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TECHNIQUES

A new method (the "Bascule method") for lymphadenectomy along the left recurrent laryngeal nerve during prone esophagectomy for esophageal cancer

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Abstract
Background In esophageal cancer, lymph nodes along the recurrent laryngeal nerves (RLNs) are thought to be highly involved. Complete dissection of these lymph nodes is recommended but there is limited working space in the left upper mediastinum and advanced dissection skills are required. We present herein a new method for lymphadenectomy along the left RLN, called the Bascule method during prone esophagectomy.
Methods The fundamental concept of this new method is to draw the proximal portion of the divided esophagus and tissue that includes the left RLN and lymph nodes through a gap between the vertebral body and the right scapula. Using this technique, a two-dimensional membrane, similar to the "esophageal mesenteriolum" (lateral pedicle), will be easily recognizable. Identification and reliable cutting of the tracheoesophageal artery and distinguishing the left RLN from the lymph nodes should be easy. This technique was evaluated in 39 consecutive cases of prone esophagectomy for squamous cell cancer.
Results There were 18 patients who underwent the new method (Bascule method; Bm) and 21 patients who underwent the conventional method (Cm). The duration of the thoracic procedure and dissection along the left RLN was significantly shorter in Bm group than in Cm group (258 ± 30 vs. 291 ± 39 min; $p = 0.007$ and 66 ± 9 vs. 75 ± 14 min; $p = 0.036$, respectively). Estimated blood loss in Bm group was 20 ± 11 g compared to 38 ± 32 g in Cm group ($p = 0.028$). No intraoperative morbidity related to the left RLN was observed in either group. The hoarseness rate in Bm group was 28 %, which was lower than that in the Cm group (48 %).
Conclusions The Bascule method for lymphadenectomy along the left RLN during prone esophagectomy is technically safe and feasible and reduces operative time and blood loss.

Keywords Prone esophagectomy · Lymphadenectomy · Left recurrent laryngeal nerve · Esophageal cancer · Lateral pedicle · Bascule method

Esophageal cancer, one of the deadliest cancers in the world, is mainly found in Asia and East Africa [1]. In Japan, esophagectomy with extended lymphadenectomy improves prognosis [2], but is associated with high morbidity and mortality [3]. In particular, as a major lymphatic chain into the neck, the lymph nodes along the recurrent laryngeal nerves (RLNs) are thought to be highly involved, and complete dissection of these nodes is recommended [2, 4–7]. On the other hand, the left RLN has a long course from the aortic arch to the neck, so injury to the nerve can occur easily during surgery. Cushieri et al. first reported on the thoracoscopic approach, which has attracted attention as a potentially less invasive procedure [8]. Recently, some investigators, including Palanivelu et al., have reported that a clear operative field could be obtained during esophagectomy in the prone position due to the working space created by gravity and pneumothorax [9]. Noshiro et al. reported that prone

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esophagectomy provides better surgeon ergonomics and better operative exposure around the left RLN during an aggressive esophagectomy [10]. However, in the left upper mediastinum, the working space for dissecting the lymph nodes along the left RLN is limited and advanced skills in dissection are required.

We present herein a new method for lymphadenectomy along the left RLN, named the Bascule method, which is technically easy, safe, and feasible during prone esophagectomy.

Patients and methods

From January 2013 to February 2014, a single-institution nonrandomized retrospective study was performed. In our institute, all surgical candidates with esophageal cancer underwent prone esophagectomy. We collected the results of 39 consecutive curative procedures for esophageal squamous cell carcinoma. The method of lymphadenectomy was decided preoperatively. There were 18 patients who underwent the new method (Bascule method; Bm) and 21 patients who underwent the conventional method (Cm). Lymphadenectomy along the left LRN was divided into 3 parts (Processes 1, 2, and 3). In the present study, cancer stage was determined according to the seventh edition of the American Joint Committee on Cancer (AJCC) Staging Manual [11]. All patients were staged preoperatively with endoscopy and enhanced computed tomography. To permit easy retraction of the trachea, a single-lumen tracheal tube was inserted into the trachea and a blocker was inserted into the right bronchus for one-lung anesthesia before the procedure. The patient was initially placed in the prone position. Five 5- or 12-mm ports were inserted in the third intercostal space (ICS) behind the midaxillary line, the fifth and seventh ICS on the posterior axillary line, the eighth ICS on the midaxillary line, and the ninth ICS on the scapular angle line, and the chest cavity was inflated via the ports with a CO_2 insufflation pressure of 6 mmHg. The endoscope was usually inserted through the ninth ICS. All procedures were performed by a single surgeon (T.O.), who had performed more than 60 esophagectomies in the prone position with conventional extended lymphadenectomy prior to this study.

Surgical technique

Process 1 (common to both methods)

① The thoracic duct is preserved. The upper esophagus is mobilized from the trachea by cutting the primary and secondary tracheal arteries (Fig. 1).

② Next, tissue that includes the left RLN and lymph nodes is dissected sharply just along the trachea and the left bronchus to delineate the ventral border of the dissection.

③ The esophagus is then divided at the level of the aortic arch by linear stapling to facilitate lymph node dissection on the left side of the esophagus [10].

Process 2

Bascule method (new method)

④ The tissue that includes the left RLN and lymph nodes is not released from the divided esophagus proximally. Using a traction suture, the proximal portion of the divided esophagus is drawn through a gap between the vertebral body and the right scapula (Fig. 2, *top left*). Tissue that includes the left RLN and the lymph nodes is also drawn through, so that a membrane similar to the "esophageal mesenteriolum" (lateral pedicle) is extended, which makes it more easily recognizable (Fig. 2, *top right, bottom left*).

⑤ Exposure of the left RLN and the division of lymph nodes along the left RLN with a merkmal clip at the level of carina is preformed next (Fig. 2, *bottom right*; Fig. 3, *bottom left*). The tissue and the esophagus are drawn through with good countertraction (Fig. 3, t*op left*) so that the tracheoesophageal artery is easily identified in the "esophageal mesenteriolum" (lateral pedicle).

⑥ Consequently, the surgeon can confidently cut this vessel (Fig. 3, *top right*, *bottom right*). The left hand of the surgeon is released from grasping the lymph nodes and is able to be used for fine dissection, which includes distinguishing the left RLN from the lymph nodes (Fig. 4, *top right*). The appearance of the proximal part of the esophagus, which drew the tissue including the left RLN and lymph nodes, looks like a bascule bridge, so we named this new method the Bascule method.

⑦ On the cranial side, the proximal esophagus and the lymph nodes are flipped up to the right and posteriorly (Fig. 4, *top left*). A few esophageal branches of the left RLN are transected sharply (Fig. 4, *bottom left and right*).

⑧ The cranial end of the lymphatic chain along the left RLN is cut with a merkmal clip between the left RLN and the trachea (Fig. 5, *top left and right*). Finally, the dissected lymph nodes along the left RLN (clip to clip), which are attached to the esophagus (Fig. 5, *bottom left*), and the preserved left RLN, which is attached to the "esophageal mesenteriolum" (lateral pedicle), (Fig. 5, *bottom right*) are confirmed.

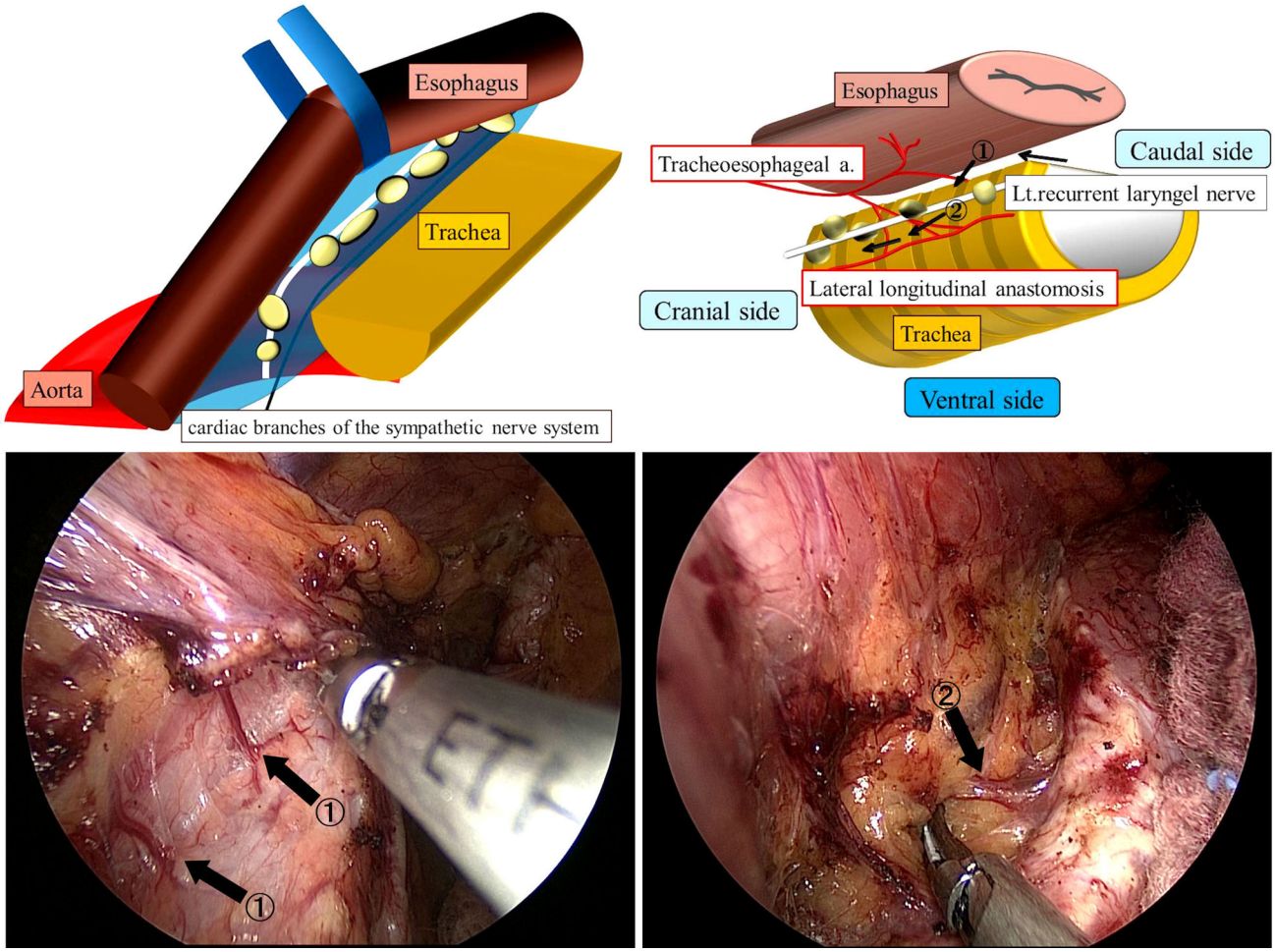

Fig. 1 *Top left* With traction on the upper esophagus, tissue that includes the left RLN and lymph nodes is dissected sharply just along the trachea and the left bronchus to make the ventral border of dissection. Cutting the esophagus in the middle is necessary because the esophagus is a hindrance in the operating field. *Top right* After transection of the tracheoesophageal fascicle, secondary tracheal branches arising from the primary esophageal artery to the posterior tracheal wall (*arrow* ①) and the primary tracheal artery that passes directly to the left of the lateral tracheal wall and the longitudinal anastomosis (*arrow* ②) are dissected to start the lymphadenectomy along the left RLN. *Bottom left* The trachea is rolled back carefully and positioned to the right and posteriorly by a grasper with a small piece of gauze in order to explore the left side of the trachea. Secondary tracheal branches arising from the primary esophageal artery (*arrow* ①) to the posterior tracheal wall should be cut. *Bottom right* The primary tracheal artery (*arrow* ②), which flows in the lateral longitudinal anastomosis from the tracheoesophageal artery, is coagulated and dissected with an ultrasonically activated scalpel

Conventional method The tissue surrounding the left RLN and lymph nodes is released from the divided esophagus proximally, toward the neck. The left hand of the surgeon maintains hold of the lymph nodes to separate them from left RLN. Finally, the left RLN is sharply isolated from the explored tissue.

Process 3 (common to both methods)

⑨ Lymph nodes along the left RLN in the caudal part of aortic arch are dissected. The recurrent portion of the left RLN, left vagus nerve, and one or two left bronchial arteries are identified and preserved on the face of the trunk of the pulmonary artery [10].

Table 1 summarizes the steps of the Bascule method.

Evaluation of the technique

The operative time for the lymphadenectomy along the left LRN (which was divided into 3 processes) and for the entire thoracic procedure; estimated blood loss during the thoracic procedure; number of harvested lymph nodes during the entire thoracic procedure and along the left RLN; intraoperative and postoperative morbidity related to the left LRN, such as the incidence of hoarseness and

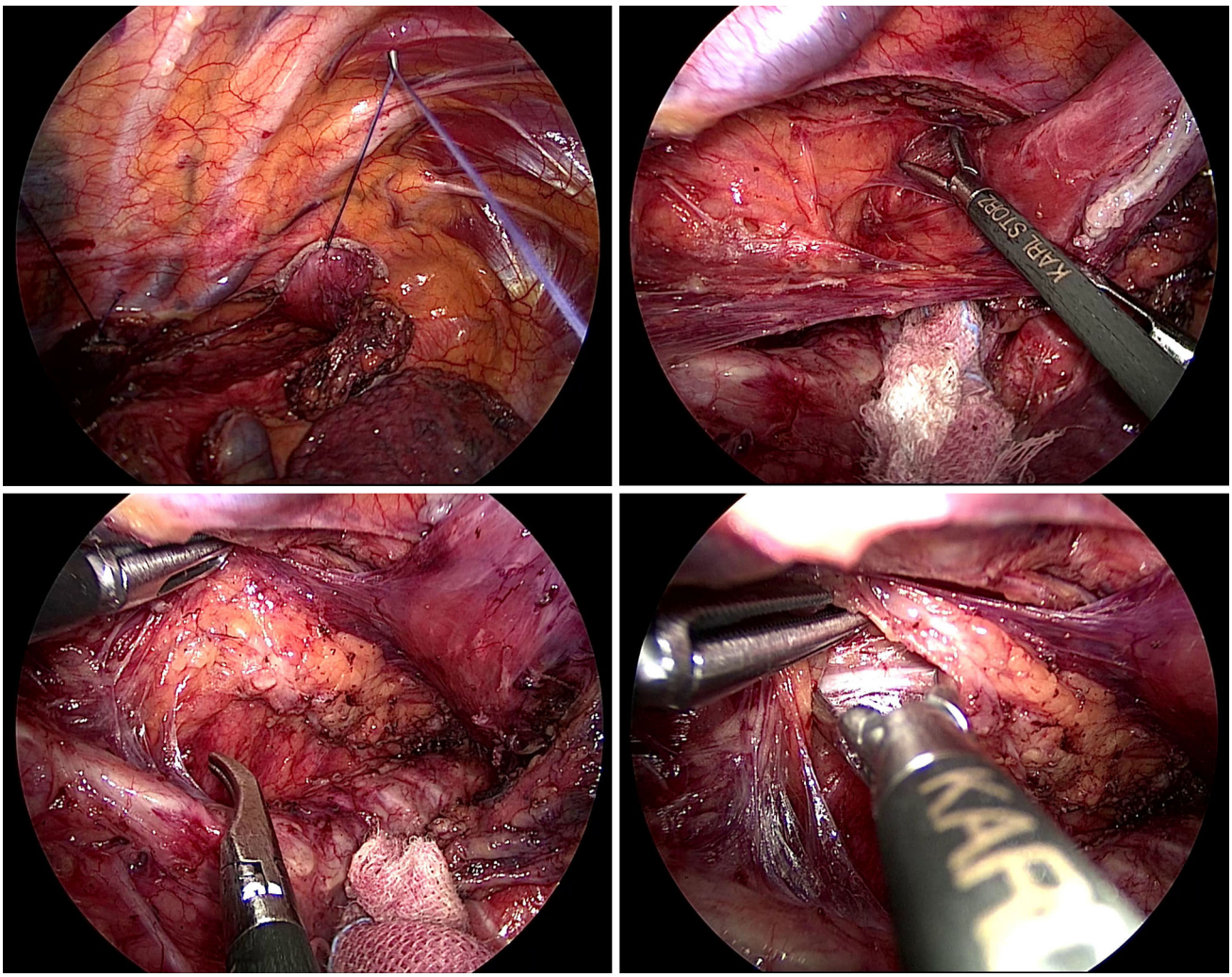

Fig. 2 *Top left* The proximal part of the divided esophagus is drawn between the landmarks, the vertebral body and the right scapula, with a traction suture. *Top right* A membrane similar to the "esophageal mesenteriolum" (lateral pedicle) that includes the left RLN and lymph nodes is exfoliated from the layer that includes the thoracic duct. *Bottom left* By pulling on the proximal side of the divided esophagus, the tissue that includes the left RLN and the left paratracheal and infra-aortic arch lymph nodes is also elevated through the esophageal branch of the left RLN. It is dissected sharply just along the trachea and the left main bronchus to make the ventral and cranial borders of the dissection. The left RLN and the lymph nodes along the left RLN are within the "esophageal mesenteriolum" (lateral pedicle). *Bottom right* The left RLN is exposed at the level of carina on the inward side of the "esophageal mesenteriolum" (lateral pedicle)

aspiration; time to resumption of ingestion; and duration of postoperative hospital stay were compared in these two groups.

Assessment of laryngopharyngeal function

Hoarseness was determined by auditory impression. Aspiration was assessed by videofluorography or clinical condition during ingestion.

Statistical analysis

Differences between the two groups were analyzed using the χ^2 test, Mann–Whitney U test, and Student's t test, as appropriate. p values less than 0.05 were considered statistically significant.

Results

Patient and tumor characteristics are listed in Table 2. There were no significant differences between the two groups in age, gender, tumor location and depth, stage, and preoperative therapy (Table 2). The duration of the thoracic procedure was significantly shorter in Bm group compared to Cm Group (258 ± 30 vs. 291 ± 39 min, $p = 0.007$). The operative time for dissection along the left RLN was also significantly shorter in Bm group than in Cm

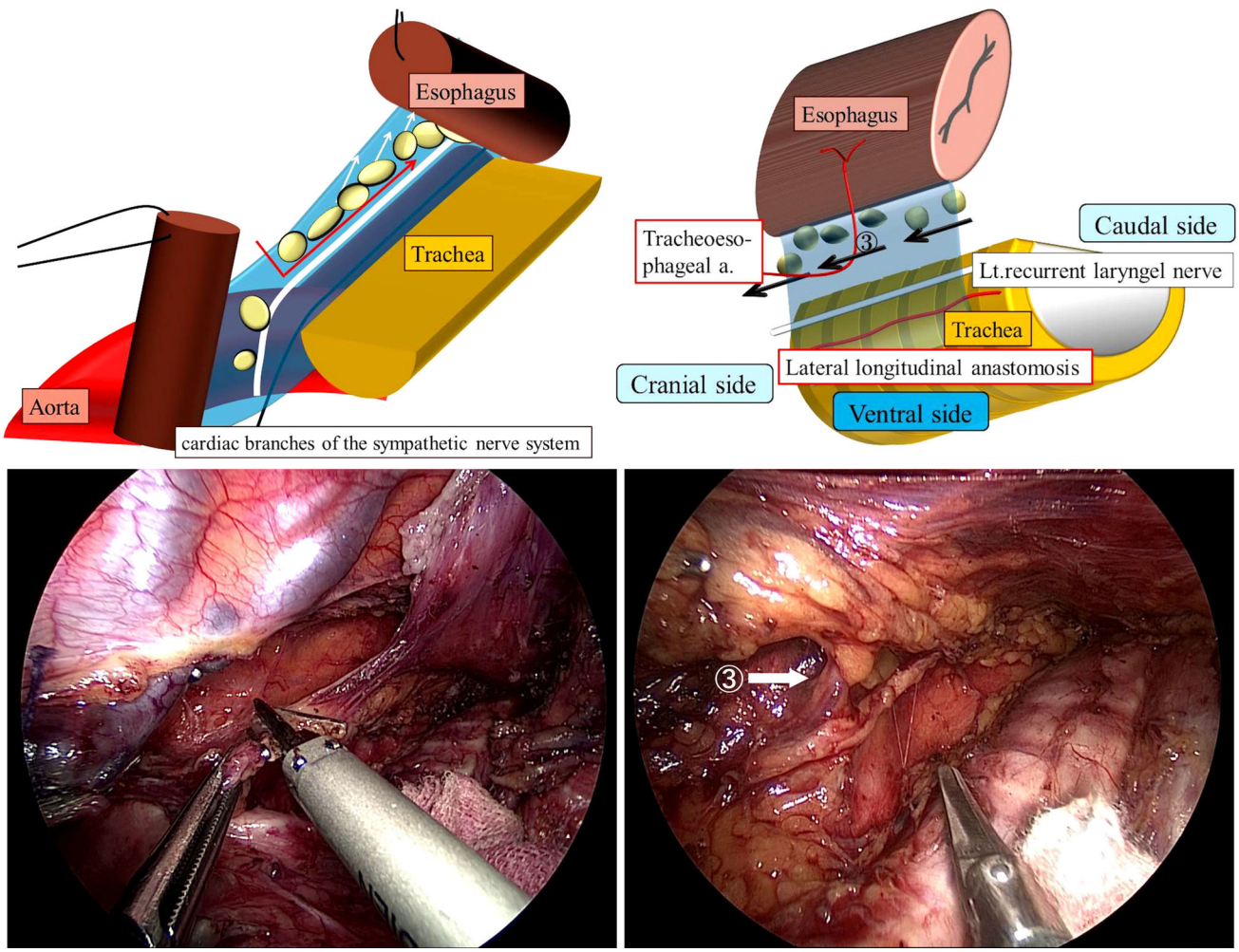

Fig. 3 *Top left* Lymph nodes along the left RLN and a part of the "esophageal mesenteriolum" (lateral pedicle) (*blue area*) are dissected toward the neck on the posterior side of the left RLN (*red arrow*). The tissue that includes the left RLN and lymph nodes along the left RLN near the esophagus are drawn (*white arrows*) with good countertraction so that the left hand of surgeon is freed from grasping the lymph nodes. *Top right* The tracheoesophageal artery (③) is easily recognized in the "esophageal mesenteriolum" (lateral pedicle). The surgeon can cut this vessel confidently with an ultrasonically activated scalpel. *Bottom left* Lymph nodes along the left RLN are divided with a merkmal clip at the level of the exposed left RLN. *Bottom right* Posterior to the left RLN, a part of the "esophageal mesenteriolum" (lateral pedicle) that includes the lymph nodes along the left RLN is dissected toward the neck. The tracheoesophageal artery (*arrow* ③), which runs perpendicular to the esophagus, could be recognized and confidently cut

group (66 ± 9 vs. 75 ± 14 min, $p = 0.036$). In particular, the duration of Process 2 was significantly shorter in Bm group than in Cm group (40 ± 5 vs. 47 ± 11 min, $p = 0.047$). Estimated blood loss in Bm group was 20 ± 11 g, which was significantly lower than that in Cm group (38 ± 32 g, $p = 0.028$). On the other hand, there were no significant differences between the two groups in the number of harvested lymph nodes along the left RLN ($p = 0.798$). Conversion to open surgery and intraoperative morbidity related to the left RLN did not occur in either group. The hoarseness rate in Bm group was 28 %, which was lower than the rate in Cm group (48 %), but this difference was not statistically significant ($p = 0.323$). None of the other operative results in groups Bm and Cm were statistically different (Table 3).

Discussion

In esophagectomy for esophageal cancer, extended lymphadenectomy improves the prognosis in Japan [2]. In particular, lymph nodes along the RLN are thought to be highly involved and complete dissection of these nodes is recommended [2, 4–7]. However, this surgical procedure involves high morbidity and mortality [3]. Osugi et al. reported that video-assisted thoracoscopic surgery (VATS),

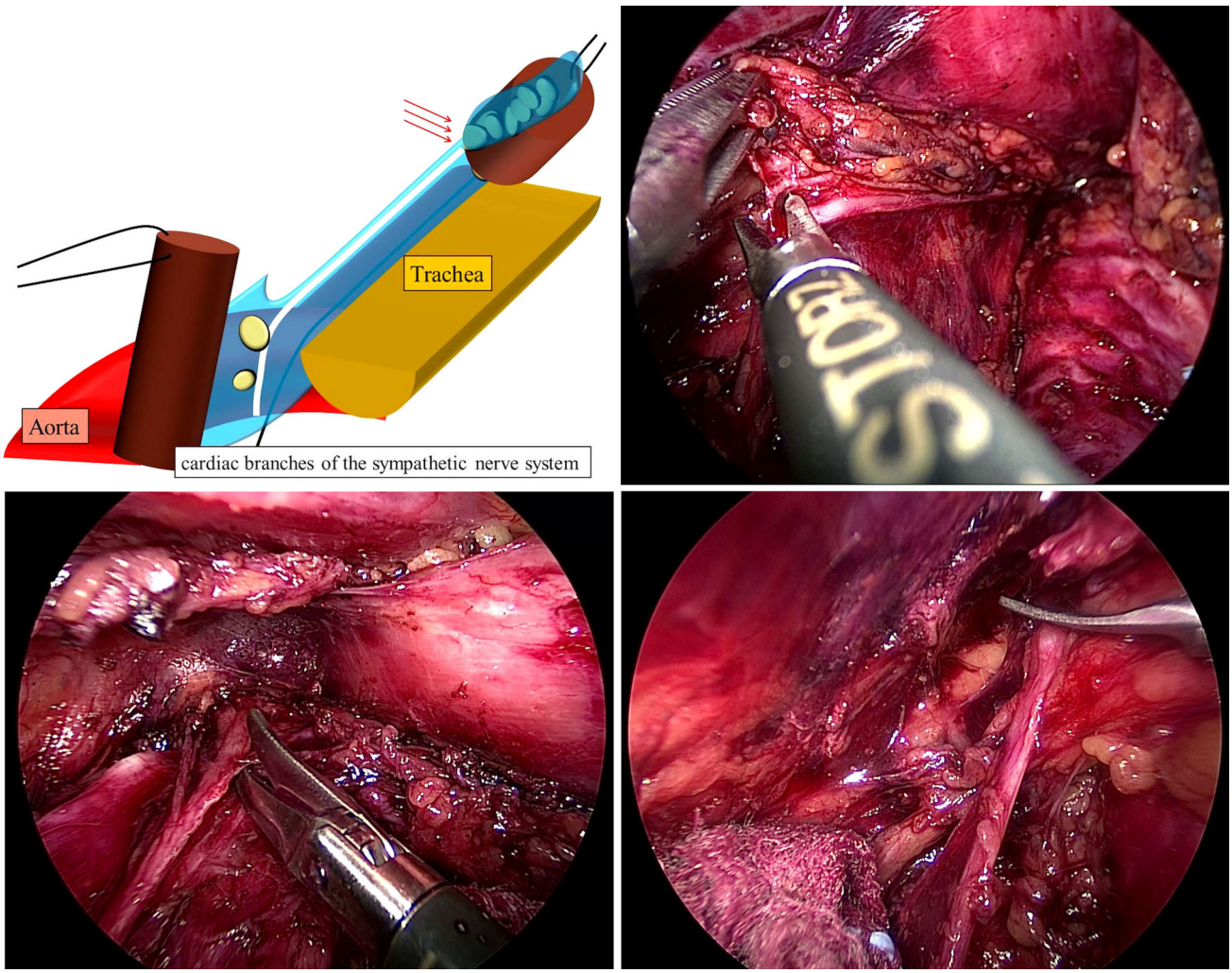

Fig. 4 *Top left* On the cranial side, lymph nodes along the left RLN exist only between the left RLN and the trachea, so approaching the lymph node dissection from the outside (*left side*) of the left RLN is logical. The proximal portion of the divided esophagus is flipped up to the right and posteriorly. *Top right* Lymph nodes along the left RLN are connected to the proximal portion of the divided esophagus. They are pulled through the esophageal branches of the left RLN. *Bottom left* On the cranial side, lymph nodes along the left RLN are also flipped up to the right with the esophagus so that ventral side of the left RLN is loose. A few esophageal branches of the left RLN are transected sharply. *Bottom right* The terminal end of the lymphatic chain along the left RLN is identified between the left RLN and the trachea, ventral to the left RLN

a less invasive method that preserves curability, provides comparable results to open radical esophagectomy [12]. However, dissecting the lymph nodes along the left RLN during VATS is challenging and requires substantial technical skill. In this procedure, there are three important anatomical structures: the left RLN, which should be preserved; lymph nodes, which should be dissected; and the left tracheoesophageal artery, which should be cut. Intermingling of these three components in the small left upper mediastinum complicates dissection of the lymph nodes along the left RLN. Understanding the interrelationship of these three anatomical structures and their logical separation is necessary. Concerning the blood supply, the tracheoesophageal artery splits to supply the esophagus and trachea as the primary esophageal and primary tracheal arteries, respectively. The primary esophageal artery frequently sends off smaller secondary tracheal branches to the posterior tracheal wall before it reaches the esophagus [13]. The primary tracheal artery and secondary tracheal branches should be cut on the left side of the trachea. Next, the layer including the thoracic duct should be exfoliated. The left RLN, lymph nodes along the left RLN, and the tracheoesophageal and primary esophageal arteries are then integrated into a two-dimensional membrane that looks like an "esophageal mesenteriolum." Salassa et al. described the lateral pedicle as consisting of an irregular sheet of connective tissue passing from the deep surface of the aorta and the innominate and subclavian arteries to the

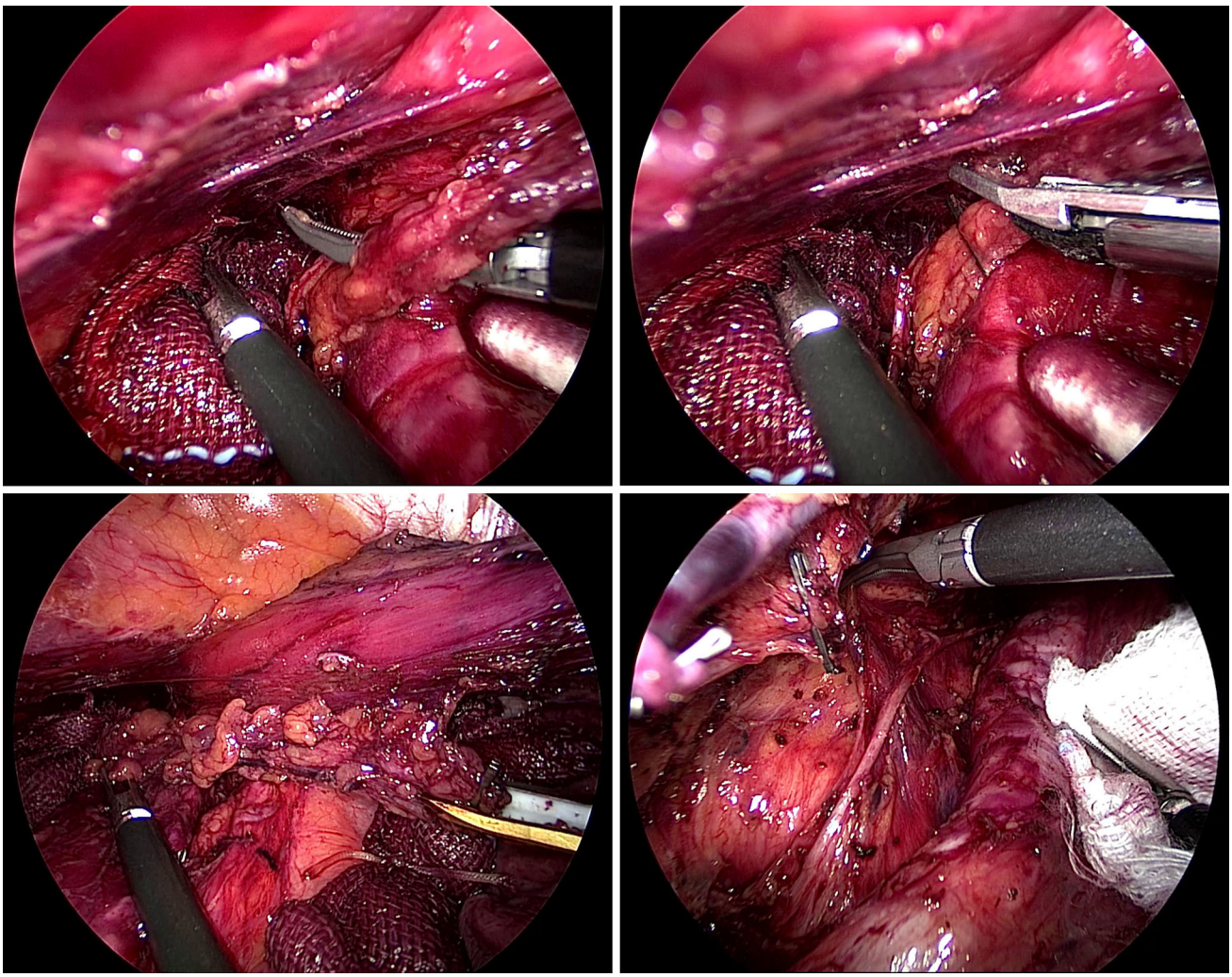

Fig. 5 *Top left and right* The terminal end of the lymphatic chain along the left RLN is cut with a merkmal clip. *Bottom left* Dissected lymph nodes along the left RLN (clip to clip) are attached to esophagus on the proximal side en bloc. *Bottom right* After lymph node resection, the preservation of the left RLN, which is attached to the "esophageal mesenteriolum" (lateral pedicle), is confirmed

Table 1 Summary of the Bascule method

Process	Steps
Process 1	①The upper esophagus is mobilized from the trachea by cutting the tracheal arteries
	②Tissue that includes the left RLN and lymph nodes is dissected sharply just along the trachea and the left bronchus
	③The esophagus is divided at the level of the aortic arch by linear stapling
Process 2	④Using a traction suture, the proximal portion of the divided esophagus and a membrane similar to the "esophageal mesenteriolum" (lateral pedicle) is drawn through a gap between the vertebral body and the right scapula
	⑤The left RLN is exposed and lymph nodes along the left RLN are divided with a merkmal clip at the level of carina
	⑥The surgeon confidently dissects the lymph nodes by cutting the "esophageal mesenteriolum" (lateral pedicle) on the posterior side of the left RLN
	⑦On the cranial side, the proximal esophagus and the lymph nodes are flipped up to the right and posteriorly. A few esophageal branches of the left RLN are transected sharply
	⑧The cranial end of the lymphatic chain along the left RLN is cut with a merkmal clip between the left RLN and the trachea
Process 3	⑨Lymph nodes along the left RLN in the caudal part of aortic arch are dissected

Table 2 Clinicopathologic characteristics of the patients with Bascule or conventional method

	Bm group	Cm group	*p*
n	18	21	
Age (years)	65.4	65.7	0.899
Gender (male/female)	16/2	18/3	>0.999
Location of the main tumor (upper/middle/lower)	6/7/5	8/6/7	0.746
Depth of tumor invasion (T1/T2/T3/T4)	9/3/6/0	6/5/10/0	0.238
AJCC stage (0–I/II–IV)	8/10	7/14	0.477
Preoperative therapy	9	13	0.455

Bm group patients treated with the Bascule method, *Cm group* patients treated with the conventional method, *AJCC* American Joint Committee on Cancer

Table 3 Surgical outcomes of the patients with Bascule or conventional method

	Bm group	Cm group	*p*
n	18	21	
Operative time (min)			
Chest	258 ± 30	291 ± 39	0.007
Dissection along the left RLN	66 ± 9	75 ± 14	0.036
Process 1	15 ± 4	16 ± 5	0.377
Process 2	40 ± 5	47 ± 11	0.047
Process 3	10 ± 6	12 ± 6	0.582
Blood loss during the thoracic procedure (g)	20 ± 11	38 ± 32	0.028
Conversion to open surgery	0	0	
Number of harvested lymph nodes			
Chest	28.8 ± 12.8	30.4 ± 13.0	0.703
Along the left RLN	6.8 ± 6.1	7.2 ± 4.1	0.798
Intraoperative morbidity related to the left RLN	0	0	
Postoperative morbidity related to the left RLN			
Hoarseness	5 (28 %)	10 (48 %)	0.323
Aspiration	2 (10 %)	2 (10 %)	>0.999
Time to resumption of ingestion (days)[a]	5	6	0.420
Postoperative hospital stay (days)[a]	15	16	0.921

Bm group patients treated with the Bascule method, *Cm group* patients treated with the conventional method, *Process 1* Development of the left aspect of the trachea to cutting of the esophagus (common procedure), *Process 2* Dissection of the lymph nodes along the left RLN in the cranial part of the aortic arch, *Process 3* Dissection of the lymph nodes along the left RLN in the caudal part of the aortic arch (common procedure), *RLN* recurrent laryngeal nerve

Data are expressed as mean ± SD unless otherwise indicated

[a] Data are given as median

tracheoesophageal structures, with branches from the thyrocervical, costocervical, subclavian, and internal thoracic arteries [13]. Therefore, we recognize "esophageal mesenteriolum" as the lateral pedicle. After the division of the esophagus, one disadvantage of the conventional procedure is the need to continue grasping the lymph nodes with the surgeon's left hand in order to separate them from the left RLN. Due to the lack of countertraction, exfoliation of lymph nodes along the border of the neck and the thorax and distinguishing the left RLN from the lymph nodes is difficult. Therefore, excellent technique is required for this procedure. On the other hand, with the Bascule method, recognizing the membrane that looks like the "esophageal mesenteriolum" (lateral pedicle) is simplified by drawing the tissue including the left RLN and lymph nodes by the proximal esophagus; this procedure distinguishes the left RLN from the lymph nodes and a reliable cut of the tracheoesophageal artery on the posterior side of the left RLN becomes easier. Drawing the "esophageal mesenteriolum" (lateral pedicle) by taping the entire length of the undivided

esophagus is also possible, but there is a limit to the amount of retraction possible. Division of the esophagus increases the amount of retraction possible, allowing for further drawing and development of the operative field. In essence, Process 2 is the core process of the Bascule method, which is associated with a significant reduction of operative time, which translates into a shorter operative time for dissection along the left RLN and the entire thoracic procedure. In addition, necessity of astriction around left RLN after lymphadenectomy, which needed about 10 min and was not included in process 1–3, is the other reason of the prolonged operative total time in the conventional group. Actually, logical vessel management results in significantly less operative blood loss. On the other hand, concerning intraoperative safety, conversion to open surgery and intraoperative morbidity related to the left RLN was not observed. There was also no evidence of a significant difference in postoperative morbidity related to the left RLN. The prevalence of hoarseness in the group undergoing the Bascule method was 28 %, which was lower than the prevalence in the conventional group (48 %), but this difference was not statistically significant ($p = 0.323$). These data could be associated with significantly lower rates of left RLN palsy as the number of cases accumulates. However, since no definitive conclusions can be drawn from such a retrospective study, a randomized prospective trial of this technique is desirable.

We conclude that the Bascule method for lymphadenectomy along the left RLN during prone esophagectomy is technically safe and feasible, and reduces operative time and operative blood loss. In addition, there may be some possibility of decreasing the rate of left RLN palsy in the future because of a better identification of the nerve and a constant and light tension by Bascule method.

Disclosures Taro Oshikiri, Takashi Yasuda, Hitoshi Harada, Hironobu Goto, Masato Oyama, Hiroshi Hasegawa, Tadayuki Ohara, Hiroyoshi Sendo, Tetsu Nakamura, Yasuhiro Fujino, Masahiro Tominaga, and Yoshihiro Kakeji have no conflicts of interest or financial ties to disclose.

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