15 Thoracolaparoscopic Esophagectomy in the Prone Position for Carcinoma of the Esophagus

C. Palanivelu, Palanivelu Praveen Raj, Palanisami Senthilnathan, and R. Parthasarathi

In open surgery for intrathoracic esophageal tumors/carcinoma, transhiatal esophagectomy was used for tumors in the lower third [1] of the esophagus and a transthoracoscopic McKeown three-hole/three-field approach with cervical anastomosis was used for tumors in the middle and upper thirds of the esophagus [2]. Initially, we followed the same principles when using a laparoscopic approach [3]. Our standard approach for thoracoscopic esophagectomies is with the patient in the prone position [4].

The use of thoracoscopic esophagectomy in the prone position for esophageal cancer was first reported by Cushieri et al. [5] in 1992. Subsequently, no other group reported using this approach. Many esophageal surgeons have been interested in performing minimally invasive esophagectomy for cancer. All of the cases reported in the literature reported using video-assisted thoracoscopic (VATS) esophagectomy with the patient in the lateral decubitus position [6–8]. 10 years after the original publication, our report of 130 cases using the approach with the patient in the prone position created great enthusiasm among many surgeons across the world, including those in Japan, Korea, and Europe [4]. The author's video using this approach received best technique awards in various congresses such as the American College of Surgeons (ACS) in 2005 [9], the 16th European Congress at Stockholm [10], and the 10th World Congress of the International Society for Diseases of the Esophagus [11]. The author performed a live thoracolaparoscopic esophagectomy on a patient in the prone position for esophageal cancer during the Hong Kong Asia Pacific Congress (ELSA) in 2005, which created great enthusiasm among the Asian group.

Two-field lymphadenectomy was used for surgeries up to the infracarinal group of lymph nodes. Decisions regarding the type of operation were based primarily on the location of the tumor with the goal of low morbidity; radical

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C. Palanivelu, MS, MCh, FRCS, FACS (✉)
Division of Oesophagastric Surgery,
GEM Hospital and Research Centre,
Pankaja Mills Road, Ramanathapuram,
Coimbatore, Tamil Nadu 64105, India
e-mail: info@geminstitute.in

P.P. Raj, MS, DNB(GI), DNB(SGI), FALS, FMAS
P. Senthilnathan, MS, DNBGen, MRCSEd,
DNB GISurg, FACS
Department of Surgical Gastroenterology,
GEM Hospital and Research Centre,
Coimbatore, Tamil Nadu, India

R. Parthasarathi, MS, FMAS
Division of Advanced Minimally Invasive
and GI Surgery, GEM Hospital and Research Centre,
Coimbatore, Tamil Nadu, India

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lymphadenectomy was not the surgical goal in the early 1990s.

Thoracoscopic en bloc esophagectomy [4] with the patient in the prone position and three-field radical lymphadenectomy (TLE–3H–3F) became our standard of practice. We found no significant change in the incidence of morbidity and mortality by adopting the three-hole transthoracic esophagectomy and cervical dissection approach in comparison with laparoscopic transhiatal esophagectomy [12].

More and more two-hole esophagectomies (TLE–2H) [13–15] with intrathoracic anastomosis are being performed, limiting the three-hole esophagectomy (TLE–3H) approach to removal of upper esophageal growths/cancer. Total mediastinal, extended two-field lymphadenectomy (TLE–2H–TM) for adenocarcinoma and thoracoscopic modified three-field lymphadenectomy including the right cervicothoracic packet of lymph nodes (TLE–2H–3F) along the right recurrent laryngeal group are becoming the standard approaches [16–19]. Esophagogastrectomy for cancer of the cardia with shorter gastric tube thoracolaparoscopic esophagectomy with two-field lymphadenectomy (TLE–2H–2F) is also performed.

Advantages of the Prone Approach

Anatomical

1. Effects of gravity
   - Liver falls caudally
   - Heart falls anteriorly
   - Mediastinum widens
2. No lung ventilation is needed

In a lateral approach, the esophagus lies in the most dependent portion of the chest, where it is often obscured by overlying lung.

Surgeon

- Positioning is comfortable for the surgeon
- Blood does not accumulate near the dissection field
- Learning curve is shorter
- Pneumothorax partially collapses the lung
- Lung falls anteriorly
- Wide exposure is obtained without lung retraction

Physiological

- Single-lumen endotracheal tube
- Double-lung ventilation
- Improved ventilation/perfusion ratio
- Incidence of postoperative pulmonary complications is lower
- Improved postoperative oxygenation

Anesthesia Effects

The TLE–3 F operative procedure can be divided into three steps (1) the thoracoscopic phase: en bloc esophagectomy and radical lymphadenectomy, (2) the abdominal phase: radical lymphadenectomy and gastric tube formation, and (3) the cervical phase: specimen extraction, gastric pull up, and cervicogastric anastomosis. Ivor Lewis esophagogastrectomy (TLE–2F) is performed in two phases (1) the laparoscopic phase: gastric mobilization and lymph node dissection, gastric tube formation, and extraction of specimen and (2) the thoracoscopic phase: esophagectomy, radical lymphadenectomy, and anastomosis. Rarely there is a second laparoscopic phase wherein the specimen extraction is performed through a Pfanneiel incision after adjusting the patient's position to supine before extubation.

General anesthesia with a single-lumen endotracheal tube and the patient in a semiprone position is our standard practice, with a specially made mechanical support (Figs. 15.1 and 15.2). The semiprone position [11] allows for a lateral thoracotomy to be performed during an emergency without changing the patient's position. The operative field of the right chest is prepared and draped anteroposteriorly from midline to midline.

Fig. 15.1 Operating table side support is fixed to the table side rails. (*A*) Center knob to adjust the arm. (*B*) Side knob to pull out the inner rod and adjust the length. (*C*) Outer knob to turn the pad in either direction

Fig. 15.2 Right forearm support

Thoracolaparoscopic Esophagectomy and Three-Field Lymphadenectomy in the Prone Position (Video 15.1)

TLE–3F: Thoracoscopic Phase

A right pneumothorax is created either by using a closed Veress needle technique or by using Visiport. Four trocars are placed into the right thoracic cavity (Fig. 15.2). The first trocar (10 mm) for the camera is placed in the fifth intercostal space corresponding to the level of the arch of the azygos vein. The second trocar (5 mm)

Fig. 15.3 Thoracoscopic ports. (*A*) Camera 10-mm port. (*B*) Left-hand working 5-mm port. (*C*) Right-hand working 5-mm port

for the work performed with the right hand is placed in the third intercostal space. The third trocar (10 mm) is placed in the seventh intercostal space. The fourth trocar (5 mm) is placed in the ninth intercostal space. The 10-mm trocar in the seventh space is useful for applying clips, vascular clamps, and taking sutures into the thorax; the camera is sometimes used in this trocar during mobilization of the lower esophagus (Fig. 15.3). Initially, the right pneumothorax at 10 mmHg partially collapses the right lung, which lies in the anterior compartment, and then the pressure is reduced to 6–8 mmHg. In addition to the pneumothorax, gravity also aids in keeping the collapsed lung in an anterior position. Two-lung ventilation is continued throughout the procedure.

The surgeon and camera operator stand at the patient's right side, and the video monitor is positioned directly opposite, on the patient's left side (Fig. 15.4). The surgeon, using a hook, incises the mediastinal pleura overlying the anterior aspect of the esophagus, and the inferior pulmonary ligament is released up to the right pulmonary vein. Anterior dissection is begun by mobilizing the esophagus away from the hilum and the pericardium [20]. Because of gravity, the heart tends to fall down anteriorly; thus, the space in front of the esophagus is widened. The mobilization extends to the level of the azygos vein, which is skeletonized and divided with double

Fig. 15.4 Team setup for thoracoscopy. The patient is in the prone position, the surgeon, camera surgeon, and assisting surgeon stand on the right side of the patient and the monitor is on the left side of the patient

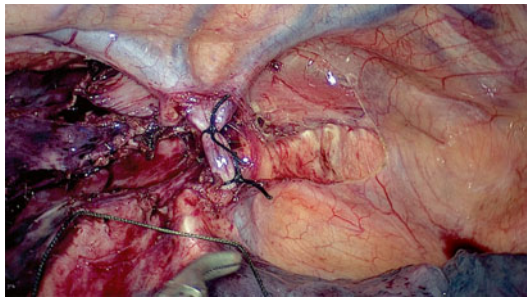

Fig. 15.5 After pleural incision and dissection of the azygos vein, the azygos arch is ligated doubly with silk

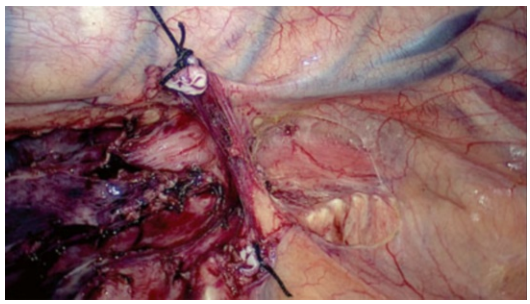

Fig. 15.6 The azygos arch is divided and the vertebral side is retracted for exposure

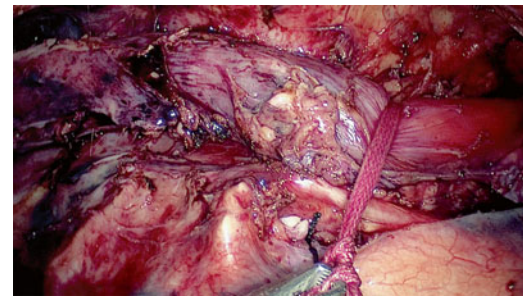

Fig. 15.7 Umbilical tape is tied around the esophagus loosely for free sliding and retraction

ligatures on both sides (Fig. 15.5). The posterior end of the thread is kept long and brought out through the posterior chest wall. Retraction of the thread dorsally separates the divided ends, providing a wider view. At the level of the aortic arch (Fig. 15.6), the azygos vein is the only structure that lies between the esophagus and the surgeon. Many surgeons prefer an endovascular (Endo GIA) stapler to divide the arch of the azygos vein. The parietal pleura posterior to the esophagus is incised from the level of the azygos arch vein to the crus. Blunt dissection is used to identify any potential thoracic duct branches and perforator vessels from the aorta. The thoracic duct is identified between the esophagus and aorta, and is not routinely divided. In case of tumor infiltration, the thoracic duct is clipped caudally at the hiatus and at the thoracic inlet at its insertion with the subclavian vein cranially and is transected. The esophagus is encircled with an umbilical tape, and traction by the assistant through the fourth port provides excellent exposure (Figs. 15.7 and 15.8). The surgeon is able to use both hands, simplifying the en bloc mobilization and lymphadenectomy. Initially, we used three ports, and have now changed to using four ports; the fourth port is used for traction. The

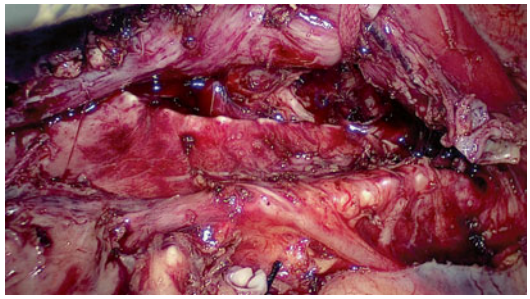

Fig. 15.8 Dissection of the esophagus from the trachea

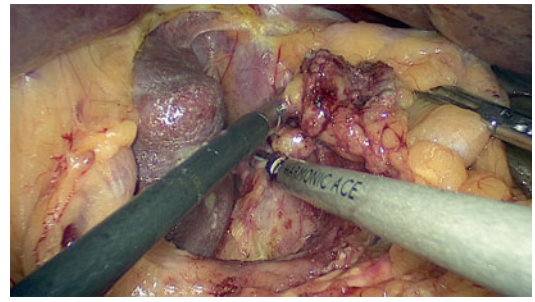

Fig. 15.10 Clearance of lymph node stations 7, 8, and 9

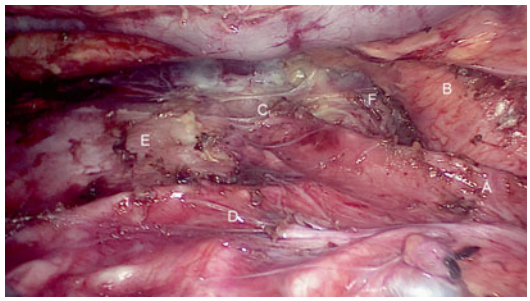

Fig. 15.9 Thoracoscopic view after complete mobilization. (*A*) Trachea. (*B*) Arch of aorta. (*C*) Left bronchus. (*D*) Right bronchus. (*E*) Pericardium. (*F*) Aortopulmonary window

operative time is shorter using the two-handed technique. The groups of lymph nodes are dissected sequentially, the subcarinal, aortobronchial, paratracheal, right recurrent laryngeal, and then left recurrent laryngeal groups (Fig. 15.9) are removed in that order [20]. The thoracoscopic approach enables removal of the cervicothoracic packet of lymph nodes along the right recurrent laryngeal nerve using a strictly "no touch" technique [16, 18].

If tumor is present in the lower esophagus, the dissection starts from the upper chest; for upper growths, the dissection may start from the lower mediastinum. The entire periesophageal tissue and the lymph nodes are removed. If the mediastinal pleura is infiltrated, it is also excised to obtain an R0 resection. In cases of advanced tumors, where we anticipate excision of both pleura, the dissection begins from the cranial end. The esophagus may be divided by stapling and retracted laterally, which exposes the entire mediastinum. Thorough irrigation and suction of the pleural cavity is performed. A single 28-F chest tube is placed through the seventh intercostal space and the lung is re-expanded.

Abdominal/Laparoscopic Phase

The patient is positioned supine and five ports are placed. The left lobe of the liver is retracted with instruments through the subxiphoid (epigastric) trocar. A 10-mm port for the camera is placed in the epigastrium. Two working ports, a 12-mm port in the right midclavicular line and a 5-mm port in the left midclavicular line are placed. One 5-mm port at the left anterior axillary line for gastric traction.

The lesser omentum is incised and the stomach retracted to the left and anteriorly with a grasper. The retroperitoneal lymphadenectomy (D2) is begun by incising the peritoneum at the upper border of the pancreas. The retroperitoneal lymphatic and areolar tissues are swept superiorly by skeletonizing the common hepatic artery, dissecting cranially along the lateral celiac group (Fig. 15.10). The left gastric vein is divided first at its insertion with the portal vein, followed by the left gastric artery, and then the celiac axis is completely cleared. The left gastric artery is clipped with Hem-o-lok and divided. The dissection is continued along the splenic artery up to the splenic hilum. This retroperitoneal dissection extends up to the dissected esophageal hiatus superiorly, the hilum of the spleen laterally, and the common hepatic artery and inferior vena cava medially. Finally, the lesser curvature and left

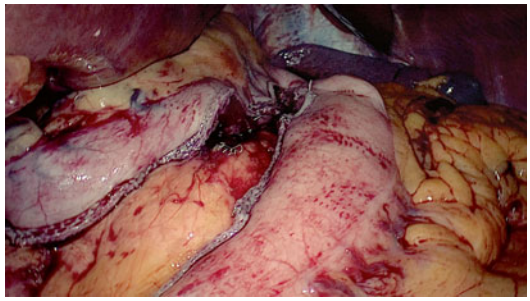

Fig. 15.11 Intracorporeal formation of the gastric tube using an Endo GIA stapler

gastric nodes are included with the specimen as the gastric tube is prepared.

The right gastroepiploic artery and the arterial arcade along the greater curve is carefully assessed early to ensure its suitability as a vascular supply to the gastric conduit. The greater omentum is divided at a safe distance from the gastroepiploic arcade, and the dissection is continued upward and to the left to divide the gastrocolic and gastrosplenic ligaments by dividing the short gastric vessels, keeping the dissection closer to the origin of the left gastroepiploic artery from the splenic origin. On the right side, the dissection continues up to the second part of the duodenum. The right gastroepiploic vein is carefully protected from injury.

Gastric Tube Formation

A 5-cm-wide gastric conduit is created by means of multiple firings of an Endo GIA 6-cm cartridge (Echelon–Ethicon) through the right midclavicle port. The stomach is stretched when stapling starts on the lesser curvature, 5 cm away from the pylorus, and progressing toward the fundus of the stomach. A golden cartridge is used to staple the antrum and blue cartridges are used for dividing the body of the stomach (Fig. 15.11).

A pyloroplasty or pyloromyotomy is performed by incising the pylorus longitudinally and the closure is performed transversely with interrupted sutures using 3-0 PDS suture. The placement of the feeding jejunostomy is at the discretion of the surgeon. Our preference is to

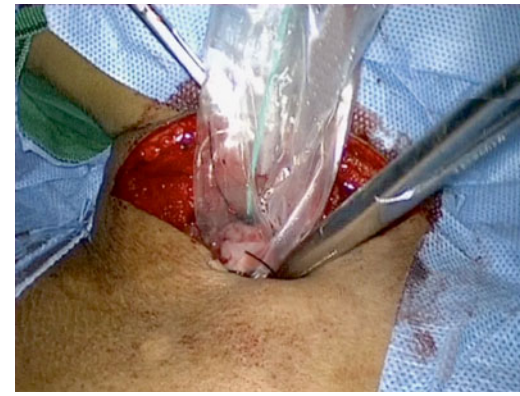

Fig. 15.12 Divided esophagus, Ryle's tube with a covering plastic sleeve is being pushed into the posterior mediastinum

place a nasojejunal feeding tube. Only in selected cases in which the patient develops a leak do we perform a feeding jejunostomy. The incidence of developing a leak is very low [13] and feeding jejunostomy is not without morbidity.

Cervical Phase

Specimen Extraction and Gastric Pull Up

The cervical esophagus is dissected through a left collar incision and divided. The distal end of the esophagus in the neck is over sewn and attached to a long Ryles tube. A long plastic sleeve is used as a protective sheath and attached to the esophagus with a separate stitch (Fig. 15.12). The pneumoperitoneum is reestablished and the esophagus is pulled down until the protective sheath reaches the peritoneal cavity. The stitch is released and the lower end of the plastic sheath opened (Fig. 15.13). The Ryles tube in the neck is used to pull the esophagus into the plastic sheath by the assistant; the surgeon working on the anterior wall of the gastric tube pushes the tube carefully, using a hand-over-hand technique and avoiding twisting or spiraling (Fig. 15.14).

Esophagogastric Anastomosis

A small vertical gastrotomy is performed with electrocautery. The posterior wall of the esophagus and the anterior wall of the stomach are then

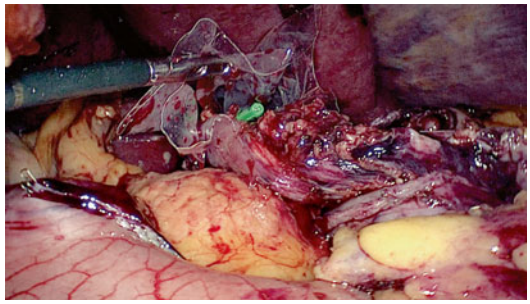

Fig. 15.13 Plastic sleeve in position (from neck wound connecting the peritoneal cavity) lying in the posterior mediastinum. (*A*) Nasogastric tube attached to the divided end of the cervical esophagus

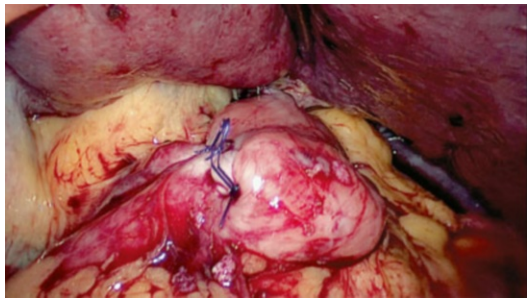

Fig. 15.14 Position of the stomach tube. The pyloroplasty wound is visible

aligned. A 3-cm long, 3.5-mm Endo GIA stapler is used to perform the posterior anastomosis. The anterior anastomosis is performed transversely using two staplers according to the modified Collard [19] or Orringer technique [21] and a wide stoma is obtained. The anterior wall may also be approximated with single-layer hand-sewn continuous suturing using a 3-0 monofilament absorbable suture, beginning at each corner and tied in the middle. After completion of the anastomosis, any redundant stomach is retracted into the abdomen. A nasogastric tube is passed carefully until it reaches the antrum of the stomach and its tip is kept above the pylorus. The gastric tube is then secured to the diaphragmatic hiatus anteriorly and laterally using long 2-0 nonabsorbable sutures to prevent intrathoracic herniation of the abdominal viscera. A nasojejunal tube is placed across the pylorus into the jejunum.

Two-Hole Esophagogastrectomy and Modified Three-Field Lymphadenectomy in the Prone Position

The abdominal dissection is performed first in the same way as in the three-hole approach. A gastric tube is formed, leaving adequate proximal stomach with the specimen. The mediastinal dissection is performed beyond the upper limit of the growth. For smaller growths confined to the cardia, the esophagus is divided transhiatally and extracted through a Pfannenstiel incision. For larger growths or if there is greater involvement of the esophagus, then the division is performed in the right pleural cavity during the thoracoscopic phase.

The patient is moved into a semiprone position. A mediastinal lymphadenectomy is performed similar to that described in the three-hole approach. The esophagus is divided high in the upper mediastinum, keeping an adequate distance from the upper limit of the growth, and is pushed into the peritoneal cavity to be removed after completing the thoracic phase. Stapling or a hand-sewn anastomosis is performed. Complete mediastinal lymphadenectomy for adenocarcinoma and a modified three-field or extended two-field lymphadenectomy by the thoracic approach is our preference [22].

Postoperative Care

Generally, the patient is extubated on the operating table and their recovery is good. Because of the absence of a thoracotomy, the patients have less pain and their breathing is comfortable. On the first day after the surgery, nothing is administered by mouth and the nasogastric tube is kept open for decompression of the gastric tube. On the second postoperative day, gastrografin contrast is administered and gastric emptying is assessed. Patients are administered enteral feeding through a nasojejunal tube, beginning with clear fluids. Between the third and fifth day, the nasogastric tube is removed and patients are allowed to take oral liquids followed by semi-

solid followed soft diet by the end of first week. If dilation of the gastric tube or delayed emptying occurs, then the postoperative care changes.

If there is any doubt about the integrity of the anastomosis or delayed emptying of the gastric conduit longer than 5 days, endoscopy is performed with the patient under sedation. If there is an area of ischemic mucosa or a leak, then contrast-enhanced computed tomography (CECT) is performed, looking for collection. Small areas of mucosal ischemia can heal without additional intervention. In this group, placement of a feeding jejunostomy is performed for enteral feeding. Obvious anastomotic leaks are treated with an endoscopic stent. If drainage fails and the CT scan result shows collection, another thoracoscopy is performed for complete drainage.

Results

More than 765 patients with esophageal cancer were treated by minimally invasive esophagectomy between 1997 and 2013 at GEM Digestive Cancer Institute, Coimbatore, India. Transhiatal esophagectomy was performed in 165 patients and thoracolaparoscopic esophagectomy in 610 patients in the prone position. Of these, 132 patients received neoadjuvant chemotherapy and/or radiotherapy for locally advanced disease as determined by staging thoracoscopy. In all except 12 patients, esophagectomy was completed successfully. In 504 patients, TLE–3F with cervical anastomosis was performed and, in 106 patients, two-hole thoracolaparoscopic esophagectomy with intrathoracic anastomosis was performed.

The anastomotic leak rate was 3 % and the mortality was 1.1 %. The mean intensive care unit (ICU) stay was 2 days and the mean hospital stay was 7.2 days. Vocal cord palsy was identified in 1.5 % of the patients, most recovered in a few days, only one case lasted for 30 days. The median number of lymph nodes identified was 21. No tracheal or bronchial injury was noted. Two cases had azygos arch venous injury that was managed by a thoracoscopic method.

Demographic characteristics

Number of patients	610		
Age range	22–87 years		
Sex (men, women)	67 %, 33 %		
Period	1997–2002	2002–2007	2007–2012
Number of patients	45	180	385
Type of pathology (squamous cell carcinoma/adenocarcinoma)	45/0	124/56	236/149
Tumor location	26 upper; 244 middle; 340 lower + cardia		

Preoperative comorbidity

	Number of patients
Hypertension	47 (8 %)
Diabetes	62 (10 %)
Cardiovascular disease	12 (2 %)
Pulmonary disease	27 (4 %)
Neoadjuvant therapy, chemotherapy and/or radiation therapy	135 (22 %)

Surgery

Type of surgery	Number of patients
Ivor Lewis	106 (17 %)
Two field (2F)	60
Modified three field (3F; 2F + cervicothoracic group)	46
Modified McKeown + neck anastomosis	504 (83 %)

Perioperative factors

Operative time	310 minutes
Blood loss	200–600 ml
ICU days	1.5 days
Anastomotic leakages	3 %
Gastric tip necrosis	1.35 %
Vocal cord paralysis/paresis	1.5 %
Pulmonary complications	2.4 %
Cardiovascular complications	3.75 %
Chylothorax	1 %
Overall morbidity	24 %
Hospital mortality	1.1 %

Pathology

Median tumor size	3.9 cm
T status	T0 8.7 %; T1 6.8 %; T2 25.2 %; T3 55.3 %; T4 3.9 %
N status	N0 42.7 %; N1 35.9 %; N2 8.7 %; N3 12.6 %
Margins positive	Proximal: 6 cases
	Distal: 0 cases
RO/R1	86 %/14 %

Number of lymph nodes harvested

Mean	24.4
Median	21
Hospital stay	7.2 days

Other complications

Pulmonary embolism	2 %
Reoperations (thoracoscopic revision)	1.15 %
Revision anastomosis	2 %
Drainage of abscess	3 %
Gastric tube pull out	2 %

Rethoracoscopy for Anastomotic Leak

After TLE with stapled anastomosis, two patients had leaks and rethoracoscopies were performed. In the first patient, the leak was diagnosed on the ninth postoperative day, just a day before their scheduled discharge. Endoscopy revealed the anastomotic leak and collection adjoining the leak. CT scanning results revealed the collection. Rethoracoscopy was performed and a pneumothorax was created using Visiport. The collection was drained, the pleural cavity thoroughly irrigated, and an intercostal drainage tube was placed next to the leak. A percutaneous feeding jejunostomy was performed. The fistula healed conservatively in 22 days. In the second patient, the fistula was a large opening and a stent was placed. After 2 weeks, the closure of the fistula was confirmed and the patient was moved to oral feeding. The stent was removed after 8 weeks. After an Ivor Lewis procedure, two patients experienced anastomotic leaks identified on the fourth and seventh postoperative days. Rethoracoscopies were performed and the anastomoses were revised. Both of these patients recovered well without further leaks. In one patient after TLE–3F, endoscopy revealed necrosis of the proximal part of the gastric tube approximately 3 cm from the tip. Rethoracoscopy was performed, the gastric tube was taken back, and a feeding gastrostomy and a cervicostomy were performed. After 2 months, coloplasty reconstruction was performed through the substernal route.

Discussion

Thoracoscopic view with the patient in the prone position is unfamiliar to most surgeons, but easily adaptable because of the excellent ergonomics. Using a single-lumen endotracheal tube and positioning the patient in a semiprone lateral approach position is easier and takes less time than using a double balloon and the prone position. The difficulty of an open conversion (posterior thoracotomy) in the case of massive hemorrhage is the only concern in an emergency with the patient in the prone position [20]. With the patient in the semiprone position, a lateral thoracotomy can be performed in an emergency without changing the position. However, we never had such an experience.

Thoracoscopic esophagectomy with the patient in the prone position has several advantages, including a wide working space, tendency of the blood to collect outside the operative field because of gravity, no need for skilled assistance, excellent ergonomic position for the surgeon, and reduction in lung injury because of the lack of lung handling [23, 24], and the two-lung anesthesia with continuous perfusion also significantly reduces postoperative pulmonary complications. The potential advantages of a prone thoracoscopic mobilization may also include shortened operative times, less surgeon fatigue, and shortening of the learning curve [25].

Use of a double-balloon endotracheal tube is not only time consuming, but also presents difficulties in exchanging the tube for a single-lumen endotracheal tube at the completion of the thoracic mobilization and repositioning the patient to a supine position for the abdominal phase. Dissection in front of the trachea and bronchus in the presence of a double-balloon endotracheal tube may precipitate traumatic injury and delayed leakage. Any untoward incidence, such as injury to the membranous bronchus or trachea, may be readily repaired as we do in open surgery [20].

Summary

Thoracoscopic esophagectomy with the patient in the prone position is a safe operation, and radical en bloc esophagectomy and lymphadenectomy may be performed perfectly in a shorter operative time, with less fatigue, reduced blood loss, and with a shortened learning curve for the surgeon. There are anatomic and physiologic advantages in addition to the ergonomic convenience for the surgeon. The thoracolaparoscopic esophagectomy with the patient in the prone position is likely to be the standard approach for this operation in the future; the two-hole or three-hole approach depends on the choice of the surgeon and the location of the tumor. The prone or semiprone approach is an excellent technique for extended radical lymphadenectomy and its aim should be to improve the survival rate. Modified thoracoscopic extended two-field and modified three-field lymphadenectomy and intrathoracic anastomosis are currently undergoing clinical trials and the early results are encouraging. A minimally invasive approach may be used with low morbidity and mortality.

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