Thoracoscopic esophagectomy for esophageal cancer: Feasibility and safety of robotic assistance in the prone position

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Objective: To assess the feasibility and safety of robot-assisted thoracoscopic esophagectomy for esophageal cancer in the prone position.

Methods: Twenty-one patients underwent robot-assisted thoracoscopic esophagectomy in the prone position by a surgical oncologist who had no prior experience with thoracoscopic esophagectomy. Hemodynamic and respiratory parameters were serially recorded to monitor changes in prone positioning.

Results: All thoracoscopic procedures were completed with a robot-assisted technique followed by cervical esophagogastrostomy. R0 resection was achieved in 20 patients (95.2%), and the number of dissected nodes was 38.0 ± 14.2. Robot console time was significantly reduced from 176.3 ± 12.3 minutes in the initial 6 patients (group 1) to 81.7 ± 16.5 minutes in the latter 15 patients (group 2) ($P = .000$). In group 2, there was less blood loss ($P = .018$), more patients could be extubated in the operating room ($P = .004$), and the number of dissected mediastinal nodes tended to be increased ($P = .093$). There was no incidence of pneumonia or 90-day mortality. Major complications included anastomotic leakage in 4 patients, vocal cord palsy in 6 patients, and intra-abdominal bleeding in 1 patient. The prone position led to an elevation of central venous pressure and mean pulmonary arterial pressure and a decrease in static lung compliance. However, cardiac index and mean arterial pressure were well maintained with the acceptable range of partial pressure of arterial oxygen and carbon dioxide.

Conclusion: Robotic assistance in the prone position is technically feasible and safe. Prone positioning was well tolerated, but preoperative risk assessment and meticulous anesthetic manipulation should be carried out. (J Thorac Cardiovasc Surg 2010;139:53-9)

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Thoracoscopic esophagectomy (ThE) has been performed in patients with esophageal cancer to reduce morbidity and mortality while preserving oncologic quality of the resection. Recent large series have reported a low incidence of pneumonia and mortality, whereas the medium-term, stage-specific survival was similar to reports from open esophagectomy.[1-3] However, ThE necessitates a substantial amount of learning, even for experienced thoracoscopic surgeons.[4]

Robot-assisted surgery has the potential to accelerate the learning curve of minimally invasive esophagectomy (MIE) because it has several advantages, including increased magnification with 3-dimensional view, articulation of instruments, improved dexterity, and better ergonomics.[5] Although the robotic system has been introduced to ThE,[6,7] its role and potential advantages have yet to be verified.

We started robot-assisted ThE as our first MIE program in 2006. The prone position was used because it is known to facilitate mediastinal dissection and minimize lung injury.[2] We hypothesized that, owing to robotic assistance and advantages of the prone position, we could transfer our surgical strategy from open transthoracic esophagectomy to MIE within a short learning period. The objective of this study was to assess the feasibility and safety of robot-assisted ThE for esophageal cancer in the prone position.

MATERIALS AND METHODS

Following 5 cases of robot-assisted surgeries for benign mediastinal tumors, robot-assisted ThEs were performed in the prone position by a single thoracic surgeon (DJK). At the time of study design, the surgeon had a low surgical volume (<4 open Ivor-Lewis operations per year) with no prior experience with MIE. A prospective data registry was used to collect clinical data, and the study was approved by the institutional review board of Yonsei University College of Medicine, Seoul, Korea.

Patients

Between July 2006 and January 2008, 25 patients with intrathoracic esophageal cancer were seen by the same thoracic surgeon. Of these, 2 patients with multiple, bulky nodal metastases underwent definitive chemoradiation; 1 patient with calcified pleural thickening underwent open

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Abbreviations and Acronyms

CI	= cardiac index
CVP	= central venous pressure
MIE	= minimally invasive esophagectomy
MPAP	= mean pulmonary arterial pressure
Pao_2	= partial pressure of arterial oxygen
$Paco_2$	= partial pressure of arterial carbon dioxide
pkAWP	= peak airway pressure
plAWP	= plateau airway pressures
ThE	= thoracoscopic esophagectomy

transthoracic esophagectomy, and 1 patient with suspicious margin involvement by tumor after endoscopic submucosal dissection refused surgery. Thus, 21 consecutive patients underwent robot-assisted ThE in the prone position.

Preoperative endoscopic biopsy was performed in all patients to confirm the histologic diagnosis of esophageal cancer. Staging workup included thorough history and physical examination, esophagogastroduodenoscopy, endoscopic ultrasonography, and integrated positron emission tomography/computed tomography scan. Operative risk was assessed by a composite risk score based on general health status, cardiopulmonary function, and other organ functions.[8] Demographic data of patients are listed in Table 1.

TABLE 1. Demographics of patients

Operative risk profile		Oncologic data	
Age, y	61.5 ± 9.6	Location	
Sex, M/F	18/3	Upper	3 (14.3%)
Body mass index, kg/m^2	20.0 ± 2.9	Middle	7 (33.3%)
		Lower	11 (52.4%)
Karnofsky index		Histology	
100	3 (14.3%)	Squamous	20 (95.2%)
90	12 (57.1%)	Adenocarcinoma	1 (4.8%)
≤ 80	6 (28.6%)	Initial stage at diagnosis	
Smoking history*	9 (42.9%)	I	12 (57.1%)
Alcohol abuse	6 (28.6%)	IIA	2 (9.5%)
COPD	2 (9.5%)	IIB	2 (9.5%)
Hypertension	5 (23.8%)	III	3 (14.3%)
Ischemic heart disease	2 (9.5%)	IV‡	2 (9.5%)
Pulmonary function test			
FEV_1, % of normal	105.1 ± 21.6	Preoperative treatment	
FVC, % of normal	93.9 ± 16.9	None	18 (85.7%)
		Chemoradiation	3 (14.3%)
Operative risk†			
Low	15 (71.4%)	Intent of surgery	
Moderate	5 (23.8%)	Curative	18 (85.7%)
High	1 (4.8%)	Salvage	3 (14.3%)

COPD, Chronic obstructive pulmonary disease; *FEV_1*, forced expiratory volume in 1 second; *FVC*, forced vital capacity. *Smoking history > 20 pack-years. †Operative risk for postoperative morbidity and mortality according to the composite risk score.[8] ‡Classified as M1 due to non-regional lymph node metastasis.

Surgical Approach

Indications for surgery were similar to those for open surgery. For resectable clinical stage I to III tumors, curative intent surgery was performed followed by adjuvant chemotherapy or chemoradiation therapy according to pathologic stage. Induction chemoradiation is not a routine protocol for a resectable lesion at the Yonsei University College of Medicine. Salvage esophagectomy was performed in selected patients who presented a good response to definitive chemoradiation. Regardless of the aim of surgery, the same surgical principle was applied. En bloc esophagectomy with extended mediastinal lymphadenectomy was performed, followed by gastric mobilization with upper abdominal lymph node dissection and cervical esophagogastrostomy. When a primary lesion was located at the upper thoracic esophagus or the upper paraesophageal lymph node was involved in middle or lower thoracic esophageal cancer, bilateral cervical lymphadenectomy was added.

The patient was intubated with a Univent bronchial blocker tube (Fuji Systems Corp, Tokyo, Japan) and turned to the prone position. Beanbags were placed under the chest and pelvis to leave the abdomen free. Four trocars were placed with inspection of the pleural space after carbon dioxide (CO_2) insufflation at 8 to 10 mm Hg: a 12-mm trocar at the 8th intercostal space for a 30-degree angled, 10-mm thoracoscope; an 8-mm trocar at the 6th intercostal space medial to the scapula for a right robotic arm; an 8-mm trocar at the 10th intercostal space for a left robotic arm; and a 12-mm trocar at the 9th intercostal space along the anterior axillary line for the accessory port (Figure E1). After docking of the da Vinci robotic cart (Intuitive Surgical, Mountain View, Calif) from the left cranial side of the patient, the right lung was collapsed with a bronchial blocker and dissection began. The arch of the azygos vein was isolated and divided by an endoscopic linear stapler. The mediastinal pleura overlying the esophagus was incised, and the upper thoracic esophagus was circumferentially mobilized from the trachea with caution to avoid injury to the membranous portion of the trachea (Figure E2). Dissection continued down to the mid-thoracic esophagus, and the vagal trunk was cut below the level of its pulmonary branch. The left side of the esophagus was dissected by incising the left pleura. The thoracic duct, mediastinal pleura, and lymph nodes at the para-esophageal, subcarinal, and peribronchial stations were dissected to remain en bloc with the esophagus. Then, the infra-aortic nodes were dissected (Figure E3), and the lymph nodes along the left recurrent laryngeal nerve were sampled systematically. A 28F chest tube was placed, and the collapsed right lung was inflated. The patient was then turned to the supine position. Gastric mobilization, tube formation, and celiac axis lymph node dissection were performed by a gastric surgeon (WJH). A laparoscopy was performed in 14 patients, robot-assisted technique was performed in 4 patients, and laparotomy was performed in 3 patients with a history of multiple intra-abdominal operations. We constructed a 3- to 4-cm–wide, narrow gastric tube without pyloroplasty. At the end of the abdominal phase, a left cervicotomy was made and the cervical esophagus was mobilized. A horizontal collar incision was chosen when bilateral cervical lymphadenectomy was indicated. The esophagogastric specimen was pulled out through a neck incision under laparoscopic control. Esophagogastric anastomosis was performed with side-to-side stapled anastomosis in 19 patients and circular-stapled anastomosis in 2 patients.

We recorded the operation time at each step of the procedure. *Pre-robot time* started from the skin incision for trocar placement and ended at the docking of the robot cart and loading of robot arms. *Console time* started from the initiation of dissection with the robot and ended at the completion of the thoracic phase. *Total operation time* started from the skin incision for trocar placement in the thoracic phase and ended at the skin closure of the neck and abdominal wounds.

Postoperative Care

All patients were transferred to the intensive care unit for monitoring. The nasogastric tube was removed on the second postoperative day, and esophagography was done on the seventh postoperative day. For patients without anastomotic leakage, diet was advanced to soft diet for 2 to 3 days, and then they were discharged. Analgesia was achieved by intravenous patient-controlled analgesia for 2 days and then by fentanyl skin patch (25 μg/h) for 4 to 6 days. Postoperative complications were graded in accordance with the National Cancer Institute's Common Terminology Criteria for Adverse Events, version 3.0.[9]