



Mediastinoscopic Subaortic and Tracheobronchial Lymph Node Dissection With a New Cervico-Hiatal Crossover Approach in Thiel-Embalmed Cadavers

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The use of mediastinal surgery for minimally invasive esophagectomy (MIE) has been proposed; however, this method is not performed as radical surgery because it has been thought to be impossible to perform complete upper mediastinal dissection, including the left tracheobronchial lymph nodes (106tbL). We herein describe a new method for performing complete dissection of the upper mediastinum. We developed a method for performing complete mediastinoscopic esophagectomy as radical surgery via the bilateral transcervical and transhiatal approach in 6 Thiel-embalmed human cadavers. The lower and middle mediastinal lymph nodes are dissected via the transhiatal approach. The dorsal side of the left recurrent nerve is dissected up to the aortic arch and left recurrent nerve lymph nodes (106recL) are dissected under pneumomediastinum. Next, the right recurrent nerve lymph nodes (106recR) are dissected. The cartilage of the left main bronchus is dissected and pushed downward, thereby obtaining a good view between the aortic arch and left main bronchus via the transhiatal approach. The 106tbL lymph nodes are dissected until the aortic arch is reached. Simultaneously, the lymph nodes are dissected via a right cervical incision. This method is termed the “cross-over technique.” We herein demonstrated that the upper mediastinal lymph nodes, including the 106tbL nodes, can be dissected using the bilateral transcervical and transhiatal

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approach under pneumomediastinum and named this method “mediastinoscopic esophagectomy with lymph node dissection” (MELD). MELD is therefore considered to be a useful modality based on our experience with Thiel-embalmed human cadavers.

Key words: Mediastinoscopic esophagectomy – Esophagectomy – Minimally invasive esophagectomy – MELD – Cross-over technique – Thiel

Minimally invasive esophagectomy (MIE) has been attempted using thoracoscopic surgery with or without laparoscopic procedures.^{1,2} However, the application of MIE with radical lymphadenectomy usually includes a transthoracic procedure; this method mandates the use of 1-lung ventilation and destruction of the thoracic wall. The administration of 1-lung ventilation is reported to induce mechanical damage to both the ventilated and collapsed lung.^{3,4} We considered that it is possible to perform radical esophagectomy without the thoracic approach, as the esophagus and regional lymph nodes are located inside the bilateral mediastinal pleura. Therefore, total transhiatal and bilateral transcervical radical lymphadenectomy may well be carried out without thoracic damage. Some reports have described the use of mediastinal esophagectomy; however, this method cannot be used to dissect the 106bL lymph nodes. To date, no authors have reported the successful dissection of these lymph nodes. We herein developed a novel technique for performing transhiatal and bilateral transcervical dissection of the total esophagus and regional lymph nodes, thereby allowing for the application of completely visualized dissection using a 2-field technique for MIE. We applied the “cross-over technique” consisting of the transhiatal and bilateral transcervical approach, which is suitable for dissection in a narrow operative field. In this article, we report our first experience with the “cross-over technique,” using transhiatal and transcervical radical esophagectomy in 6 Thiel-embalmed human cadavers.

Materials and Methods

We developed a method for performing complete mediastinoscopic esophagectomy as a radical operation via the transcervical and transhiatal approach in 6 Thiel-embalmed human cadavers. The cadavers were donated to the Department of Anatomy, Tokyo Medical and Dental University. Before the patients died, they signed documents agreeing to donate their body for use in clinical studies. The format of

the document meets the criteria for the Japanese “Act on Body Donation for Medical and Dental Education.”

All cadavers were embalmed using the method described by Thiel.^{5,6} The cadavers were embalmed in a water-based solution consisting of salt with a small amount of formaldehyde for fixation, boric acid for disinfection, glycol, chlorocresol, and ethanol; this precipitation results in tissue homogenization. The skin is life-like, and the joints are fully flexible. We chiefly applied this method for upper mediastinal dissection. The procedures were performed using a pneumoperitoneum apparatus system (Evis Lucera Spectrum WM-NP1; Olympus, Tokyo, Japan). In addition, the thoracic and abdominal aorta was inflated by the agar gel injection method in order to imitate live patient conditions.

Results

Procedure

The Thiel-embalmed human cadavers were placed in the supine position. For “mediastinoscopic esophagectomy with lymph node dissection” (MELD), two approaches were used: the transhiatal approach and the bilateral transcervical approach. We first performed the transhiatal approach.

(1) Abdominal and transhiatal approach

Hand-assisted laparoscopic surgery (HALS) was used for gastric conduit mobilization according to the method previously reported.⁷ An upper abdominal incision was created approximately 7 cm for the insertion of the left hand. Then, five 10-mm trocars were inserted into the left subcostal, infraumbilical, left and right lower quadrant of the abdomen following the induction of pneumoperitoneum with CO₂ to a pressure of 10 mmHg (Fig. 1). Gastric mobilization was carried out as in open surgery conserving the right gastroepiploic vessels. Dissection was performed using the ENSEAL (Ethicon Endo-surgery, Cincinnati, Ohio) when needed. The central tendon of the diaphragm was subsequently divided in order to enlarge the

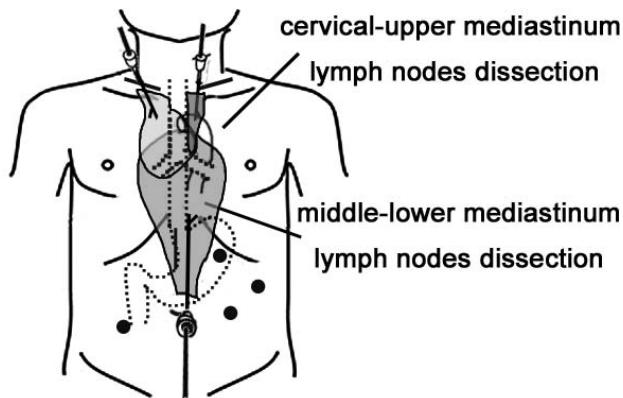


Fig. 1 Trocar location and each area of dissection according to the cross-over technique. It is possible to perform complete dissection of the upper mediastinum, including the 106tbL lymph nodes, using the bilateral transcervical and transhiatal approach in cooperation.

hiatus. Then, we used the Lone Star Retractor System (Yufu Itonaga Co Ltd, Tokyo) at the bilateral crura of the diaphragm to obtain a wide view. First, transhiatal dissection was performed between the pericardium and esophagus, then between the aorta and the esophagus, next between the left pleura and the esophagus, and finally the remaining right side of the esophagus was dissected. The pericardium, inferior bilateral pulmonary vein, inferior border of the carina tracheae is clearly exposed and lymph nodes at the bifurcation (107)

and left main bronchus (109L) were dissected (Fig. 2).

(2) Transcervical approach

We now demonstrate the transcervical approach. First, a left cervical collar incision was made and a sufficient working space was made between the tracheoesophageal and the left carotid sheath. Open surgery on the left side was subsequently changed to the pneumomediastinum method after identifying the left recurrent nerve. The Alexis wound retractor (Applied Medical, Rancho Santa Margarita, California) was placed at the above-mentioned space and deployed, a single-port laparoscopic access device (Free Access; Top Corporation, Tokyo, Japan) were attached and three 5-mm trocars were placed in a triangle configuration. A pneumomediastinum was then established with CO₂ to a pressure of 10 mmHg, and the 106recL lymph nodes were dissected along the left common carotid artery, subclavian artery, thoracic duct, and only dorsal area of the left recurrent nerve for the safety of the operation from the right cervical area. We can determine the ramus cardiacus of sympathetic nerve and the thoracic duct (Fig. 3). Finally, the esophageal wall was divided from the membranous trachea in order to be followed by dissection of the 106tbL lymph nodes via the right cervical approach.

Then, a right cervical incision was made, and a flap was created as described for the left side. Open

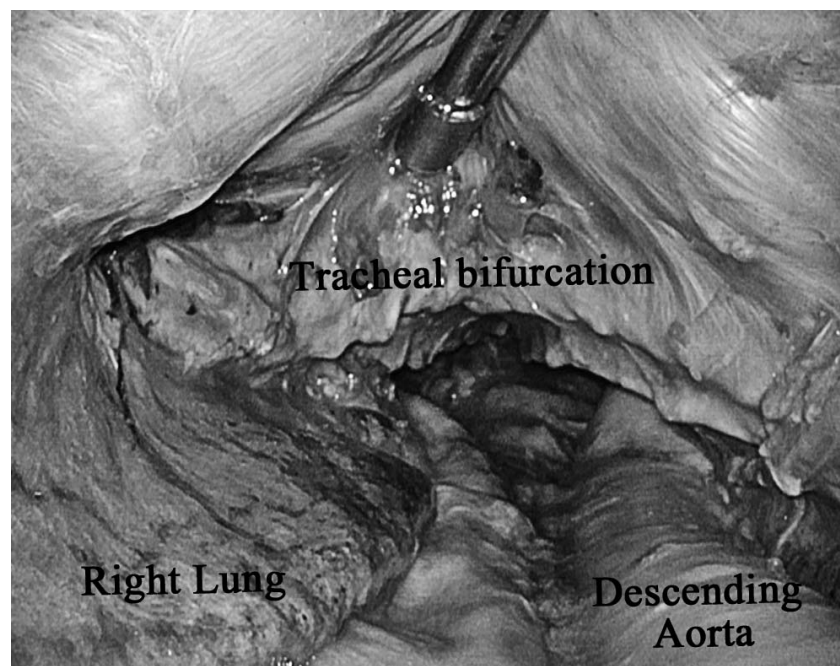


Fig. 2 Surgical technique. The pericardium, inferior bilateral pulmonary vein, and inferior border of the carina tracheae are dissected from the esophagus, and the No.107 and 109L lymph nodes are removed. It is shown after esophagectomy.

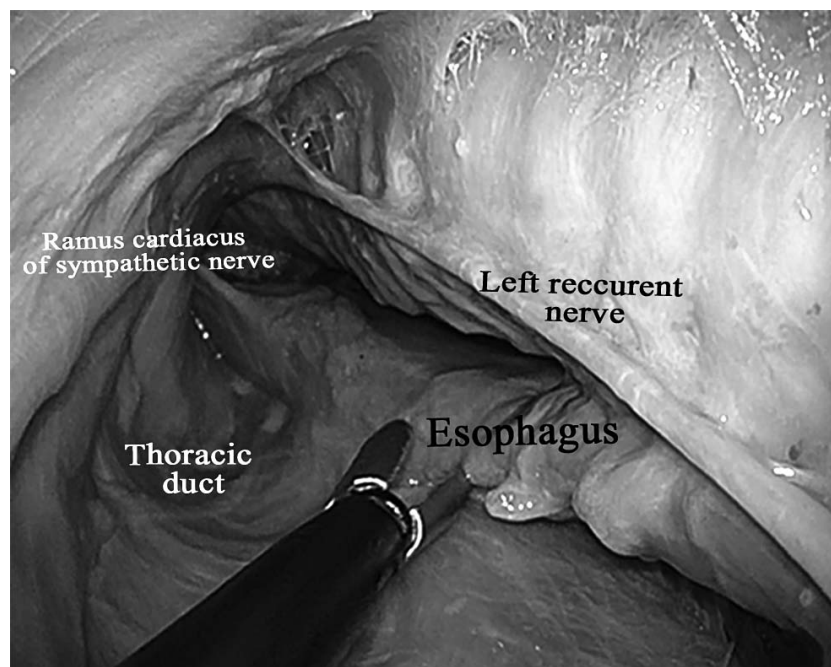


Fig. 3 Surgical technique (continued). The 101L and 106recL lymph nodes are dissected along the left main bronchus, common carotid artery, subclavian artery, thoracic duct, aortic arch, and inferior area only of the left recurrent nerve for the safety of the operation from the right cervical area. The ramus cardiacus of sympathetic nerve can be detected, along with the left subclavian artery in all cadavers.

surgery on the right side was changed to the pneumomediastinum method after identifying the right recurrent nerve, similar to that performed on the left side. The right recurrent nerve was dissected, and the ventral side of the right cervical paraesophageal lymph nodes (101R) only was dissected for the safety of the right recurrent nerve. The presence of the right recurrent nerve at the subclavian artery and the region of the right vagus

nerve was confirmed. A single-port laparoscopic access device was then placed beneath the above-mentioned area and deployed, and three 5-mm trocars were placed in a triangle configuration, as carried out on the left side. Using the pneumomediastinum method, the 101R and 106recR lymph nodes were dissected along the right mediastinal pleura, proximal portion of azygos vein and right bronchial artery (Fig. 4). The esophagus was

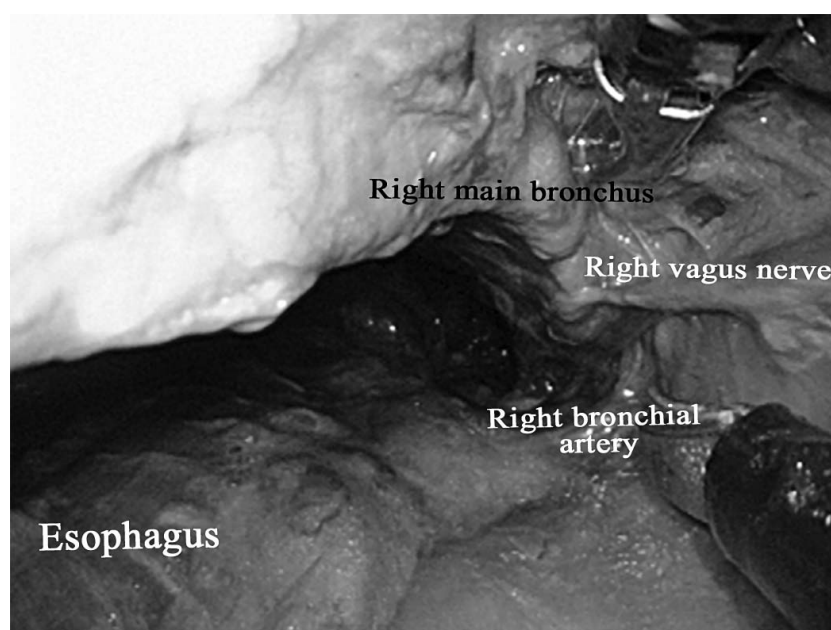


Fig. 4 Surgical technique (continued). The 101R and 106recR lymph nodes are dissected along the right mediastinal pleura, azygos vein, right bronchial artery, and right vagus nerve, detected beneath the right main bronchus.

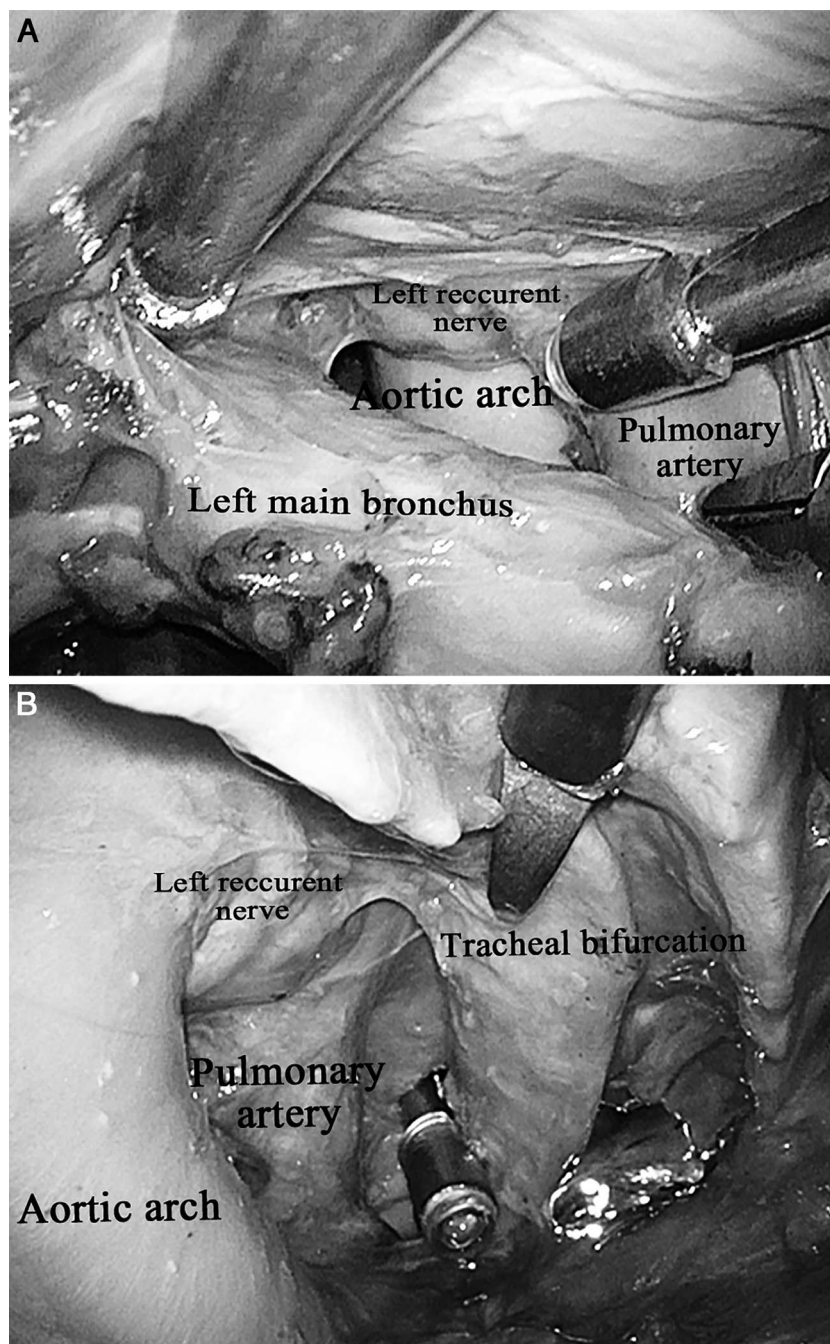


Fig. 5 Surgical technique (continued). (A) The front wall of the left main bronchus is depressed downward using the transhiatal approach. The 106tbL lymph nodes are dissected until the aortic arch is reached. It is possible to detect the pulmonary artery as well as the left recurrent nerve above the aortic arch via the transhiatal approach. (B) The 106tbL lymph nodes are dissected via the right cervical approach. It is very important that the left main bronchus is depressed dorsally by the retractor via the transhiatal approach.

dissected from the prevertebral layer in the posterior region, left main bronchus, and aortic arch on the left side.

For dissection of the 106tbL lymph nodes, we used the “cross-over technique.” First, the front wall of the left main bronchus was dissected and depressed downward using the transhiatal approach, thus obtaining a good view between the aortic arch and cartilage of the left bronchus. The

106tbL lymph nodes were then dissected until the aortic arch was reached (Fig. 5A). Simultaneously, the lymph nodes were dissected via right cervical incisions (Fig. 5B). The left recurrent nerve around the trachea can be observed via the transhiatal approach (Fig. 6). In another case, a mark is left between the aortic arch and left recurrent nerve via the left cervical approach (Fig. 7A). It is possible to detect both the mark and pulmonary artery as well

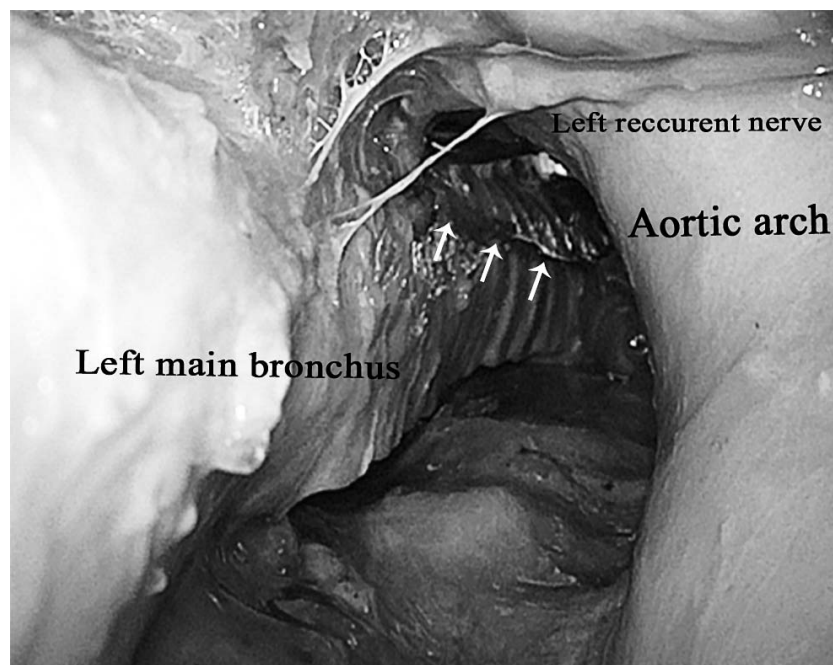


Fig. 6 Surgical technique (continued). The left recurrent nerve can be detected not only around the aortic arch but also the upper trachea (arrows) via the transhiatal approach.

as the left recurrent nerve above the aortic arch via the transhiatal approach (Fig. 7B). The shema is shown in Fig. 7C. Finally, the 106recL lymph nodes on the ventral side were dissected from the left cervical side.

After these operations, I confirm how many lymph nodes dissected in 106tbL area by thoracotomy. It is revealed that these lymph nodes are almost completely dissected in MELD as well as in open esophagectomy and the pulmonary artery, the left recurrent nerve at the aortic arch and the bronchial artery are safely exposed and reserved (Fig. 8).

Discussion

Conventional transhiatal esophagectomy is recognized as a minimally invasive surgery.^{8,9} In this method, the upper mediastinal lymph nodes are usually not dissected. It has traditionally been very difficult to dissect the 106tbL lymph nodes using the mediastinoscopic method because the mediastinal area is narrow and contains very important structures, such as the bilateral main bronchus, recurrent nerve, aortic arch, and pulmonary artery. Previous reports have described the use of mediastinal esophagectomy. For example, Bumm and colleagues recently used an endodissector to eliminate “blind” mediastinal dissection.^{10,11} In that method, endodissection is performed via the

left cervical approach. At the tip, the instrument provides a tissue dilatator and several openings for the fiber optic bundle, a working channel, and flushing and suction devices. Instruments such as monopolar thermocautery devices, biopsy forceps, and microscissors can be applied through the working channel. Meanwhile, the other team dissects the terminal esophagus from the hiatus and prepares the interposition graft. This method is very convenient and useful for dissecting the esophagus and does not require the use of pneumomediastinum during surgery. However, this method cannot be used to perform complete dissection of the upper mediastinum, including the 106tbL lymph nodes; therefore it is inadequate for upper mediastinum dissection. Tangoku and colleagues reported the application of mediastinoscope-assisted transhiatal esophagectomy (MATHE) with a mediastinoscope and 5-mm-diameter mirror scope attached to a retractor with a transparent flat tip via the left neck.¹² However, this method is also inadequate for achieving complete upper mediastinum dissection. In another article, the transcervical (left side only) approach with transhiatal esophagectomy using pneumomediastinum for either high-risk patients or for those with early esophageal carcinoma alone.¹³ However, this method is not sufficient for upper mediastinum dissection. Ikeda and colleagues reported the same mediastinum method in which an additional transthoracic proce-

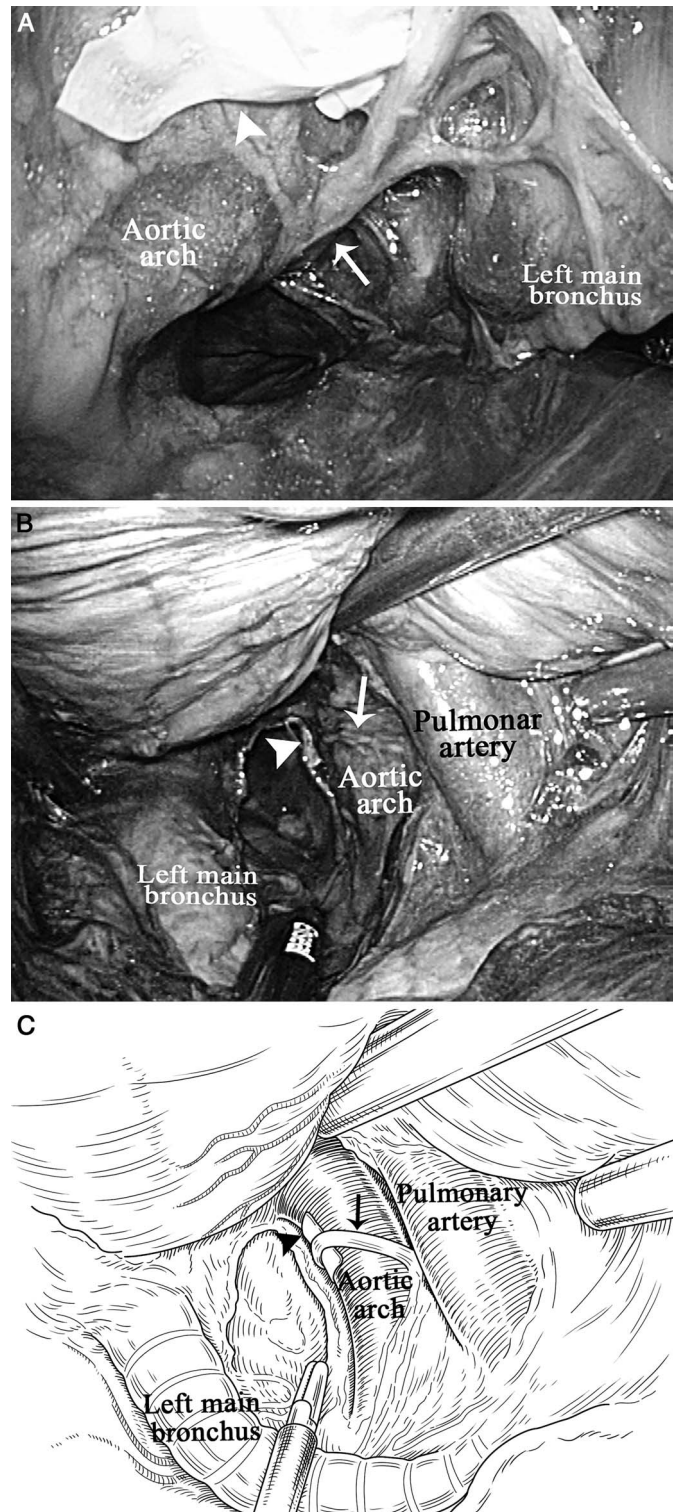


Fig. 7 Surgical technique (continued). (A) A mark (arrowhead) is left between the aortic arch and left recurrent nerve via the left cervical approach in another cadaver. (B) The front wall of the left main bronchus is depressed downward using the transhiatal approach in the Fig. 8 case. It is possible to detect the mark between the aortic arch and left recurrent nerve via the transhiatal approach. It is very important that the left main bronchus be depressed dorsally. (C) A schematic drawing. Arrow: left recurrent nerve; arrowhead: the mark.

ture is performed, if necessary, for further dissection, including dissection of the lymph nodes.^{14,15} Therefore, a transthoracic approach for radical esophagectomy is needed.

We considered whether transhiatal esophagectomy is adequate for radical esophagectomy. Performing transhiatal dissection of the lower mediastinal field is possible, although carrying out such dissec-

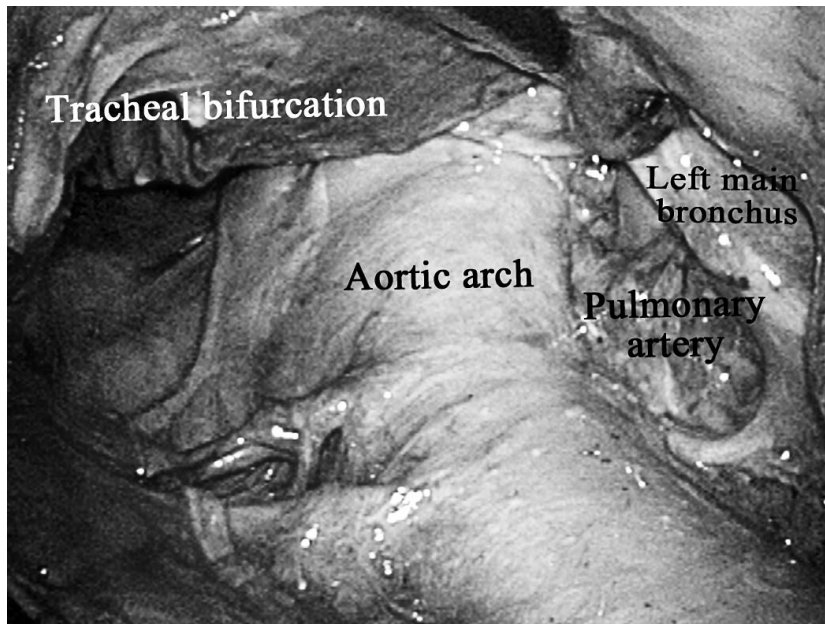


Fig. 8 The evaluation of the dissection status in 106tbl lymph nodes. After these operations, it is confirmed how many lymph nodes dissected in 106tbl area by thoracotomy. It is revealed that these lymph nodes are almost completely dissected. The pulmonary artery, the left recurrent nerve at the aortic arch, and the bronchial artery are safely exposed and reserved.

tion of the upper field is difficult according to conventional methods. Additionally, the degree of motion of the endoscopic forceps suffers from increasing limitations, such as that observed in single-incision laparoscopic surgery (SILS), in which the right- and left-hand devices are parallel to one another. Mori thus reported the use of robotic-assisted transhiatal lymphadenectomy as radical esophagectomy,¹⁶ which can be performed in a few limited institutions. However, we consider that the hiatus of the esophagus should be widely opened in order to improve the surgical view. Therefore, we applied the Lone Star Retractor System to the bilateral crura of the diaphragm. When the bilateral crura are widely opened, the stability of the scope is increased, and the right- and left-hand devices are no longer parallel. It is therefore possible to dissect the 106tbl lymph nodes from the ventral side of the left main bronchus to the aortic arch via the transhiatal approach.

The pneumomediastinum method can be used to enlarge the range of dissection among the bilateral cervical field over that obtained with the transhiatal approach. It is thus possible to dissect the lymph nodes in the area of the left recurrent nerve at the aortic arch via a left cervical incision. Dissection of the 106tbl lymph nodes can be easily performed in the right cervical area. In this region, the adipose tissue adheres only on the caudal side of the aortic arch, as the ventral side of the left main bronchus has already been dissected via the transhiatal approach. We emphasize that obtaining traction for

the trachea in the ventral direction from the left cervical area is very important. We named this procedure the “cross-over technique” due to the importance of cooperation in the bilateral cervical and transhiatal area (Fig. 1). We subsequently cut the esophagus in the left cervical area and pulled the tissue in the caudal direction. This demonstrated that the esophagus was totally separated, allowing the lymph nodes, including the 106tbl lymph nodes, to be dissected from the upper to lower mediastinum. Although 3-field lymphadenectomy is needed to perform radical esophagectomy for esophageal cancer, dissecting the 106tbl lymph nodes is very difficult without the use of the transthoracic approach. We herein demonstrated that the “cross-over technique” under pneumomediastinum from the transhiatal and bilateral cervical approach can be applied to dissect the 106tbl lymph nodes relatively easily. The key success factors regarding this treatment modality include 3 points as follows:

1. It is the use of a combined transhiatal and transcervical operation, in which the transhiatally and transcervically lymph nodes are both removed at the same time.
2. It is increasing the size of the mediastinal working space by establishing pneumomediastinum.
3. The 106tbl lymph nodes are dissected from the front wall of the left main bronchus, but not from the dorsal wall of one.

This new method represents a dramatic change in the way of thinking when dissecting the 106tbl lymph nodes.

Using this method, radical esophagectomy can be performed without both robotic procedures and the transthoracic approach. Therefore, a truly minimally invasive procedure for performing radical esophagectomy that does not require transthoracic surgery is now established. We believe that our initial experience with this procedure is a breakthrough that will lead to the development of truly minimally invasive surgery for thoracic esophageal cancer.

Conclusion

We conclude that performing MELD under pneumomediastinum using the bilateral transcervical and transhiatal approach is a useful modality based on our experience with Thiel-embalmed human cadavers.

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