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ORIGINAL ARTICLE

The usefulness of a bilateral trans-cervical pneumomediastinal approach for mediastinoscopic radical esophagectomy: a right transcervical approach is an available option

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Abstract

Objective We investigated the merits and demerits of right cervical open surgery with right trans-cervical pneumomediastinal approach in mediastinoscopic esophagectomy.

Methods Ten thoracic esophageal cancer patients were treated using this approach. Under pneumomediastinum via a right neck incision, the right cervical and upper mediastinal paraesophageal lymph nodes were dissected. The left recurrent nerve lymph nodes were dissected using a left trans-cervical pneumomediastinal approach. The subaortic arch to the left tracheobronchial lymph nodes was dissected with a combined right and left trans-cervical crossover approach.

Results The average number of dissected lymph nodes among the right cervical and upper mediastinal paraesophageal lymph nodes identified with a right cervical open/right trans-cervical mediastinoscopic/right thoracoscopic approach was 3.2/4.0/0.6, respectively. The average number of dissected lymph nodes among the subaortic arch to the left tracheobronchial lymph nodes with a right trans-cervical mediastinoscopic/right thoracoscopic approach was 1.5/0.6, respectively. These findings indicate that, without using the right trans-cervical pneumomediastinal approach, it might be impossible to successfully remove some of the right cervical and upper mediastinal paraesophageal lymph nodes and the subaortic arch to the left tracheobronchial lymph nodes lymph nodes. Regarding surgical complications, one case of bilateral recurrent nerve palsy as well as two cases on the right and two cases on the left were noted.

Conclusions Although the rate of recurrent nerve palsy should still be reduced, a bilateral (especially right-sided) trans-cervical pneumomediastinal approach is an available option for achieving sufficient upper mediastinal lymph node dissection and esophagectomy.

Keywords Trans-cervical approach · Esophageal cancer · Mediastinoscopic radical esophagectomy · Pneumomediastinum · Lymph node dissection

Introduction

Non-transthoracic esophagectomy (transhiatal esophagectomy) has been developed as a method of minimally invasive esophagectomy (MIE) for thoracic esophageal cancers, but it is difficult to maintain the operation field for esophagectomy and upper mediastinal lymph node dissection using this approach [1, 2]. To resolve this issue, open surgery via bilateral neck incisions or various mediastinoscopic surgery [3–10] has been considered. Recently, a pneumomediastinum technique has been applied in mediastinoscopic surgery, and progress toward MIE using a non-transthoracic approach has been made [11, 12].

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We developed and reported the "mediastinoscopic esophagectomy with lymph node dissection (MELD)" procedure under pneumomediastinum with a combined bilateral trans-cervical and transhiatal crossover approach [13]. Its features differ from those of other mediastinoscopic esophagectomies in the use of a bilateral trans-cervical pneumomediastinal approach. We applied this procedure to clinical cases as a clinical trial from 2015.

We herein report our detailed operative procedure based on the results of that trial and describe the integrity of upper mediastinal lymph node dissection especially that of the right cervical and upper mediastinal paraesophageal lymph nodes and the subaortic arch to the left tracheobronchial lymph nodes. The subaortic arch to the left tracheobronchial lymph nodes include the left tracheobronchial lymph nodes and the most caudal part of the left recurrent nerve lymph nodes, located between the distal part of the aortic arch and trachea. The advantages of this approach to upper mediastinal lymph node dissection are discussed, along with associated adverse events.

Methods

In 10 patients, we performed MELD using the bilateral trans-cervical approach under pneumomediastinum from September 1, 2015, to March 31, 2018. These patients had histologically proven squamous cell carcinoma of the thoracic esophagus, resectable disease, age ≥ 20 years and sufficient organ function, excluding T4, bulky primary lesion or distant metastasis. Written informed consent was obtained about esophagectomy with the MELD procedure and reconstruction using a gastric tube, including consent for conversion to thoracotomy or laparotomy. This study was approved by our institutional review board (M2000-2006).

Surgical procedures

In the MELD procedure, the right cervical approach is performed first, followed by the left cervical approach and laparoscopic-transhiatal approach.

Right cervical approach

A right cervical collar incision (about 4 cm in length) is made 4 cm above the right clavicle, and sufficient working space is created between the tracheoesophageal groove and right carotid sheath. The right cervical paraesophageal lymph nodes and part of the right recurrent nerve lymph nodes are dissected in open surgery. Pneumomediastinum with CO_2 (to 8 mmHg) is then introduced. A single-port laparoscopic access device (EZ Access; Hakko Corporation, Nagano, Japan) with three 5-mm trocars is set between the tracheoesophageal groove and carotid sheath. Another 5-mm trocar is inserted 4 cm above the right cervical collar incision as a scope port (Fig. 1). The esophageal and lymph node dissection maneuver is chiefly performed using a LigaSure™ Maryland (Medtronic, Minneapolis, MN, USA) (see Video, Online Resource). The remaining right recurrent nerve lymph nodes and right upper thoracic paraesophageal lymph nodes under the right mediastinal pleura are dissected. The right vagus nerve, proximal portion of the azygos vein and right intercostal bronchial artery are visualized and preserved (Fig. 2). The thoracic duct is also clearly recognized beneath the visceral sheath [14, 15] (Fig. 3). With this right-sided approach, the visceral sheath of the upper mediastinum around the esophagus is more easily recognized and preserved than with the left-sided approach. The esophagus is separated from the membranous trachea.

In the middle mediastinum, the tracheal carina, bilateral tracheobronchial angles, the thoracic duct and descending aorta are also easily separated from the esophagus.

Finally, the dissection of the right recurrent nerve and upper mediastinal paraesophageal lymph nodes is performed via a right trans-cervical approach under pneumomediastinum (Fig. 4).

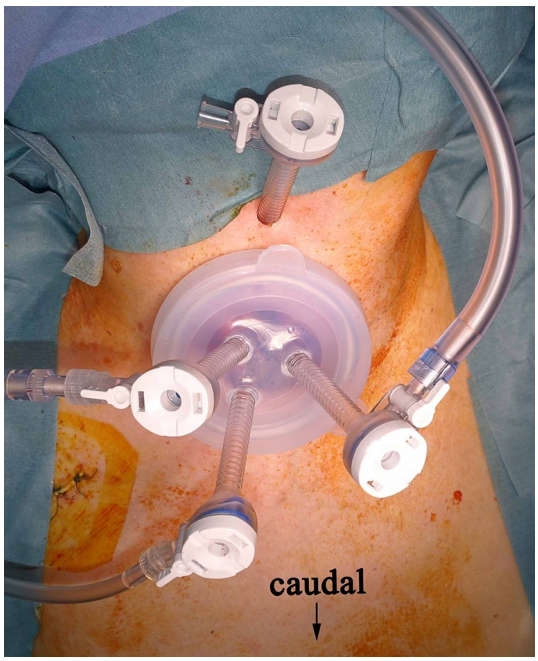

Fig. 1 The location of the single-port laparoscopic access device in the cervical approach. This figure shows the right cervical area. A single-port laparoscopic access device with three 5-mm trocars is placed in a triangle configuration. Another 5-mm trocar was inserted 4 cm above the right cervical collar incision as a scope port

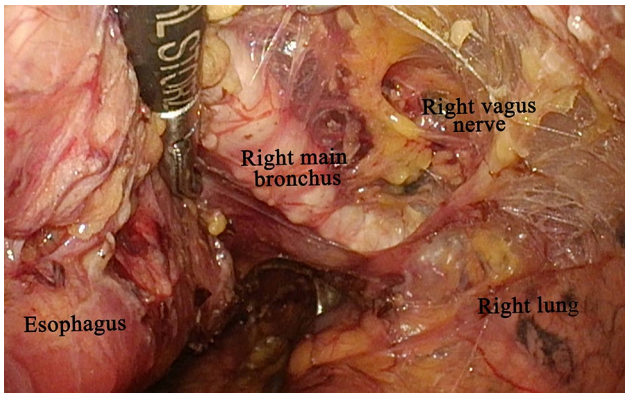

Fig. 2 Upper mediastinal paraesophageal lymph node dissection via a right trans-cervical approach under pneumomediastinum. The right vagus nerve is visualized and preserved. The right lung is observed through the right mediastinal pleura. The right upper mediastinal paraesophageal lymph nodes are completely dissected. With the right trans-cervical approach, a very wide working space can be obtained

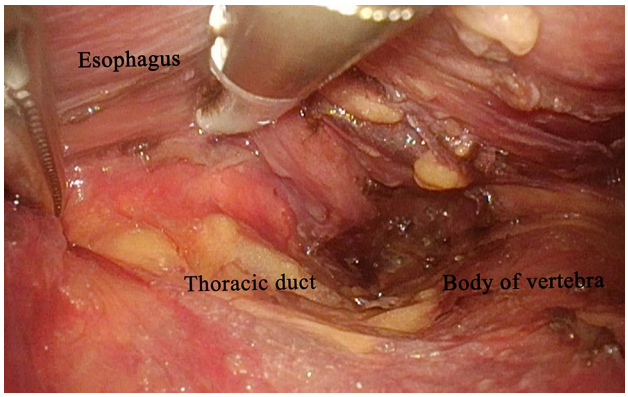

Fig. 3 The thoracic duct via a right trans-cervical approach under pneumomediastinum. The esophagus is dissected along the "visceral sheath", and the thoracic duct is separated from the esophagus

Left cervical approach followed by right-to-left crossover approach

A left cervical collar incision and scope port site are made symmetrically. The left cervical paraesophageal lymph nodes are then dissected, and the cranial portion of the left recurrent nerve is identified by the open method. A single-port laparoscopic access device is attached, and left trans-cervical pneumomediastinum is applied (see Video, Online Resource). The left recurrent nerve lymph nodes are dissected along the tracheal wall while preserving the left recurrent nerve and its tracheal branches. The cardiac branch of the sympathetic nerve and thoracic duct are determined, and the esophageal wall is divided from the membranous trachea, left main bronchus and aortic arch

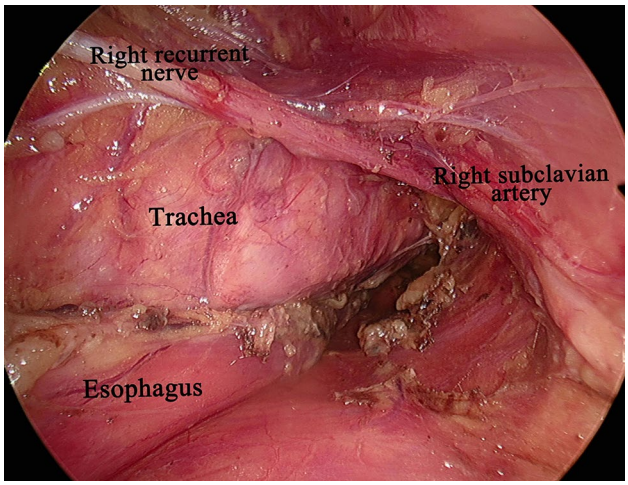

Fig. 4 The dissection of the right recurrent nerve and upper mediastinal paraesophageal lymph nodes via a right trans-cervical approach under pneumomediastinum. These lymph nodes were sufficiently dissected via a right trans-cervical approach under pneumomediastinum

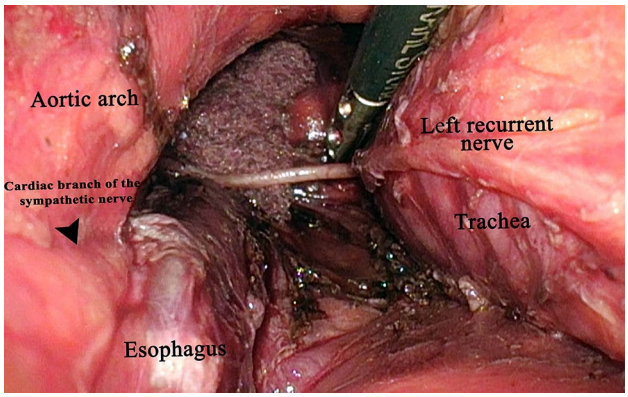

Fig. 5 The dissection of the left recurrent nerve lymph nodes via a left trans-cervical approach under pneumomediastinum. The left recurrent nerve lymph nodes are dissected along the left side of the tracheal wall, common carotid artery, subclavian artery, thoracic duct, aortic arch and left recurrent nerve. The cardiac branch of the sympathetic nerve can be detected along with the left subclavian artery. However, the left tracheobronchial lymph nodes are tangentially dissected

(Fig. 5) along the visceral sheath before being cut at the level of the upper esophagus.

For dissection of the subaortic arch to the left tracheobronchial lymph nodes, we have typically used the previously reported "cervico-hiatal cross-over technique" [13]. However, we have recently introduced the "right-to-left-cervical cross-over technique" too. In this technique, the trachea is retracted with a thin retractor via the left cervical port, thus obtaining a good operation field between the lower margin of the aortic arch and the cartilage of the

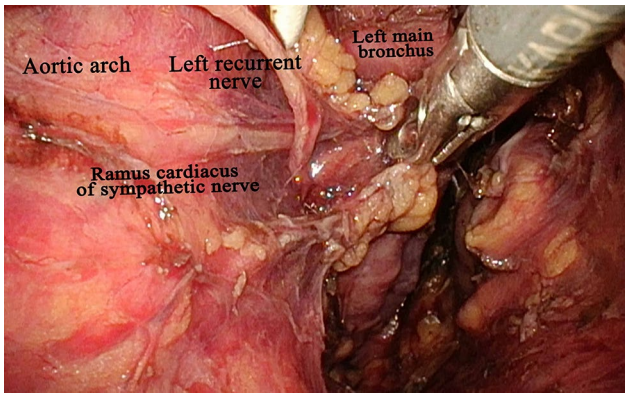

Fig. 6 The field of view before dissection of the area from the left tracheobronchial lymph nodes via a right trans-cervical approach under pneumomediastinum. We used the "crossover technique". The trachea was retracted ventrally with forceps inserted via a left cervical port. A good view of the aortic arch and the cartilage of the left bronchus was obtained. The left recurrent nerve and cardiac branch of the sympathetic nerve can be clearly seen

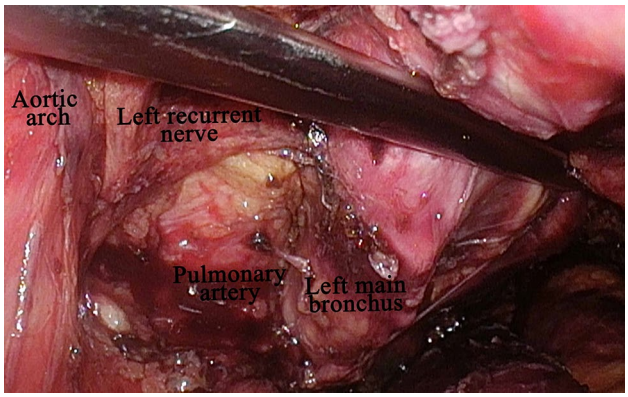

Fig. 7 The field of view after dissection of the subaortic arch to the left tracheobronchial lymph nodes via a right trans-cervical approach under pneumomediastinum. The subaortic arch to the left tracheobronchial lymph nodes is easily dissected via the right trans-cervical approach under pneumomediastinum. This region can be seen in a tangential view when using the left trans-cervical approach, but an angular view with a wider working space can be obtained when using the right trans-cervical approach

left tracheobronchial angle (Fig. 6). These lymph nodes can then be dissected via the right cervical ports again (Fig. 7). In contrast to the left trans-cervical approach (Fig. 5), the subaortic arch to the left tracheobronchial lymph nodes is dissected less tangentially in the right trans-cervical approach (see Video, Online Resource, which shows the difference in the operation field between the right and left trans-cervical approaches). Furthermore, these lymph nodes were able to be observed more frontally via the right trans-cervical approach than via the left approach.

Laparoscopic and transhiatal approach

Laparoscopic surgery is performed to dissect the upper abdominal lymph nodes and achieve gastric conduit mobilization. Transhiatally, the middle to lower thoracic esophagus and mediastinal lymph nodes, including the subcarinal nodes, are dissected [16].

In our clinical trial, a thoracoscopic procedure was added in order to determine whether or not the mediastinal lymph nodes had been satisfactorily dissected [17].

The evaluation of the integrity of upper mediastinal lymph node dissection

To assess the integrity of mediastinal lymph node dissection in the right cervical and upper mediastinal paraesophageal lymph nodes and the subaortic arch to the left tracheobronchial lymph nodes, thoracoscopic observation and, if necessary, additional lymph node dissection were performed. We counted all lymph nodes in the right cervical and upper mediastinal paraesophageal lymph nodes dissected with the right cervical open/right trans-cervical mediastinoscopic/right thoracoscopic approaches. We also counted the number of dissected lymph nodes in the subaortic arch to the left tracheobronchial lymph nodes dissected with the right trans-cervical mediastinoscopic/right thoracoscopic approach. Every lymph node was confirmed histopathologically.

Results

The characteristics and clinicopathological features of the 10 patients are shown in Table 1.

The integrity of upper mediastinal lymph node dissection

The average total number of dissected lymph nodes among the right cervical and upper mediastinal paraesophageal lymph nodes identified with a right cervical open/right trans-cervical mediastinoscopic/right thoracoscopic approach was 3.2/4.0/0.6, respectively (range 0–9/0–12/0–3) (Table 2). These lymph nodes were almost completely dissected using the right trans-cervical pneumomediastinal approach (Fig. 4).

The average total number of dissected lymph nodes among the subaortic arch to the left tracheobronchial lymph nodes with a right trans-cervical mediastinoscopic/right thoracoscopic approach was 1.5/0.6, respectively (range

Table 1 Clinical characteristics of the patients

Gender	
Male/female	10/0
Mean age, years	66.8 (range 57–82)
Tumor location	
Ut	2
Mt	4
Lt	4
cTNM*	
cT1a/1b/2/3	1/5/4/0
cN0/1/2	7/2/1
cM0/1	10/0
cStage	
cIA/IIB/IIIA/IIIB	6/3/1/0
pTNM*	
pT1a/1b/2/3	1/8/0/1
pN0/1/2	5/3/2
pM0/1	10/0
pStage*	
pIA/IIB/IIIA/IIIB	5/3/1/1

Data are shown as the number unless otherwise indicated

cT clinical depth of primary tumor, *cN* clinical regional lymph node metastasis, *cM* clinical distant metastasis, *cStage* clinical stage, *Lt* lower thoracic esophagus, *Mt* middle thoracic esophagus, *pT* pathological depth of primary tumor, *pN* pathological regional lymph node metastasis, *pM* pathological distant metastasis, *pStage* pathological stage, *Ut* upper thoracic esophagus

*According to the Union for International Cancer Control (UICC), TNM Classification of Malignant Tumours, 8th edition [18]

Table 2 Number of dissected lymph nodes in the right cervical and upper mediastinal paraesophageal lymph nodes

Case no.	Approach for lymph node dissection			Total
	Right cervical open	Right trans-cervical mediastinoscopic	Right thoracoscopic	
1	1	1	0	2
2	5	4	1	10
3	3	3	1	7
4	3	8	0	11
5	1	0	0	1
6	9	2	0	11
7	3	12	1	16
8	0	1	0	1
9	3	9	0	12
10	4	0	3	7
Average	3.2	4.0	0.6	7.8

0–4/0–5) (Table 3). These lymph nodes were not dissected completely in the first half of the study period, although they were completely dissected in the cases treated in the latter half using the right trans-cervical mediastinoscopic approach under pneumomediastinum (Fig. 7).

Table 3 Number of dissected lymph nodes of the subaortic arch to the left tracheobronchial region

Case no.	Approach for lymph node dissection		Total
	Right trans-cervical mediastinoscopic	Right thoracoscopic	
1	1	0	1
2	0	0	0
3	2	5	7
4	0	1	1
5	0	0	0
6	0	0	0
7	4	0	4
8	4	0	4
9	1	0	1
10	3	0	3
Average	1.5	0.6	2.1

Among short-term outcomes reported previously [17], the adverse event of recurrent nerve palsy was thought to be associated with and important for our bilateral trans-cervical pneumomediastinal approach. We noted one case of bilateral recurrent nerve palsy (10%) as well as two cases on the right (20%) and two cases on the left (20%). In the one patient with bilateral recurrent nerve palsy, the right nerve palsy recovered within six months. Among the four cases of unilateral recurrent nerve palsy, three recovered within six months. All cases were confirmed endoscopically.

Discussion

Previous reports have described the performance of transhiatal esophagectomy [3–6, 8, 10]. This technique is recognized as minimally invasive surgery but not as radical surgery for thoracic esophageal cancer because the upper mediastinal lymph nodes, including those from the subaortic arch to the left tracheobronchial lymph nodes, are not usually dissected with this conventional procedure.

We previously reported on the usefulness of the cervicohiatal crossover approach under pneumomediastinum using Thiel-embalmed cadavers [13], and dissection of the subaortic arch to the left tracheobronchial lymph nodes could be performed with our method. Mediastinoscopic procedures were recently reported from several other institutes [11, 19], using only the left trans-cervical and transhiatal approaches under pneumomediastinum.

The findings from our clinical trial suggest that mediastinoscopic procedures with the right trans-cervical pneumomediastinal approach are useful for ensuring the

integrity of mediastinal lymph node dissection in the thoracic paraesophageal lymph nodes, right recurrent nerve lymph nodes and subaortic arch to the left tracheobronchial lymph nodes. Our right-sided trans-cervical pneumomediastinal approach may have some merits. First, with this approach, a wide working space can be obtained in the right upper mediastinum, as fewer shield objects, such as the aortic arch, are located in this region. In addition, the view obtained with this approach is similar to that via the right transthoracic approach, and dissection of the esophagus can be smoothly performed. This is because the "visceral sheath" arises from the right subpleural region and surrounds the dorsal side of the esophagus [15]. Second, the subaortic arch to the left tracheobronchial lymph nodes can be observed more frontally via the right trans-cervical approach, rather than tangentially, without hindrance by the aortic arch (Figs. 6, 7). Additional traction of the trachea toward the ventral side also enables us to approach these lymph nodes.

However, several drawbacks were also observed. First, in this series of patients, right recurrent nerve palsy occurred more frequently than with thoracoscopic esophagectomy [20]. Several reasons may underlie the recurrent nerve injury, such as extension during the maneuver, crush injury of the recurrent nerve between the forceps and tracheal cartilage and thermal injury with energy devices. Use of intraoperative nerve monitoring (IONM) is thought to be useful for evaluating recurrent nerve injury and improving the surgical procedure [21, 22]. Second, our method is rather elaborated, requiring a relatively long operation time. These drawbacks will need to be addressed in the future.

Several limitations associated with the present study warrant mention. First, this study was performed in only 10 patients as a single-arm trial, making it a relatively small study. Second, we did not directly compare the integrity of upper mediastinal lymph node dissection using our mediastinoscopic procedure with that using a thoracoscopic procedure or that using the left trans-cervical and transhiatal approaches under pneumomediastinum for right cervical open surgery.

In conclusion, given the integrity of upper mediastinal lymph node dissection, the bilateral especially right sided trans-cervical pneumomediastinal approach is considered as an available option for achieving sufficient lymph node dissection and esophagectomy; however, some improvements will be required.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflicts of interest.

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