Pulmonary Function After Lobectomy: Video-Assisted Thoracoscopic Surgery Versus Muscle-Sparing Mini-thoracotomy

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Abstract Although pulmonary function was better after video-assisted thoracoscopic surgery (VATS) lobectomy than after open thoracotomy lobectomy, it is unclear whether postoperative pulmonary function after VATS lobectomy is better than that after mini-thoracotomy lobectomy. The aim of this study is to determine whether the former is better than the latter. VATS lobectomies were performed using endoscopic techniques through a 3–4-cm skin incision spread by a silicon rubber retractor and two or three trocars. Mini-thoracotomy lobectomies were performed through a 7–12-cm skin incision spread by rib retractors made of metal and one or two trocars. Pulmonary function tests were performed a week before surgery and 3 months after surgery. There were 14 males and 11 females in VATS lobectomy and 32 males and 30 females in mini-thoracotomy lobectomy. For lobe location (right upper/right lower/left upper/left lower), there were 12/1/8/4 in VATS lobectomy and 16/19/13/14 in mini-thoracotomy lobectomy, respectively. The percent predicted postoperative forced vital capacity (FVC) (postoperative FVC/predicted postoperative FVC $\times$ 100) (110 ± 15 %) of VATS lobectomy was significantly higher than that (101 ± 16 %) of mini-thoracotomy lobectomy ($P=0.0124$). The percent predicted postoperative forced expiratory volume in 1 s (FEV1) (postoperative FEV1/predicted postoperative FEV1 $\times$ 100) (110 ± 15 %) of VATS lobectomy was not significantly higher than that (104 ± 15 %) of mini-thoracotomy lobectomy ($P=0.091$). Multiple regression analysis revealed that operative procedure (VATS lobectomy or mini-thoracotomy lobectomy) was the only

significant variable contributing to percent predicted postoperative FVC ($P=0.0073$) and percent predicted postoperative FEV1 ($P=0.0180$). Postoperative FVC after VATS lobectomy is better than after mini-thoracotomy lobectomy.

Keywords Lung cancer · Lobectomy · Pulmonary function · Video-assisted thoracoscopic surgery (VATS) · Mini-thoracotomy

Abbreviations

VATS	Video-assisted thoracoscopic surgery
NSCLC	Non-small cell lung cancer
Pre FVC	Preoperative forced vital capacity
Pre FEV1	Preoperative forced expiratory volume in 1 s
Post FVC	Postoperative FVC 3 months after surgery
Post FEV1	Postoperative FEV1 3 months after surgery
Predicted post FVC	Predicted postoperative FVC
Predicted post FEV1	Predicted postoperative FEV1

Introduction

Stage I and II non-small cell lung cancer (NSCLC) is primarily treated through surgical resection. The procedure consists of a pulmonary lobectomy and dissection of hilar and mediastinal lymph nodes. These lobectomies have been performed through a large thoracotomy incision. Video-assisted thoracoscopic surgery (VATS) lobectomy can achieve cure rates similar to those performed via thoracotomy [1] and

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appears to be a less morbid operation than lobectomy via thoracotomy [2–4].

Early postoperative pulmonary function was significantly better after VATS than after thoracotomy [5], and pulmonary function was better after VATS lobectomy than after open thoracotomy in which a 30- to 40-cm posterolateral incision was made, which was reported in 2000 [6]. Today, the average thoracotomy in most centers measures less than 30 cm and lobectomy via mini-thoracotomy has become one of the popular operative procedures. But, it is unclear whether postoperative pulmonary function after VATS lobectomy is better than that of mini-thoracotomy lobectomy. Postoperative lung function after lobectomy was not evaluated in a randomized trial whether VATS lobectomy has the advantages over muscle-sparing mini-thoracotomy lobectomy [7]. The aim of this study is to determine whether postoperative pulmonary function after VATS lobectomy is better than that of mini-thoracotomy lobectomy.

Patients and Methods

This was a clinical retrospective single-center study dealing with routine operations and routine lung function examinations. This retrospective study was approved by the Institutional Review Board of Kanazawa Medical University (approval number: No. 274). Written informed consent was obtained from each patient after discussing the risks, benefits of the operation, and pulmonary function assessment with their surgeons.

From May 2010 through May 2013, 147 lobectomies were performed for patients with lung cancer. Mini-thoracotomy lobectomies were performed in 82 patients, VATS lobectomies were performed in 25 patients, and standard thoracotomy lobectomies were performed for the residual 40 patients. Right middle lobectomies were excluded from the study. Lung cancers were resected through VATS lobectomy or muscle-sparing mini-thoracotomy lobectomy combined with video support. During this period, postoperative pulmonary function tests were performed in 62 out of 82 patients who underwent a mini-thoracotomy lobectomy and 25 patients who underwent a VATS lobectomy. All the seven authors performed both mini-thoracotomy lobectomies and VATS lobectomies. They had access to patient-identifying information. The surgeries described in our study were performed as a part of routine care.

Operative Procedure

Epidural catheters were inserted into the epidural space. After double-lumen intubation, patients were placed in the lateral position. In VATS lobectomy, the lobectomy involved endoscopic techniques with monitor vision with a 3–4-cm utility

incision in the ventral axillary line along the fourth intercostal space for upper lobectomy or along the fifth intercostal space for lower lobectomy. A non-rib spreader with a silicon rubber retractor (Wound Retractor; Applied Medical, New York, USA) was used for the utility incision. A 30° thoracoscope was placed in the seventh or eighth midaxillary intercostal space, followed by one or two trocars anteriorly and/or posteriorly. In mini-thoracotomy lobectomy, the lobectomy was performed with a muscle-sparing 7–12-cm skin incision along the fourth intercostal space for upper lobectomy or along the fifth intercostal space for lower lobectomy with direct and monitor vision. The latissimus dorsi muscle was retracted posteriorly or split in the direction of the fibers. The serratus anterior muscle was split in the direction of the fibers. The intercostal space for mini-thoracotomy was spread by rib retractors made of metal. A 30° thoracoscope was placed in the seventh or eighth midaxillary intercostal space, followed by one or two trocars anteriorly and/or posteriorly. In both groups, lobectomies followed the same hilar and mediastinal lymph node dissection technique. The pulmonary artery, vein, and bronchus were routinely closed with an end stapler. The incomplete fissures were severed by an end stapler.

Preoperative forced vital capacity (pre FVC), preoperative forced expiratory volume in 1 s (pre FEV1), postoperative FVC 3 months after surgery (post FVC), and postoperative FEV1 3 months after surgery (post FEV1) were measured and recorded. Predicted postoperative FVC (predicted post FVC) and predicted postoperative FEV1 (predicted post FEV1) were calculated based on the number of functioning unobstructed segments to be resected during surgery, in keeping with the British Thoracic Society's recommendation [8]: the segments taken were the following: right upper lobe (3), middle lobe (2), right lower lobe (5), left upper division (3), lingual (2), and left lower lobe (4) (total = 19). Percent predicted postoperative FVC (percent predicted post FVC) = $\text{post FVC} / \text{predicted post FVC} \times 100$. Percent predicted postoperative FEV1 (percent predicted post FEV1) = $\text{post FEV1} / \text{predicted post FEV1} \times 100$.

TNM classification and the lymph node stations of lung cancer were classified according to the definition of UICC [9].

Statistical Analysis

Statistical analysis was performed using StatView for Windows (version 5.0; SAS Institute Inc., Cary, NC, USA). The data is expressed as the mean $\pm$ standard deviation. A two-tailed Student's *t* test was used for comparison of differences in continuous data. A contingency table analysis was used to examine correlations between two factors with several categories. Multiple regression analysis was used for determining variables contributing to percent postoperative

pulmonary function. A P value of <0.05 was considered statistically significant.

Results

Patient Characteristics

There were 14 males and 11 females in VATS lobectomy and 32 males and 30 females in mini-thoracotomy lobectomy (not significant (N.S.)). The mean ages were 68.4 ± 9.0 in VATS lobectomy and 67.7 ± 9.1 in mini-thoracotomy lobectomy (N.S.). The maximum diameters of tumor shadow (mm) were 25.7 ± 13.4 in VATS lobectomy and 32.6 ± 27.2 in mini-thoracotomy lobectomy (N.S.). For clinical N factor, there were 25 with N0 in VATS lobectomy and 56 with N0, 5 with N1, and 1 with N2 in mini-thoracotomy lobectomy (N.S.). For clinical stage, there were 19 with stage IA, 5 with stage IB, and 1 with stage IIA in VATS lobectomy. There were 37 with stage IA, 12 with stage IB, 8 with stage IIA, 3 with stage IIB, and 2 with stage IIIA in mini-thoracotomy lobectomy (N.S.). For lobe location (right upper/right lower/left upper/left lower), there were 12/1/8/4 in VATS lobectomy and 16/19/13/14 in mini-thoracotomy lobectomy, respectively. For the laterality (right side/left side), there were 13/12 in VATS lobectomy and 35/27 in mini-thoracotomy lobectomy (N.S.), respectively. For location (upper lobe/lower lobe), there were 20/5 in VATS lobectomy and 29/33 in mini-thoracotomy lobectomy ($P=0.0096$), respectively. For nodal dissection (hilar/mediastinal), there were 2/23 in VATS lobectomy and 3/59 in mini-thoracotomy lobectomy (N.S.), respectively. Lengths of skin incision (cm) were 3.9 ± 0.7 in VATS lobectomy and 9.1 ± 2.7 in mini-thoracotomy lobectomy ($P<0.0001$). Durations of operation (min) were 280.9 ± 75.1 in VATS lobectomy and

396.5 ± 96.6 in mini-thoracotomy lobectomy (N.S.). Bleeding amounts (ml) were 114.9 ± 105.3 in VATS lobectomy and 139.0 ± 126.8 in mini-thoracotomy lobectomy (N.S.) (Table 1).

Post FVC and Post FEV1

In VATS lobectomy, post FVC (2.72 ± 0.74) was not significantly lower than pre FVC (3.08 ± 0.72) ($P=0.084$) (Fig. 1a) whereas post FVC (2.23 ± 0.62) was significantly lower than pre FVC (2.87 ± 0.73) in mini-thoracotomy lobectomy ($P<0.0001$) (Fig. 1b). Similarly, post FEV1 (1.99 ± 0.50) was not significantly lower than pre FEV1 (2.28 ± 0.61) in VATS lobectomy ($P=0.0695$) whereas post FEV1 (1.69 ± 0.46) was significantly lower than pre FEV1 (2.07 ± 0.50) in mini-thoracotomy lobectomy ($P<0.0001$). Postoperative FEV1 % was not statistically different from preoperative FEV1 % in VATS lobectomy (75.7 ± 11.1 vs 75.3 ± 10.4 , N.S.) or in mini-thoracotomy lobectomy (76.6 ± 10.0 vs 73.3 ± 9.4 , N.S.)

Comparison of Pulmonary Function Without a Bias of Lobe Location

There was a significant bias in the number of resected lobe locations between VATS lobectomy and mini-thoracotomy lobectomy. The percent predicted post FVC and percent predicted post FEV1 were calculated for the unbiased comparison between the two groups. The percent predicted post FVC (110 ± 15 %) of VATS lobectomy was significantly higher than that (101 ± 16 %) of mini-thoracotomy lobectomy ($P=0.0124$) (Fig. 2a). The percent predicted post FEV1 (110 ± 15 %) of VATS lobectomy was not significantly higher than that (104 ± 15 %) of mini-thoracotomy lobectomy ($P=0.091$) (Fig. 2b). Further analysis was

Table 1 Comparison of preoperative and operative characteristics of patients

Factors	VATS lobectomy	Mini-thoracotomy lobectomy	Significance
Gender (male/female)	14/11	32/30	N.S.
Age (years)	68.4 ± 9.0	67.7 ± 9.1	N.S.
Maximum diameter of tumor shadow (mm)	25.7 ± 13.4	32.6 ± 27.2	N.S.
cN (N0/N1/N2)	25/0/0	56/5/1	N.S.
cStage (IA/IB/IIA/IIB/IIIA)	19/5/1/0/0	37/12/8/3/2	N.S.
Laterality (right/left)	13/12	35/27	N.S.
Location (upper lobe/lower lobe)	20/5	29/33	$P=0.0096$
Nodal dissection (hilar/mediastinal)	2/23	3/59	N.S.
Length of skin incision (cm)	3.9 ± 0.7	9.1 ± 2.7	$P<0.0001$
Duration of operation (min)	280.9 ± 75.1	396.5 ± 96.6	N.S.
Bleeding amount (ml)	114.9 ± 105.3	139.0 ± 126.8	N.S.

Mean $\pm$ S.D.

N.S. Not significant

Fig. 1 Change of FVC before and after lobectomy. **a** VATS lobectomy ($n = 25$). **b** Mini-thoracotomy lobectomy ($n = 62$)

done in the 28 patients who underwent right upper lobectomy, which was the most frequent lobectomy in this series. In the 28 patients, the percent predicted post FVC (112 ± 14 %) of VATS lobectomy was significantly higher than that (96 ± 16 %) of mini-thoracotomy lobectomy ($P = 0.0114$) (Fig. 3a). The percent predicted post FEV1 (110 ± 12 %) of VATS lobectomy was not significantly higher than that (100 ± 15 %) of mini-thoracotomy lobectomy ($P = 0.053$) (Fig. 3b).

Multivariate Analysis for Postoperative Lung Function After Lobectomy

Multiple regression analyses were performed for several variables: operative procedure (VATS lobectomy or mini-thoracotomy lobectomy), gender, age, maximum diameter of tumor shadow, location (upper lobe/lower lobe), laterality (right side/left side), nodal dissection, duration of operation, bleeding amount, and pathological

stage contributing to percent predicted post FVC and percent predicted post FEV1. Multiple regression analysis for variables contributing to percent predicted post FVC revealed that operative procedure was the only significant variable ($P = 0.0073$) contributing to percent predicted post FVC (Table 2). Multiple regression analysis for variables contributing to percent predicted post FEV1 revealed that operative procedure was the only significant variable ($P = 0.0180$).

Discussion

Pulmonary lobe volume differs between lobes. It was reported that FVC percentage of the patients who received right lower lobectomy was decreased most significantly compared with the preoperative values [10]. The comparison between postoperative pulmonary function of VATS lobectomy and that of mini-thoracotomy lobectomy has a bias of resected lobe location and has to be performed using

Fig. 2 Comparisons of percent predicted post FVC (a) and percent predicted post FEV1 (b) between VATS lobectomy and mini-thoracotomy lobectomy

Fig. 3 Comparisons of percent predicted post FVC (**a**) and percent predicted post FEV1 (**b**) in patients with right upper lobectomy between VATS and mini-thoracotomy

predicted post FVC, predicted post FEV1, percent predicted post FVC, and percent predicted post FEV1 which do not have a bias of resected lobe location. Predicted post FVC and predicted post FEV1 were calculated based on the number of functioning unobstructed segments to be resected during surgery, in keeping with the British Thoracic Society's recommendation [8]. To the authors' knowledge, there has been no paper which deals with postoperative pulmonary function between VATS lobectomy and muscle-sparing mini-thoracotomy lobectomy. The two groups in this study adopted almost the same procedure of lobectomy and lymph node dissection, except the methods of chest wall fenestration. There were no significant differences in patient characteristics between the two groups, except lobe location and length of skin incision. In this multiple regression analysis for variables contributing to percent predicted post FVC or percent predicted post FEV1, operative procedure was the only significant variable. In patients who had VATS lobectomy, there was little damage of intercostal muscles and intercostal nerves,

which was likely to result in less pain, less morbidity, and less pleural adhesion. Whereas in patients who had mini-thoracotomy lobectomy, there was some damage of intercostal muscles, intercostal nerves, serratus anterior muscles, and latissimus dorsi muscles, which would cause morbid condition such as chest pain, numbness, or partial contracture of the chest wall. Compared to mini-thoracotomy lobectomy, VATS lobectomy had less postoperative pain and faster recovery [11, 12]. VATS lobectomy has advantages not only on postoperative pulmonary function over lobectomy via thoracotomy [5] but also on postoperative pulmonary function over lobectomy via muscle-sparing mini-thoracotomy. Improved condition of postoperative chest wall in patients who had VATS lobectomy resulted in improved postoperative pulmonary function compared to patients who had muscle-sparing mini-thoracotomy lobectomy. Good preservation of postoperative pulmonary function is a great benefit to patients with lung cancer, because these patients are often elderly, and with poor pulmonary reserve.

Table 2 Results of multiple regression analysis for variables contributing to percent predicted post FVC

Variables	Regression coefficient	Standardized regression coefficient	P value
Operative procedure	−0.11	−0.311	0.0073
Location (upper lobe/lower lobe)	0.049	0.151	0.196
Pathological stage	−0.052	−0.159	0.225
Maximum diameter of tumor shadow	0.001	0.135	0.280
Gender	0.034	0.106	0.345
Nodal dissection	−0.058	−0.106	0.354
Duration of operation	−0.00016	−0.090	0.491
Age	0.001	0.049	0.677
Laterality (right/left)	−0.008	−0.024	0.824
Bleeding amount	0.000011	0.008	0.952

Limitations in the Study

First, this was a retrospective study which dealt with pulmonary function after lobectomy via VATS and mini-thoracotomy, and there was a significant bias of resected lobe location. A randomized controlled study of pulmonary function after lobectomy between VATS and mini-thoracotomy would be recommended. Second, in this study, postoperative pulmonary function was measured only 3 months after surgery. For better comparison, postoperative pulmonary function should be measured at least 6 months and 1 year after surgery.

Conclusion

It is concluded that the patients who undergo VATS lobectomy maintain better pulmonary function at 3 months after lobectomy than that of patients who undergo mini-thoracotomy lobectomy, although this trial was neither prospective nor randomized.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

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