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ORIGINAL ARTICLE

THORACIC

Comparison of thoracoscopic segmentectomy and thoracoscopic lobectomy on the patients with non-small cell lung cancer: a propensity score matching study†

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Abstract

OBJECTIVES: Thoracoscopic lobectomy has been widely performed on patients with early-stage lung cancer; meanwhile indications of thoracoscopic segmentectomy have not been clearly defined due to technical difficulties and unclear oncological outcomes. The aim of this study was to compare early and late outcomes between thoracoscopic segmentectomy and thoracoscopic lobectomy.

METHODS: Between January 2005 and December 2013, 100 thoracoscopic segmentectomies and 1049 thoracoscopic lobectomies were performed on patients with lung cancer in our institute. Preoperative clinical parameters including gender, age, tumour size, pathological stage, histology and forced expiratory volume in 1 s (FEV_1) were used for propensity score matching. After propensity score matching, 94 thoracoscopic segmentectomies and 94 lobectomies were selected and compared.

RESULTS: Thoracoscopic segmentectomies were performed on patients with normal lung function (mean FEV_1 = 101.6 ± 24.1%), small-sized tumour (mean diameter 1.7 ± 1.0 cm), early-stage cancer (Stage I 93.7%) and predominant adenocarcinoma (81.9%). The lobectomy group had similar clinical features with the segmentectomy group. Most commonly performed procedures were left upper lobe upper division segmentectomy (19%) and right lower lobe superior segmentectomy (17%). Segmentectomies were performed in all lobes except the right middle lobe. There were no differences between segmentectomy and lobectomy in terms of operation time (166.3 ± 54.7 min vs 181.1 ± 85.2 min, $P = 0.47$) and hospital stay (6.2 ± 5.2 days vs 7.1 ± 7.1 days, $P = 0.31$). Incidence of postoperative complications was non-significantly higher in the lobectomy group (17.2 vs 10.6%, $P = 0.1$), and postoperative mortality rates were also non-significantly higher in the segmentectomy group (1.1 vs 2.1%, $P = 0.56$). Postoperative FEV_1 decrease was non-significantly lower in the segmentectomy group (8.9 ± 10.8 vs 11.0 ± 13.1, $P = 0.36$). The 3-year overall survival and recurrence-free survival was not different between the two groups (94 and 87% in the segmentectomy group and 96 and 94% in the lobectomy group, $P = 0.62$ and $P = 0.69$, respectively).

CONCLUSIONS: Thoracoscopic segmentectomy could achieve equal short-term surgical results and long-term oncological outcomes compared with thoracoscopic lobectomy.

Keywords: Non-small-cell lung carcinoma • Video-assisted thoracoscopic surgery • Segmentectomy • Lobectomy • Survival analysis

INTRODUCTION

Lobectomy with systemic mediastinal lymph node dissection is a standard treatment for early-stage non-small-cell lung cancer (NSCLC), whereas sublobar pulmonary resection (segmentectomy and wedge resection) remains to be a controversial topic in thoracic surgery. In 1995, a prospective, randomized, multi-institutional trial reported by the Lung Cancer Study Group (LCSG) compared sublobar resection with lobectomy for T1N0M0 NSCLC patients. This study showed that sublobar resection was associated with lower overall survival (OS) rate and higher regional recurrence rate than lobectomy [1]. Since then, sublobar resection has been frequently performed to treat patients who are not considered for a lobectomy because of advanced age, severely compromised pulmonary function or other comorbidities. However, the unfavourable results of sublobar resection in the LCSG study may have been related to the fact that 40 of the 122 patients who were treated by sublobar resection underwent wedge resection, resulting in recurrence and poorer outcomes compared with segmentectomy [2]. The results of the LCSG study have potential biases concerning the result of segmentectomy. As recently reported, lung cancers tend to be diagnosed at an early stage, and segmentectomy is indicated more frequently [3]. At the same time, several retrospective reports have demonstrated that segmentectomy for small-sized (diameter ≤ 2.0 cm) Stage IA NSCLC may have

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a prognosis and local recurrence rate that is comparable with lobectomy [4, 5]. Nevertheless, indications of segmentectomy for lung cancer have not been clearly claimed due to technical difficulties and unclear oncological outcomes.

Over the past decade, the surgical technique of video-assisted thoracic surgery (VATS) has greatly evolved to perform anatomical lobectomy for the treatment of early-stage lung cancer. Current data suggest that this approach is associated with better perioperative outcomes and may be equivalent to open resection in terms of oncological outcomes [6]. Similarly, it is postulated that the thoracoscopic approach to segmentectomy may have more advantages than an open approach. However, thoracoscopic segmentectomy has continued to be a controversial approach because of the inherent complications of the procedure and the greater concern about local recurrence. Only a few single-centre studies have evaluated the outcomes of VATS versus open segmentectomy for lung cancer [7]. Thus, in the light of growing concern for minimally invasive surgery, it becomes significant and even necessary to compare and evaluate clinical outcomes in between thoracoscopic segmentectomies and thoracoscopic lobectomies.

The goal of our study was to compare early and late outcomes between thoracoscopic segmentectomy and thoracoscopic lobectomy on patients with NSCLC, adjusted for preoperative factors including sex, age, preoperative forced expiratory volume in 1 s (FEV_1), tumour size, staging and histology to minimize the effect of the patient selection bias.

MATERIALS AND METHODS

The study population was composed of consecutive NSCLC patients who underwent 1049 thoracoscopic lobectomies or 100 segmentectomies with curative intent in Seoul National University Hospital between January 2005 and December 2013. This study was reviewed and approved by the Institutional Review Board of Seoul National University Hospital (#1405-061-578). Medical records were retrospectively reviewed to assess clinico-pathological characteristics, postoperative morbidity and mortality, recurrence and survival rate. Anatomical pulmonary resection and systematic lymph node dissection were the standard procedure for surgery of NSCLC during the study period. Surgical decision between thoracoscopic lobectomy and segmentectomy was made depending on the preoperative pulmonary function and cancer stage. The indications for thoracoscopic lobectomy were clinical T1–3 disease, N0–1, single station N2 and absence of distant metastasis. The eligibility criteria for segmentectomy in this study were as follows: patients who had cT1N0M0 NSCLC 2 cm or smaller in all dimensions on thin-sliced computed tomography (CT) or limited pulmonary function (FEV_1 <40% of predicted) or other lesions that need resection.

Preoperative staging work-up and intraoperative lymph node analysis

All patients underwent preoperative work-up with pulmonary function test, computed tomographic chest scanning, with or without positron emission tomography (PET)-CT scan, flexible bronchoscopy and brain magnetic resonance imaging. Mediastinoscopy was performed only on patients with lymph node >10 mm on computed tomographic chest scan or positive lymph node findings on PET-CT scan. When lymph node enlargement was noted or lymph node metastasis was suspected, frozen-section biopsies were additionally performed during the operation.

Surgical technique

All surgical procedures were performed under general anaesthesia with double-lumen endotracheal tube intubation. Patients were placed in the full lateral decubitus position. A 3–4-cm long utility access port was added to the 2 or 3 ports. All procedures were performed by visualization through a television monitor, a so-called complete VATS. The intrathoracic procedure regarding hilar and intralobar vessel treatment was the same in both segmentectomy and lobectomy; however, the difference was segmental plane management by electrocautery or stapler. The approach to thoracoscopic segmentectomy began with ligation of the segmental pulmonary vein, followed by either the bronchus or artery, depending on the segment. Bi- to trisegmentectomy was performed when tumours were close to intersegmental fissures. If the intraoperative examination of hilar or interlobar lymph nodes by frozen section showed metastases, segmentectomy was converted to lobectomy. Both procedures were followed by systemic mediastinal lymph node dissection.

Follow-up

All patients who underwent lung resection were followed up from the day of surgery. Postoperative follow-up procedures, including physical examination and chest radiograph every 3 months and a chest CT examination every 6 months, were performed for the first 2 years after operation. Subsequently, physical examination and chest radiograph were performed every 6 months, and a chest CT examination was performed every year. Every patient was followed up until January 2014. Whenever recurrence was suspected, we attempted to obtain histological or unequivocal radiological proof. Recurrence was classified into loco-regional recurrence and distant metastasis. In lost cases, a telephone interview was conducted to determine outcomes. The operative mortality was defined as 30-day mortality or in-hospital mortality. Survival duration was defined as the time from the date of operation to the last date of the follow-up or to the date of adverse events. Disease-free survival (DFS) was defined as the time from the date of operation to recurrence or death.

Statistical analysis

The propensity scores, which were calculated from the logistic regression models, including the following variables: sex, age, preoperative FEV_1 as a percentage of the predicted, tumour size, pathological staging and histology, represent the probability of being assigned to either the thoracoscopic segmentectomy or the thoracoscopic lobectomy groups. Through the matching procedure for propensity scores, the thoracoscopic segmentectomy and lobectomy groups showed similar distributions of propensity scores, indicating that the differences in covariates between the two groups were minimized. We matched propensity scores one by one using nearest neighbour methods, no replacement and 0.1 caliper width. Finally, matched 94 patients from the thoracoscopic lobectomy group and 94 patients from the thoracoscopic segmentectomy group were included in the analysis. The characteristics of both the thoracoscopic segmentectomy and lobectomy groups were compared before and after propensity score matching. For comparison between the matched groups, Student's *t*-test or the Wilcoxon rank-sum test was used to compare continuous variables, depending on the normality of distribution. The χ^2 test or Fisher's exact tests was used to compare categorical variables. Survival was estimated by the Kaplan–Meier method and the significance of difference was examined using a log-rank test. All statistical tests were two-sided, with a significance level set at 0.05, utilizing the Statistical Package for the Social Sciences (SPSS) software (version 21, IBM, Armonk, NY, USA).

RESULTS

From January 2005 to December 2013, a total of 1149 patients were enrolled for the analysis. Demographic data are presented in Table 1. Of these, 1049 patients underwent thoracoscopic lobectomy and 100 patients underwent thoracoscopic segmentectomy. There were no differences in age ($P = 0.69$), sex ($P = 0.38$) and histology of lung cancer ($P = 0.50$); however, the results of pulmonary function tests (PFT) were significantly worse in thoracoscopic segmentectomies than in thoracoscopic lobectomies. Thoracoscopic lobectomy was performed significantly more for patients with large tumour size ($P < 0.01$) and pathologically advanced stage tumours ($P < 0.01$). Detailed procedures in thoracoscopic segmentectomy are illustrated in Table 2.

Table 1: Demographic and clinical patient characteristics

Variable	Segmentectomy ($n = 100$)	Lobectomy ($n = 1049$)	*P*-value
Age, year (mean ± SD)	63.0 ± 9.9	62.9 ± 10.0	0.92
Female (%)	47 (47%)	514 (49%)	0.75
FEV_1 (%)	99.8 ± 24.6	107.6 ± 18.5	0.003
FVC (%)	99.7 ± 16.6	104.7 ± 14.7	0.004
DLco (%)	92.5 ± 17.5	100.5 ± 17.6	<0.001
Smoking history (PYR)	10.78 ± 17.8	14.9 ± 22.3	0.03
Tumour size (cm, mean ± SD)	1.65 ± 0.1	2.46 ± 1.3	<0.001
Histological type (%)			0.70
Adenocarcinoma	80 (80%)	856 (81.6%)	
Squamous cell carcinoma	15 (15%)	142 (13.5%)	
Others	5 (5%)	50 (4.8%)	
Stage (%)			<0.001
AIS	27 (27%)	64 (6.1%)	
IA	58 (58%)	481 (45.9%)	
IB	9 (9%)	287 (27.4%)	
IIA	1 (1%)	80 (7.6%)	
IIB	1 (1%)	27 (2.6%)	
III or IV	4 (4%)	109 (10.4%)	
Comorbidity	69 (69%)	653 (62.2%)	0.74
COPD	15 (15%)	212 (20.2%)	
CAOD	9 (9%)	51 (4.8%)	
CVA	5 (5%)	41 (3.9%)	
Diabetes	13 (13%)	143 (13.6%)	
Hypertension	40 (40%)	352 (33.6%)	
Previous cancer	18 (18%)	155 (14.8%)	

FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity; DLco: carbon monoxide diffusing capacity; PYR: pack year; AIS: adenocarcinoma *in situ*; COPD: chronic obstructive pulmonary disease; CAOD: coronary artery occlusive disease; CVA: cerebro-vascular accident accident.

Propensity scores were obtained by previously described statistical methods. Propensity score matching was performed according to the model and matched 94 patients from the thoracoscopic segmentectomy group and 94 patients from the thoracoscopic lobectomy group were included in the analysis. The distribution of clinical parameters included in propensity score matching is listed in Table 3. The distribution of baseline patient characteristics was well balanced between patients who underwent the thoracoscopic segmentectomy versus lobectomy after matching by the propensity score. Thoracoscopic segmentectomies were performed in 65 patients (69.1%) with small-sized lung cancer, 14 patients (14.9%) with poor cardiopulmonary reserve and 15 patients (16.0%) with other lesions that need resection.

Operative data and early postoperative outcomes are presented in Table 4. There were no differences between segmentectomy and lobectomy in terms of operation time (166.3 ± 54.7 min vs 181.1 ± 85.2 min, $P = 0.47$) and hospital stay (6.2 ± 5.2 days vs 7.1 ± 7.1 days, $P = 0.31$). The lobectomy group had significantly more number of dissected lymph nodes (24.4 ± 11.9 vs 19.7 ± 10.8, $P < 0.01$). Incidence of postoperative complications was non-significantly higher in the lobectomy group (17.2 vs 10.6%, $P = 0.1$). Specific complications in each group are listed in Table 5. Operative mortality rates were non-significantly higher in the segmentectomy group (1.1 vs 2.1%, $P = 0.56$). The causes of death were acute respiratory distress syndrome in 1 patient and pneumonia in 2 patients. Postoperative FEV_1 decrease was non-significantly smaller in the segmentectomy group (8.9 ± 10.8 vs 11.0 ± 13.1, $P = 0.36$.

The median follow-up duration was 20 months (range; 1–188). The 3-year DFS rates were 87% in the segmentectomy group and 94% in the lobectomy group (Fig. 1). There were no significant differences in DFS rates between two groups ($P = 0.69$). Recurrence occurred in 4 patients in the segmentectomy group and 7 patients in the lobectomy group. Loco-regional and distant recurrence occurred in 3 (3.2%) and 1 (1.1%) patient in the segmentectomy group, and 4 (4.3%) and 3 (3.2%) patients in the lobectomy group. At the end of the follow-up period, there were 173 surviving patients (92%). The 3-year OS was not significantly different

Table 2: Type of segmental resection by anatomical location ($n = 100$)

Type	No. ($n = 100$)
Right upper lobe	**10**
Anterior segmentectomy	5
Posterior segmentectomy	5
Right lower lobe	**33**
Superior segmentectomy	17
Anterior basal segmentectomy	3
Medial basal segmentectomy	1
Bisegmentectomy	1
Trisegmentectomy	1
Basilar segmentectomy	10
Left upper lobe	**41**
Upper division bisegmentectomy	33
Lingular segmentectomy	8
Left lower lobe	**16**
Superior segmentectomy	9
Posterior basal segmentectomy	1
Bisegmentectomy	3
Trisegmentectomy	1
Basilar segmentectomy	2

Table 3: Demographic and clinical patient characteristics after propensity score matching

Variable	Segmentectomy (n = 94)	Lobectomy (n = 94)	P-value
Age (year)	62.5 ± 10.0	63.6 ± 10.2	0.46
Female (%)	45 (47.9%)	45 (47.9%)	1
FEV1 (%)	101.6 ± 24.0	100.7 ± 17.8	0.77
FVC (%)	100.8 ± 16.3	100.3 ± 13.9	0.84
DLco (%)	92.7 ± 17.4	100.7 ± 17.5	0.006
Smoking history (PYR)	9.4 ± 16.5	12.2 ± 18.2	0.16
Tumour size (cm, mean ± SD)	1.70 ± 1.0	1.72 ± 0.8	0.89
Histological type (%)			0.81
Adenocarcinoma	77 (81.9%)	85 (90.5%)	
Squamous cell carcinoma	12 (12.8%)	6 (6.4%)	
Others	5 (5.3%)	3 (3.2%)	
Stage (%)			0.45
AIS	26 (27.7%)	15 (16.0%)	
IA	53 (56.4%)	58 (61.7%)	
IB	9 (9.6%)	15 (16.0%)	
IIA	1 (1.1%)	4 (4.3%)	
IIB	1 (1.1%)	2 (1.5%)	
IIIA	4 (4.3%)	0 (0%)	
Comorbidity	63 (67.2%)	62 (66.0%)	0.88
COPD	12 (12.8%)	22 (23.4%)	0.60
CAOD	8 (8.5%)	7 (7.4%)	0.79
CVA	5 (5.3%)	5 (5.3%)	1.0
Diabetes	12 (12.8%)	18 (19.1%)	0.23
Hypertension	37 (39.4%)	33 (35.1%)	0.54
Previous cancer	18 (19.1%)	18 (19.1%)	1.0

FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity; DLco: carbon monoxide diffusing capacity; PYR: pack year; AIS: adenocarcinoma *in situ* COPD: chronic obstructive pulmonary disease; CAOD: coronary artery occlusive disease; CVA: cerebro-vascular accident.

Table 4: Operative outcomes and follow-up

Variable	Segmentectomy (n = 94)	Lobectomy (n = 94)	P-value
Follow-up (month, median)	16.8 ± 13.8 (13.13)	24.5 ± 19.5 (18.36)	0.002
Hospital stay (day)	6.2 ± 5.2	7.1 ± 7.1	0.31
Operative time (min)	166.3 ± 54.7	181.1 ± 85.2	0.47
Dissected lymph nodes (n)	19.7 ± 10.8	24.4 ± 11.9	0.005
Complications (n)	10 (10.6%)	16 (17.2%)	0.1
Perioperative mortality	2 (2.1%)	1 (1.1%)	0.52
Recurrence	4 (4.3%)	7 (7.4%)	0.35
Loco-regional	3 (3.2%)	4 (4.3%)	
Distant	0	2 (2.0%)	
Both	1 (1.1%)	1 (1.1%)	
Δ FEV_1 (%)	8.9 ± 10.8	11.0 ± 13.1	0.36

Δ FEV_1: decreased forced expiratory volume in 1 s.

between two groups (P = 0.62). The 3-year OS rates were 96 and 94% in the segmentectomy and the lobectomy group, respectively (Fig. 2).

Table 5: Postoperative complications

Complications	Segmentectomy (n = 94)	Lobectomy (n = 94)
Pneumonia	3 (3.2%)	4 (4.3%)
ARDS	1 (1.1%)	1 (1.1%)
Atrial fibrillation	2 (2.0%)	6 (6.4%)
Prolonged air leakage (d > 7)	4 (4.3%)	4 (4.3%)
Chylothorax	0	1 (1.1%)
Total	10 (10.6%)	16 (17.2%)

ARDS: acute respiratory distress syndrome.

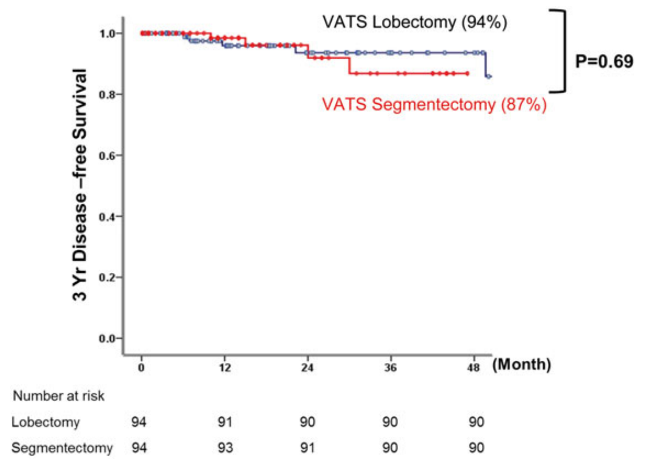

Figure 1: Disease-free survival of patients undergoing thoracoscopic lobectomy or segmentectomy.

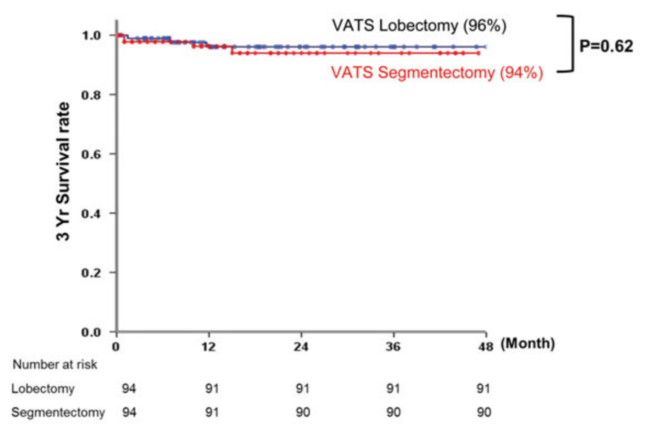

Figure 2: Overall survival of patients undergoing thoracoscopic lobectomy or segmentectomy.

DISCUSSION

In the current study, we were encouraged to evaluate by comparing the thoracoscopic segmentectomy and the thoracoscopic lobectomy using propensity score matching in order to reduce selection bias for each surgical procedure. To simulate an intention-to-treat situation, preoperative variables including demographic data, clinical stages and pulmonary function were considered in calculating propensity scores. After the matching process, we compared early postoperative and long-term oncological outcomes between the two groups. There was no difference in surgical quality parameters including the pathological complete resection rate. Early postoperative outcomes including 30-day mortality and postoperative complications were also comparable between the two groups. Finally, long-term oncological outcomes including OS, recurrence-free survival and location of recurrence were also not different between the two groups.

In 1939, Churchill and Belsey [8] first described pulmonary segmentectomy for the treatment of bronchiectasis, performing lingulectomy in 86 patients. In the following decades, thoracic surgeons began to treat patients with primary lung cancers with segmentectomy. Nevertheless, in 1995, the LCSG performed a randomized controlled trial and it demonstrated that limited pulmonary resection for tumours smaller than 3 cm resulted in increased loco-regional recurrences compared with lobectomy. Consequently, segmentectomy has generally been only chosen for patients who could not tolerate lobectomy because of marginal lung function, significant medical comorbidities or both [9]. Recently, as the clinical use of the computed tomographic scanning increased, thoracic surgeons have focused on the evaluation of segmentectomy and lobectomy for patients with small-sized peripheral NSCLC, drawing both encouraging and discouraging conclusions [10–12]. Several meta-analysis studies reported that, for Stage IA patients with 2 cm-sized tumour or smaller, segmentectomy had an equivalent effect as that of lobectomy. Notably, Shapiro *et al.* [13] showed that thoracoscopic segmentectomy may be an acceptable oncological procedure in patients with pulmonary reserve. They reported that thoracoscopic segmentectomy is a safe and feasible procedure in small-sized Stage IA lung cancer.

This study demonstrates that thoracoscopic segmentectomy may have some advantages over thoracoscopic lobectomy in selected patients. Although thoracoscopic segmentectomy is more complicated than thoracoscopic lobectomy, intentional thoracoscopic segmentectomy in NSCLC has similar perioperative outcomes and identical oncological outcomes compared with thoracoscopic lobectomy. The two groups have been found to have similar postoperative complication rates, lengths of hospital stay, local recurrence rates, 3-year DFS rates and 3-year OS rates.

Postoperative complication rates were significantly low in our patients: 10.2% for the thoracoscopic segmentectomy group. In previously published reports, average rates of postoperative complications were 17.6–31.3% after thoracoscopic segmentectomy [13–16]. There was no conversion from VATS to thoracotomy in our study. Similarly, an operative mortality rate of 2.3% in our study is within the range in published reports, from 1.7 to 7.7% [10]. We have also documented that an adequate lymph node dissection, which is important for proper staging and OS rate, can be performed during thoracoscopic segmentectomy. The importance of the surgeon's experience is emphasized on the finding. The thoracoscopic segmentectomy is still a technically challenging procedure and naturally requires a certain level of technical expertise.

There were no significant differences in 3-year OS and DFS rates between the two groups. It is consistent with the previously published data [17]. Furthermore, the loco-regional recurrence rates were relatively low; 3.2 and 4.3% for thoracoscopic segmentectomy and thoracoscopic lobectomy, respectively, in comparison with other studies reporting 7.9–14.7% [10, 13]. These results suggest that for current tumours, which may be smaller and of a different histological type than in earlier eras, thoracoscopic segmentectomy may be an acceptable operation from an oncological aspect.

In addition, we included patients who underwent thoracoscopic segmentectomy due to poor cardiopulmonary function or contralateral lesions that needed resection in order to understand the role of segmentectomy in early-stage lung cancer as well as Stage IA lung cancer. Thoracoscopic segmentectomy was shown to preserve slightly greater pulmonary function than thoracoscopic lobectomy. D'Amico *et al.* [10] showed that as many as 11.5% of patients undergoing surgery for lung cancer have additional primary cancers develop within their lifetimes and thus require additional resection. In our study, 15 patients who had other lesions that need resection were considered as candidates for thoracoscopic segmentectomy. Among them, only 1 patient underwent additional pulmonary resection in 1 year after previous thoracoscopic segmentectomy because of a growing mass in the contralateral lung. That was considered as double primary lung cancer rather than metastatic lung cancer. Thoracoscopic segmentectomy can offer patients higher tolerance for resection of secondary cancers than lobectomy. Theoretically, segmentectomy has an anatomical functional advantage over lobectomy as some segments of lung tissue that would be removed by the latter could be preserved. Harada *et al.* [18] analysed PFT preoperatively and at 2 and 6 months after radical segmentectomy in 38 patients and lobectomy in 45 patients. The extent of removed lung parenchyma directly affected postoperative functional loss even at 6 months after surgery, and segmentectomy offered significantly better functional preservation compared with lobectomy. During the postoperative course, statistically significant differences were observed between the two groups in the ratios of postoperative to preoperative forced vital capacity ($P < 0.001$) and FEV_1 ($P < 0.001$). Yoshikawa *et al.* [19] in a prospective multi-institution study showed that postoperative pulmonary functional loss, measured 1 year after surgery, was 13.4% in FEV_1.

In our study, postoperative FEV_1 decrease was smaller in the segmentectomy group (8.9 ± 10.8 vs 11.0 ± 13.1), but without statistical significance. Above all, the extent of the resected segment had a bad impact on the postoperative preservation of pulmonary function. The postoperative reduction of FEV_1 was 8.3, 11.7 and 13.8% in the one-segment resection group, two-segment resection group and the more than three-segment resection groups, respectively, without significant difference ($P = 0.18$). In terms of location of the removed pulmonary lobe, there was no difference in postoperative pulmonary functional loss. Interestingly, segmentectomy of the left upper lobe led to larger decrease in postoperative FEV_1 at 12.6% than those of other lesions (9.3% in the right upper lobe, 8.2% in the right lower lobe and 8.3% in the left lower lobe, $P = 0.46$). It was conjectured to result from a considerable number of left upper division segmentectomies. In the thoracoscopic lobectomy group, the postoperative FEV_1 decrease was 11.0%, which is a relatively low value compared with other studies reporting 24.9–33.3% [20]. In contrast, the decline in postoperative FEV_1 after left lower lobectomy was 25% which is the only significant change compared with 8.3% in thoracoscopic segmentectomies of the left lower lobe. These results implied that thoracoscopic segmentectomies of the lower lobe except for bilateral basilar segmentectomy had considerable benefits in preserving postoperative pulmonary function over lobectomy.

This study has some limitations. First, this was a retrospective study without a comprehensive prospective protocol. Although we used a scientific way to reduce bias, it is not conclusive that we could eliminate all the selection bias in both groups. Because thoracoscopic segmentectomy is not frequently done, we cannot assume that the analysis in the study do not fully represent to detect all clinically significant differences in recurrence between two groups. The role of thoracoscopic segmentectomy may be clarified by the two conducted randomized controlled trials Cancer and Leukemia Group B (CALGB) 140 503 [21] and JCOG0802/WJOG4707L [22]. Secondly, there were no objective selection criteria for the surgical procedure. Based on current data, we considered thoracoscopic segmentectomy for patients with ground-glass pulmonary nodules <2 cm in diameter, particularly in patients with advanced age and poor cardiopulmonary reserve. Further research is required regarding selection criteria for thoracoscopic segmentectomy. Thirdly, the thoracoscopic segmentectomy group had a shorter median follow-up period (16.8 months) than the thoracoscopic lobectomy group (28.5 months) because thoracoscopic segmentectomy has been started more recently in our institution. The DFS rate and recurrence rate may have overestimated the benefit of thoracoscopic segmentectomy. We should follow-up all the patients to identify the precise long-term oncological outcomes in the thoracoscopic segmentectomy group.

In conclusion, the oncological outcomes of thoracoscopic segmentectomy are comparable to those of thoracoscopic lobectomy for patients with early-stage NSCLC, as determined by the matched model adjusted for preoperative clinical factors. And thoracoscopic segmentectomy could be resulted in comparable early postoperative outcomes in the management of selected patients with small sized NSCLC or compromised lung cancer with previous pulmonary resection or limited cardiovascular reserve. We strongly believe that thoracoscopic segmentectomy rather than thoracoscopic lobectomy is an effective approach on patients with a primary lesion originating from the lower lobes to achieve minimal postoperative respiratory dysfunction.

Conflict of interest: none declared.

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