World J Surg (2014) 38:410–418
DOI 10.1007/s00268-013-2258-4

World Journal of Surgery

# Clinical Utility of a Novel Hybrid Position Combining the Left Lateral Decubitus and Prone Positions During Thoracoscopic Esophagectomy

**Takuji Kaburagi · Hiroya Takeuchi · Hirofumi Kawakubo · Tai Omori · Soji Ozawa · Yuko Kitagawa**

Published online: 8 October 2013


**Abstract**
*Background* We developed a hybrid of the prone and left lateral decubitus positions for thoracoscopic esophagectomy (TE) in 2009. This study aimed to evaluate the feasibility of applying this novel TE position.
*Methods* We retrospectively analyzed 78 patients who underwent TE at our institution between 2005 and 2010. Altogether, 33 patients underwent TE in the left lateral decubitus position (LD-TE) from 2005 to 2008, and 45 underwent TE in the hybrid position (hybrid-TE) from 2009 to 2010. Radical lymphadenectomy along the bilateral recurrent laryngeal nerves was performed in both groups. The thoracic duct was preserved in the LD-TE group and resected in the hybrid-TE group. In the LD-TE group, all thoracic procedures were performed with the patient in the left lateral decubitus position. In the hybrid-TE group, the upper mediastinal procedure was performed with the patient in the left lateral decubitus position, and procedures at the middle and lower mediastinum were performed with the patient in the prone position under $CO_2$ pneumothorax.
*Results* Hybrid-TE was associated with increased operating time. The number of harvested mediastinal nodes and the $PaO_2/FiO_2$ ratio on postoperative day 1 were both greater in this position. Although vocal cord palsy was observed more frequently in the hybrid-TE group, there was no significant difference in the rate of other complications or in-hospital mortality between the two groups.
*Conclusions* The novel hybrid position is believed feasible for use during TE. We believe that this position facilitates a more radical mediastinal lymphadenectomy with minimal intraoperative pulmonary damage.

T. Kaburagi · H. Takeuchi (✉) · H. Kawakubo · T. Omori · Y. Kitagawa
Department of Surgery, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan
e-mail: hiroyatakeuchi@aol.com

S. Ozawa
Department of Gastroenterological Surgery, Tokai University School of Medicine, 143 Kasuya, Isehara, Kanagawa 259-1193, Japan

## Introduction

Esophageal cancer is a highly aggressive malignancy that frequently involves the lymph nodes and is associated with a poor prognosis. Esophagectomy remains the mainstay of curative treatment for localized disease. Because esophagectomy with radical lymphadenectomy is highly invasive, esophagectomy through a thoracoscopic approach is attracting attention as a less invasive procedure. Since Cuschieri et al. [1] first reported thoracoscopic esophagectomy (TE) in 1992, many groups have described various TE techniques [2–6]. Although TE is generally performed with the patient in the left lateral decubitus position, Palanivelu et al. [7] reported a case series wherein TE was performed in the prone position. In their series, excellent operative field exposure was achieved with the patient in the prone position because gravity retracts the right lung and stretches the mediastinum in an anteroposterior direction.

We first performed TE in the left lateral decubitus position (LD-TE) for esophageal cancer in 1996. In 2009, we adopted one aspect of the prone TE concept and evolved a novel TE method in which the thoracic procedure was performed with the patient in a hybrid position that took advantage of both the left lateral decubitus and prone positions (hybrid-TE) [8].

With our novel TE method, the upper mediastinal procedure is performed with the patient in the left lateral decubitus position, and the middle and lower mediastinal procedures are performed with the patient in the prone position. We introduced hybrid-TE for the following reasons: (1) mobilization and lymphadenectomy around the middle and lower esophagus are easier in the prone position; (2) lymphadenectomy along the left recurrent laryngeal nerve (RLN) is more reliable and precise when performed in the left lateral decubitus position; and (3) unexpected events requiring conversion to thoracotomy (e.g. massive bleeding, injury of other organs, dense intrathoracic adhesion, resection of adjacent organs) are easier to manage in the left lateral decubitus position.

In this study, we retrospectively analyzed patients who underwent TE to report and compare the short-term outcomes of LD-TE and hybrid-TE. We also evaluated the clinical utility of hybrid-TE based on the hypothesis that hybrid-TE facilitates (1) more precise lymphadenectomy at the middle to lower mediastinum than that with LD-TE and (2) less pulmonary damage due to decreased intraoperative manipulation of the lung.

## Patients and methods

### Patients

Between 2005 and 2010, a total of 78 patients with histologically confirmed esophageal cancer underwent TE at Keio University Hospital and were subsequently included in this retrospective analysis. TE was performed in the left lateral decubitus position in 33 patients between 2005 and 2008 and in the hybrid position in 45 patients between 2009 and 2010.

Exclusion criteria of TE candidates included the following: distant metastasis, cT4 cancer (invasion to adjacent structures), previous radiotherapy of the thorax, history of thoracic surgery, bulky node metastasis, and the need for reconstruction of any organ other than the stomach. We considered that cervical node metastasis with no other distant metastasis was neither distant nor unresectable. Therefore, some patients with clinical cervical node metastases were considered eligible for TE. Patients were staged using the tumor–node–metastasis staging system (7th edition) set by the Union for International Cancer Control [9].

### Surgical procedures

As per routine clinical protocol, an epidural cannula was inserted into each patient for the administration of intraoperative and postoperative analgesia. All surgeries were performed under general anesthesia with selective intubation to block the right lung. In patients in whom anastomosis in the neck was planned, the thoracoscopic procedure was performed followed by an abdominal procedure. Thereafter, cervical esophagogastrostomy was accomplished. In patients in whom anastomosis in the thorax was planned, the thoracoscopic procedure was performed following an abdominal procedure. Intrathoracic esophagogastrostomy was performed thereafter.

A single surgical team that included three operators performed all of the LD-TEs and hybrid-TEs. Two of the three surgeons always participated in each of the LD-TEs or hybrid-TEs.

#### *Hybrid-TE*

Patients were placed in the left semiprone position using beanbags. Thoracic procedures were performed in the optimal position (left lateral decubitus or prone positions) by rotating the operating table (Fig. 1) [8].

A 4- to 5-cm minithoracotomy was made, and trocars were placed as shown in Fig. 2a. The upper mediastinal procedure was performed by initially placing the patient in the left lateral decubitus position. The azygos arch was divided using a linear stapler, and the posterior portion of the right upper mediastinal pleura was incised along the posterior edge of the esophagus up to the right subclavian vein. The dorsal and left sides of the upper esophagus were dissected along with the thoracic duct. The right upper mediastinal pleura was incised along the right vagal nerve from the level of the azygos arch to the edge of the right subclavian vein. The right RLN was then identified at the caudal end of the right subclavian artery. Lymph nodes around the nerve were dissected and resected up to the cervical level with meticulous care to prevent nerve injury. Next, the anterior part of the upper esophagus was dissected from the trachea, and the upper esophagus was circumferentially dissected along with the surrounding nodes. By shifting the taped esophagus posteriorly and retracting the trachea anteriorly, it was possible to approach the left side of the trachea. The nodes around the left RLN were dissected from the aortic arch to the cervical level. The left pulmonary artery was exposed to dissect the left tracheobronchial lymph nodes between the aortic arch and the left main bronchus. The thoracic duct was clipped and divided at the level of the thoracic inlet.

The operating table was then rotated so the patient was in the prone position, and $CO_2$ pneumothorax was induced using a minithoracotomy lid. The mediastinal pleura was incised along the anterior edge of the vertebrae to the hiatus. The posterior side of the middle to lower esophagus was dissected to expose the aortic arch and descending aorta. The thoracic duct was clipped behind the lower

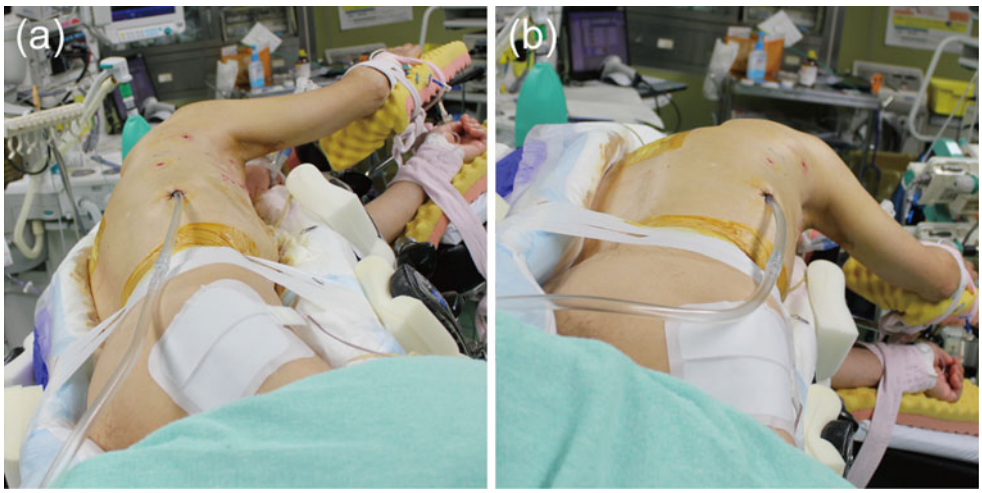


**Fig. 1** Thoracoscopic esophagectomy in the hybrid position. The patient's position can be changed from the left lateral decubitus position (**a**) to the prone position (**b**) by rotating the operating table

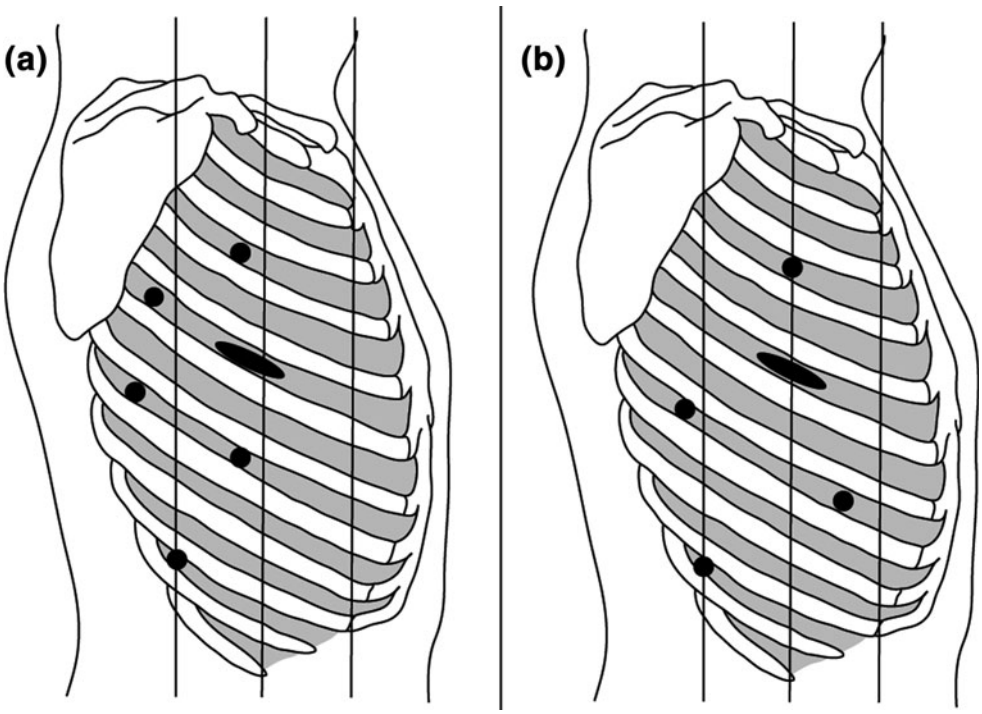


**Fig. 2** Placement of a minithoracotomy and insertion of trocars for thoracoscopic esophagectomy in the hybrid position (**a**) and left lateral decubitus position (**b**)

esophagus and resected together with the esophagus. The mediastinal pleura anterior to the esophagus was then incised. The esophagus was divided using a linear stapler above the primary tumor, and the caudal stump of the esophagus and surrounding tissue were dissected up to the hiatus. The subcarinal nodes were separately resected. Esophageal mobilization and mediastinal lymphadenectomy were thus completed.

*Left lateral decubitus position*

A 4- to 5-cm minithoracotomy was made, and trocars were placed as shown in Fig. 2b. The procedure was performed as described with the following exceptions: LD-TE was entirely performed in the left lateral decubitus position without $CO_2$ pneumothorax. Anterior retraction of the lung was necessary for subsequent dissection of the middle and lower esophagu. The thoracic duct was generally preserved in LD-TE.

*Abdominal procedures*

The abdominal procedures were performed through an upper midline abdominal incision or by hand-assisted laparoscopic surgery (HALS). HALS procedures were

performed through a transverse minilaparotomy (7 cm) in the right upper quadrant, with one port below the navel and two ports in the left abdomen. The following procedure was identical for both open surgery and HALS.

The greater omentum, short gastric vessels, and lesser omentum were divided while avoiding injury to the right gastroepiploic and right gastric vessels. The distal esophagus was dissected and mobilized. The fat tissue over the left gastric artery was dissected, and the artery was divided. The distal stump of the esophagus and the dissected mediastinal tissue were then extracted from the thorax to the abdomen. The stomach was then divided from the lesser curvature to the fornix using linear staplers. Thus, gastric conduit formation and abdominal lymphadenectomy were completed.

*Anastomosis*

Esophagogastrostomy was performed in the neck or thorax. In patients with cervical anastomoses, the gastric conduit was pulled up to the neck through the posterior mediastinal route. The cervical esophagus and gastric conduit were then anastomosed using a circular stapler. If the gastric conduit was not of sufficient length for mechanical anastomosis, the anastomosis was hand-sewn. In patients with intrathoracic anastomoses, esophagogastrostomy was performed using a circular stapler at the level of the thorax through a minithoracotomy [8].

### Postoperative management

After surgery, each patient was admitted to the intensive care unit (ICU), and mechanical ventilation was continued overnight. The fractional inspired oxygen concentration ($FiO_2$) was usually set at 0.4–0.5, and the positive end-expiratory pressure was set at 5 cm $H_2O$. If the patient's cardiopulmonary condition was stable, the patient was extubated on postoperative day (POD) 1 and was admitted to the general surgical ward on POD 2. Postoperative analgesia was provided through patient-controlled epidural analgesia. After a contrast study of the anastomosis on POD 7, the nasogastric tube was removed. Oral intake of thick liquids was initiated, then gradually changed to jelly-like food and then to solid food. Patients were discharged when they could ingest solid food.

### Morbidity and mortality following TE

The incidence of postoperative complications was determined through inspection of medical records. Vocal cord palsy was defined as hoarseness at the time of discharge. Pneumonia was defined as an abnormal shadow on a chest radiograph with fever (>38 °C), positive sputum, and/or a white blood cell count of $\geq$12,000/mm$^3$.

Postoperative complications were categorized using the Clavien–Dindo classification as follows [10]: grade I, any deviation from the normal postoperative course without the need for pharmacologic treatment or surgical, endoscopic, or radiologic intervention; grade II, requiring pharmacologic treatment with drugs; grade III, requiring surgical, endoscopic, or radiologic intervention; grade IV, life-threatening complication requiring ICU management; and grade V, death.

### Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics version 19 (IBM, Armonk, NY, USA). Categoric data were analyzed using Fisher's exact test. Quantitative data were analyzed using an unpaired Student's $t$ test and the Mann–Whitney $U$ test. A value of $p < 0.05$ was considered statistically significant. Survival outcomes were analyzed using the Kaplan–Meier method and log-rank tests.

## Results

### Clinical characteristics

Patient demographics are summarized in Table 1. The mean patient age was lower in the LD-TE group than in the hybrid-TE group. The number of patients with cStage III or IV disease was lower in the LD-TE group than in the hybrid-TE group. More patients in the hybrid-TE group received neoadjuvant chemotherapy than those in the LD-TE group.

### Surgical results

Surgical results are shown in Table 2. Four patients (5.1 %) required conversion to open surgery. The reasons for conversion to thoracotomy included bleeding of the bronchial artery at the time of anastomosis in one patient and dense thoracic adhesions in three patients. The number of patients in whom thoracic esophagogastrostomy was performed was significantly greater in the hybrid-TE group than in the LD-TE group. Although no significant difference was observed between the two groups in terms of intraoperative blood loss, operating time was longer in the hybrid-TE group than in the LD-TE group. The number of harvested lymph nodes was significantly greater in the hybrid-TE group than in the LD-TE group for mediastinal nodes plus abdominal nodes ($p = 0.008$), mediastinal

**Table 1** Clinical characteristics

| Characteristic | Overall ($n = 78$) | | Left lateral decubitus position ($n = 33$) | | Hybrid position ($n = 45$) | | $p$ |
|---|---|---|---|---|---|---|---|
| Age (years) | | | | | | | 0.014* |
| Mean ± SD | 61.5 ± 7.7 | | 59.0 ± 7.7 | | 63.3 ± 7.2 | | |
| Sex | | | | | | | 0.716 |
| Male | 70 | 89.7 % | 29 | 87.9 % | 41 | 91.1 % | |
| Female | 8 | 10.3 % | 4 | 12.1 % | 4 | 8.9 % | |
| Tumor location (esophagus) | | | | | | | 1.000 |
| Upper thoracic | 10 | 12.8 % | 4 | 12.1 % | 6 | 13.3 % | |
| Middle thoracic | 41 | 52.6 % | 21 | 63.6 % | 20 | 44.4 % | |
| Lower thoracic | 27 | 34.6 % | 8 | 24.2 % | 19 | 42.2 % | |
| Preoperative therapy | | | | | | | |
| Endoscopic resection | 4 | 5.1 % | 2 | 6.1 % | 2 | 4.4 % | 1.000 |
| Neoadjuvant chemotherapy | 35 | 44.9 % | 5 | 15.2 % | 30 | 66.7 % | <0.001* |
| cT category | | | | | | | 1.000 |
| cT1 | 33 | 42.3 % | 17 | 51.5 % | 16 | 35.6 % | |
| cT2 | 23 | 29.5 % | 8 | 24.2 % | 15 | 33.3 % | |
| cT3 | 22 | 28.2 % | 8 | 24.2 % | 14 | 31.1 % | |
| cN category | | | | | | | 0.362 |
| cN0 | 35 | 44.9 % | 17 | 51.5 % | 18 | 40.0 % | |
| cN1-3 | 43 | 55.1 % | 16 | 48.5 % | 27 | 60.0 % | |
| cM category | | | | | | | 0.634 |
| cM0 | 74 | 94.9 % | 32 | 97.0 % | 42 | 93.3 % | |
| cM1 (LYM) | 4 | 5.1 % | 1 | 3.0 % | 3 | 6.7 % | |
| cStage | | | | | | | 0.018* |
| I + II | 63 | 80.8 % | 31 | 93.9 % | 32 | 71.1 % | |
| III + IV | 15 | 19.2 % | 2 | 6.1 % | 13 | 28.9 % | |

*Statistically signficant

nodes ($p = 0.001$), upper mediastinal nodes ($p = 0.001$), and middle to lower mediastinal nodes ($p = 0.023$).

## Histopathologic characteristics

Overall, 67 patients (85.9 %) had squamous cell carcinomas and 8 (10.3 %) had adenocarcinomas. In all, 30 patients (90.9 %) in the LD-TE group and 39 (86.7 %) in the hybrid-TE group underwent R0 resection. In the LD-TE group, 21 patients (63.6 %) had pT1, 3 (9.1 %) had pT2, and 9 (27.3 %) had pT3 tumors. In the hybrid-TE group, one patient (2.2 %) achieved complete remission after neoadjuvant chemotherapy, 23 (51.1 %) had pT1, 7 (15.6 %) had pT2, 13 (28.9 %) had pT3, and one (2.2 %) had pT4a tumors. Altogether, 17 patients (51.5 %) in the LD-TE group and 18 (40.0 %) in the hybrid-TE group had pN0 tumors. No significant differences were observed between the two groups in terms of histologic types, pT, pN, or R categories.

## Postoperative results

Postoperative results are summarized in Table 3. The $PaO_2/FiO_2$ (P/F) ratio on POD 1 was significantly higher in the hybrid-TE group (median 290 in the LD-TE group and 398 in the hybrid-TE group; $p < 0.001$). The duration of hospital stay after TE was similar in the two groups. No difference was observed in the duration of ICU stay, as the median was 2 days in each group.

Two in-hospital deaths were recorded. One patient died from severe pneumonia on POD 54. The other patient's hospital stay was extended because of postoperative pulmonary complications, and the patient ultimately died from cancer recurrence on POD 144. There were no 30-day mortalities in either groups.

Postoperative morbidity rates are shown in Table 4. Temporal vocal cord palsy after surgery was more frequent in the hybrid-TE group than in the LD-TE group. However, no significant difference was observed in the rates of other

**Table 2** Surgical results

| Parameter | Overall ($n = 78$) | Left lateral decubitus position ($n = 33$) | Hybrid position ($n = 45$ | $p$ |
|---|---|---|---|---|
| Conversion to thoracotomy | 4 (5.1 %) | 2 (6.1 %) | 2 (4.4 %) | 1.000 |
| Abdominal procedure | | | | |
| Open | 7 (9.0 %) | 2 (6.1 %) | 5 (11.1 %) | 0.692 |
| HALS | 71 (91.0 %) | 31 (93.9 %) | 40 (88.9 %) | |
| Extent of lymphadenectomy | | | | |
| Two-field | 33 (42.3 %) | 13 (39.4 %) | 20 (44.4 %) | 0.817 |
| Three-field | 45 (57.7 %) | 20 (60.6 %) | 25 (55.6 %) | |
| Site of esophagogastrostomy | | | | |
| Cervical anastomosis | 57 (73.1 %) | 31 (93.9 %) | 26 (57.8 %) | <0.001* |
| Intrathoracic anastomosis | 21 (36.9 %) | 2 (6.1 %) | 19 (42.2 %) | |
| Intraoperative blood loss (ml)[a] | 152 (75–267) | 147 (91–300) | 160 (20–243) | 0.332 |
| Operating time (min)[a] | 529 (464–591) | 461 (400–488) | 587 (545–616) | <0.001* |
| Nodes harvested (no.)[a] | | | | |
| Mediastinal + abdominal | 35 (30–47) | 33 (27–40) | 36 (34–50) | 0.008* |
| Mediastinal | 21 (14–26) | 15 (13–23) | 23 (18–31) | 0.001* |
| Upper mediastinal | 7 (4–11) | 6 (4–7) | 9 (5–13) | 0.001* |
| Middle + lowermediastinal | 12 (8–17) | 11 (7–16) | 13 (10–18) | 0.023* |

*HALS* hand-assisted laparoscopic surgery, *IQR* interquartile range

[a] Median number and IQR

**Table 3** Postoperative results

| Parameter | Left lateral decubitus position ($n = 33$) | Hybrid position ($n = 45$) | $p$ |
|---|---|---|---|
| $PaO_2/FiO_2$ on POD 1[a] | 290 (240–399) | 398 (341–420) | <0.001* |
| Hospital LOS after surgery (days) | 22 (17–38) | 22 (20–34) | 0.939 |
| Postoperative mortality rate | | | |
| 30-day | 0 | 0 | 1.000 |
| In-hospital | 1 (3.0 %) | 1 (2.2 %) | 1.000 |

*POD* postoperative day

[a] Results are given as the median and IQR

complications or in-hospital mortality between the two groups. The morbidity rates (≥grade III according to the Clavien–Dindo classification), including vocal cord palsy, were similar in the two groups.

### Survival

The median follow-up in the censored patients was 51.1 months in the LD-TE group and 41.1 months in the hybrid-TE group. In all, seven patients (21 %) in the LD-TE group and 13 (29 %) in the hybrid-TE group died. Recurrence after surgery was observed in 13 patients (39 %) in the LD-TE group and 18 patients (40 %) in the hybrid-TE group. The 1- and 3-year overall survivals were, respectively, 91 and 81 % in the LD-TE group and 90 and 72 % in the hybrid-TE group ($p = 0.7412$). The 1- and 3-year relapse-free survivals were, respectively, 85 and 62 % in the LD-TE group and 74 and 56 % in the hybrid-TE group ($p = 0.3767$).

Lymph node recurrence was observed in 12 patients (36 %) in the LD-TE group and 15 (33 %) in the hybrid-TE group. Mediastinal node recurrence was observed in ten patients (30 %) in the LD-TE group and 8 (18 %) in the hybrid-TE group ($p = 0.2770$).

## Discussion

Since TE was first reported by Cuschieri et al. [1], several groups have reported various TE techniques. Although most advocated thoracoscopic procedures in the left lateral decubitus position, Cuschieri et al. [11] reported on TE in the prone position. Thereafter, Palanivelu et al. [7] reported on their experience of performing TE in the prone position in 130 patients. They reported that the prone position enabled excellent exposure of the operative field and provided the surgeon with superior ergonomics. In their original report, they used a single-lumen endotracheal tube with possible two-lung ventilation (left-lung ventilation with possible intermittent ventilation of the right lung) under $CO_2$ pneumothorax. Also all thoracoscopic procedures were performed in the prone position. Many other groups have since switched to TE in the prone position [12–14].

We agree that TE in the prone position provides significant advantages. The prone position provides the surgeon with an excellent operative field, particularly in the

**Table 4** Postoperative morbidity

| | Left lateral decubitus position ($n = 33$) | | | | Hybrid position ($n = 45$) | | | | $p$ |
|---|---|---|---|---|---|---|---|---|---|
| | Any grade | | ≥Grade III[a] | | Any grade | | ≥Grade III[a] | | Any/≥grade III[a] |
| Any complication | 18 | 54.5 % | 10 | 30.3 % | 31 | 68.9 % | 13 | 22.2 % | 0.239/1.000 |
| Vocal cord palsy | 6 | 18.2 % | 1 | 3.0 % | 23 | 51.1 % | 4 | 8.9 % | 0.004*/0.389 |
| Pneumonia | 5 | 15.2 % | 3 | 9.1 % | 11 | 24.4 % | 2 | 4.4 % | 0.564/0.645 |
| Anastomotic leakage | 5 | 15.2 % | 5 | 15.2 % | 9 | 20.0 % | 9 | 20.0 % | 0.767/0.767 |
| Wound infection | 8 | 24.2 % | 1 | 3.0 % | 4 | 8.9 % | 0 | – | 0.110/0.423 |
| Pyothorax | 2 | 6.1 % | 2 | 6.1 % | 2 | 4.4 % | 2 | 4.4 % | 0.571/0.571 |
| Chylothorax | 0 | – | 0 | – | 3 | 6.7 % | 2 | 4.4 % | 0.258/0.505 |

[a] According to the Clavien–Dindo classification [10]

*Statistically significant

region of the middle to lower mediastinum, because gravity and $CO_2$ pneumothorax retract the right lung and stretch the mediastinum. However, these favorable effects do little to facilitate the surgeon's approach to the left side of the upper mediastinum. We believe the left lateral decubitus position to be superior for lymphadenectomy along the left RLN. In addition, this approach facilitates conversion to thoracotomy. Therefore, in 2009, we introduced a TE method that was performed with the patient with hybrid positioning that included the left lateral decubitus and prone positions. These hybrid-TE procedures are performed with the patient in two different positions (the left lateral decubitus and prone positions) and hence require placement of one additional port (5 mm). However, we believe that this additional 5-mm port has little effect on postoperative pain or pulmonary function.

We also modified the extent of the upper mediastinal lymphadenectomy to enable more radical lymphadenectomy along the left RLN. With this approach, the thoracic duct is resected, and the lymphatic fatty tissue at the upper mediastinum is thoroughly dissected. In eastern Asia, squamous cell carcinomas of the thoracic esophagus are the most commonly observed among esophageal cancers. Such cancers are associated with a high incidence of widespread lymph node metastasis (from the neck to the abdomen) and a relatively high risk of metastasizing to the upper mediastinum along the bilateral RLNs [15, 16]. Therefore, we consider lymphadenectomy of the upper mediastinum as an essential part of esophagectomy for thoracic esophageal cancer.

We retrospectively analyzed a series of patients who underwent TE to evaluate the clinical utility of our novel hybrid-TE technique versus the conventional TE technique. An analysis of the results revealed that neoadjuvant chemotherapy was administered to a greater number of patients in the hybrid-TE group than in the LD-TE group. This finding is probably because our institution adopted neoadjuvant chemotherapy as standard therapy for advanced esophageal cancer in 2009 on the basis of the results of a randomized trial in Japan [17, 18]. Furthermore, the number of patients who underwent intrathoracic anastomosis was significantly greater in the hybrid-TE group because we introduced intrathoracic anastomosis in 2009 as a standard procedure for patients undergoing two-field lymphadenectomy [8].

Our retrospective review of the patients' medical records demonstrated that hybrid-TE was associated with a greater number of upper mediastinal lymph nodes harvested during radical mediastinal lymphadenectomy. This finding was attributed to resection of the thoracic duct and subsequent expansion of the operative field during upper mediastinal lymphadenectomy. The number of nodes dissected from the middle to lower mediastinum was also significantly greater in the hybrid-TE group than in the LD-TE group. This finding can be attributed to the effect of gravity in the prone position, which provides an excellent operative field that enables more precise and radical dissection in the area from the middle to lower mediastinum.

Various research groups have reported the number of lymph nodes dissected during TE. In general, the number of harvested lymph nodes is greater when the surgery involves lymphadenectomy along the RLNs [13, 14, 19–24]. At our institution, a median of 23 mediastinal lymph nodes were harvested during hybrid-TE. This number is greater than that cited in reports of TE without radical upper mediastinal lymphadenectomy [13, 19–21].

On the other hand, upper mediastinal lymphadenectomy expansion in the hybrid-TE group resulted in more cases of vocal cord palsy due to temporal RLN palsy than in the LD-TE group. However, our statistical analysis of grade III or higher complications showed that no significant difference was observed in the incidence of vocal cord palsy between the two groups. Postoperative hoarseness usually resolved within several months, although the symptoms persisted for prolonged periods in a few patients. Based on our experience, we believe the rate of vocal cord palsy associated with hybrid-TE is acceptable.

More patients with cStage III or IV were in the hybrid-TE group ($p = 0.018$) (Table 1). Nonetheless, no significant difference was observed in survival between the two groups. In addition, there tended to be less mediastinal nodal recurrence in the hybrid-TE group than in the LD-TE group but without a significant difference. Therefore, we believe that the radicalization of mediastinal lymphadenectomy with hybrid-TE may improve locoregional control and survival.

Hybrid-TE did not increase the risk of postoperative pneumonia in our case series, although this risk is generally increased in patients with vocal cord palsy [25]. In addition, the $PaO_2/FiO_2$ ratio on POD 1 was significantly higher in the hybrid-TE group than in the LD-TE group. These results imply that by placing the patient in the prone position during procedures involving the middle to lower mediastinum the severity of intraoperative pulmonary damage decreases, as described by Palanivelu et al. [7].

Decker et al. [26] reviewed various reports on minimally invasive esophagectomy. This approach was associated with the following: postoperative mortality rate 2.9 %; overall complication rate 48 %; pulmonary complication rate 22 %; vocal cord palsy incidence 7.1 %. In this review [26], studies using transhiatal approaches were included in the analyses. Moreover, radical mediastinal lymphadenectomy was not performed in many studies, and upper mediastinal lymphadenectomy along the bilateral RLNs was even less common. Therefore, our results cannot be directly compared with those included in the meta-analysis [26]. However, we do note that the in-hospital mortality rate in our TE case series (2.2 %) was lower than that reported by Decker et al. (2.9 %).

## Conclusions

Hybrid-TE appears to be feasible for routine application clinically. This approach facilitates a more radical mediastinal lymphadenectomy. The evidence presented here suggests that this hybrid position may also improve disease control and decrease the severity of intraoperative pulmonary damage. In the future, we will analyze long-term outcomes after a longer follow-up period to confirm the oncologic feasibility and/or advantages of this approach.

**Conflict of interest** The authors declare no conflicts of interest.

## References


1. Cuschieri A, Shimi S, Banting S (1992) Endoscopic oesophagectomy through a right thoracoscopic approach. J R Coll Surg Edinb 37:7–11
2. Akaishi T, Kaneda I, Higuchi N et al (1996) Thoracoscopic en bloc total esophagectomy with radical mediastinal lymphadenectomy. J Thorac Cardiovasc Surg 112:1533–1540 (discussion 1540–1531)
3. Kawahara K, Maekawa T, Okabayashi K et al (1999) Video-assisted thoracoscopic esophagectomy for esophageal cancer. Surg Endosc 13:218–223
4. Smithers BM, Gotley DC, McEwan D et al (2001) Thoracoscopic mobilization of the esophagus: a 6-year experience. Surg Endosc 15:176–182
5. Luketich JD, Alvelo-Rivera M, Buenaventura PO et al (2003) Minimally invasive esophagectomy: outcomes in 222 patients. Ann Surg 238:486–494 (discussion 494–485)
6. Osugi H, Takemura M, Higashino M et al (2003) A comparison of video-assisted thoracoscopic oesophagectomy and radical lymph node dissection for squamous cell cancer of the oesophagus with open operation. Br J Surg 90:108–113
7. Palanivelu C, Prakash A, Senthilkumar R et al (2006) Minimally invasive esophagectomy: thoracoscopic mobilization of the esophagus and mediastinal lymphadenectomy in prone position—experience of 130 patients. J Am Coll Surg 203:7–16
8. Takeuchi H, Oyama T, Saikawa Y et al (2012) Novel thoracoscopic intrathoracic esophagogastric anastomosis technique for patients with esophageal cancer. J Laparoendosc Adv Surg Tech A 22:88–92
9. Sobin LH, Gospodarowicz MK, Wittekind C (2009) TNM classification of malignant tumours, 7th edn. Wiley-Blackwell, Oxford
10. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240:205–213
11. Cuschieri A (1994) Thoracoscopic subtotal oesophagectomy. Endosc Surg Allied Technol 2:21–25
12. Leibman S, Smithers BM, Gotley DC et al (2006) Minimally invasive esophagectomy: short- and long-term outcomes. Surg Endosc 20:428–433
13. Biere SS, van Berge Henegouwen MI, Maas KW et al (2012) Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet 379:1887–1892
14. Ozawa S, Ito E, Kazuno A et al (2013) Thoracoscopic esophagectomy while in a prone position for esophageal cancer: a preceding anterior approach method. Surg Endosc 27:40–47
15. Isono K, Sato H, Nakayama K (1991) Results of a nationwide study on the three-field lymph node dissection of esophageal cancer. Oncology 48:411–420
16. Akiyama H, Tsurumaru M, Udagawa H et al (1994) Radical lymph node dissection for cancer of the thoracic esophagus. Ann Surg 220:364–372 (discussion 372–363)
17. Igaki H, Kato H, Ando N et al (2008) A randomized trial of postoperative adjuvant chemotherapy with cisplatin and 5-fluorouracil versus neoadjuvant chemotherapy for clinical stage II/III squamous cell carcinoma of the thoracic esophagus (JCOG 9907). J Clin Oncol 26:4510
18. Ando N, Kato H, Igaki H et al (2012) A randomized trial comparing postoperative adjuvant chemotherapy with cisplatin and 5-fluorouracil versus preoperative chemotherapy for localized advanced squamous cell carcinoma of the thoracic esophagus (JCOG9907). Ann Surg Oncol 19:68–74
19. Smithers BM, Gotley DC, Martin I et al (2007) Comparison of the outcomes between open and minimally invasive esophagectomy. Ann Surg 245:232–240
20. Luketich J, Pennathur A, Catalano PJ et al (2009) Results of a phase II multicenter study of minimally invasive esophagectomy

(Eastern Cooperative Oncology Group Study E2202). J Clin Oncol 27:4516
21. Nguyen NT, Hinojosa MW, Smith BR et al (2008) Minimally invasive esophagectomy: lessons learned from 104 operations. Ann Surg 248:1081–1091
22. Osugi H, Takemura M, Higashino M et al (2002) Video-assisted thoracoscopic esophagectomy and radical lymph node dissection for esophageal cancer: a series of 75 cases. Surg Endosc 16:1588–1593
23. Yamamoto S, Kawahara K, Maekawa T et al (2005) Minimally invasive esophagectomy for stage I and II esophageal cancer. Ann Thorac Surg 80:2070–2075
24. Kunisaki C, Kosaka T, Ono HA et al (2011) Significance of thoracoscopy-assisted surgery with a minithoracotomy and hand-assisted laparoscopic surgery for esophageal cancer: the experience of a single surgeon. J Gastrointest Surg 15:1939–1951
25. Gockel I, Kneist W, Keilmann A et al (2005) Recurrent laryngeal nerve paralysis (RLNP) following esophagectomy for carcinoma. Eur J Surg Oncol 31:277–281
26. Decker G, Coosemans W, De Leyn P et al (2009) Minimally invasive esophagectomy for cancer. Eur J Cardiothorac Surg 35:13–20 (discussion 20–11)