



# Radical minimally invasive esophagectomy for esophageal cancer via transcervical and transhiatal approaches: a narrative review

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**Objective:** Minimally invasive esophagectomy (MIE) has been widely applied for the treatment of esophageal carcinoma. It is much less invasive, as it avoids employing a transthoracic procedure.

**Background:** MIE via transcervical and transhiatal approaches has been adopted in our center. In this approach, with the assistance of single-port techniques or robotic-assisted surgical systems, the esophagus is mobilized under visualization, which is followed by the removal of esophageal and mediastinal lymph nodes.

**Methods:** Increasing the surgical space by mediastinal insufflation or by elevation of the sternum with a hook may improve intraoperative identification of tissues and facilitate intraoperative mobilizations. The procedure can be performed simultaneously via both cervical and abdominal approaches without the need for intraoperative turning of the patient, which shortens the operative time. Also, there is no need for thoracotomy or single-lung ventilation, which avoids disturbance to the respiratory and circulation systems.

**Conclusions:** Suitable instruments, especially state-of-the-art energy instruments, facilitate surgical separation and hemostasis. This surgical procedure has become increasingly sophisticated over the past decade, and its modular operation has been widely recognized. The feasible place of the neck-esophageal hiatus rendezvous is on the left main bronchus around the subcarinal region. Here we describe the technical features, key steps, and necessary precautions of this minimally invasive surgery for esophageal carcinoma.

**Keywords:** Esophageal cancer; transcervical approach; transhiatal approach; minimally invasive esophagectomy (MIE); lymph node dissection

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## Introduction

Minimally invasive esophagectomy (MIE) has become more popular and widely accepted for the treatment of esophageal cancer (1). Most minimally invasive surgeries for esophageal cancer are performed with single-lumen intubation and right-sided artificial pneumothorax. During the 4-port minimally invasive operation, the esophagus is mobilized

and mediastinal lymph nodes are removed; after the stomach is mobilized under laparoscopy, a small midline incision is made at the epigastric region for the construction of the tubular stomach; finally, a left cervical esophagogastric anastomosis is created. Lymphadenectomy along bilateral recurrent laryngeal nerves (RLNs) is particularly important, and the role of cervical lymphadenectomy has increasingly

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been recognized.

Patients undergoing single-lumen tracheal intubation with right-sided artificial pneumothorax typically experience increased intraoperative ventilation pressure and postoperative left-sided pulmonary edema, which are particularly evident on chest radiographs on the first postoperative day. In patients undergoing double-lumen or single-lumen intubation with right-sided occlusion, postoperative left-sided pulmonary edema is also commonly seen. Intraoperative arrhythmias are common in minimally invasive transthoracic esophagectomy, and intraoperative hypertensors are often required. Minimally invasive transthoracic surgery undoubtedly increases the burden on the respiratory and circulatory systems.

In our center, a minimally invasive surgery for esophageal carcinoma via transcervical and transhiatal approaches successfully reduces the disturbance to the respiratory and circulatory systems and removes the mediastinal lymph nodes. A single-lumen intubation is carried out with two-lung ventilation during the surgery. The following objectives are met: (I) the facilitation of lymph node dissection and hemostasis under endoscopy, (II) the ability to forego one-lung ventilation, (III) the ability to forego intraoperative turning of the patient and the shortening of the operative time by simultaneous completion of the surgery via the cervical and abdominal approaches, (IV) a more anatomically and physiologically feasible replacement of the esophagus with a tubular stomach, and (V) the left cervical anastomosis of esophagus and stomach. Without the thoracotomy is a key characteristic to reduce pulmonary complications after esophagectomy.

Preoperative contrast-enhanced CT examination can reveal the anatomy of the esophagus and bronchial artery, which is extremely helpful for intraoperative management. Three-dimensional (3D) endoscopy is helpful in identifying the surgical field. Bleeding control through titanium clip placement in the mediastinum is not recommended, as the titanium clips may interfere with the operation or may be dislocated; in particular, the possible side injuries from scraping and squeezing of the uplifted tubular stomach should be avoided.

The feasible place of the neck-esophageal hiatus rendezvous is on the left main bronchus around the subcarinal region. It is easy for the two surgery teams dissecting to the rendezvous. The specific procedure is described in the following section. The transcervical approach minimal invasive procedure is addressed.

We present the following article in accordance with the

Narrative Review reporting checklist (available at <https://dx.doi.org/10.21037/jtd-21-1205>).

### Mediastinal insufflation and MIE

A 5-mm rigid endoscope camera with a 30° perspective is used. CO<sub>2</sub> insufflation is performed at 8–12 mmHg. After insufflation, the mediastinal space is enlarged, which facilitates the operation, as the adipose tissue spaces in the operative field are easy to identify.

Long, narrow surgical instruments are required due to the anatomic features of the mediastinum. With a specially designed mediastinal pulling hook in the left hand and a LigaSure Maryland Jaw Sealer/Divider (Covidien) in the right hand, the operator separates and dissects the tissues. As a single and practical device, the LigaSure Maryland Jaw Sealer/Divider has many advantages: (I) it is a safe and reliable option for electrocoagulation of esophageal artery and bronchial artery; (II) the small, rounded shield of the blade head can be used as tissue sorting forceps, which avoids instrument replacement during the surgery; (III) the low degree of atomization during electrocoagulation minimizes the obscuring of the operative field; and (IV) the lower tissue heat transfer (compared with high-intensity focused ultrasound (HIFU)/electric hook) helps to protect RLNs and other tissues/organs.

#### *Mobilization of the mediastinum via the left cervical esophagus*

The patient is placed in a supine position, with the head turned to the right side. A 4-cm incision is created superior to the left sternoclavicular joint and medial to the sternocleidomastoid muscle. After the platysma fascia is incised, the sternohyoid and the sternothyroid are divided and mobilized. The incision reaches deep into the esophagus medially along the trachea and laterally along the cervical vessels. The esophagus is bluntly mobilized using fingers, with the membranous part of the trachea and the left RLN being well protected. The cervical lymph nodes are removed. A protective incision sleeve is placed between the skin margin and the deep fascia. After the membrane sleeve is fastened and closed, 3 trocars form a right-angle triangle, with the camera port at the top and 2 operating ports at the bottom. Two conditions must be met before mediastinal emphysema is successfully established: (I) no air leakage from the protective sleeve and (II) no subcutaneous emphysema.

The modular operation of esophageal mobilization proceeds as follows: (I) the operation is performed along the bilateral vagus nerves; (II) the anterior wall of the esophagus is mobilized first, which is followed by the mobilization of the posterior wall; and (III) the right side of the esophagus is mobilized first to reach the azygous vein, which is followed by the mobilization of the left side, allowing for more satisfactory visualization of the operating space.

Lymph nodes near the left RLN are removed along the outer membrane of the left common carotid until the aortic arch is reached. Any injury to the thoracic duct should be avoided. After left upper mediastinal lymph node dissection is completed, the trachea is lifted posterior to the trachea along the gap between the esophagus and trachea with an instrument in the left hand; meanwhile, the esophagus is pulled leftwards to expose the right RLN, where the nearby lymph nodes are dissected. The azygous vein must be carefully protected during middle mediastinal lymph node dissection. Dissection of subcarinal lymph nodes can be particularly challenging. The carina can be exposed along the right parietal pleura, during which the bronchial arteries should be carefully identified. After the exposure meets the laparoscopic operation, the lymph nodes are removed at the meeting site. Meanwhile, the esophagogastric anastomosis is performed via the left neck.

The authors observed the surgical operation performed by Qingdong Cao's team in November 2019. The transjugular mobilization of the esophagus and the transabdominal mobilization of the stomach were performed simultaneously, and then the mediastinal lymph nodes were dissected and the mediastinal organs were skeletonized. The operative time was 90 minutes in one patient with a T<sub>1</sub>N<sub>0</sub>M<sub>0</sub> cancer and 2 hours and 20 minutes in another patient who had received 2 cycles of preoperative neoadjuvant chemotherapy. Two groups of operators performed the operation simultaneously, and the subcarinal lymph nodes were removed via the esophageal hiatus after the 2 operations met. Single-port mediastinoscopic and simultaneous laparoscopic esophagectomy has satisfactory short-term outcomes, with few complications; it further enables total esophageal mesenteric excision and lymph node dissection. Thus, it is an effective and feasible procedure (2). Specially, for the early stage esophageal carcinoma without dissecting of the right cervical lymph nodes.

Fujiwara *et al.* (3) performed single-port mediastinoscope-assisted transhiatal esophagectomy in 60 patients with thoracic esophageal cancer. Pretreatment diagnoses were stage III in most patients, and preoperative neoadjuvant

chemotherapy was performed for two-thirds of the patients. The incidence of pneumonia significantly decreased after the surgery. There was 1 patient who underwent conversion to thoracotomy due to bronchial injury.

The risk of pleural rupture is high during an intramediastinal operation. The operator may enlarge the pleural fissure and ask the anesthesiologist for positive pressure ventilation, which mostly does not affect the operation but will slightly reduce the operative field. Also, a closed-chest drainage tube may be placed intraoperatively to avoid tension pneumothorax. According to a report by Parker *et al.* (4), simultaneous mediastinal and abdominal insufflation could not be tolerated by 3 of 4 obese patients, in whom hypercapnia and hemodynamic disturbances were noted.

#### *Mobilization of the mediastinum via the right cervical esophagus*

The incision at the right neck is the same as that of the left transcervical approach. A protective sheath and trocar are placed via the transcervical incision, which is followed by mediastinal insufflation.

The right RLN can be easily exposed through the right transcervical approach, which also allows the dissection of lymph nodes near the esophagus and right RLN under direct vision.

The right transcervical approach is superior to the left one in terms of the visualization of mediastinal paraoesophageal tissue and the exposure of the operative field: (I) after the esophagus and trachea are separated, the trachea is pushed ventrally with a special retractor to mobilize the left RLN, which significantly enlarges the visual field and widens the operating angle; (II) when the subaortic arch and the left paraoesophageal lymph nodes are exposed through the right approach, the wide operative field and large visual tangent angle offer a large space for instrument motion (in contrast, the left approach has a small tangent angle and a narrow space); (III) the subcarinal lymph nodes are mobilized via the right neck, which offers a larger operating space (in contrast, the left approach has a narrow space due to the restriction of the aortic arch); and (IV) the endoscopic observation of the esophagus from the right pleural apex via the right approach has a similar operative field to that of thoracoscopy, which allows experienced operators to quickly master this technique.

Tokairin *et al.* (5) explored the value of dissecting right cervical and upper mediastinal paraoesophageal lymph nodes in patients with stage I–III thoracic esophageal cancer with a

right transcervical pneumomediastinal approach. Here, the mediastinal paraesophageal tissues are almost skeletonized after the mediastinal lymph nodes are completely removed. The thoracic duct can be clearly visualized. The lower edge of the aortic arch and the left tracheobronchial rings can be easily identified in the operative field, making it convenient and feasible to remove the lymph nodes in these areas. Moreover, the right transcervical approach enables better visualization of the above structures (compared with the left approach); in particular, the lymph nodes are more clearly exposed, which facilitated the dissection. This approach makes dissecting the lymph nodes near the right RLN and the right superior mediastinal lymph nodes even easier.

Subsequently, the left cervical lymph nodes can be dissected through the left cervical incision, followed by the removal of lymph nodes near the left RLN. The left cervical anastomosis of esophagus and stomach is the completed.

Emphasis should be placed on the neck-esophageal hiatus rendezvous technique. The right RLN should be carefully protected as the nerve is susceptible to distraction and compression due to the impact of the surgical approach. For patients who have undergone neoadjuvant therapy or for those who require neck dissection, this surgical approach is preferred over the left transcervical approach.

### ***Robotic-assisted mobilization of the mediastinum via the left cervical esophagus***

When a surgery is performed in the narrow mediastinum (especially in the middle mediastinum), the observation angle is often restricted by the azygous vein, root of the left RLN, and the aortic arch. The slender and long instruments often interfere with each other during manual operation; furthermore, the subcarinal lymph nodes are often located in the ventral portion, and the anterior sides of the instruments are often obstructed by the surrounding tissues, resulting in poor operating angles.

The robotic operation has the following advantages: (I) robotic surgical systems allow stable, high-definition, and three-dimensional (3D) visualization of the operative field and provide accurate and safe instrument maneuverability; (II) the plier head of a robot has rotatable joints, which allow flexible and accurate operations at variable angles; (III) the robots allow refined operations, especially in dissecting the lymph nodes near RLNs, as they can control the joint scissors stably and accurately, without any trembling, which helps to protect the RLNs; (IV) robotic mediastinal lymph node dissection has a clear visual field, which enables easy

identification of lymph nodes, even the lymph nodes in the inferior pulmonary ligament, and thus the subcarinal lymph nodes can be easily removed or mobilized; and (V) the robotic arms do not collide or interfere with each other in the long and narrow operative field (6). Comparing the mediastinoscopic esophagectomy, from technical point of view, this approach using non-articulating, straight, long forceps is extremely challenging, especially in the middle mediastinal area. Its technical difficulties could be attenuated using robot-assisted minimally invasive esophagectomy.

In a Japanese series (7), lymphadenectomy was robotically completed via the transcervical approach. Up to 83% of patients underwent neoadjuvant chemotherapy (stage II–III), and all the resection margins were pathologically confirmed to be negative. The average number of lymph nodes removed was 20.5. The dissection of mediastinal lymph nodes, including the subcarinal lymph nodes and the lymph nodes at bifurcations of the primary bronchi, was also not difficult, and the incidence of postoperative cardiopulmonary complications was low.

Postoperative hoarseness due to RLN injury tends to recover within 3 to 6 months postoperatively. The injury is mostly due to strain, thermal injury, and/or RLN demyelination, which should be taken seriously. Tracheal and bronchial membrane injuries can also be caused by energy instruments but can be prevented by blunt mobilization (6,7). Robotic surgery has been rapidly adopted by hospitals in Europe, the United States, and Japan.

### **Transcervical extended mediastinal lymphadenectomy (TEMLA) for esophageal cancer**

TEMLA has also been adopted in the treatment of esophageal cancer. By using a sternal lift retractor and VATS technique, TEMLA enables the removal of lymph node stations 1, 2, and 4 under direct vision and the dissection of stations 7 and 8 with the assistance of a thoracoscope.

TEMLA for esophageal cancer includes the following steps. (I) A collar-shaped incision (5–8 cm) is created above the sternum for adequate blunt mobilization of the platysma and retrosternal tissues, which increases the surgical space. (II) A special retractor is used to lift the manubrium sterni 2–4 cm forwards to increase the surgical entrance, and the upper third of left main bronchus is operated under direct vision. (III) Bilateral RLNs should be carefully protected and have relatively fixed anatomical positions.

It usually takes 1 minute to identify the right RLN and 1–3 minutes to find the left RLN. (IV) The bilateral vagus nerves, which are important anatomical landmarks for the surgery, should be identified and mobilized. (V) Lymph node dissection begins at the root of left RLN, during which the blood supply to the nerve should be protected. Lymph node stations 2L (typically anterior to the left RLN) and 4L (typically posterior to the left RLN) are resected separately. En bloc removal of stations 2R and 4R can be performed under direct vision. (VI) The esophagus is mobilized from the left approach. After the subcarinal area is reached, the mobilization continues 4–5 cm distally, and the lymph node stations 7 and 8 are resected en bloc under the thoracoscope. (VII) After the mediastinal lymph nodes are dissected, the membranous connective tissues around the esophagus can be easily identified and mobilized. The simultaneous operations in the abdominal cavity will be met at the levels of carina and left main bronchus.

TEMLA was proposed by Dr. Zieliński (8), who visited our center in July 2019 and demonstrated the transcervical MIE. TEMLA may be the most minimally invasive technique for esophageal cancer. In one study, it was associated with high therapeutic effectiveness and low incidence of postoperative complications, with no intraoperative conversion to open surgery being reported (0/32) (9). For the removal of lymph nodes near RLNs (especially the left RLN), energy instruments should be used with caution. Preserving the mesentery of nerve is preferable to circular mobilization, as it lowers the incidence of postoperative hoarseness. Left RLN injury is more likely to arise. One study reported that the vast majority of RLN injuries from the TEMLA procedure were temporary (20/928), with permanent RLN injuries occurring in near 0.5% (5/928) of the TEMLA patients (10). Injuries to the tracheal membranous wall were found in 2 cases and were promptly and satisfactorily managed with biohemostatic fibers. Pulling of the carotid artery should be avoided if there is significant carotid atherosclerosis.

According to our experience (unpublished), the use of the Linder-Dahan spreadable video-mediastinoscope (Richard Wolf, Knittlingen, Germany) greatly facilitates lymphadenectomy in the upper and middle esophagus and the mediastinum. This can be done cost-effectively with a thoracoscopic suction device and HIFU, during which neither a special protective incision sleeve nor a LigaSure Maryland Jaw Sealer/Divider is required. Even the presence of a pleural injury will not affect adequate surgical field visualization.

### The transabdominal approach

During transabdominal operation, the esophageal hiatus is enlarged anteriorly via the crura diaphragmatis or through use of a sealer or divider under the endoscope. The anterior wall of the esophagus is mobilized upwards along the bilateral vagus nerves to expose the lymph nodes at left inferior pulmonary vein; subsequently, the left main bronchus is isolated until the subcarinal region, where the carina and right main bronchus are exposed. Subcarinal lymph nodes are then removed. The azygous vein and the right pleura at the right side must be carefully protected (11). The posterior wall of the esophagus is mobilized along the thoracic aorta toward the aortic arch. Realignment can be achieved at the level of left main bronchus, followed by the transection of the vagus nerve above the esophageal hiatus (4).

During the transabdominal procedure, the stomach is mobilized via an anteromedian incision; alternately, the stomach can be mobilized after insufflation under laparoscopy. The tubular stomach is created via a small abdominal incision.

### Conclusions

Transmediastinal esophagectomy conforms to the physiological and anatomical features of esophageal cancer. Compared with the mediastinal lymph node dissection via a transcervical videoscopic approach, left transthoracic esophagectomy, and right transthoracic esophagectomy, transmediastinal esophagectomy has many advantages in terms of operative time, lymph node dissection, and intraoperative blood loss, especially the incidence of cardiopulmonary complications. Those are the major reasons of reducing complications and hospital mortality. Because the operation is performed under direct vision, there is no increased damage to RLNs (12,13).

This procedure broadens the indications for esophagectomy to following: (I) patients with a history of thoracic surgery and those with pleural adhesions due to severe pulmonary inflammation, (II) high-risk patients with low pulmonary function and various comorbidities, and (III) preferably those patients with early-stage esophageal cancer. This procedure is not recommended for large tumors because its surgical space is obtained mainly by compressing the esophagus and its surrounding tissues.

In April 2018, transmediastinal MIE for esophageal

cancer was included in the Japanese universal health insurance coverage system, and its value has been well recognized by Japanese thoracic surgeons and tumor patients. Minimally invasive approaches to esophageal resection, as described in this paper, have increased the spectrum of patients able to undergo surgical treatment of esophageal cancers. While maintaining oncologic principles. Life sciences research is advancing rapidly, and breakthrough technologies are developed almost every 10 years. All of the progresses are depending the valuable insight into the biology of the disease. MIE has become a mainstream technique, and we should learn more from our international peers and regularly update our techniques and skills.

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