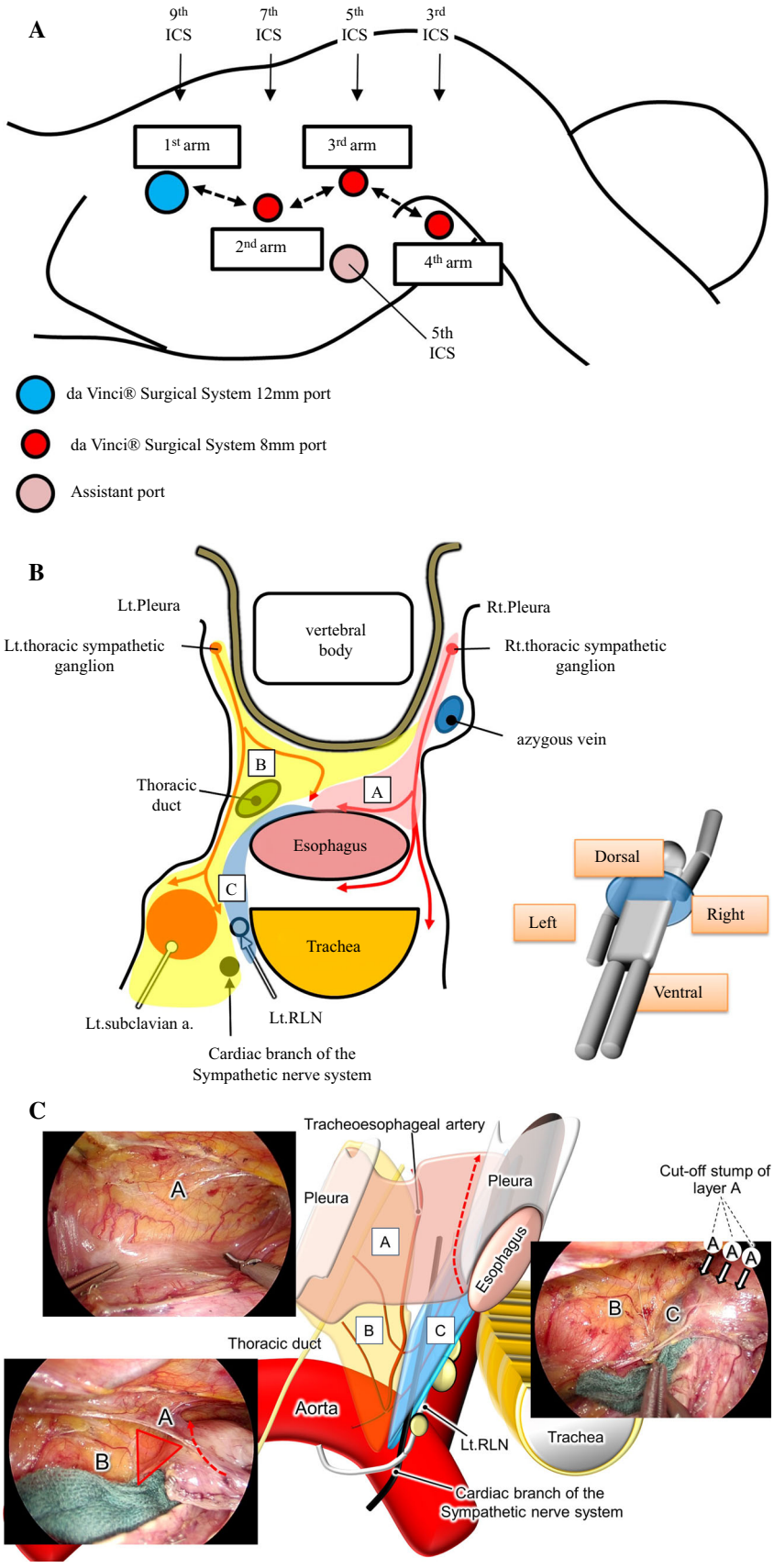

FIG. 1 **A** Patient positioning and robotic deployment for robot-assisted minimally invasive esophagectomy (RAMIE). Ports are inserted into the intercostal spaces along the middle axillary line. **B** The basic anatomic concept of the modified bascule method. The left upper mediastinum comprises three layers: layer A (autonomous nerve branches from the right thoracic sympathetic ganglion), layer B (the thoracic duct and autonomous nerve branches from the left thoracic sympathetic ganglion), and layer C (left recurrent laryngeal nerve [RLN] and lymph nodes [LNs] along the nerve. **C** Three-dimensional image of layers A, B, and C. Drawing of the proximal portion of the divided esophagus toward the right side and exfoliation of the gap allows for the easy recognition of the inverted triangle space (red inverted triangle) created by the three layers, A, B, and C. Layer C, which includes the left RLN and LNs, is the target of lymphadenectomy

esophagus makes it easy to confirm the esophageal mesenteriolum-like membrane, which includes the left RLN and LNs along the nerve. At this point, this membrane still consists of multiple layers (video 1).

Concept of a Novel Modified Bascule Method The novel "modified bascule method" was developed for RAMIE based on recognizing substantial layers to simplify the left upper mediastinum anatomy. The basic anatomic concept of the modified bascule method is that the left upper mediastinum consists of three layers (Fig. 1B). Specifically, these three layers include layer A (consisting of autonomous nerve branches from the right thoracic sympathetic ganglion), layer B (consisting of the thoracic duct [TD] and autonomous nerve branches from the left thoracic sympathetic ganglion), and layer C (consisting of the left RLN and LNs along the nerve) (Fig. 1B).

A three-dimensional image of layers A, B, and C is presented in Fig. 1C. After the esophagus is divided and the proximal portion of the divided esophagus is drawn toward right side, recognizing the inverted triangle space through the exfoliating the gap between the three layers becomes easy. Layer B, which covers the TD, should be preserved. Layer A should be cut along the esophagus given that only layer C is the target for lymphadenectomy along the left RLN (Fig. 1C).

Procedures of a Novel Modified Bascule Method Exfoliation of the gap between layers A, B, and C can be performed easily using robotic articulated forceps (Fig. 2, top left and right). Layer A is cut along the divided upper esophagus, which subsequently accentuates layer C (Fig. 2, bottom left and right, video 2). From the ventral side to the dorsal side, LNs are collected between the left RLN and the proximal portion of the divided esophagus (Fig. 3, top left and right).

After this procedure, only the left RLN remains attached to layer C. The LNs collected toward the esophagus are hidden behind the green gauze (Fig. 3, bottom left). Layer C then is cut between the left RLN and the LNs collected toward the esophagus. Next, the left RLN is attached to the residual layer C to preserve immobilization and stability (Fig. 3, bottom right). In the cranial area, paracervical esophageal LNs are dissected via the thoracic cavity, with preservation of the left RLN attached to the residual layer C (Fig. 4, top left and right).

Finally, the lymphatic chain is cut using clips and scissors (Fig. 4, bottom left). Dissected LNs are attached to the resected layer C with the esophagus (Fig. 4, bottom right; Fig. 5, top left), while the preserved left RLN is attached to the residual layer C and ventral tissue, leading to the immobilization and stability of the nerve (Fig. 4, bottom right; Fig. 5, top right and bottom left). Through the cervical wound, the clip used for cutting the lymphatic chain after paracervical esophageal LN dissection in the thoracic procedure can be confirmed inside the left RLN (Fig. 4, bottom left and right; Fig. 5, bottom right) (video 3).

Outcomes

Postoperative Clinical Course Evaluation The following parameters were assessed: operative time for the overall and thoracic procedure including the console part; number of harvested LNs of the thoracic portion and along the left RLN; mortality rate; incidence rates of left RLN palsy, pneumonia, and anastomotic leakage; and postoperative hospital stay. Postoperative morbidities were analyzed according to the Clavien–Dindo (C–D) classification system.[19] Additionally, left RLN and anastomotic leakages were estimated using Edophagectomy Complications Consensus Group (ECCG) definitions.[20] Regarding pneumonia, the Uniform Pneumonia Score also was used. A score of two points or more with at least one point assigned based on pulmonary radiography indicated treatment of suspected pneumonia.[21] For all the patients, RLN palsy was estimated by evaluating vocal cord mobility under laryngoscoy on postoperative day 7.

All continuous data are presented as medians (ranges), whereas all categorical data are presented as numbers (percentages). All statistical analyses were performed using JMP 14 (SAS Institute, Cary, NC, USA).

RESULTS

Patient Characteristics

The patient characteristics are outlined in Table 1. Between 2018 and 2020, 46 patients (29 men and 17 women with a median age of 67 years; range 49–82 years) underwent RAMIE in the prone position by two surgeons. For 57% of the patients, neoadjuvant chemotherapy was introduced. Three-filed lymphadenectomy was performed for only 7% of the patients (Table 1).

Operative Outcomes

The operative outcomes are summarized in Table 2. The median time for the thoracoscopic procedure was 438 min (range, 344–625 min), and console time was 351 min (range, 273–518 min). The median number of LNs harvested from the thoracic portion and along the left RLN were respectively 24 (range, 8–34) and 4 (range, 0–10). The mortality rate was 0%.

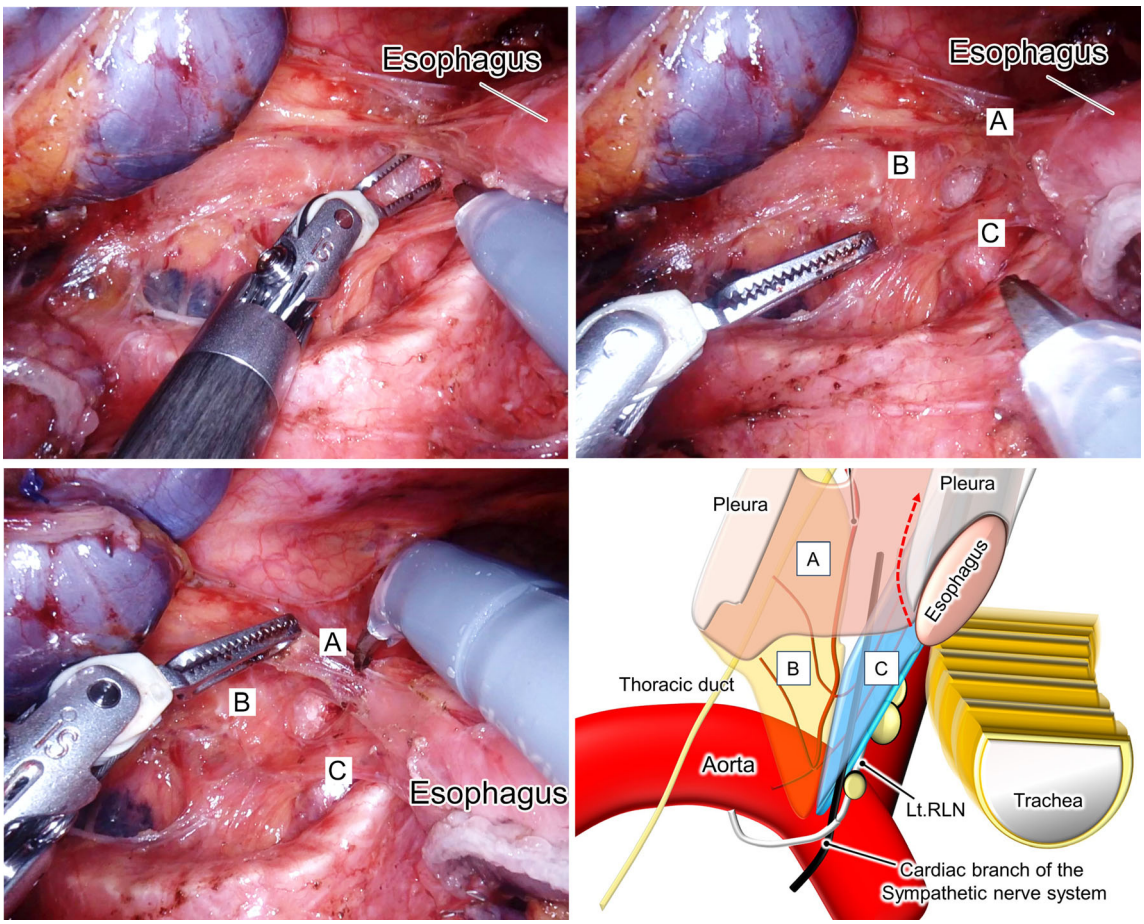

FIG. 2 Exfoliation of the gap between layers A, B, and C. Top left and right: Exfoliation of the gap between layers A, B, and C using robotic articulated forceps allows for the easy identification of each layer. Bottom left and right: Layer A is cut along the divided upper esophagus, subsequently highlighting layer C

The patients experienced postoperative left RLN palsy (C–D[19]: grade 1 [n = 9, 19%], grade 2 or higher [n = 0, 0%]; ECCG definitions[20]: type 1 [n = 9, 19%]; type 2 or higher [n = 0, 0%]), pneumonia (C–D[19]: grade 1 [n = 1, 2%], grade 2 [n = 6, 13%], grade 3 or higher [0%]; Uniform Pneumonia Score[21]: 0 [n = 38, 83%], 1 [n = 1, 2%], 2 [n = 3, 6%], 3 [n = 4, 9%], $\geq$4 [n = 0, 0%]), and anastomotic leakage (C–D[19]: grade 1 [n = 0, 0%], grade 2 [n = 1, 2%], grade 3a [n = 8, 17%], grade $\geq$3b [n = 0, 0%]; ECCG definitions[20]: type 1 [n = 1, 2%], type 2 [n = 8, 17%], type 3 [n = 0, 0%]).

DISCUSSION

The current study found that with RAMIE using the new modified bascule method, lymphadenectomy along the left RLN was performed safely even during the learning phase by surgeons comfortable performing C-MIE via the traditional bascule method. It is important to start a new procedure (RAMIE) at the same quality of the latest traditional procedure (C-MIE). Contrary to expectations, evidence showing whether RMIE is superior to C-MIE in preventing RLN palsy has been unclear.[14,22] Certainly, skeletonization of the RLN has been made easier with robotics given the articulated and non-tremulous arms. However, to prevent palsy during lymphadenectomy along the RLN, care should be taken to avoid touching and stretching of the RLN. Accordingly, maintaining the left RLN in its normal anatomic position has been found to prevent it from being touched and stretched.[23] As shown in Figs. 3, 4 and 5, the left RLN has been attached to layer C during lymphadenectomy by the modified bascule method, allowing it to maintain its normal anatomic position.

The TD ascends from the caudal side to the cranial side beside the esophagus and left RLN. Thoracic duct resection has been recommended for sufficient mediastinal lymphadenectomy around the TD.[24] However, as we showed previously, not only does TD resection not improve survival among patients with ESCC, but it also increases left RLN palsy rates.[25] This occurs because the TD and left

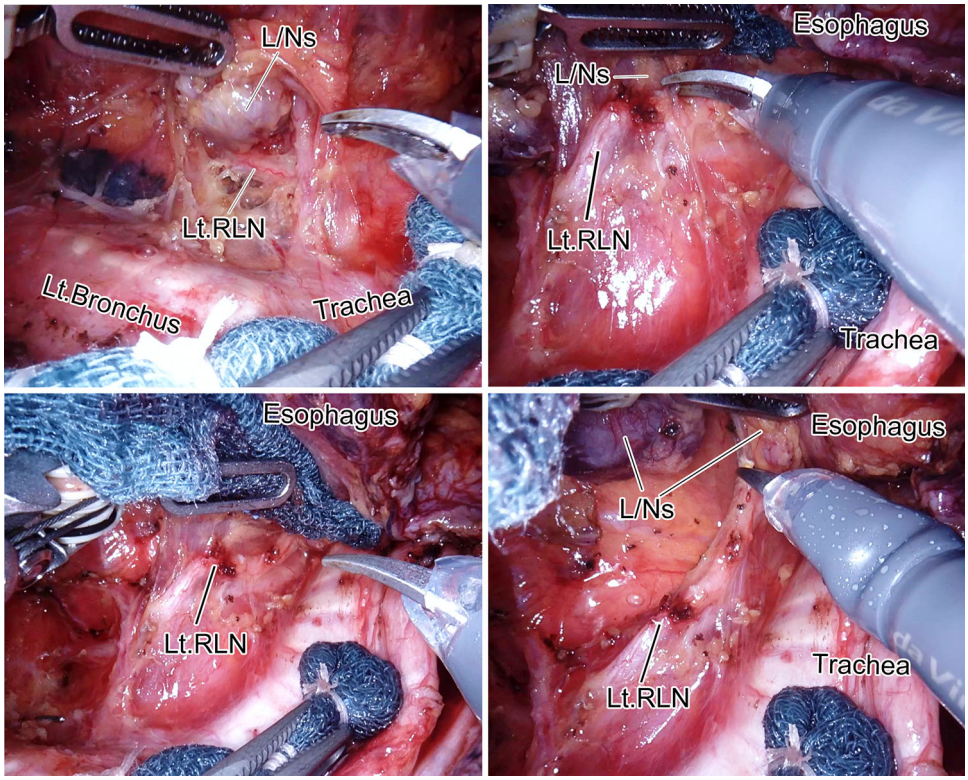

FIG. 3 Collection of lymph nodes (LNs) toward the esophagus while the left recurrent laryngeal nerve (RLN) is kept attached to layer C. Inside layer C. Top left and right: From the ventral to the dorsal side, LNs are collected between the left RLN and the proximal portion of the divided esophagus. Bottom left: LNs are collected toward the esophagus using the green gauze. With this procedure, only the left RLN remains attached to layer C. Bottom right: Layer C is cut behind the left RLN. LNs are dissected with the esophagus. After attachment of the left RLN to the residual layer C, no touching or stretching of the nerve occurred during lymphadenectomy, which could decrease RLN palsy rates

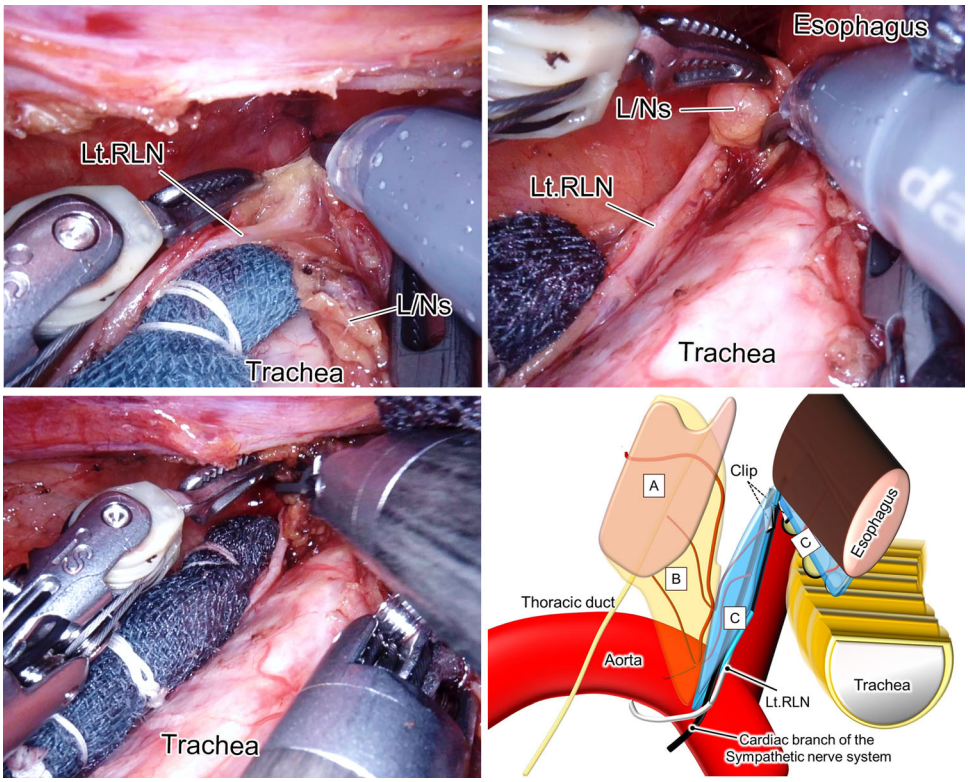

FIG. 4 En bloc lymphadenectomy while the left recurrent laryngeal nerve (RLN) is kept attached to layer C. Top left and right: In the cranial area, paracervical esophageal lymph nodes (LNs) are dissected via the thoracic cavity while the left RLN attached to the residual layer C is preserved. Bottom left: Finally, the lymphatic chain is cut using clips and scissors. Bottom right: Final image of the modified bascule method. In particular, dissected LNs are attached to the resected layer C with the esophagus, while the left RLN is attached to the residual layer C

RLN run parallel to each other in the upper mediastinum but get closer at the thoracic inlet. Thus, injury of the left RLN might occur within this area during TD resection.[25]

The concept behind the modified bascule method involves covering the TD with layer B, which consists of branches from the left thoracic sympathetic ganglion. By

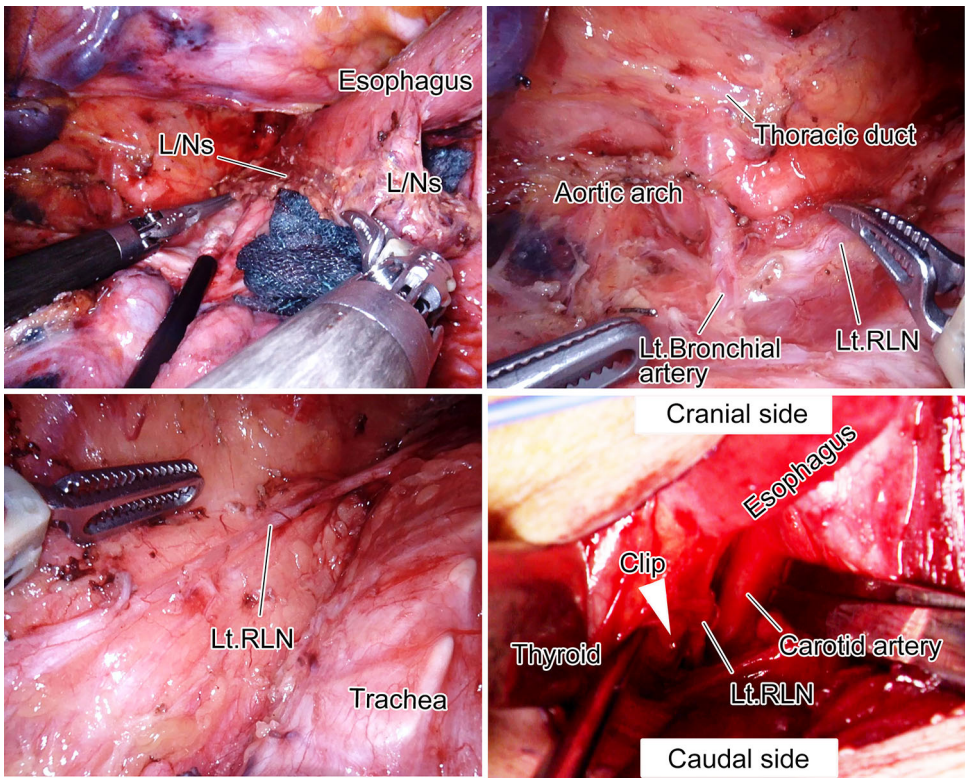

FIG. 5 Mediastinal and cervical views after lymphadenectomy. Top left: Dissected lymph nodes (LNs) are attached to the resected layer C with the esophagus. Top right and bottom left: The preserved left recurrent laryngeal nerve (RLN) is attached to the residual layer C, leading to fixation to ventral tissue. Bottom right: Through the cervical wound, the clip used for cutting the lymphatic chain at the end of thoracic procedure can be confirmed (arrow)

TABLE 1 Demographic and clinical characteristics

Characteristics	*n* (%)
Age: years (range)	
Sex	
Male/female	29 (63)/17 (37)
Tumor location	
Upper/middle/lower	12 (26)/18 (39)/16 (35)
Histology	
SCC/others	39 (85)/7 (15)
Depth of tumor invasion	
cT1/cT2/cT3	20 (43)/6 (14)/20 (43)
Lymph node metastasis	
cN+/cN–	24 (52)/22 (48)
UICC cStage	
1/2/3/4	20 (43)/9 (20)/15 (33)/2 (4)
Neoadjuvant chemotherapy	
Yes/no	26 (57)/20 (43)
Abdominal procedure	
Laparoscopy/open	45 (98)/1 (2)
Lymph node dissection	
3-Field/2-field	3 (7)/43 (93)

SCC, squamous cell carcinoma; UICC, Union for International Cancer Control

recognizing of layer B, a certain portion of the TD can be preserved, which consequently prevents left RLN palsy. However, in some cases, TD resection might be recommended. For bulky and invasive tumors that may need TD resection, another approach might be considered.

As previously mentioned, the fundamental concepts behind the modified bascule method include four factors; identifying and segregating target layer C, which includes the left RLN and LNs; recognizing layer B, which leads to TD preservation; collecting LNs between the left RLN and esophagus without injuring layer C, and; cutting layer C while keeping the left RLN attached to it, possibly leading to an ideal lymphadenectomy along the left RLN.

Of course, the concept of the modified bascule method may possibly be indicated not only for RAMIE but also for C-MIE. However, RAMIE using articulated robot arms preferably embodies the concept of the modified bascule method, which requires finer techniques.

Another feature of RAMIE with the modified bascule method is that it provides satisfactory results even when performed during its learning period because it allows the left RLN to maintain its normal anatomic position. Indeed, the median number of LNs harvested along the left RLN was four (range, 0–10). The left RLN palsy rate was 19%. All the palsies were grade 1 and type 1.[19,20] These results were not inferior to those of previous studies because the

TABLE 2 Operative outcomes

Characteristics			
Median operative time: min (range)			
Overall procedure		803 (603–1327)	
Thoracic procedure		438 (344–625)	
Console part		351 (273–518)	
Median no. of harvested lymph nodes (range)			
Thoracic portion		24 (8–34)	
Along the left RLN		4 (0–10)	
Mortality: *n* (%)		0 (0)	
Median postoperative hospital stay: days (range)		26 (15–96)	
Left RLN palsy *n* (%)		9 (19)	
C–D classification[a] *n* (%)		ECCG definitions[b] *n* (%)	
1	9 (19)	Type I	9 (19)
≥ 2	0 (0)	≥ Type II	0 (0)
Pneumonia: *n* (%)		7 (15)	
C–D classification[a]		Uniform Pneumonia Score[c]	
1	1 (2)	0	38 (83)
2	6 (13)	1	1 (2)
≥ 3	0 (0)	2[d]	3 (6)
		3	4 (9)
		≥ 4	0 (0)
Anastomotic leakage		9 (19)	
C–D classification[a]		ECCG definitions[b]	
1	0 (0)	Type 1	1 (2)
2	1 (2)		
3a	8 (17)	Type 2	8 (17)
≥ 3b	0 (0)	Type 3	0 (0)

RLN, recurrent laryngeal nerve; C–D, Clavien–Dindo classification

[a]Grades are based on the Clavien–Dindo classification of surgical complications.

[b]Types are based on the Edophagectomy Complications Consensus Group definitions.

[c]Scores are based on the Uniform Pneumonia Score, which is a definition for hospital-acquired pneumonia after esophagectomy.

[d]A score ≥2 with at least 1 point on pulmonary radiography indicates treatment of suspected pneumonia.

mean number of harvested LNs along the left RLN was five, and the left RLN palsy rates were 17.5% (7/40) to 21% (7/34).[26,27]

A study including more than 300 RAMIEs concluded that the learning curve for RAMIE consisted of the first 70 cases.[16] Considering the limited number of esophagectomies for esophageal carcinoma relative to the gastrectomies for gastric carcinoma, the colectomies for colorectal carcinoma, and other surgeries, a surgeon may need some time to experience 70 RAMIEs. Therefore, a procedure that provides satisfactory results during its learning phase can be quite significant and may suggest much better outcomes after the learning curve.

To date, although ESCC has remained more common in Eastern countries, adenocarcinoma has been more popular in Western countries.[1,28] Thus, some discrepancies in the concept of lymphadenectomy along the RLN may exist between the two regions. However, studies have shown that LN metastasis rates along the RLN are high among patients who have cardia gastric adenocarcinoma (CGA) with esophageal involvement of more than 4 cm.[4] Considering the increasing occurrence of CGA in the Western world due to increasing incidences of gastroesophageal reflux disease and obesity, a growing demand for lymphadenectomy along the RLN may be expected not only for ESCC, but also for esophageal adenocarcinoma.[29] Thus, our novel modified bascule method for upper mediastinal lymphadenectomy can be useful for surgeons practicing in both Eastern and Western countries.

One limitation of the present study was its single-center retrospective design. Therefore, larger prospective or retrospective studies are required to validate the findings presented in this report.

CONCLUSIONS

The current study showed that our novel modified bascule method for RAMIE based on a logical and simple understanding of the left upper mediastinum anatomy can promote feasible lymphadenectomy along the left RLN even when performed during the learning period.

DISCLOSURES

There are no conflicts of interest.

ACKNOWLEDGMENTS Informed consent was obtained from patients for the publication of this report and any accompanying data. Patient anonymity was maintained.

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