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Trainees Can Safely Learn Video-Assisted Thoracic Surgery Lobectomy despite Limited Experience in Open Lobectomy

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Background: The aim of this study was to establish whether pulmonary lobectomy using video-assisted thoracic surgery (VATS) can be safely performed by trainees with limited experience with open lobectomy. ***Methods:*** Data were retrospectively collected from 251 patients who underwent VATS lobectomy at a single institution between October 2007 and April 2011. The surgical outcomes of the procedures that were performed by three trainee surgeons were compared to the outcomes of procedures performed by a surgeon who had performed more than 150 VATS lobectomies. The cumulative failure graph of each trainee was used for quality assessment and learning curve analysis. ***Results:*** The surgery time, estimated blood loss, final pathologic stage, thoracotomy conversion rate, chest tube duration, duration of hospital stay, complication rate, and mortality rate were comparable between the expert surgeon and each trainee. Cumulative failure graphs showed that the performance of each trainee was acceptable and that all trainees reached proficiency in performing VATS lobectomy after 40 cases. ***Conclusion:*** This study shows that trainees with limited experience with open lobectomy can safely learn to perform VATS lobectomy for the treatment of lung cancer under expert supervision without compromising outcomes.

Key words: 1. Education
2. Lobectomy
3. Lung neoplasms
4. Minimal invasive surgery
5. Thoracic surgery, video-assisted

INTRODUCTION

Video-assisted thoracic surgery (VATS) lobectomy was introduced in 1991 [1], and has become increasingly common in the treatment of lung cancer over the last decade. Recent review articles have suggested that VATS lobectomy in selected patients with early stage non-small cell lung cancer is a viable alternative to open lobectomy [2,3]. Furthermore, VATS lobectomy has the advantage of involving decreased postoperative pain [4,5], reduced cytokine release [6], shorter chest tube duration and hospital stay, and, consequently, lower hospital costs [7-9].

Several articles have reported that VATS lobectomy, which is believed to be more complex and technically demanding than open lobectomy, can be taught to new trainees without compromising morbidity or mortality rates [10-13]. However,

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Table 1. Patient demographics by group

Variable	Expert (n=101)	Trainee 1 (n=50)	Trainee 2 (n=50)	Trainee 3 (n=50)	p-value
Age (yr)	62.8±9.4	60.5±9.6	60.0±11.3	65.5±8.8	0.020
Sex (female)	44 (44)	25 (50)	21 (42)	16 (32)	0.326
Smoking history	38 (38)	24 (48)	22 (44)	16 (32)	0.356
History of pulmonary tuberculosis	9 (9)	1 (2)	6 (12)	3 (6)	0.256
One-second forced expiratory volume (%)	94.3±29.4	96.5±30.0	94.0±29.8	96.9±23.7	0.929
Tumor location					0.288
Right upper lobe	26 (26)	8 (16)	13 (26)	14 (28)	
Right middle lobe	9 (9)	4 (8)	5 (10)	3 (6)	
Right lower lobe	29 (29)	13 (26)	15 (30)	7 (14)	
Left upper lobe	19 (20)	18 (36)	9 (18)	12 (24)	
Left lower lobe	18 (18)	7 (14)	8 (16)	14 (28)	
Tumor size (cm)	2.5±1.3	2.6±1.3	2.5±1.2	2.7±1.6	0.940

Values are presented as mean±standard deviation or number (%).

the trainees discussed in the above studies were experienced surgeons who were already proficient in performing open lobectomy. Moreover, several of the above studies discuss a stepwise approach to the transition from open lobectomy to VATS lobectomy. Since VATS lobectomy is becoming more popular, surgeons who have had little experience performing open lobectomy are finding it increasingly difficult to obtain opportunities to practice this procedure. Therefore, in this study, we investigated whether VATS lobectomy can be safely performed by junior surgeons without extensive experience in performing open lobectomy.

METHODS

1) Patients

Data were retrospectively collected on consecutive patients who underwent pulmonary lobectomy for lung cancer between October 2007 and April 2011. Three trainees were involved in this study. Each trainee had experience as the primary surgeon in $<$five cases of open lobectomy, had performed $>$50 minor VATS procedures, and had assisted on $>$50 VATS lobectomies.

Each patient was evaluated by chest radiography and a pulmonary function test, along with a thoracic computed tomography (CT) scan, a positron emission tomography (PET) scan, or a PET/CT scan. Cervical mediastinoscopy was performed only when metastasis to the N2 node was suspected based on PET or PET/CT imaging. The preoperative patient characteristics recorded for each case included age, gender, history of smoking, history of pulmonary tuberculosis, one-second forced expiratory volume, and tumor location (Table 1).

2) Surgical technique

Each patient was placed in the lateral decubitus position, with flexion of the operating table in order to widen the intercostal spaces. Intubation was performed using a double-lumen endotracheal tube to enable single-lung ventilation. A 3–5-cm utility incision was made, usually at the anterior axillary line over the fourth or fifth intercostal space, without spreading the ribs. Another two or three incisions were made to allow the insertion of a camera, stapler, and endoscopic instruments for the surgeon and assistant. Endoscopic instruments were used as frequently as possible. The operation was performed entirely with thoracoscopic visualization. The pulmonary artery, pulmonary vein, and bronchus were individually dissected using endolinear staples, and systematic dissection of the mediastinal lymph nodes was performed in all cases.

3) Trainees

The trainees were three fellows who had been members of the department of thoracic surgery for at least one year. The trainees had previously assisted in VATS lobectomy procedures in Severance Hospital, thereby gaining proficiency in the following steps of the VATS lobectomy procedure in gradual increments under the constant supervision of an accomplished mentor: proper trocar placement, gentle exposure of hilar structures, camera control, handling of endoscopic instruments and staplers, pulmonary vein isolation, fissure development, and pulmonary artery isolation.

After the trainees achieved the prerequisite skills for performing VATS lobectomy by performing more than 50 minor VATS procedures and obtaining secondhand experience by assisting in multiple VATS lobectomies, they began performing VATS lobectomy with the help of well-trained assistants under the supervision of expert surgeons. In the early stages of training, trainees were assigned cases with small tumors, tumors located in the lower lobes, and well-developed fissures. As the trainees gained proficiency, cases involving upper lobe tumors or fused fissures were gradually introduced.

4) Assessment

The surgical outcomes of the VATS lobectomies performed by each of the three trainees under the supervision of a senior surgeon were compared to the outcomes of the same procedure performed by an expert surgeon who had performed more than 150 VATS lobectomies. In order to visualize the trainees' learning curves with maximum clarity, the first 50 cases performed by the expert surgeon were excluded from this study.

The quality assessment and analysis of each learning curve was performed using cumulative failure graphs. For these analyses, we defined failure as the occurrence of any of the following: (1) major perioperative morbidity and mortality; (2) intraoperative blood loss $>$1,000 mL in the absence of severe pleural adhesion, or blood loss greater than 2,000 mL in the presence of severe pleural adhesion; or (3) duration of surgery more than two standard deviations above the departmental average ($>$260 minutes in the absence of severe pleural adhesion or $>$320 minutes in the presence of severe pleural adhesion). Major morbidities were defined to include pulmonary complications requiring readmission to the intensive care unit, myocardial infarction, cerebrovascular pathology, and hemorrhages requiring reoperation.

5) Statistical analysis

All statistical analyses were performed with PASW Statistics for Windows ver. 18.0 (SPSS Inc., Chicago, IL, USA). Categorical variables were compared with the chi-square test or the Fisher's exact test. The independent t-test was used for the comparison of continuous variables. All p-values $<$0.05 were considered to indicate statistical significance. Cumulative failure graphs were drawn using SAS ver. 9.2 (SAS Institute Inc., Cary, NC, USA).

RESULTS

1) Preoperative demographics

Data from 251 patients were included in this study. The patient characteristics of each group (expert surgeon vs. each trainee) are presented in Table 1. Although the age of the patients in the group treated by trainee 3 was higher than in other groups, individual parameters including smoking history, incidence of tuberculosis, pulmonary function, tumor location, and tumor size were not significantly different among the groups.

2) Surgical outcomes

No significant difference was observed among the groups with respect to the presence of moderate to severe pleural symphysis during VATS lobectomy. The operative time, estimated blood loss, final pathologic stage, thoracotomy conversion rate, duration of chest tube support, duration of hospital stay, complication rate, and mortality rate were also comparable in each of the groups (Table 2). The number of retrieved lymph nodes in the trainee groups was higher than in the expert surgeon group.

3) Cumulative failure graphs

Cumulative failure graphs for each group are shown in Fig. 1. For trainee 1, the operative time was longer than the arbitrary cutoff time of 260 minutes in one case without moderate to severe pleural symphysis. In the group treated by trainee 2, two surgical failures occurred: one patient, who had contralateral lung disease, did not survive the procedure, and in another case, the surgery lasted longer than the 260-minute cutoff time. In the group treated by trainee 3, there were three failures: one patient had more than 1,000 mL of intraoperative blood loss, one operation lasted longer than 320 mi-

Table 2. Surgical outcomes by group

Variable	Expert (n=101)	Trainee 1 (n=50)	Trainee 2 (n=50)	Trainee 3 (n=50)	p-value
Operation time (min)	155 (60–295)	150 (70–280)	152 (77–290)	158 (68–330)	0.896
Blood loss (mL)	137 (0–1,200)	185 (0–800)	204 (0–1,200)	233 (0–1,500)	0.210
Severe pleural adhesion	12 (12.0)	1 (2.0)	2 (4.1)	3 (6.0)	0.104
No. of lymph nodes	19.5 (6–40)	24.1 (12–42)	24.2 (10–36)	25.0 (15–48)	<0.001
Pathologic stage (I, II, III)	85, 9, 7	41, 1, 9	40, 5, 5	33, 7, 10	0.063
Open conversion	3 (3)	1 (2)	3 (6)	3 (6)	0.708
Chest tube duration (hr)	5 (2–30)	5 (2–12)	4 (2–25)	3 (2–51)	0.617
Hospital stay (day)	6 (3–117)	6 (3–16)	5 (3–38)	5 (3–109)	0.896
No. of complications	16 (16)	6 (12)	3 (6)	8 (16)	0.397
Pulmonary complication	4 (4)	1 (1)	3 (6)	1 (2)	
Atrial fibrillation	1 (1)	1 (2)	0	3 (6)	
Prolonged air leak	8 (8)	3 (6)	0	2 (4)	
Hemorrhage (reoperation)	0	0	0	0	
Chylothorax	2 (2)	1 (2)	0	1 (2)	
Mortality	2 (2)	0	1 (2)	0	0.570

Values are presented as mean (range), number (%), or mean±standard deviation.

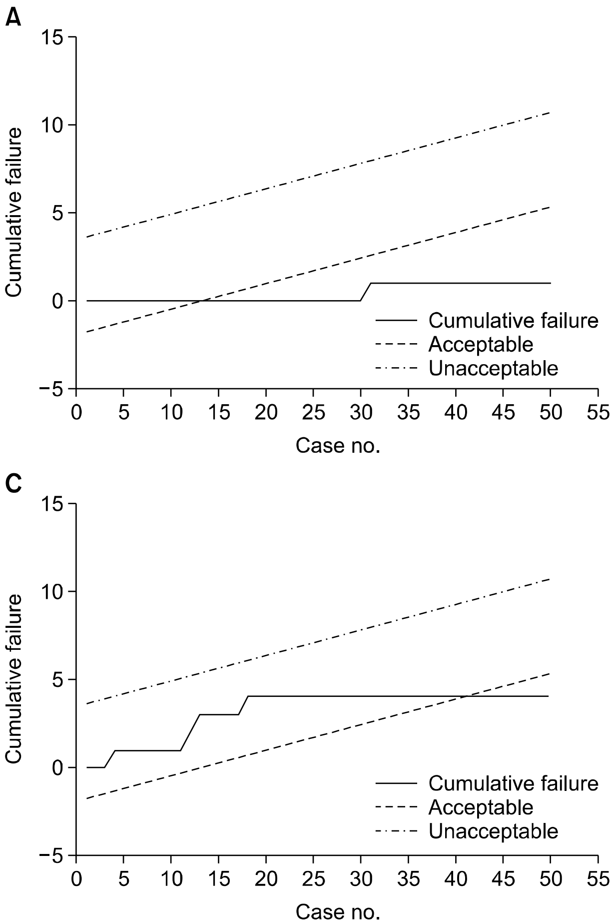

Fig. 1. Cumulative failure graphs for each group. (A) Trainee 1. (B) Trainee 2. (C) Trainee 3.

nutes (in the presence of severe pleural symphysis), and one patient suffered from atrial fibrillation and a subsequent cerebrovascular accident, requiring readmission to the intensive care unit.

DISCUSSION

This study demonstrates that new trainees can safely learn to perform VATS lobectomy for the treatment of lung cancer under expert supervision without compromising outcomes, even if they have limited experience performing open lobectomy.

Since 1991, when VATS lobectomy was first introduced [1], many studies have provided strong evidence that VATS lobectomy is an acceptable alternative to open lobectomy for early stage non-small cell lung cancer [2-9]. In addition, a recent propensity-matched analysis from the Society of Thoracic Surgeons database demonstrated that VATS lobectomy is associated with a lower incidence of complications than lobectomy via thoracotomy [14]. However, nearly 70% of all lobectomies reported to the Society of Thoracic Surgeons database were still performed via open thoracotomy [15], even though approximately 90% of lobectomies can be performed via VATS [16]. Despite the fact that VATS lobectomy has several advantages, this technique has yet to be widely disseminated. One possible reason for the limited use of VATS lobectomy is that it is a more complex and technically demanding procedure that requires intensive training.

Several articles about learning to perform VATS lobectomy have been published, directed towards experienced surgeons who had previously performed open lobectomy. Other articles outline a stepwise transition from open lobectomy to VATS lobectomy [10-13].

Previous experience with open lobectomy could potentially increase the surgeon's confidence when performing hilar dissection during VATS lobectomy. However, we postulated that even with limited experience performing open lobectomy, trainees should be able to learn VATS lobectomy in a stepwise fashion by obtaining experience assisting during VATS lobectomies.

Konge et al. [17] have recently reported that extensive experience with open procedures was not needed to learn to perform VATS lobectomy, much as we hypothesized. However, our study included more trainees and more cases than their report, which means that it may be more likely for our study to facilitate the broader acceptance of this proposal.

Assessing the results of surgical training poses interesting challenges. Direct observation by supervisors is a way of monitoring individual competence, but is likely to be subjective. The cumulative summation methodology, which has been suggested as a useful statistical technique to assess learning and training in physicians and surgeons [18], allows for the objective and quantitative monitoring of surgical performance using well-defined failure situations. In this study, each cumulative failure graph represents the outcome of 50 VATS lobectomies performed by each trainee. Even in the early period of training, no trainee's cumulative failure plot extended above the threshold of minimum acceptability (the upper line), thus indicating that the performance of each trainee was acceptable during this period. The cumulative failure graph crossed the threshold of proficiency (lower line) after 15 cases treated by trainee 1, 20 cases treated by trainee 2, and 40 cases treated trainee 3, which indicates that each surgeon gained proficiency in performing VATS lobectomy after 15 to 40 cases. It is likely that more procedures were needed to reach the desired level of proficiency in trainee 3 because the indications for VATS lobectomy have recently been expanded in Severance Hospital, and cases involving advanced age or severe pleural adhesion were represented more frequently in the group treated by trainee 3.

The cumulative summation technique, however, offers no panacea for assessing the competency of trainees [19]. Failure can be defined in a somewhat arbitrary manner, as exemplified by our criterion dealing with the amount of bleeding. On one hand, 1,000 mL of blood loss might be considered quite extensive, but the absolute amount of blood loss is less important than keeping vital signs stable and deciding whether thoracotomy conversion should be performed in the face of uncontrolled bleeding during VATS. Therefore, we also included failure criteria involving major perioperative morbidity and mortality, which can result from uncontrolled bleeding during the operation. Moreover, determining what constitutes an acceptable failure rate is difficult because there is a paucity of data in the literature relating to the failure rates of trainees. In most clinical training settings, therefore, it is appropriate to assess trainees based on comparison with the performance of their supervisors or colleagues with similar experience levels. Thus, in this study, comparison with an expert was given priority over the application of the cumulative summation curve for the overall assessment of trainees.

Our results show that VATS lobectomy can be safely taught to trainees without compromising surgical outcomes, as reflected by parameters such as estimated blood loss, complication rates, and mortality rates. Our outcomes, as quantified by the above parameters, were similar to the outcomes reported by two expert centers in the United States [20,21]. The number of retrieved lymph nodes in the groups treated by trainees was higher than in the group treated by the expert surgeon. We hypothesize that this difference may have stemmed from differences in some demographic category (for example, more old patients were included in the expert surgeon group), differences in the strategy of lymph node dissection according to the tumor location, and the presence of more patients with bronchioloalveolar cell carcinoma in the group treated by trainee 1.

The fact that trainees, even with limited experience with open lobectomy, can achieve comparable surgical outcomes and follow the projected learning curve, may be due to several factors. First, port placement and overall surgical technique are performed in a similar fashion by the three senior surgeons in Severance Hospital. This provides consistency during second-hand training, which enables trainees to learn effectively without needing to develop skills to replicate different techniques used by different surgeons. Second, surgical error, especially during hilar dissection and fissure development, was reduced by direct supervision using magnified images of procedures performed by the expert surgeons. Finally, trainees were able to review video recordings of their performances, allowing them to correct and improve their skills in an efficient manner.

There is one major limitation in our study. Clear and objective training assessment parameters were not established in the beginning of the training period. During this period, the only way of monitoring individual competency was potentially subjective observation by a supervisor Since the proficiency, learning curve, and cumulative failure graph of each trainee were retrospectively analyzed and compared to the outcomes of procedures performed by an expert surgeon, it was not possible to thoroughly control for confounding variables such as the degree of intervention by an expert surgeon, pre-existing differences in the degree of technical proficiency in the use of thoracoscopic instruments, or differences in the proficiency of assistants.

In conclusion, this study shows that trainees, even with limited experience in open lobectomy, can safely learn to perform VATS lobectomy for the treatment of lung cancer under expert supervision, without compromising outcomes, after they established significant second-hand experience with VATS lobectomy and other minor VATS procedures. In the near future, objective assessment tools and procedure simulations are expected to be incorporated into resident and fellowship training programs.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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