Feasibility of video-assisted thoracoscopic surgery segmentectomy for selected peripheral lung carcinomas

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Received 10 September 2008; received in revised form 27 December 2008; accepted 8 January 2009; Available online 23 February 2009

Abstract

Objective: Segmentectomy for non-small cell lung cancer (NSCLC) is believed to increase the rates of recurrence and postoperative air leak. We sought to present our clinical data and outcome of VATS (video-assisted thoracoscopic surgery) segmentectomies with systematic node dissection for selected NSCLC patients.

Methods: Inclusion criteria were clinical T1N0M0 peripheral NSCLC measuring ≤2 cm (n = 38) and NSCLC with interlobar invasion, which cause positive surgical margin with malignancy after lobectomy of a primary lesion and only partial resection of invasion site (n = 3). Outcome variables include hospital course, complications, mortality, recurrence patterns and survival. The intersegmental border was identified using the intersegmental veins as landmark and the demarcation between the resected (inflated) and preserved (collapsed) lungs. The intersegmental plane was divided by an endoscopic stapler and electrocautery.

Results: The mean operative time and intraoperative bleeding were 220 min (range 100—306) and 183 ml (30—730), respectively. The number of stapler cartridges used for intersegmental division was 2 (1—5). Postoperative air leak (>7 days), which required no surgical intervention, occurred in two patients. The chest tube drainage duration was 3 days. There were no in-hospital deaths. The numbers of resected subsegments and reserved subsegments in comparison with lobectomy were 5 (2—13) and 5 (3—13), respectively. The FEV1.0 after VS was higher than the predictive FEV1.0 after lobectomy, if the latter was performed as standard procedure. We experienced four cases of distant metastasis after segmentectomy, but there was no case of local recurrence. The 5-year survival and recurrence-free survival rates in pathological stage IA NSCLC were 89.9% and 93.3%, respectively.

Conclusions: VATS segmentectomy with systematic node dissection is a reasonable treatment option for selected peripheral NSCLC.

Keywords: Segmentectomy; Video-assisted thoracoscopic surgery; Early lung cancer

1. Introduction

Lobectomy is considered the standard surgical therapy for operable patients with completely resectable clinical stage I non-small cell lung cancer (NSCLC) [1]. Sublobar anatomic resection or segmentectomy has been proposed for selected patients with marginal pulmonary function. The explosive increase of early detected small-sized NSCLCs is in concordance with the advancement of radiographic tools and the widespread practice of screening. In some institutes, radical segmentectomy with lymph node assessment has been aggressively performed not only in high-risk patients but also in low-risk patients with clinical stage IA tumors ≤2 cm [2—4]. The potential advantage of segmentectomy compared with lobectomy is the preservation of pulmonary function; whereas, in comparison with wedge resection, improved oncologic outcome is noted with segmentectomy. However, reports on thoracoscopic segmentectomy are limited. This review describes the techniques used for thoracoscopic segmentectomy and the clinical results of the procedure.

2. Patients and methods

2.1. Patient population and inclusion/exclusion criteria

This retrospective study involving a cohort of patients who underwent segmentectomy with systematic node dissection for clinical stage I NSCLC from January 2000 to December 2007 in our institute (Table 1).

All VS patients were radiographically diagnosed with clinical T1N0M0 disease, wherein lobectomy would be an acceptable standard radical procedure, as well. All patients gave written informed consent before the operation. Patients who refused VS were excluded from the study.

Radionuclide bone scan and CT examination of the brain, chest, and upper abdomen were routinely required to detect...
possible metastases. Inclusion criteria are clinical T1N0M0 peripheral NSCLC ≤2 cm (n = 38) and NSCLC with interlobar invasion, which cause positive surgical margin with malignancy after lobectomy of a primary lesion and only partial resection of invasion site (n = 3). In adenocarcinoma, the proportion of ground-glass opacity in the tumor on high-resolution computed tomography was more than 50% [5,6]. The segment(s) for resection were determined based on tumor size and peripheral location in order to critically secure a segmental margin of >20 mm. Lobectomy was selected when the intraoperative node sampling showed node involvement.

2.2. Pulmonary function test

A complete pulmonary function evaluation including forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1.0) was conducted in all patients preoperatively and at about 6 months after surgery. The prediction of the postoperative lung function in patients with lung cancer was simply performed using a formula, \( T = \frac{(A - B)}{(A - T) \times C} \), where C is preoperative VC or FEV1.0, A and B are subsegment number of whole lung (if normal, A = 42) and number of functioning subsegments in the resected lung respectively. T is determined as follows: (a) a tumor located in the periphery of the lung has a corresponding, T factor equal to 1 if a tumor measures 3 cm or less in its largest dimension and equal to 2 if a tumor more than 3 cm; and (b) a tumor obstructing the large airways is designated a T factor equal to the number of subsegments involved in atelectasis or obstructive pneumonia [7,8]. In our cases, T is 1 for 39 patients and 2 for 2 patients. In this study, we did not use ventilation-perfusion scintigraphy.

2.3. Surgical techniques

VS was performed under general anesthesia with single-lung ventilation provided by either a double-lumen endotracheal tube or single lumen endotracheal tube with bronchial blocker. Thoracic epidural was routinely used. Patients were placed either right or left lateral decubitus. The surgeon was positioned on the anterior side of the patients. Two thoracopors were placed on the sixth or seventh intercostal space (ICS) on the anterior axillary line and seventh or eighth ICS on the posterior axillary line. The anterolateral utility mini-thoracotomy (35–60 mm, average 40 mm) was made on the fourth ICS for segmentectomy of the upper lobe or on the fifth ICS for the middle or lower lobe. A Lap Protector Mini (Hakko Medical Co., Tokyo, Japan) was placed on the site of the mini-thoracotomy to cover the skin, subcutaneous tissue, rib and parietal pleura without rib-spread. Pulmonary vessel management was performed by using forceps or scissors for conventional surgery through a utility thoracotomy. These vessels were divided following double ligation with a 1-0 or 2-0 silk suture or clipping at the proximal and distal portions. The bronchial management was usually performed using endo stapler devices (Endo-GIA, United States Surgical Corp, Norwalk, CT; ETS-45, Ethicon, Cincinnati, OH). The intersegmental veins were preserved. The intersegmental plane was identified using the intersegmental veins as landmark and the demarcation between the resected (inflated) and preserved (collapsed) lungs. This status of the lung was induced by the following three steps: temporarily reinflating the whole lung, ligating the resected segmental bronchus and deflating preserved lung. The intersegmental plane of the parenchyma was divided by an endoscopic stapler and electrocautery. A commercially available fibrin sealant composed of fibrinogen and thrombin was hardly used in order to prevent air leakage from the remaining lung after segmental division. We applied 4-0 PDS horizontal mattress suture with absorbable pledges and/or oxidized regenerated cellulose (Surgicel Absorbable Hemostat, Ethicon Inc., Somerville, NJ) when air leak was observed in the raw surface of the remaining lung.

Sampling or dissection of segmental, lobar, and hilar nodes followed by frozen-section analysis was mandatory to decide the applicability of segmentectomy. It was specified that when the surgical margin was found to be imperfect (<2 cm) or any lymph node was found to be diseased, lobectomy had to be performed instead (n = 3; 2 of insufficient margin, 1 of n1 disease). These three cases were excluded from this study. After segmentectomy, systematic node dissection was performed. Routinely, the pleural cavity was drained with a single chest tube, which was inserted through the anterolower incision initially established.

2.4. Pathological diagnosis

Resected specimens were examined histopathologically, and histologic typing was done according to the World Health Organization classification [9]. Surgical—pathologic staging was performed according to the New International Staging System for Lung Cancer [10].

2.5. Follow-up

Anesthesia and operating room data were recorded for each patient. Major complications were defined to include as follows: cardiac—congestive heart failure, myocardial infarction, heart block and cardiac arrest; Pulmonary—pneumonia,
empyema, bronchopleural fistula, and respiratory failure requiring mechanical ventilation and tracheostomy; and others—septicemia, pulmonary embolism, and stroke. All patients were followed up postoperatively at 2 weeks, at intervals of 4–6 months for the first 3 years, and then yearly thereafter with CT scans. Mean follow-up was 70 months (95%CI 58–83). Follow-up assessment included physical examination, hematologic and biochemical analysis including tumor markers, and chest roentgenograms.

Locoregional recurrence was defined as evidence of tumor within the same lobe, hilum, or mediastinal lymph nodes. Distant recurrences were defined as evidence of tumor in another lobe, or elsewhere outside the hemithorax.

### 2.6. Statistical analysis

The statistical analysis was performed using SPSS 11.0 software (SPSS Inc, Chicago, Illinois). Unless otherwise specified, continuous variables are expressed as mean ± one standard deviation. Differences between the two groups were assessed by means of unpaired Student’s t-test after the assurance of homogeneity by Levene’s test or paired Student’s t-test. Disease-free and cumulative survival curves were constructed by the Kaplan–Meier method. Survival and recurrence free survival rates are presented with standard errors. All reported probability values were two-tailed, and p values of less than 0.05 were considered statistically significant.

### 3. Results

#### 3.1. Perioperative data

The types of segmentectomy are shown in Table 2. The numbers of actually resected subsegments and reserved subsegments in comparison with lobectomy (or pneumonectomy in interlobar invasion cases) were 5 ± 3 (2–13) and 5 ± 2 (3–13), respectively.

The mean operative time and intraoperative bleeding were 220 min (range 100–306) and 183 ml (30–730), respectively. The numbers of dissected nodes and node stations were 25 (9–48) and 8 (4–11), and the numbers of dissected mediastinal nodes and mediastinal node stations were 15 ± 7 (2–30) and 4 ± 1 (1–7), respectively. The total number of stapler cartridges intraoperatively used was 6 (3–10). Of them, the number of stapler cartridges used for intersegmental division was 2 (1–5), while for bronchial division, pulmonary artery division, pulmonary vein division and interlobar division was 1 (1–3), 0 (0–2), 0 (0–1) and 2 (0–3), respectively.

The mean chest tube drainage duration was 3 days (1–9 days). Postoperative prolonged air leak (>7 days), which required no surgical intervention, occurred in two patients and atrial fibrillation in two patients. There were neither major complications nor in-hospital deaths (Table 3).

#### 3.2. Postoperative pulmonary function data

The actual FVC and FEV1.0 after VS were higher than the predictive FVC and FEV1.0 after lobectomy (or pneumonectomy), if the latter was performed as standard procedure. Additionally, the said values were similar to the predictive values after segmentectomy (Table 4).

#### 3.3. Actuarial survival and disease-free survival rate

We experienced four cases of distant metastasis after segmentectomy (one patient with stage IA adenocarcinoma progressed to brain metastasis, one with stage IIIA adenocarcinoma had bilateral lung metastasis, one with stage IIIA squamous cell carcinoma had brain and contralateral lung metastasis and one with stage IIIA adenocarcinoma had brain and contralateral lung metastasis).

### Table 2

<table>
<thead>
<tr>
<th>Location of burdened lung</th>
<th>NRSS</th>
<th>NPSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>
| NRSS, number of resected subsegments; NPSS, number of preserved subsegments; S1, apical; S2, posterior; S3, anterior; S6, superior; S7, medial basal; S8, anterior basal; S9, lateral basal; S10, posterior basal; LUD, left upper division; LLD, left lingar division.

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>n = 41</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation time (min)</td>
<td>220 ± 36 (100–306)</td>
</tr>
<tr>
<td>Estimated blood loss (ml)</td>
<td>183 ± 195 (30–730)</td>
</tr>
<tr>
<td>No. of</td>
<td></td>
</tr>
<tr>
<td>Nodal stations dissected</td>
<td>8 ± 2 (4–11)</td>
</tr>
<tr>
<td>Mediastinal nodal stations dissected</td>
<td>4 ± 1 (1–7)</td>
</tr>
<tr>
<td>Dissected nodes</td>
<td>25 ± 10 (9–48)</td>
</tr>
<tr>
<td>Mediastinal nodes dissected</td>
<td>15 ± 7 (2–30)</td>
</tr>
<tr>
<td>No. of stapler cartridges for</td>
<td></td>
</tr>
<tr>
<td>Segmentectomy</td>
<td>6 ± 1 (3–10)</td>
</tr>
<tr>
<td>Inter segmental plane division</td>
<td>2 ± 1 (1–5)</td>
</tr>
<tr>
<td>Chest tube duration (days)</td>
<td>3 ± 2 (1–9)</td>
</tr>
<tr>
<td>Morbidity</td>
<td></td>
</tr>
<tr>
<td>Cardiac</td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>2</td>
</tr>
<tr>
<td>Lung</td>
<td></td>
</tr>
<tr>
<td>Air leak &gt;7 days</td>
<td>2</td>
</tr>
<tr>
<td>Major complications</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 4
Postoperative pulmonary function and POP pulmonary function.

<table>
<thead>
<tr>
<th>Variable</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO value</td>
<td>POP value</td>
<td>POP value</td>
<td>A–B</td>
<td>A–C</td>
</tr>
<tr>
<td>VC (%)</td>
<td>3.12 ± 0.77</td>
<td>2.61 ± 0.63</td>
<td>3.11 ± 0.80</td>
<td>0.007</td>
</tr>
<tr>
<td>%VC (%)</td>
<td>101.0 ± 24.5</td>
<td>86.7 ± 21.9</td>
<td>102.2 ± 24.3</td>
<td>0.006</td>
</tr>
<tr>
<td>FEV1 (%)</td>
<td>2.34 ± 0.54</td>
<td>1.88 ± 0.49</td>
<td>2.23 ± 0.58</td>
<td>0.001</td>
</tr>
<tr>
<td>FEV1% (%)</td>
<td>77.1 ± 9.9</td>
<td>58.8 ± 10.3</td>
<td>68.7 ± 9.4</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Postoperative pulmonary function and POP pulmonary function were compared using paired t test. The actual FVC and FEV1.0 after VATS segmentectomy were higher than the predictive VC and FEV1.0 after VATS lobectomy (or pneumonectomy), if the latter was performed as standard procedure. Additionally, the said values were similar to the predictive values after VATS segmentectomy.

PO, postoperative predictive; PO, postoperative; lob, lobectomy; seg., segmentectomy; VC, vital capacity; FEV1, forced expiratory volume in 1 s.

Fig. 1. Kaplan–Meier estimate of patient survival for VATS segmentectomy.

Fig. 2. Kaplan–Meier estimate of patient disease-free survival for VATS segmentectomy.

rate for all cases and pathological stage IA cases was 80.7 ± 8.8% and 93.3 ± 6.4%, respectively (Fig. 2).

4. Discussion

The outcome of the randomized study by the Lung Cancer Study Group [11] demonstrated that sublobar resections including wedge resections resulted in a higher rate of local recurrence than lobectomy in patients with stage IA NSCLC, and described the escalating incidence of nonanatomic stapled wedge resection. After the reports, sublobar resection has not been considered as an alternative for stage IA NSCLC. However, the series included a high proportion of wedge resections in the sublobar resection group (32.8%, 40/122) for tumors up to 3 cm in diameter. It is likely then that the predominance of wedge resection might have influenced the frequency of local recurrence and has contributed to the poor results.

In concordance with the recent development of radiographic devices such as high resolution computed tomography and the widespread practice of low-dose helical computed tomography for screening, an increase in the early detection of ever-smaller NSCLCs was caused. In some institutes, patients, who are candidate for radical sublobar resection, are selected by the use of positron emission tomographic findings and the correlation between CT findings and bronchioloalveolar carcinoma component. We believe that some cases of lung cancer in the early stage will suffice with sublobar resection as the radical procedure of resection.

It remains to be established whether segmentectomy is an appropriate procedure for patients with NSCLC who would tolerate lobectomy. This concept may be addressed by a study conducted by the Cancer and Leukemia Group B (CALGB 14053), a phase III randomized trial of lobectomy versus sublobar resection (either thoracoscopic or open) for small (<2 cm) NSCLC. Furthermore, the inclusion criteria for segmentectomy for stage I NSCLC remains controversial. Limited lung resection may indeed be an acceptable operation for patients with small peripheral lung cancer (<2 cm), negative nodal involvement by intraoperative pathological lymph node staging, and wide resection margin (>2 cm) [12]. On the other hand, Schuchert et al. reported that margin/tumor ratio of less than 1 is associated with a higher rate of recurrence. Therefore, lobectomy should be considered as the primary therapy when such margins are not obtainable with segmentectomy in the good-risk patient [13].

Recently, several authors have reported that sublobar resection is not inferior to lobectomy concerning the prognosis of selected patients with small-sized stage I NSCLC [4,14,15]. These reports have demonstrated that segmentectomy in carefully selected patients with stage I tumors can produce recurrence rates and survivals equivalent to lobectomy (5-year survival and disease-free survival rates were 85.9% and 89.6%, respectively for the sublobar resection group; and 83.4% and 89.1%, respectively for the lobar resection group [4]) and that sublobar resection should be considered as an alternative for stage IA non-small cell lung cancers 2 cm or less, even in low-risk patients. Our data is similar to the results of the said studies.
The VATS procedure causes less surgical trauma and stress to the chest wall than conventional thoracotomy and may therefore minimize harmful postoperative inflammatory reactions [16,17] and procedure-related pain [18,19]. Additionally, VATS can minimize surgical damage on the respiratory muscle, resulting in preserved respiratory function after surgery. Thus, the VATS procedure is now recognized as a minimally invasive surgical approach for early-stage NSCLC. Although thoracoscopic lobectomy has achieved increased safety and utilization over the past several years, thoracoscopic segmentectomy has merely been superficially mentioned in the literature [3]. In a case matched study [20], it was described that left upper trisegmentectomy may be a suitable standard treatment if the tumor is small and the suspected margins are well away from the lingula.

In ACCP Evidence-Based Clinical Practice Guideline (2nd edition) [21], in patients undergoing resection for stages I and II NSCLC, it is recommended that intraoperative systematic mediastinal lymph node sampling or dissection be performed for accurate pathologic staging (grade of recommendation, 1B). We think that systematic node dissection should not be omitted even in early clinical stage NSCLC patients who are eligible for segmentectomy to ensure accurate nodal staging because of the present status without a credible and high-precision method for determining accurate node staging. Node sampling does not necessarily provide accurate node status in stage IA NSCLC [22]. Postoperatively, if nodal involvement is proved by pathological examination of resected specimens, we did not subject the patient to additional surgery for completion lobectomy or pneumonectomy for dissection of intrapulmonary nodes in the residual segments. In surgical N0 and postoperatively pathological N1/2 cases, additional pulmonary resection may not affect late surgical outcome. At present, our surgical treatment policy is not far off because no locoregional recurrence occurred in our series.

For patients with stage I NSCLC, segmental resection offers preservation of pulmonary function compared with lobectomy and does not compromise survival. The FVC, FEV1, and maximum voluntary ventilation were all significantly better in patients who underwent sublobar resection at 6 months after surgery. At 1 year, lobectomy patients experienced significant reduction in FVC (85.5—81.1%), FEV1 (75.1—66.7%), maximum voluntary ventilation (72.8—65.2%), and diffusing capacity (79.3—69.6%). In contrast, a decline in diffusing capacity was the only significant change seen after segmental resection [15]. Furthermore, Harada et al. reported that the extent of removed lung parenchyma directly affected the postoperative functional loss even at 6 months after surgery, and segmentectomy offered significantly better functional preservation compared with lobectomy [23]. Our data also shows a higher postoperative FVC and FEV1 than postoperative predictiv VC and FEV1.0 after lobectomy (or pneumonectomy) as a conventional pulmonary resection.

In general, segmentectomy is technically more difficult than lobectomy, which requires deep three-dimensional image of the bronchoarterial relationships and possible anomalies of arterial branches. It is more difficult to be performed VS, because only two-dimensional images can be demonstrated. Furthermore, it is difficult to detect especially the intersegmental plane using VATS approach. Lately, Okada et al. [24] developed a new method to detect the intersegmental plane in segmentectomy that involves selective jet ventilation under bronchofiberscopy. With this method the segment to be removed can be inflated while keeping the segments to be preserved collapsed. We have not employed this method yet, though it seems promising in the detection of the intersegmental plane in VATS. Segmental vein is best ligated last, after the intersegmental plane has been outlined. Although air leak is a troublesome issue after segmental resection, segmental division by stapler devices minimizes this dilemma. Small alveolopleural fistulas may seal, leaving a neutral air space that usually reabsors with gradual expansion of the lung because the residual space after segmentectomy is smaller than that after lobectomy.

The rate of postoperative complications for thoracoscopic segmentectomy is similar to the complication profile of the open segmentectomy group [25]. In our study, the postoperative mortality was nil without major postoperative complications.

5. Limitations

This is a retrospective study of patients who underwent segmentectomy for stage I NSCLC. The small number of patient population may affect the results. Additionally, postoperative pulmonary function is compared not with postoperative pulmonary function of patients who underwent conventional lobectomy, but postoperative predictive pulmonary function when lobectomy is performed. We did not evaluate postoperative pulmonary function after lobectomy if the postoperative course was uneventful or if preoperative pulmonary function was poor.

In conclusion, VS with systematic lymph node dissection is a safe and feasible procedure for selected patients with small peripheral stage I NSCLC. In this procedure, pulmonary function is preserved compared with lobectomy and survival is not compromised.

References


Appendix A. Conference discussion

Dr R. Santosham (Chennai, India): I have two quick questions. You had a large number of early bronchogenic carcinoma cases. How did you pick them up? Do you have mass screening? How did you pick them up so early? Most of them would have been totally asymptomatic. How did you pick up so many cases so early?

Dr Watanabe: In Japan we use preoperative diagnosis by CT. Many Japanese use chest CT in medical check up. Thin-slice CT can show small, small nodules.

Dr Santosham: Why did these patients come to the hospital? What symptoms did they come with? How did you pick that large number up so early? And in the same period of time, how many cases did you have to do lobectomy during the same period of time when you did the segmental resection?

Dr Watanabe: Sorry!

Dr Santosham: You have done segmental resection for stage I. During the same period of time, how many cases were in a higher stage where you had to do a lobectomy during the same period of time?

Dr Watanabe: Segmentectomy was about 10%. Between 2000 and 2006 we performed major pulmonary resection in 610 patients, 610 major pulmonary resections, and 10% was segmentectomy. The most part of these patients had medical check up a year or long-term follow-up for the other disorder.

Dr D. Grunewald (Paris, France): It was a retrospective study. Why did you choose to do this VATS segmentectomy in patients who had, if I remember, a very good pulmonary function, more than 70%? Why did you choose this approach in patients who had a very good pulmonary function?

Dr Watanabe: The volume of the lung parenchyma resected is small by segmentectomy. So pulmonary function is preserved better. If the surgical treatment effect is similar between segmentectomy and lobectomy for lung cancer. We think we should select segmentectomy in order to keep the patient’s pulmonary function.