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Video-Assisted Thoracic Surgery Esophagectomy

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Thoracoscopic esophagectomy for esophageal cancer can be performed in multiple positions, such as the lateral decubitus position or prone position, using various techniques. Each approach has its own advantages and disadvantages, and surgeons can select an appropriate approach based on their preferences. Except for the reduction of pulmonary complications, the benefits of thoracoscopic esophagectomy, including oncologic outcomes, have not been proven scientifically. This review describes the approaches and procedures of thoracoscopic esophagectomy and presents scientific evidence for this procedure.

Keywords: Esophageal cancer, Thoracoscopy

Introduction

Despite advances in perioperative management, esophagectomy for esophageal cancer remains one of the most invasive gastrointestinal surgical procedures, with serious postoperative complications [1]. The morbidity and mortality rates have been reported to be up to 60% and 3.4%, respectively, according to a large Japanese national report [2]. Therefore, esophagectomy via the thoracoscopic and/or laparoscopic approach can be a very attractive and less invasive alternative to conventional open esophagectomy for reducing postoperative morbidity and mortality. This increase in the popularity of thoracoscopic esophagectomy might also be related to technical advances in thoracoscopic equipment such as dissectors, laparoscopic coagulating shears, and vessel-sealing systems, which are now available for thoracoscopic esophageal resection and extended mediastinal lymphadenectomy [1]. Historically, thoracoscopic esophagectomy was first introduced in 1992 by Cuschieri et al. [3], in a report presenting a series of 5 patients who underwent thoracoscopic surgery combined with laparotomy. DePaula et al. [4] reported their experience of laparoscopic transhiatal esophagectomy in 1995 and Luketich et al. [5] reported acceptable outcomes from 222 patients who underwent a combined thoracoscopic and laparoscopic approach for esophageal cancer in 2003. Currently, various approaches for thoracoscopic esophagectomy are being attempted.

Various approaches of thoracoscopic esophagectomy

Thoracoscopic esophagectomy can be performed with the patient in the lateral decubitus position. It can offer a similar view to traditional thoracotomy, with the advantage that urgent thoracotomy conversion can be performed easily. However, this position requires total lung collapse with one-lung ventilation, which is frequently associated with pulmonary complications. To overcome the issues related to one-lung ventilation, thoracoscopic esophagectomy in the prone position has also been attempted. Palanivelu et al. [6] reported that thoracoscopic transthoracic esophagectomy in the prone position in 130 patients was technically feasible, with a low respiratory complication rate and a shorter operative time due to the excellent exposure of the operative field and better ergonomics. However, it is difficult to perform urgent conversion to traditional thoracotomy. In addition, dissection of the left recurrent laryngeal nerve (RLN) lymph nodes, where metastasis most frequently develops in esophageal squamous cell carcinoma, is technically challenging in the prone position. To overcome the abovementioned problem while maintaining the benefits of the prone position, thoracoscopic esophagectomy in the semi-prone position has recently become popular among

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surgeons [7].

Surgeons have also attempted transhiatal and transcervical esophagectomy. Transhiatal open esophagectomy was first reported by Orringer and Sloan [8] and is regarded as less invasive and radical than transthoracic open esophagectomy. This procedure can be modified with laparoscopy and can be considered a minimally invasive esophagectomy. Although the transhiatal approach is regarded as less invasive than the transthoracic approach, mediastinal lymph node dissection is insufficient for the treatment of esophageal cancer. Therefore, the video-assisted transcervical approach for the dissection of the proximal and mid-esophagus has been implemented in combination with a transhiatal approach to improve the quality of mediastinal lymph node dissection without transthoracic dissection and one-lung ventilation at some Japanese institutions [9]. This procedure is not popular in Korea.

Personal procedures performed by the author

The author prefers McKeown 3-field esophagectomy with cervical anastomosis using thoracoscopy. This section describes the author's personal procedures of thoracoscopic esophagectomy in the lateral decubitus position. The patient is placed in the left lateral decubitus position after double-lumen intubation. A 4-cm working window is made first at the fourth intercostal space anterior axillary line to confirm pleural adhesion. After the absence of pleural adhesion is confirmed, CO_2 (20 mm Hg) was used for lung collapse. After sufficient lung collapse with CO_2 insufflation, the full size of the working window and other trocars are inserted at the sixth intercostal space of the scapular tip and the seventh (or eighth) intercostal space, as shown in Fig. 1. The author personally prefers a working window because a thick instrument such as a tracheal retractor can be inserted through a working window.

The sequence of the procedures is described in Fig. 2. The dissection is initiated at the azygos arch; the mediastinal pleura over the azygos vein is opened, and the azygos vein is stapled with an endoscopic vascular stapler. The right bronchial artery, which arises from the intercostal artery, can be detected below the azygous vein, and the right bronchial artery is usually sacrificed with a metal clip (Fig. 3A). At this level, the thoracic duct can be found between the azygous vein and aorta, with the dissection plane just outside of the thoracic duct for *en bloc* resection of the thoracic duct (Fig. 3B). The dissection of the dorsal side of the upper esophagus continued from the upper mediastinum to the thoracic inlet (Fig. 4A). For the blunt dissection of this rea, any energy device such as a harmonic scalpel is usually used. After dissection to the thoracic inlet, the mediastinal pleura over the vagus nerve is opened from the

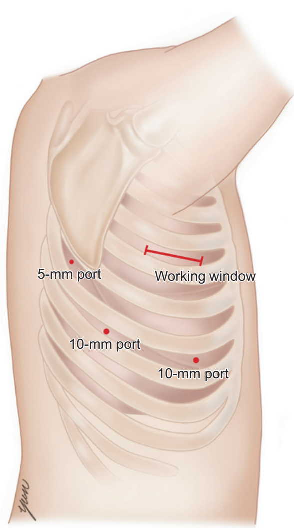

Fig. 1. The position and placement of the trocars in thoracoscopic esophagectomy with the patient in the lateral decubitus position. A 4-cm-long working window is made at the fourth intercostal space, a 5-mm port is placed at the sixth intercostal space and scapular tip, and two 10-mm ports are placed at the seventh or eighth intercostal space.

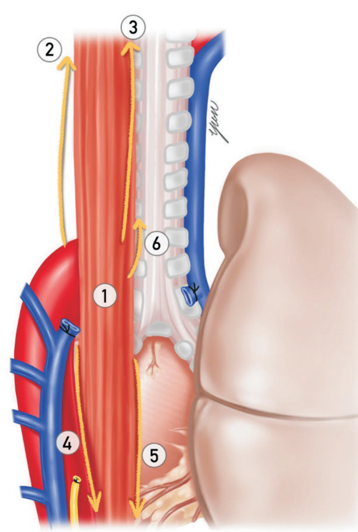

Fig. 2. The sequence of thoracoscopic esophagectomy. 1, division of the azygos vein; 2, dissection of the dorsal side of the upper esophagus; 3, dissection of the right recurrent laryngeal nerve lymph nodes; 4, dissection of the dorsal side of the lower esophagus; 5, dissection of the subcarinal lymph nodes and the ventral side of the esophagus; 6, dissection of the left recurrent laryngeal nerve lymph nodes.

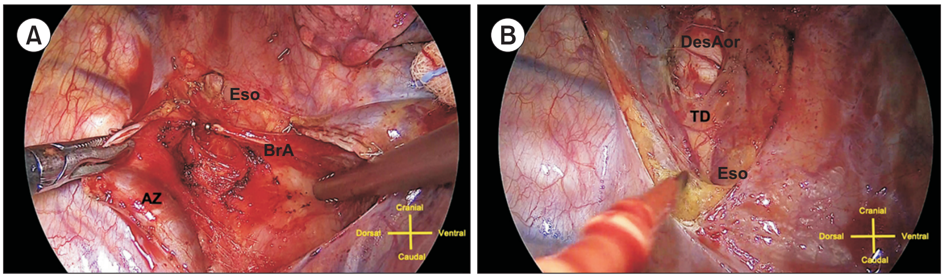

Fig. 3. Division of the azygos vein. (A) The right bronchial artery below the azygos vein is divided with a metal clip. (B) The thoracic duct can be found between the azygous vein and aorta. AZ, azygos vein; BrA, right bronchial artery; Eso, esophagus; TD, thoracic duct; DesAor, descending thoracic aorta.

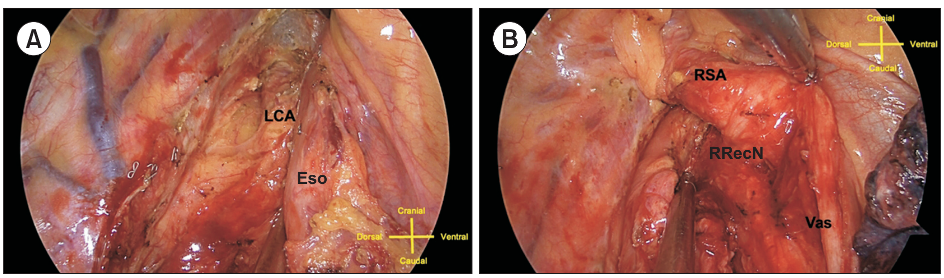

Fig. 4. Dissection of the upper esophagus. (A) Dissection of the dorsal side of the upper esophagus to the thoracic inlet. (B) Dissection of the right recurrent laryngeal nerve lymph nodes. Eso, esophagus; LCA, left carotid artery; RSA, right subclavian artery; Vas, vagus nerve; RRecN, right recurrent laryngeal nerve.

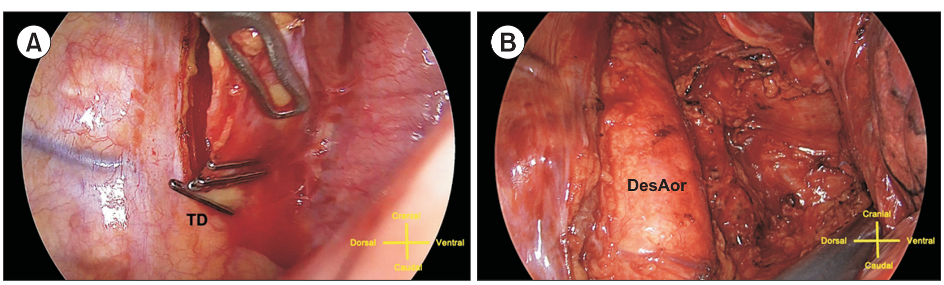

Fig. 5. Dissection of the lower esophagus. (A) Ligation of the thoracic duct at the diaphragm level. (B) Dissection of the lower esophagus with denudation of the descending thoracic aorta. TD, thoracic duct; DesAor, descending thoracic aorta.

azygous vein level to the edge of the right subclavian artery. At this level, the right RLN lymph nodes are carefully dissected after finding and preserving the right RLN. The RLN is identified at the caudal end of the right subclavian artery. Lymph nodes around the nerve are dissected and resected up to the cervical level with meticulous care to prevent nerve injury (Fig. 4B). The sharp dissection around the nerve is usually done with long Metzenbaum scissors to prevent thermal injury. Next, the anterior part of the upper esophagus is dissected from the trachea.

After dissection of the upper esophagus, dissection between the vertebral body and esophagus is performed on the diaphragm side. The thoracic duct is attached to the specimen side (esophagus) for *en bloc* resection. At the diaphragm level, the thoracic duct is ligated to the metal clip to prevent chylothorax (Fig. 5A). Dissection of the lower esophagus is performed, with the contralateral mediastinal pleura (left side mediastinal pleura) usually saved in cT1 or T2 lesions (Fig. 5B). In the case of a T3 lesion at the lower esophagus, the left side mediastinal pleura is also dissected *en bloc*. Then, dissection of the subcarinal lymph nodes begins. The pulmonary branches of the vagus nerve, which runs along the right main bronchus, are preserved, and the vagus nerve is cut just below the pulmonary branches of the right vagus nerve (Fig. 6A). With the retraction of the pulmonary branches to the cranial side, the subcarinal lymph nodes are dissected from the main bronchus with an *en bloc* attachment to the esophagus (Fig. 6B). At this phase, the dissection must be performed carefully to avoid injury to the left main bronchus and inferior pulmonary vein. After the dissection of the subcarinal lymph nodes, the dissection continues to the diaphragm side, and the right crus muscle can be found during the thoracic phase.

The esophagus is then lifted upward and dissection around the left side of the esophagus is performed to identify the left RLN. These dissections usually begin just above the left main bronchus, with the left RLN, which encircles the aortic arch, found easily at this level. The left pulmonary artery is exposed to dissect the left tracheobronchial lymph nodes between the aortic arch and the left

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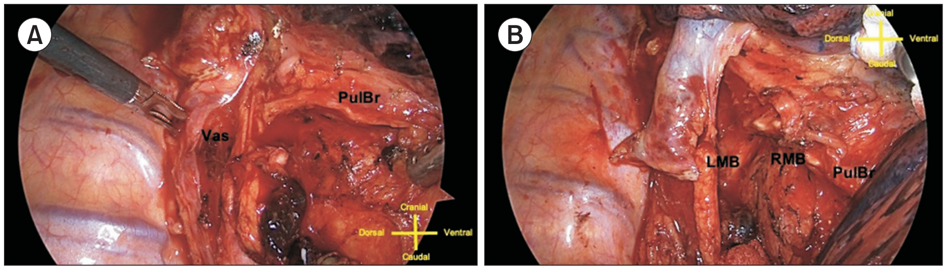

Fig. 6. Dissection of subcarinal lymph nodes. (A) Saving the right pulmonary branches of the vagus nerve during subcarinal lymph node dissection. (B) The subcarinal lymph nodes are dissected while attached to the esophagus, in an *en bloc* manner. Vas, vagus nerve; PulBr, right pulmonary branch of the vagus nerve; RMB, right main bronchus; LMB, left main bronchus.

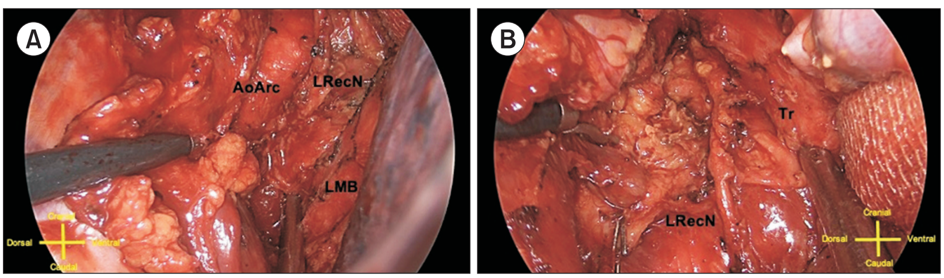

Fig. 7. Dissection of the left recurrent laryngeal area. (A) Dissection of the left tracheobronchial lymph nodes. (B) Dissection of the left recurrent laryngeal nerve lymph nodes. AoArc, aortic arch; LMB, left main bronchus; LRecN, right recurrent laryngeal nerve; Tr, trachea.

main bronchus (Fig. 7A). The tissues between the esophagus and trachea are dissected and the trachea is retracted anteriorly by an assistant using a tracheal retractor. The soft tissues and lymph nodes around the left RLN are carefully dissected from the aortic arch to the cervical level (Fig. 7B). Thus, esophageal mobilization and mediastinal lymphadenectomy are completed.

Abdominal procedures are performed through an upper midline abdominal incision, giving access to the greater omentum, short gastric vessels, and lesser omentum, while avoiding injury to the right gastroepiploic and right gastric vessels. The fat tissue over the left gastric artery is dissected, the artery is divided, and the paracardial, left gastric, and celiac lymph nodes are dissected. Then, bilateral neck dissection is performed via a collar incision, and an anastomosis is made at the neck. The gastric conduit is pulled up to the neck through the posterior mediastinal or substernal route. The cervical esophagus and gastric conduit are then anastomosed using a hand-sewn maneuver. The anastomosis can also be performed at the thoracic inlet, similar to the Ivor-Lewis operation; the methods of anastomosis will be described in other papers.

Surgical pitfalls

During left RLN lymph node dissection, the trachea must be retracted gently. Rough retraction can result in catastrophic events, such as tracheal injury. In addition, the esophagus must be lifted upward carefully to avoid traction injury of the left RLN. Dissection must also be performed carefully around the left main bronchus. The left inferior pulmonary vein is located at the end of the left main bronchus, which can be injured during dissection. Some surgeons believe that saving the right bronchial artery is important for preventing pulmonary complications, but the author's routine practice is ligation of the right bronchial artery for better exposure of the left RLN area. Sacrificing the right bronchial artery did not seem to increase pulmonary complications.

Literature review

Despite the increased popularity of thoracoscopic esophagectomy, scientific evidence for this procedure is unclear. The short-term and long-term outcomes of thoracoscopic esophagectomy in retrospective studies are summarized in Table 1. In many studies, the operative time was found to be longer in thoracoscopic esophagectomy than in open esophagectomy [2,10-12]. However, in terms of blood loss, hospital stay, and pulmonary complications, several papers reported better outcomes for thoracoscopic esophagectomy. Tapias et al. [13] also reported that thoracoscopic esophagectomy could be done safely even after neoadjuvant therapy. Regarding overall survival, several

Table 1. Comparison of the short-term outcomes between thoracoscopic and open esophagectomy in retrospective series

Author (year)	No. of cases	Operation time (min)	Blood loss (mL)	Mortality (%)	Hospital stay (day)	Pulmonary complication (%)	Anastomotic leakage (%)	Vocal cord palsy (%)	No. of dissected LNs	OS (yr)
Osugi et al. [11] (2003)	TE (77) vs. OE (72)	227 vs. 186[a]	284 vs. 310	0 vs. 0	-	15.6 vs. 19.4	1.3 vs. 2.8	14.3 vs. 19.4	33.9 vs. 32.8	55 vs. 57 (5-yr OS)
Daiko and Nishimura [12] (2012)	TE (29) vs. OE (30)	322 vs. 335[a]	527 vs. 435	0 vs. 0	20 vs. 20	3 vs. 3	14 vs. 10	17 vs. 20	-	-
Miyasaka et al. [14] (2013)	TE (68) vs. OE (30)	483 vs. 508	364 vs. 975[a]	2.9 vs. 13.3	35.0 vs. 85.5[a]	32.4 vs. 43.3	7.4 vs. 16.7	25 vs. 30	37 vs. 41.5	61.5 vs. 26.7 (5-yr OS)[a]
Hsu et al. [10] (2014)	TE (66) vs. OE (63)	511 vs. 461[a]	462 vs. 615	7.6 vs. 7.9	-	10.6 vs. 25.4[a]	27.3 vs. 30.3	-	28.3 vs. 25.7	70.9 vs. 47.6[a]
Takeuchi et al. [2] (2014)	TE (1,751) vs. OE (3,603)	523 vs. 450[a]	466 vs. 618[a]	3 vs. 3.6	-	15.0 vs. 15.5	14.9 vs. 12.5[a]	-	-	-
Tapias et al. [13] (2016)	TE (56) vs. OE (74)	337.4 vs. 361.6	200 vs. 250[a]	0 vs. 2.7	7 vs. 9[a]	8.9 vs. 29.7[a]	0 vs. 1.4	0 vs. 4	20 vs. 20	49.6 vs. 60.9

LN, laryngeal nerve; TE, thoracoscopic esophagectomy; OE, open esophagectomy; OS, overall survival.
[a]Statistically significant.

Table 2. Comparison of the short-term outcomes between thoracoscopic esophagectomy and open esophagectomy in nationwide or prospective data

Author (year)	Country	Study design	Period	No. of cases (OE vs. TE)	Respiratory complications (OE vs. TE)	Surgical complications (OE vs. TE)	30-Day mortality (OE vs. TE)
Biere et al. [19] (2012)	Europe	Randomized controlled trial	2005–2008	56 vs. 59	29% vs. 9%, p=0.008	Equivalent except for pulmonary complications	0% vs. 2%, p=0.580
Seesing et al. [16] (2017)	Netherlands	National data (propensity score matching)	2011–2015	433 vs. 433	34.2% vs. 35.8%, p=0.669	More frequent anastomotic leakage, intraabdominal abscess, and reintervention in TE	3% vs. 4.9%, p=0.209
Mamidanna et al. [17] (2012)	England	National data (population-based study)	2005–2010	6,347 vs. 1,155	Equivalent	More frequent reoperation and reintervention in TE	4.8% vs. 4.2%, p=0.605
Takeuchi et al. [18] (2017)	Japan	National data	2011–2012	3,515 vs. 3,515	5.1% vs. 3.6%, p=0.002	More frequent reoperation (5.3% vs. 7%) and recurrent laryngeal nerve palsy (8.1% vs. 10.3%) in TE	0.9% vs. 1.1%

OE, open esophagectomy; TE, thoracoscopic esophagectomy.

retrospective studies showed better overall survival in patients who underwent thoracoscopic esophagectomy [10,14], but the results must be interpreted cautiously because of possible confounding factors or selection bias. A recent meta-analysis found comparable long-term survival rates between thoracoscopic esophagectomy and conventional open esophagectomy [15]. However, as no randomized controlled trials have been performed to compare the long-term survival of patients undergoing thoracoscopic esophagectomy and open esophagectomy, the benefits of thoracoscopic esophagectomy for oncologic patients have not been scientifically shown, especially in patients with esophageal squamous cell carcinoma.

Nationwide studies and prospective studies have also reported data on the short-term outcomes of thoracoscopic esophagectomy (Table 2). Interestingly, the incidence of pulmonary complications seems to be lower after thoracoscopic esophagectomy, whereas overall surgical complications are more common after esophagectomy; anastomotic leakage [16], intraabdominal abscess [16], reintervention [16,17], reoperation [17,18], and RLN palsy [18] were reported more frequently in thoracoscopic esophagectomy than in open esophagectomy. However, operative mortality was similar between the 2 surgical methods. The TIME trial, which was a phase III randomized controlled trial that compared thoracoscopic esophagectomy to open esophagectomy, also reported that the incidence of pulmonary infection was considerably lower in the thoracoscopic esophagectomy group than in the open esophagectomy group, and the other complications were comparable between the 2 groups [19]. Based on the results from previous retrospective, nationwide, and prospective studies, thoracoscopic esophagectomy has been shown to reduce the occurrence of postoperative respiratory complications, whereas other complications are comparable or slightly increased. Therefore, the 2017 esophageal cancer practice guidelines published by the Japan Esophageal Society do not strongly recommend thoracoscopic esophagectomy.

Conclusion

Thoracoscopic esophagectomy for esophageal cancer can be performed in various positions, such as the lateral decubitus position or prone position, using various techniques. Each approach has advantages and disadvantages, and surgeons can select an appropriate approach based on their preferences. Thoracoscopic esophagectomy in the lateral decubitus position offers a familiar anatomical view like conventional open thoracotomy. The benefits of thoracoscopic esophagectomy, including oncologic outcomes, have not been proven scientifically, except for the reduction of pulmonary complications.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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