Anatomic segmentectomy for stage I non–small-cell lung cancer: Comparison of video-assisted thoracic surgery versus open approach

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Objectives: Anatomic segmentectomy is increasingly being considered as a means of achieving an R0 resection for peripheral, small, stage I non–small-cell lung cancer. In the current study, we compare the results of video-assisted thoracic surgery (n = 104) versus open (n = 121) segmentectomy in the treatment of stage I non–small-cell lung cancer.

Methods: A total of 225 consecutive anatomic segmentectomies were performed for stage IA (n = 138) or IB (n = 87) non–small-cell lung cancer from 2002 to 2007. Primary outcome variables included hospital course, complications, mortality, recurrence, and survival. Statistical comparisons were performed utilizing the *t* test and Fisher exact test. The probability of overall and recurrence-free survival was estimated with the Kaplan-Meier method, with significance being estimated by the log-rank test.

Results: Mean age (69.9 years) and gender distribution were similar between the video-assisted thoracic surgery and open groups. Average tumor size was 2.3 cm (2.1 cm video-assisted thoracic surgery; 2.4 cm open). Mean follow-up was 16.2 (video-assisted thoracic surgery) and 28.2 (open) months. There were 2 perioperative deaths (2/225; 0.9%), both in the open group. Video-assisted thoracic surgery segmentectomy was associated with decreased length of stay (5 vs 7 days, $P < .001$) and pulmonary complications (15.4% vs 29.8%, $P = .012$) compared with open segmentectomy. Overall mortality, complications, local and systemic recurrence, and survival were similar between video-assisted thoracic surgery and open segmentectomy groups.

Conclusions: Video-assisted thoracic surgery segmentectomy can be performed with acceptable morbidity, mortality, recurrence, and survival. The video-assisted thoracic surgery approach affords a shorter length of stay and fewer postoperative pulmonary complications compared with open techniques. The potential benefits and limitations of segmentectomy will need to be further evaluated by prospective, randomized trials. (J Thorac Cardiovasc Surg 2009;138:1318-25)

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Over recent years, video-assisted thoracic surgery (VATS) approaches have gained increased popularity in the performance of anatomic lung resections.[1,2] VATS lobectomy techniques have been developed and refined and are associated with decreased pain,[3,4] fewer complications,[5] shorter lengths of stay,[6] and greater discharge independence[7] compared with open techniques. VATS lobectomy techniques have been adopted as the preferred approach in many centers. Long-term results for VATS lobectomy are now available demonstrating similar morbidity and mortality profiles, as well as equivalent long-term oncologic efficacy, when compared with open lobectomy.[8,9]

To date, limited data exist regarding the application of VATS techniques in the setting of anatomic segmentectomy. The purpose of the current study was to compare the perioperative outcomes of patients having anatomic segmentectomy by either a VATS or an open approach for stage I non–small-cell lung cancer (NSCLC). Outcome variables included operative data, length of stay, morbidity, mortality, recurrence, and survival.

PATIENTS AND METHODS

Patients

Approval for this study was provided by the Institutional Review Board of the University of Pittsburgh (IRB 0408107), and individual patient consent was waived given the retrospective nature of the analysis. A total of 225

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Abbreviations and Acronyms
NSCLC = non–small-cell lung cancer
VATS = video-assisted thoracic surgery

consecutive patients having anatomic segmentectomy for stage I NSCLC from 2002 to 2008 were identified by the Thoracic Tumor Registry and from the billing records of the Heart, Lung and Esophageal Surgery Institute of the University of Pittsburgh Medical Center. Only patients with pathologic stage I disease were included in this study. VATS segmentectomy was performed in 104 patients, with the remaining 121 patients having anatomic segmentectomy via an open approach (see Appendix E1). Patient demographics and tumor characteristics are detailed in Table 1.

Preoperative Evaluation

All patients underwent careful preoperative staging with computed tomography scan (with or without positron emission tomography) within 6 weeks of surgery as well as pulmonary function testing. Additional diagnostic testing (brain magnetic resonance imaging, bone scan) was performed at the discretion of the individual surgeon, based upon patient symptoms and clinical findings. Mediastinoscopy was not used routinely in the preoperative evaluation of this group of patients. Flexible bronchoscopy was performed prior to surgical resection in all cases. All patients were staged on final pathologic review as stage IA (n = 138) or IB (n = 87) according to the TNM classification of the American Joint Committee for Cancer Staging and the Revised International System for staging lung cancer.[10]

Operative Technique and Hospital Course

Thoracotomy was performed in 121 (54%) patients, with a VATS approach used in 104 (46%) patients. All of the principal anatomic segments were resected (Table 2). All procedures were performed by 1 of 11 surgeons, though 167 (74.2%) of the procedures was performed by a single surgeon (R.J.L.). The largest determinants in selecting a patient for segmentectomy were limited functional status, comorbidities, and surgeon judgment regarding resectability using a segmental approach.

Open segmental resection was performed by either muscle-sparing axillary thoracotomy or posterolateral minithoracotomy. The VATS approach was performed as described previously.[11,12] Anatomic segmentectomy was performed with individual isolation and division of the corresponding artery and bronchus. In addition, an extended parenchymal margin was obtained during stapling, which carried the line of division into the adjacent segmental parenchyma (extended segmentectomy).

Most patients were monitored in the intensive care unit overnight and were transferred to the floor the following day. Chest tube management and discharge planning were individualized based upon patient clinical characteristics and surgeon judgment. Chest tubes are usually removed when air leaks cease and drainage decreases to less than 250 mL/d. Patients were discharged after chest tube removal when clinically stable. In cases of prolonged air leaks (VATS: 8 [7.7%] vs open: 8 [6.6%]), patients were discharged after placement of a Heimlich valve and ensuring stability of lung expansion. Discharge criteria were not influenced by clinical pathways or the type of surgery performed.

Follow-up

Perioperative and follow-up data were collected from the hospital chart, anesthesia, and operating room records as well as the electronic medical record for each patient. Major complications were defined to include (1) cardiac: myocardial infarction and cardiac arrest; (2) pulmonary: pneumonia, empyema, bronchopleural fistula, respiratory failure requiring reintubation and tracheostomy; (3) other: septicemia, pulmonary embolism, and stroke. All patients were followed postoperatively at 2 weeks and at 4- to 6-month intervals for the first 2 years, then yearly thereafter with computed tomography scans. Locoregional recurrence was defined as evidence of tumor within the same lobe, the hilum, or the mediastinal lymph nodes. Distant recurrences were defined as evidence of tumor in another lobe or elsewhere outside the hemithorax. In addition to the data derived from the electronic medical record and the University of Pittsburgh Lung Cancer Registry,

TABLE 1. Patient and tumor characteristics

	VATS segmentectomy (n = 104)	Open segmentectomy (n = 121)	*P* value
Age			
Mean ± SD	69.9 ± 7.9	69.9 ± 10.1	.95
Range	45–100	47–91	
Gender	55 M, 49 F	55 M, 66 F	.29
Histology			
Adenocarcinoma	57 (55%)	70 (57%)	.69
Squamous cell carcinoma	30 (28%)	39 (32%)	.66
Large-cell carcinoma	6 (6%)	3 (2%)	.31
Adenosquamous	4 (4%)	4 (3%)	.99
Bronchoalveolar	1 (1%)	2 (2%)	.99
Other	6 (6%)	3 (2%)	.31
Stage			
IA	66 (63%)	72 (60%)	.58
IB	38 (37%)	49 (40%)	
Tumor size			.05
Mean ± SD (cm)	2.1 ± 1.1	2.4 ± 1.2	
Range (cm)	0.5–6.0	0.2–7.0	
PFTs (preoperative)			
FEV_1 (%)	1.83 (69%)	1.74 (71%)	.58
DLCO (%)	14.7 (64%)	13.8 (67%)	.54

DLCO, Lung diffusion capacity for carbon monoxide; *FEV_1*, forced expiratory volume in 1 second; *PFT*, pulmonary function tests; *SD*, standard deviation; *VATS*, video-assisted thoracic surgery.

TABLE 2. Segmental resections performed

	VATS segmentectomy (n = 104)	Open segmentectomy (n = 121)	*P* value
RUL	22 (21.2%)	42 (34.7%)	.03
Anterior	4 (3.8%)	7 (5.8%)	.55
Posterior	11 (10.6%)	17 (14.0%)	.54
Apical	5 (4.8%)	8 (6.6%)	.78
Apicoposterior	2 (1.9%)	10 (8.3%)	.04
RML	14 (13.5%)	10 (8.3%)	.28
RLL	19 (18.3%)	23 (19.0%)	.99
Superior	10 (9.6%)	13 (10.7%)	.83
Basilar	9 (8.7%)	10 (8.3%)	.99
LUL	35 (33.7%)	31 (25.6%)	.19
Upper division	24 (23.1%)	26 (21.5%)	.87
Lingula	11 (10.6%)	5 (4.1%)	.07
LLL	14 (13.5%)	15 (12.4%)	.84
Superior	4 (3.8%)	10 (8.3%)	.27
Basilar	10 (9.6%)	5 (4.1%)	.11

LLL, Left lower lobe; *LUL*, left upper lobe; *RLL*, right lower lobe; *RML*, right middle lobe; *RUL*, right upper lobe; *VATS*, video-assisted thoracic surgery.

TABLE 3. Perioperative outcomes

	VATS segmentectomy (n = 104)	Open segmentectomy (n = 121)	*P* value
Operative time (min)	136 (120–152)	143 (132–154)	.42
EBL (mL)	171 (133–209)	220 (171–269)	.16
LN harvested	6.4 (5.3–7.5)	9.1 (7.8–10.4)	.003
LOS (median), d*	5 (mean = 6.4; 5.5–7.3)	7 (mean = 8.2; 7.3–9.1)	<.001
Complications (%)			
Overall	27 (26.0%)	41 (33.9%)	.24
Major	6 (5.8%)	15 (12.4%)	.11
Pulmonary	16 (15.4%)	36 (29.8%)	.012
Mortality (30 d)	0 (0%)	2 (1.7%)	.50

Results shown are n (95% confidence intervals) or n (%). *EBL*, Estimated blood loss; *LOS*, length of stay; *LN*, lymph nodes. *Percentage of patients with complication type are expressed in parentheses.

mortality data were obtained from the Social Security Death Index. The primary end points for this analysis were perioperative outcomes, morbidity and mortality rates, as well as disease-free and overall survival. Perioperative mortality was defined as any patient who died within the first 30 days after surgery. Mean follow-up was 16.2 months in the VATS segmentectomy group and 28.2 months in the open group.

Statistical Analysis

Comparisons of VATS and open segmentectomy cohorts were performed on the basis of clinical, demographic, and pathologic data. Student *t* test and Mann-Whitney test were used to compare the distributions of continuous data (age, tumor size, number of lymph nodes removed, operative time, estimated blood loss, length of stay). Fisher exact test was used to compare the frequencies of categorical measures (sex, histology, stage, etc). All comparisons were 2-tailed. Disease-free survival was defined as the time from surgery to the first diagnosis of local, regional, or distant disease recurrence or until last-follow-up. Overall survival was defined as the time from surgery to death or last follow-up. Disease-free and overall survival curves were estimated with the Kaplan-Meier method. Significance was assessed with the log-rank test.

A propensity-matched analysis was performed comparing outcomes following VATS and open segmentectomy. Propensity scores were determined for each patient and were included in the Cox regression analysis in addition to patient age, gender, comorbidities, preoperative pulmonary function testing, tumor size, tumor stage, and number of lymph nodes harvested.

RESULTS

Patient and Tumor Characteristics

Patient and tumor characteristics are summarized in Table 1. There were no significant differences in age, gender, histology, stage (1A or 1B), tumor size, or pulmonary function tests between the VATS and open segmentectomy groups. Adenocarcinoma constituted the most common pathologic subtype of NSCLC in both groups (VATS = 55%, open = 57%), followed by squamous cell carcinoma (VATS = 28%, open = 32%). The most common segmental resection performed in both groups was the formal left upper-division resection (VATS = 23.1%, open = 21.5%). The distribution of segmentectomies performed was similar between groups, except for right upper-lobe apicoposterior segment (VATS: 1.9% vs open: 8.3%, *P* = .04; Table 2).

Perioperative Outcomes

The median operative time (VATS = 136 minutes; open = 143 minutes) and estimated blood loss (VATS = 171 mL; open = 220 mL) were similar between VATS and open segmentectomy groups (Table 3). Fewer lymph nodes were harvested on average during VATS segmentectomy, compared with open segmentectomy (6.4. vs 9.1, *P* = .003). There were 2 perioperative deaths, both in the open group (1.7%). Median hospital stay was 5 days after VATS segmentectomy and 7 days after the open approach. Complications occurred in 68 patients (30.2%) and are outlined in Table 4. The most common complication was atrial fibrillation, which occurred in 17 (9.2%) patients. Prolonged air leak (>5 days) was encountered in 8 patients in both the VATS (7.7%) and open (6.6%) groups. There were 2 conversions (1.9%) from VATS to open segmentectomy secondary to intraoperative hemorrhage. There was no significant difference in overall (26.0% vs 33.9%) or major complications (5.8 vs 12.4%) comparing VATS and open segmentectomy, respectively. Pulmonary complications were more common after open segmentectomy (29.8% open vs 15.4% VATS; Tables 3 and 4).

Recurrence Patterns and Survival

There were 46 recurrences during the follow-up period (20.4%): 18 locoregional, 28 distant. Mean time to recurrence was 13.8 months. Overall recurrence was similar between VATS (16.3%) and open (24.0%) groups (Table 5). There was no difference in recurrence-free (Figure 1) or overall survival (Figure 2) between VATS and open segmentectomy groups. Propensity analysis similarly revealed no apparent difference in recurrence-free (*P* = .996) or overall (*P* = .605) survival.

Overall, there were 13 (12.5%) deaths in the VATS group and 36 (29.7%) deaths in the open group. Deaths due to cancer were similarly increased in the open group (Table 5). This may be due, in part, to the longer mean follow-up in the open cohort (VATS = 16.0 months; open = 28.2 months).

DISCUSSION

Though lobectomy remains the gold standard in the management of NSCLC, there has been a resurgence of interest in the use of anatomic segmentectomy for early stage lung

TABLE 4. Segmentectomy complications

Complication type	VATS segmentectomy (n = 104)	Open segmentectomy (n = 121)	p value
Cardiac	11	10	.65
A-fib	10 (9.6%)	7 (5.8%)	.32
Cardiac arrest	0 (0%)	2 (1.7%)	.5
MI	1 (1.0)	1 (0.8%)	.99
Pulmonary	26	49	.016
Air leak	8 (7.7%)	8 (6.6%)	.8
Pneumonia	1 (1.0%)	6 (5.0%)	.13
Bronchoscopy	3 (2.9%)	10 (8.3%)	.095
Pneumothorax	9 (8.2%)	7 (5.8%)	.44
Respiratory failure	2 (1.9%)	8 (6.6%)	.11
Tracheostomy	2 (1.9%)	2 (1.7%)	.99
Empyema	1 (1.0%)	4 (3.3%)	.38
Effusion/drainage	0 (0%)	3 (2.5%)	.25
B-P fistula	0 (0%)	1 (0.8%)	.99
Infections	3	13	.035
Pneumonia	1 (1.0%)	6 (5.0%)	.13
Empyema	1 (1.0%)	4 (2.5%)	.38
Clostridium difficile	0 (0%)	1 (0.8%)	.99
Wound infection	0 (0%)	0 (0%)	.99
Septicemia	1 (1.0%)	2 (1.7%)	.99
Other	4	2	.42
PE	0 (0%)	1 (0.8%)	.99
Renal failure	0 (0%)	1 (0.8%)	.99
CVA	0 (0%)	1 (0.8%)	.99
Bleeding/reoperation	1 (1%)	1 (0.8%)	.99
DVT	1 (1%)	0 (0%)	.46
Total	46	74	.016

A-fib, Atrial fibrillation; *B-P fistula,* bronchopleural fistula; *CVA,* cerebrovascular accident; *DVT,* deep vein thrombosis; *MI,* myocardial infarction; *PE,* pulmonary embolism; *VATS,* video-assisted thoracic surgery.

TABLE 5. Recurrence and survival patterns

	VATS segmentectomy (n = 104)	Open segmentectomy (n = 121)	P value
NED	87 (83.7%)	92 (76.0%)	.19
Overall	17 (16.3%)	29 (24.0%)	.10
Locoregional	5 (4.8%)	13 (10.7%)	.14
Distant	12 (11.5%)	16 (13.2%)	.84
Total deaths	13 (12.5%)	36 (29.8%)	.002
Deaths due to cancer	7 (6.7%)	20 (16.5%)	.025

NED, No evidence of disease.

cancer, especially in compromised patients who might not otherwise tolerate lobectomy.[13] The use of sublobar resection has been historically associated with an increased risk of local recurrence.[14,15] Emerging data over the last decade, however, have suggested that anatomic segmentectomy can achieve comparable recurrence and survival rates compared with lobectomy in patients with small (≤2 cm), peripheral tumors and when adequate surgical margins can be obtained.[11,16] Limited data are currently available assessing the potential advantages of VATS techniques in the setting of anatomic segmentectomy.

Nearly 70 years ago, segmental pulmonary resection was used for the treatment of bronchiectasis and infectious lesions.[17,18] Subsequently, surgeons have explored the utility of this approach for the treatment of early stage NSCLC in patients with cardiopulmonary compromise.[19-21] In the early 1990s, use of anatomic segmentectomy fell out of favor due to its perceived technical complexity and concerns regarding increased local recurrence rates compared with lobectomy.[22] The Lung Cancer Study group conducted the only randomized study comparing sublobar resection with lobectomy for patients with stage IA NSCLC.[14] The principal finding in this study was a threefold increase in local recurrence (17.2% vs 6.4%) in patients who had sublobar resection. Two years later, another prospective, multicenter nonrandomized study demonstrated a similar trend for increased local recurrence in patients having sublobar resection.[15] These and other studies have established lobectomy as the modern surgical approach of choice in patients with early stage lung cancer.

The increased identification of small NSCLC tumors by enhanced computed tomography screening protocols in higher-risk surgical patients[23] has led many surgeons to question the appropriateness of lobectomy for these tumors.[24] Sublobar resections have been demonstrated to achieve lower perioperative morbidity and mortality rates[25,26] and to preserve pulmonary function compared with lobectomy,[27,28] and may represent the only feasible surgical option in high-risk patients with compromised cardiopulmonary function. Furthermore, studies from Japan,[28-31] the United States,[32,33] and Europe[34] have demonstrated recurrence and survival rates similar to that achieved by lobectomy for small (<2 cm), peripheral lesions, especially when adequate surgical margins are obtainable.[11,35]

Little data currently exist on the use of VATS segmentectomy in the treatment of stage I NSCLC. Roviaro and colleagues[36] were the first to report a series of thoracoscopic anatomic lung resections, including a patient treated with segmentectomy. Several reports including small cohorts of patients having VATS segmentectomy suggested that this procedure could be performed safely; however, its oncologic efficacy remained in question.[33,37,38] Houck and associates[39] reported on a series of 11 patients having left upper-lobe trisegmentectomy using a VATS approach, with no operative mortality and no evidence of recurrence at 13.5 months. The first report evaluating a larger series of patients having VATS segmentectomy was published by Shiraishi and associates in 2004.[40] In this study, 34 patients having VATS segmentectomy were compared with 25 patients having open segmentectomy. VATS segmentectomy was associated with increased operative times (VATS = 240.2 minutes vs open = 203.5 minutes) as well as decreased

GTS

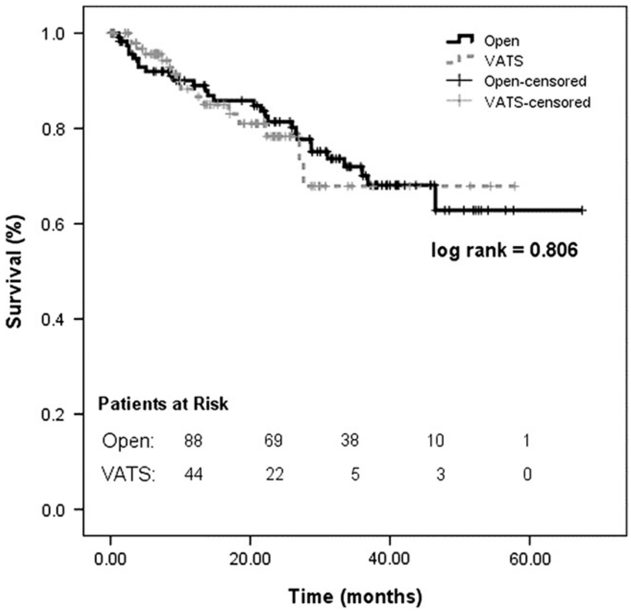

FIGURE 1. Recurrence-free overall survival after VATS *(gray)* and open *(black)* segmentectomy. *VATS,* Video-assisted thoracic surgery.

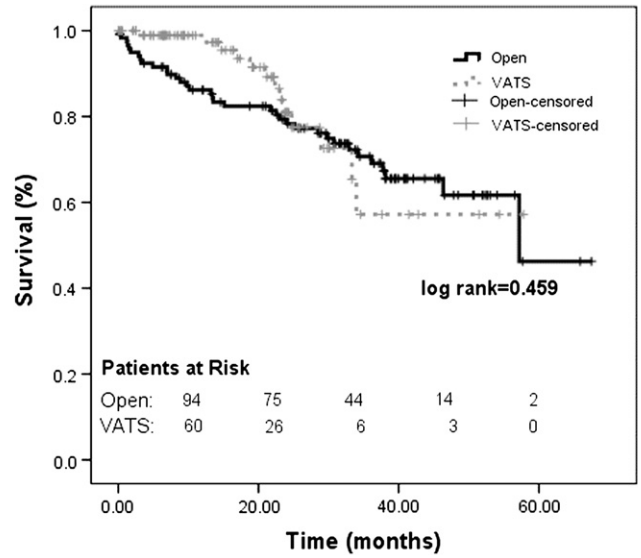

FIGURE 2. Overall survival after VATS *(gray)* and open *(black)* segmentectomy. *VATS,* Video-assisted thoracic surgery.

length of hospital stay (VATS = 12 days vs open = 16 days). There were similar rates of morbidity between the 2 groups. Atkins and coworkers[41] reported a series of 48 patients having thoracoscopic segmentectomy and compared the perioperative outcomes with 29 patients having open segmentectomy. VATS segmentectomy resulted in shorter hospital stay (VATS = 4.3 days vs open = 6.8 days) and was associated with improved overall survival compared with the open group.

In the current study, we evaluated the outcomes of 104 patients who had VATS segmentectomy for stage I NSCLC and compared the outcomes with 121 patients having open segmentectomy. The groups were well matched for age, gender, histology, stage, and preoperative pulmonary function (Table 1). In this series, all varieties of segmental resections were performed in the VATS and open groups (Table 2). Perioperatively, there was no difference in operative time or estimated blood loss. The principle findings of the current study were that VATS segmentectomy was associated with decreased length of stay and decreased pulmonary complications compared with open segmentectomy (Table 3), with no difference in recurrence-free or overall survival (Table 5, Figures 1 and 2). These findings mirror the advantages that have been documented in VATS lobectomy compared with the corresponding open approaches.[5,6,8,9] There were no operative deaths in the VATS group, and there was a significantly lower number of pulmonary complications (Table 3). Though the total number of deaths and deaths due to cancer were greater in the open group, this likely reflects the longer mean follow-up in this group. This contention is supported by the equivalent Kaplan-Meier estimates for long-term recurrence-free survival (Figure 2). Though there was no significant difference in survival between the VATS and open approaches (Figure 1), the VATS group demonstrated a trend for early survival advantage within the first 2 years. This finding may be due, in part, to the decreased pulmonary complications seen perioperatively in the VATS group and perhaps to a concomitant diminished physiologic impact with the VATS approach, though this is purely speculative. There was an increased number of late deaths seen in the VATS group (unrelated to tumor recurrence), which negated this early survival advantage.

The perioperative outcomes with VATS segmentectomy in this series compare quite favorably with previously published open series. The early results of the ACOSOG Z0030 trial provide important information on the modern-day mortality and morbidity associated with anatomic lung resection for NSCLC, including anatomic segmentectomy.[42] The mortality (0.9%) and complication rates (26%) of the current study are comparable to those of Z0030 for open segmentectomy (3% and 46%, respectively).

Tumor size and adequacy of surgical margin have been previously demonstrated to impact on recurrence risk subsequent to anatomic segmentectomy.[11,16] Among the 225 patients having anatomic segmentectomy for stage I NSCLC, disease recurred in 46 (20.4%): 18 locoregional, 28 distant. There was no apparent difference in overall (19.7% vs 20.8%) or locoregional recurrence (9.9% vs 6.7%) between those patients with tumors $\leq$2 cm or $\geq$2 cm, respectively. Interestingly, patients with a margin:tumor size ratio>1 had significantly fewer recurrences (14.7%) than those with a ratio $\leq$1 (28.9%, $P = .037$), underscoring the importance of maintaining an adequate margin during segmental resection.

There are several limitations with this study. The retrospective nature of this analysis has the potential for introducing bias in patient selection and perioperative management. In addition, this report is derived from the experience of a single institution with extensive experience in VATS techniques, thus limiting the general applicability of the reported findings to thoracic surgical practice. Though great effort was taken to thoroughly identify and report the complications encountered in these groups, the assessment of complications is always more accurate when compiled prospectively. Due to the more recent employment of VATS techniques during the study period, follow-up is noted to be necessarily longer in the open group compared with the VATS group, thus complicating assessment of recurrence and survival. When adjusting for follow-up in the VATS and open groups, however, no significant differences were seen in postoperative mortality or recurrence.

In our experience, the ideal lesions for VATS anatomic segmentectomy are small ($\leq$2 cm) and peripherally located in the outer third of the lung parenchyma. The lesions should reside in a delineated segmental boundary, so that an R0 resection can be obtained with adequate margins (ideally larger than the size of the tumor). This technique may be particularly advantageous for elderly patients with impaired cardiopulmonary function or in those patients with ground glass opacities that are associated with low metastatic potential.[43]

Taken together, these data suggest that the VATS approach is safe and effective when performing anatomic segmentectomy in experienced centers. Though not directly assessed in the current analysis, the results of this study demonstrate recurrence and survival curves similar to those seen following lobectomy for stage I NSCLC. Several recent reports have documented equivalent recurrence and survival rates when comparing segmentectomy and lobectomy in the setting of stage I NSCLC,[11,16] especially for tumors<2 cm in size.[32] A national, prospective randomized trial (CALGB 140503) is currently underway comparing lobar versus sublobar (segmentectomy, extended wedge) resection for stage I NSCLC. Such randomized data will be necessary to more precisely and reliably establish the advantages and disadvantages of anatomic segmentectomy (whether performed VATS or open) in this setting.

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Discussion

Dr Giancarlo Roviaro *(Milan, Italy)*. I would like to thank Dr Schuchert and coworkers for presenting this good experience in anatomic segmentectomies, which once again seems to confirm the validity of VATS in the treatment of early-stage lung cancer. The paper is good, well done, and the analysis of the patients, of the outcomes and of survival, is totally correct. Before asking you my questions, I would like to make some personal observations regarding the so-called VATS lobectomies and anatomic resections.

When, 17 years ago, I started my experience of thoracoscopic lobectomies, the majority of thoracic surgeons in the United States (except 10, or maximum 20, and some of them are present here today) were completely against these operations, considering these operations absurd, catastrophic, and oncologically not correct. In these years, the technique has surely been improved. Many authors, in order to reduce the technical difficulties, have presented different options to perform this operation, and at this moment I don't know what a VATS lobectomy really is. I don't know how many types of VATS lobectomy exist, and when it's possible to call them VATS lobectomies, thoracoscopic lobectomies, or open lobectomies only because the thoracoscope is introduced with a 10-cm, 15-cm incision and a wide incision of intercostal muscles using forceps, Duval, and all the other instrumentation for conventional surgery.

In the literature, many surgeons, with perfect selection of patients and good experience, have a high conversion rate. On the other hand, other surgeons don't have conversions and consider these so-called VATS lobectomies the ideal operation for every patient. They also present sleeve lobectomies in this way. Are these the same operation or must we change the name to avoid the confusion?

In your paper, Dr Schuchert, you have written that, in the early '90s, the anatomic open segmentectomies fell out of favor due to technical difficulties. Up to now, open sublobar resections have been accepted as an appropriate alternative to lobectomy in compromised patients. Recently, many authors have presented good results after wedge resection, similar to those after lobectomy, even for fit patients.

My question is, when CT scan discovers a peripheral lesion less than 1 or 2 cm, how do you decide whether to perform a wedge resection instead of a segmentectomy or a formal lobectomy? How do you select the open versus the thoracoscopic approach, and how many VATS or open lobectomies did you perform in comparison with 225 segmentectomies?

Dr Schuchert. Thank you, Dr Roviaro, for your comments.

Addressing the first question regarding small lesions, when 1-2 cm nodules are identified and are confined to a specific bronchopulmonary segment, we would consider performing an anatomic segmentectomy in an effort to preserve function, especially in elderly patients or patients in whom lobectomy may be considered a higher risk option. We generally prefer anatomic segmentectomy over a simple wedge resection because of the concern regarding an increased local recurrence rate associated with wedges compared to segments. El-Sherif and colleagues found a 3.8% versus 14.5% locoregional recurrence rate when comparing anatomic segmentectomy versus wedge resection (*Ann Surg Oncol*. 2007;14:2400-5). So when performing a sublobar resection for small lesions confined to a distinct bronchopulmonary segment, we would prefer a formal anatomic segmentectomy as opposed to a wedge. If we encounter a larger lesion (>3 cm) that crosses segmental boundaries, or if N1 lymph node involvement is suspected or documented, a lobectomy would be advocated.

The second question relates to the open versus VATS approach. I think a lot of that comes down to technical experience and surgical judgment. The principal investigators in this study have extensive experience in VATS techniques and have developed a technical approach that facilitates resident teaching and is flexible in implementation, whether performing a segmentectomy or lobectomy. Of primary importance, great effort is undertaken to avoid compromising the fundamental principles of the procedure, and to try to emulate as specifically as possible the open approach when using the VATS technique. We use many of the same dissection instruments and stapling equipment, perform the same type of selective approach to the hilar structures, and try to achieve the exact same surgical margins that we would under open conditions.

During the same period of this study, our group has performed approximately 250 lobectomies for pathological stage 1 non–

small-cell lung cancer. Similar to the segmentectomy approach, the majority have been performed open. Over recent years, however, there has been a significant increase in the use of the VATS approach for lobectomy.

Dr Roviaro. My second question regards the old problem of lymphadenectomy and videothoracoscopy. Is lymphadenectomy feasible in the same way as in open surgery, or must we exclude the patients in which the frozen section during the operation demonstrated N1 or N2? As you know, lymph node enlargement is not a sure sign of malignancy. On the other hand, small lymph nodes can be metastatic. Do you always perform a complete lymphadenectomy or do you sample each level, or else do you just harvest local lymph nodes? Does your attitude differ in open or in the videothoracoscopic approach?

Dr Schuchert. Our group tends to perform systematic lymph node sampling of the standard stations on each side. We do place an importance on obtaining an adequate sample from each station. The results of the ACOSOG Z0030 trial will add important information regarding the utility of lymph node dissection versus sampling in the setting of clinical stage 1 non–small-cell lung cancer.

Dr Roviaro. For my last question, in my experience I have performed a limited resection only in very compromised patients. Survival rates have been significantly decreased due to causes unrelated to cancer, whereas recurrence was not always a determinant of the decreased survival in these patients. What has been the impact of non–cancer-related causes on your survival, and, at the end, why did you operate on a 100-year-old patient?

Dr Schuchert. The majority of deaths in our group were due to noncancer causes. Those that were due to malignancy were more commonly associated with disseminated disease. This pattern supports the notion that a distinct survival advantage might not be attained by doing a more aggressive resection in this select group of patients in whom the disease exhibits a more systemic biology.

Advanced age is viewed as a relative contraindication in selecting patients for surgery. We certainly encounter elderly patients who are extremely fit. We prefer to focus on a patient's physiologic age, their estimated ability to withstand the procedure, and their personal disposition toward pursuing surgery aggressively. It's an individualized decision when choosing to operate on an elderly patient.

Dr Roviaro. Thank you.

Dr L. Penfield Faber *(Chicago, Ill).* I saw those indications up there for segmental resection and I am very pleased to say that I'm happy I qualify. Dr Jensik and Dr Faber are very pleased to see that, indeed, there is a renewed interest in segmental resection. Our first series in 1973 with 65 cases (it was subsequently expanded to over 350 cases) had a mortality rate of 1.6% and a 5-year actuarial survival rate of 56%. Now, in those days, we didn't stage as well as we stage nowadays, and certainly I think if we had staged better, we had measured the size of the tumor, and taken out all the lymph nodes that should be taken out, survival would have been better. But with new techniques, stapling techniques, indeed I think that morbidity and mortality will be much less. I am a little disappointed that you reserve it for individuals over the age of 75 because I think the operation you are describing has the potential to be an operation of choice for the lesion 2 cm and less. We must remember that, in the lung cancer study group, 40 wedges were included in that series. The end result was that survival was the same despite an increase in local recurrence. I would certainly want to say that a segmentectomy by stapling technique, VATS technique, should not be a deep wedge resection, and it must be an anatomic resection—pulmonary artery, pulmonary bronchus, and lymph node resection.

So my question is, as you are doing your VATS segmentectomy and you encounter a lymph node at level 11 or level 12 and frozen section reveals metastatic microcancer, because we're going to hear a paper about understaging, what do you do then?

Dr Schuchert. When we encounter a level 11 or 12 lymph node during the course of dissection, we would definitely consider lobectomy in an effort to obtain an R0 resection. In all surgical resections, we also carefully assess the standard mediastinal lymph node stations so that we accurately stage those patients.

Dr Raja Flores *(New York, NY).* First of all, I want to state that I am a huge proponent of VATS lobectomy and VATS segmentectomy. However, many surgeons who support open thoracotomy will frequently state that there is a huge selection bias when we perform these studies of open and VATS patients, which leads me to conversion. The number of patients that you presented, I'm sure there must have been some conversions in there.

Dr Schuchert. Yes.

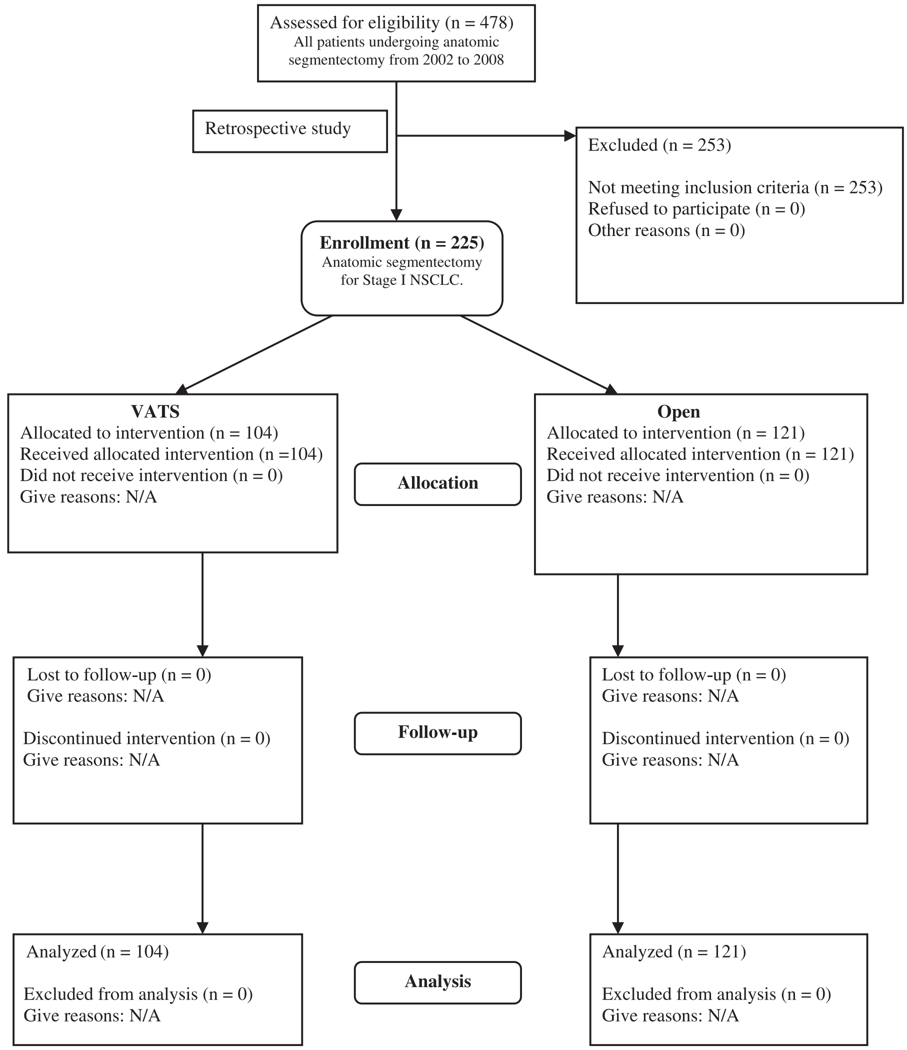
Dr Flores. What was your conversion rate from VATS segmentectomy to open segmentectomy and from VATS segmentectomy to VATS lobectomy, and how did you handle that in your analysis?

Dr Schuchert. There were 2 conversions in this series, both for bleeding. I do not have the answer as to how many patients started off as a segmentectomy and went on to lobectomy because the patients analyzed in this series were only those who ended up being treated ultimately with segmentectomy. Patients undergoing a VATS segmentectomy who underwent conversion to an open approach were included in the VATS cohort because the intention was to treat via VATS.

Dr Tomasz Grodzki *(Szczecin, Poland).* I would like to congratulate you on an excellent paper. I think segmentectomy is a surgery of choice for really small tumors. My question regards the time of surgery. Open segmentectomy took 2½ hours in your hands. My simple question is, what have you been doing there so long?

Dr Schuchert. Your comments are appreciated. I think a lot of that is a testament to our faculty's dedication to teaching and training young personnel to do this procedure. Anatomic segmentectomy is a procedure that residents do not have as much experience with compared to lobectomy. There are different anatomic and intraoperative decision-making issues that have to be considered. Like most minimally invasive procedures, operative time tends to decrease with surgeon experience.

Dr Grodzki. Thank you.



APPENDIX E1. CONSORT diagram.