Introduction

Video-assisted thoracic surgery (VATS) has become an important part of minimally invasive thoracic surgery. VATS has been proved safe and effective for a large variety of thoracic tumors. A prospective multi-institutional study\(^1\) and 2 meta-analyses\(^2,3\) of the Cancer and Leukemia Group B revealed VATS lobectomy as an appropriate procedure for early-stage non-small cell lung cancer (NSCLC) compared with open thoracotomy (OT). VATS lobectomy can be performed with low postoperative complications and mortality, and it has a similar 5-year survival rate to that of OT lobectomy, demonstrating similar oncologic efficacies. However, there are controversies on the safety and efficacy of minimally invasive esophagectomy (MIE) for esophageal cancer\(^4,5\) and minimal invasive thymectomy for thymoma\(^6,7\). In the present study, the safety and

ABSTRACT

**Objective:** To evaluate the short-term outcomes of video-assisted thoracic surgery (VATS) for thoracic tumors.

**Methods:** The data of 1,790 consecutive patients were retrospectively reviewed. These patients underwent VATS pulmonary resections, VATS esophagectomies, and VATS resections of mediastinal tumors or biopsies at the Cancer Institute & Hospital, Chinese Academy of Medical Sciences between January 2009 and January 2012.

**Results:** There were 33 patients converted to open thoracotomy (OT, 1.84%). The overall morbidity and mortality rate was 2.79% (50/1790) and 0.28% (5/1790), respectively. The overall hospitalization and chest tube duration were shorter in the VATS lobectomy group (n=949) than in the open thoracotomy (OT) lobectomy group (n=753). There were no significant differences in morbidity rate, mortality rate and operation time between the two groups. In the esophageal cancer patients, no significant difference was found in the number of nodal dissection, chest tube duration, morbidity rate, mortality rate, and hospital length of stay between the VATS esophagectomy group (n=81) and open esophagectomy group (n=81). However, the operation time was longer in the VATS esophagectomy group. In the thymoma patients, there was no significant difference in the chest tube duration, morbidity rate, mortality rate, and hospital length of stay between the VATS thymectomy group (n=41) and open thymectomy group (n=41). However, the operation time was longer in the VATS group. The median tumor size in the VATS thymectomy group was comparable with that in the OT group.

**Conclusions:** In early-stage (I/II) non-small cell lung cancer patients who underwent lobectomies, VATS is comparable with the OT approach with similar short-term outcomes. In patients with resectable esophageal cancer, VATS esophagectomy is comparable with OT esophagectomy with similar morbidity and mortality. VATS thymectomy for Masaoka stage I and II thymoma is feasible and safe, and tumor size is not contraindicated. Longer follow-ups are needed to determine the oncologic equivalency of VATS lobectomy, esophagectomy, and thymectomy for thymoma vs. OT.

**KEY WORDS**

Video-assisted thoracic surgery (VATS); non-small cell lung cancer (NSCLC); esophageal cancer; thymoma
feasibility of VATS pulmonary lobectomy, VATS esophagectomy, and VATS thymectomy were explored.

Materials and methods

Clinical data

The medical records of 1,790 consecutive patients were reviewed. These patients underwent VATS pulmonary resections, VATS esophagectomies, VATS resections of mediastinal tumors, and VATS biopsies at the Cancer Institute & Hospital, Chinese Academy of Medical Sciences between January 2009 and January 2012. This study was approved by the Institutional Review Board of the Cancer Institute & Hospital, Chinese Academy of Medical Science. In the same period, 753 lobectomies, 81 esophagectomies, and 41 thymectomies via OTs (OT group) were randomly selected as controls. The clinical variables of paired groups were compared, including age, sex, tumor location, forced expiratory volume in one second (FEV1), FEV1%, operation time, number of lymph nodal dissection (LND), number of lymph node stations, chest tube duration, morbidity, mortality, and hospital length of stay (LOS). Lung cancer and esophageal cancer staging were carried out according to AJCC 2009 cancer staging8,9. Thymoma staging were carried out according to Masaoka thymoma staging10.

Surgery

Pulmonary resection

Techniques of VATS resection for NSCLC have been described in our previous report11 and are outlined as follows. General anesthesia with selective lung ventilation was performed using a double lumen endotracheal tube. Patients were placed in a lateral decubitus position on the operation table. In the VATS group, one thoracoport was initially placed in the seventh or eighth intercostal space on the middle axillary line as observation port. A window (3-6 cm long) was used as the utility incision. The thoraocotomy was openend centering around the third or fourth intercostal space on the middle axillary line as observation port. A window (3-6 cm long) was used as the utility incision. The thoracotomy was opened centering around the third or fourth intercostal space with no rib spreading. The third port hole was made based on the location of the tumor. Finally, systematic LND was performed. In the OT group, conventional posterolateral incisions were made for lobectomy (20-30 cm long) and pulmonary wedge resection (10-20 cm long). All specimens were placed in an impermeable bag and removed through the utility incision.

Esophagectomy

VATS esophagectomy was performed by the method of Luketich et al.12. VATS esophagectomy includes total VATS esophagectomy and hybrid VATS esophagectomy. The former consists of thoracoscopic esophagectomy, laparoscopic gastric preparation, and cervical anastomosis; the latter comprises only thoracoscope surgery. In the OT group, esophagectomy was performed by the McKeown method13.

Thymectomy

VATS thymectomy was performed by the method of Landreneau et al.14 and OT thymectomy via sternotomy, or anterior thoracotomy according to the thymoma location.

Statistical analysis

The SPSS software package 13.0 for Windows was used for the statistical analysis. Data were presented as median values (interquartile range) for continuous variables and as percentages for dichotomous variables. Continuous variables were analyzed by the t-test or nonparametric test, and categorical variables were analyzed by the χ² test. The significant level was set as a P value less than 0.05.

Results

This cohort included 1,790 patients (1,206 males and 584 females) with a median age of 59 years (19 to 86 years). The overall morbidity rate was 2.79% (50/1,790). The complications included severe cardiac arrhythmia requiring medication (n=23), respiratory failure (n=6), postoperative bleeding (n=5), pneumonia (n=2), atelectasis (n=3), bronchial pleural leakage (n=2), bronchial leakage after esophageal surgery (n=1), esophageal anastomotic leakage (n=2), and wound infection (n=6). The mortality rate was 0.28% (5/1,790). Three patients with lung cancer died of acute respiratory distress syndrome, one patient with lung cancer died of pulmonary embolism, and one patient with esophageal cancer died of bronchial leakage.

VATS resections were performed in 1,790 patients, with 33 conversions to OT as a result of pleural adhesion (n=11) and intraoperative bleeding [bleeding of the pulmonary artery branch (n=13), pulmonary vein (n=5), azygous vein (n=2), and innominate vein (n=2)]. The VATS procedures and diagnosis of all patients are summarized in Table 1.

The overall hospitalization and chest tube durations were shorter in the VATS lobectomy group than in the OT lobectomy group, but the operation time was longer in the VATS lobectomy group. There was no significant difference in the morbidity and mortality rates between the two groups. There was no significant difference in the number of LND and number of lymph node
stations between the VATS lobectomy and OT lobectomy groups for pathological stage I and II NSCLC. However, there was a significant difference in the number of lymph node stations in pathological stage III between the two groups (Table 2).

In the VATS esophagectomy group, there were 42 esophagectomies and 39 hybrid esophagectomies. No significant difference was found in the number of nodal dissection, chest tube duration, morbidity rate, mortality rate, or hospital LOS between the VATS esophagectomy and open esophagectomy (OE) groups. Patients who underwent VATS esophagectomies had longer operation time (Table 3).

There was no significant difference in the chest tube duration, morbidity rate, mortality rate, and hospital LOS between VATS thymectomy and open thymectomy for thymoma. Patients who underwent VATS thymectomies had longer operation time than those who underwent OT thymectomy. The median tumor size of 5.4 cm in the VATS group was comparable with that of 4.5 cm in the open thymectomy group (Table 4).

### Discussion

With the advances in endoscopic equipment and surgical skills, VATS has become a useful modality for the management of many intrathoracic diseases. Compared with VATS esophagectomy

| Table 1 Diagnosis and procedures for 1,790 patients who underwent VATS |
|---------------------------------|-----------------|----------|
| Diagnosis                        | Procedure        | Number   |
| NSCLC                           | Lobectomy        | 949      |
|                                 | Pneumonectomy    | 9        |
|                                 | Wedge resection  | 306      |
|                                 | Bilobectomy      | 17       |
|                                 | Sleeve lobectomy | 5        |
|                                 | Segmentectomy    | 16       |
|                                 | Biopsy           | 8        |
| SCLC                            | Lobectomy        | 16       |
|                                 | Wedge resection  | 6        |
| Pulmonary metastasis            | Lobectomy        | 12       |
|                                 | Wedge resection  | 63       |
| Benign lung tumor, inflammatory lung disease and congenital lung disease | Lobectomy | 40 |
|                                 | Wedge resection  | 104      |
|                                 | Biopsy           | 2        |
| Esophageal cancer               | Total VATS esophagectomy | 42 |
|                                 | Hybrid VATS esophagectomy | 39 |
| Esophageal stromal tumor        | Complete resection | 5 |
| Thyroma                         | Complete resection | 41 |
|                                 | Biopsy           | 13       |
| Thymic cancer                   | Complete resection | 4 |
| Thymic hyperplasia              | Biopsy           | 7        |
|                                 | Complete resection | 21 |
| Germ cell tumor                 | Complete resection | 6 |
|                                 | Biopsy           | 1        |
| Mediastinal cyst                | Complete resection | 5 |
| Lymphoma, small cell cancer and metastatic tumor | Biopsy | 6 |
| Neurogenic tumor                | Complete resection | 25 |
| Pleural fibrous tumor           | Complete resection | 3 |
| Metastatic pleural tumor        | Biopsy           | 19       |
and VATS dissection of mediastinal tumors, VATS lobectomy is increasingly being performed for early lung cancer worldwide. Hence, there is a tendency for VATS lobectomy to replace most open lobectomy procedures\textsuperscript{15}.

In this VATS lobectomy series (NSCLC group), the postoperative morbidity and mortality rates were 2.4\% and 0.4\%, respectively. The postoperative LOS and chest tube duration were shorter in the VATS lobectomy group than in the OT

### Table 2 Comparison of short-term outcomes between VATS lobectomy and open lobectomy for NSCLC (n=1702)

| Characteristics                      | VATS group (n=949)     | OT group (n=753)     | P      |
|---------------------------------------|-----------------------|---------------------|--------|
| Age (years)                           | 59 (52-65)            | 57 (52-61)          | <0.001 |
| Male (%)                              | 583 (61.4)            | 439 (58.3)          | 0.195  |
| History of smoking (%)                | 368 (38.8)            | 315 (41.8)          | 0.213  |
| Charlson scores                       | 0 (0-1)               | 0 (0-0)             | <0.001 |
| Tumor location (%)                    |                      |                     | 0.998  |
| LUL (24.4)                            | 232 (24.4)            | 189 (25.1)          |        |
| LLL (17.6)                            | 167 (17.6)            | 132 (17.5)          |        |
| RUL (28.8)                            | 273 (28.8)            | 212 (28.2)          |        |
| RML (6.1)                             | 58 (6.1)              | 47 (6.2)            |        |
| RLL (21.3)                            | 219 (21.3)            | 173 (23.0)          |        |
| FEV\textsubscript{1} (L)              | 2.38 (2.05-2.89)      | 2.60 (2.37-3.01)    | <0.001 |
| FEV\textsubscript{1} (%)              | 70.4 (69.2-88.9)      | 91.7 (82.1-101.0)   | <0.001 |
| Operation time (h)                    | 2.6 (2.0-3.3)         | 2.7 (2.3-3.2)       | 0.074  |
| No. of LND                             |                      |                     |        |
| Stage I                               | 16 (11-24)            | 15 (10-21)          | 0.647  |
| Stage II                              | 20 (15-24)            | 23 (19-25)          | 0.055  |
| Stage III                             | 19.0 (10.5-30.0)      | 21.0 (18.0-24.0)    | 0.139  |
| No. of station of LND                 |                      |                     |        |
| Stage I                               | 6 (4-7)               | 5 (4-6)             | 0.122  |
| Stage II                              | 6 (5-7)               | 6 (5-7)             | 0.679  |
| Stage III                             | 4 (3-4)               | 6 (5-6)             | 0.001  |
| Histology (%)                         |                      |                     | 0.003  |
| Squamous cell carcinoma               | 226 (23.8)            | 228 (30.3)          |        |
| Adenocarcinoma                        | 672 (70.8)            | 47.5 (63.1)         |        |
| Others                                | 51 (5.4)              | 50 (6.6)            |        |
| Chest tube duration (d)               | 4.0 (4.0-5.5)         | 5.0 (4.0-6.0)       | <0.001 |
| Pathological stage (%)                |                      |                     | 0.520  |
| I                                     | 683 (72.0)            | 493 (65.5)          |        |
| II                                    | 141 (14.9)            | 140 (18.6)          |        |
| III                                   | 125 (13.2)            | 120 (15.9)          |        |
| Morbidity (%)                         | 23 (2.4)              | 25 (3.3)            | 0.303  |
| Mortality (%)                         | 4 (0.4)               | 2 (0.3)             | 0.699  |
| Hospital LOS (d)                      | 15.0 (13.5-18.0)      | 17.0 (15.0-20.0)    | <0.001 |
| Postoperative LOS (d)                 | 9.0 (8.0-11.0)        | 11.0 (9.0-12.0)     | 0.205  |

VATS, video-assisted thoracic surgery; OT, open thoracotomy; LUL, left upper lobe; LLL, left lower lobe; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; FEV\textsubscript{1}, forced expiratory volume in one second; LND, lymph node dissection; LOS, length of stay.
Swanson et al. also showed similar results. Hence, the safety of VATS lobectomy is comparable with that of OT lobectomy for operable NSCLC with reduced LOS and chest tube duration.
hand, there was a significant difference in the number of LND stations for pathological stage III in the present study. Dellinger et al.\textsuperscript{19} found that the number of N\textsubscript{2}-level LND in the VATS lobectomy group is less than that in the OT group, and attributed the deficit in LND to the learning curve. Recently, Kim et al.\textsuperscript{20} found that for clinical stage I NSCLC patients with pathologic N\textsubscript{1} or N\textsubscript{2} disease after VATS lobectomy, survival was comparable with that after lobectomy through a thoracotomy. Therefore, based on literature and our experience, VATS has similar efficacy and results in similar long-term survival to OT for clinical early-stage NSCLC patients planned for lobectomy.

Despite considerable improvements in esophageal cancer staging and patient selection, generally high complication rates encourage the search for alternative operative techniques that can achieve similar cure rates but with less morbidity. With this objective, MIE has been introduced under the form of various combinations of thoracoscopy and laparoscopy. The VATS approaches for the treatment of esophageal cancer are currently still considered investigational and under clinical evaluation\textsuperscript{4,5,21,22}. The indication for MIE is similar to that for OT, which is resectable esophageal cancer\textsuperscript{4}.

This study showed no significant difference in the number of nodal dissection, chest tube duration, morbidity rate, mortality rate, and hospital LOS between the VATS esophagectomy and OE groups. However, the operation time was longer in the VATS esophagectomy group. Zingg et al.\textsuperscript{21} reported similar results. On the other hand, the morbidity rate after operation was still moderately high in our series; 7 patients had complications, including severe arrhythmias requiring medication in 3 cases, wound infection in 1 case, esophageal anastomotic leakages in 2 cases, and bronchial leakage in 1 case which resulted in the only death in our series. Luketich\textsuperscript{15} reported 27 anastomotic leaks accounting for 11.7% of the 222 patients, and tracheal tear was found in 2 patients. The overall mortality was 1.4% (3/222). Nguyen et al.\textsuperscript{22} reported 8 cases of gastrointestinal leaks and 4 cases of anastomotic intrathoracic leaks in 104 MIE operations, and the in-hospital mortality was 2.9%. Tan et al.\textsuperscript{23} reported 5 cases of anastomotic leaks in 36 MIE patients. However, no peri-operative death occurred because the esophagogastric anastomosis was in the neck. All these results showed that MIE can be safely performed only in large medical centers, although devastating results can occur after MIE.

Currently, there are two MIE techniques, including totally VATS esophagectomy and hybrid VATS esophagectomy. Although there is no evidence of a specific advantage of one technique over another\textsuperscript{4}, minimally invasive Ivor-Lewis esophagectomy (thoracoscopy plus laparoscopy) with two-field lymph node dissection in patients with resectable esophageal cancer is the preferred approach in Pittsburgh Medical Center, the biggest MIE center for esophageal cancer in the USA\textsuperscript{4}. With the development of surgical techniques, similar to total VATS pulmonary lobectomy becoming the gold standard for the surgical treatment of lung cancer requiring lobectomy\textsuperscript{24}, total MIE may become the gold standard for the surgical treatment of resectable esophageal cancer in the near future.

Neurologic fibroma is safe for VATS dissection for benign mediastinal tumors, such as thymic cyst. The most common indication for VATS thymectomy is the treatment of myasthenia gravis\textsuperscript{25}. The controversies surrounding the indication of VATS thymectomy for thymoma\textsuperscript{6,7,26,27} has two aspects, namely, tumor size and tumor staging. The median tumor size of thymoma was 5.4 cm in the VATS group, which was comparable with the 4.5 cm in the open thymectomy group in our series. Li et al.\textsuperscript{27} reported that resections of noninvasive bulky solid thymomas by complete thoracoscopy are feasible and safe. The mean tumor size was 7.1 cm (5 to 10 cm) and patients survived 5 to 75 months without evidence of recurrence or metastasis. Pennathur et al.\textsuperscript{7} reported that 40 early-stage patients (14 of stage I and 26 of stage II) received thymectomy (open thymectomy for 22 patients and VATS for 18). No significant difference was found in the estimated recurrence-free and overall 5-year survival rates (83%-100%) between the two groups. The median tumor size of thymomas was 4 cm (3 to 8 cm), and all patients (4 of stage I and 7 of stage II) underwent complete dissection. Tumor size alone is not absolute contraindication. Therefore, based on literature and our results, VATS thymectomy for early-stage thymoma (Masaoka stage I and II) is safe and feasible.

In the present study, the VATS lobectomy patients were younger than those in the studies reported by Swanson et al.\textsuperscript{16} and Scott et al.\textsuperscript{18}, in which the median ages were 66 and 72 years, respectively. On the other hand, the median age of 59 years in our lobectomy series was comparable with that in other medical centers in China. Yang et al.\textsuperscript{26} reported an average age of 59 years for patients receiving lobectomy in a multi-center series of 600 consecutive cases of VATS lobectomy. For thymoma patients, the median age of 52 years in our series was within the range (44 to 63 years) of previous reports\textsuperscript{7,29}.

The operation time in the VATS group (including VATS esophagectomy and VATS thymectomy) was longer than that in the OT group. Learning curves are important in these procedures. Osugi et al.\textsuperscript{30} reached a plateau of VATS esophagectomy after performing 34 procedures. Toker et al.\textsuperscript{31} demonstrated that a thoracic surgeon must perform at least 30 VATS thymectomies to reach a success rate of 80%.

The median postoperative LOS of 9 days in the VATS lobectomy group in this study was longer than that in the
studies of Swanson et al.\textsuperscript{16} and Scott et al.\textsuperscript{18}, in which the median LOS values were 6.1 and 4.5 days, respectively. In the multi-center VATS lobectomy series of Yang et al.\textsuperscript{28} in China, the median LOS was 11.8 days, which was comparable to that in the present report.

This study had several limitations. First, it was retrospective. Second, only short-term outcomes were observed and long-term survival needs further evaluation. Finally, the results were obtained from one cancer center and may not be generalized to other medical centers.

Conclusions

For early-stage (I/II) NSCLC patients who underwent lobectomy, VATS had similar short-term outcomes to those of OT approach. For pulmonary wedge resection, VATS was superior to the OT approach, with shorter chest tube duration and hospital LOS. For resectable esophageal cancer, VATS esophagectomy had similar morbidity and mortality to those of OT esophagectomy. There is a tendency for total MIE (thoracoscopy plus laparoscopy) to become the preferred approach for resectable esophageal cancer. VATS thymectomy for Masaoka stage I and II thymoma is feasible and safe, and tumor size is not contraindicated. Longer follow-ups are needed to determine the oncologic equivalency of VATS lobectomy, pulmonary wedge resection, esophagectomy, and thymectomy for thymoma versus OT.

Conflict of interest statement

No potential conflicts of interest are disclosed.

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