Lung cancer resection combined with lung volume reduction in patients with severe emphysema

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Read at the Eighty-third Annual Meeting of The American Association for Thoracic Surgery, Boston, Mass, May 4-7, 2003.

Received for publication May 2, 2003; revisions received Nov 5, 2003; accepted for publication Nov 10, 2003.

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J Thorac Cardiovasc Surg 2004;127:1323-31
0022-5223/\$30.00

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doi:10.1016/j.jtcvs.2003.11.046

Objective: Certain patients with resectable lung cancer and severe respiratory limitation due to emphysema may have a suitable operative risk by combining cancer resection with lung volume reduction surgery. The purpose of this study is to review our experience with such patients.

Methods: A review was conducted on 21 patients with lung cancer in the setting of severe emphysema who underwent an operation designed to provide complete cancer resection and volume reduction effect.

Results: In the 21 patients, the mean preoperative forced expiratory volume in 1 second was 0.7 ± 0.2 L (29% predicted), residual volume was 5.5 ± 1.0 L (271%), and diffusing capacity for carbon monoxide was 8.0 ± 2.2 mL/min/mm Hg (34% predicted). In 9 patients, the cancer was located in a severely emphysematous lobe and the lung volume reduction surgery component of the procedure was accomplished with lobectomy alone. In the remaining 12 patients, the cancer resection lobectomy ($n = 9$) and wedge resection ($n = 3$) were supplemented with lung volume reduction surgery. Final pathologic staging was stage I in 16 patients, stage II in 2 patients, and stage III in 2 patients. One patient was found to have stage IV disease due to multifocal tumors in separate lobes. There were no hospital deaths. Postoperative complications included prolonged air leak in 11 patients, atrial fibrillation in 6 patients, and reintubation for ventilatory assistance in 2 patients. All patients showed improved lung function postoperatively. Survival was 100% and 62.7% at 1 and 5 years, respectively.

Conclusions: Patients with severe emphysema and resectable lung cancer who have a favorable anatomy for lung volume reduction surgery may undergo a combined cancer resection and lung volume reduction surgery with an acceptable risk and good long-term survival.

Early-stage non-small cell lung cancer is best treated by complete anatomic resection. Patients with resectable lung cancer but with associated advanced emphysema are often precluded from surgery due to severe respiratory limitation. For these patients alternative treatment strategies including radiation therapy, with or without chemotherapy, yield comparatively poor results.^{1,2} Furthermore, radiation therapy may lead to the same degree of reduction in pulmonary function as

surgical resection. Thus, patients with severely limited pulmonary function represent as much a management problem for the radiation oncologist as for the surgeon.³ This dilemma is further compounded for surgeons by the lack of a precisely definable point at which the risk-to-benefit ratio for resection becomes unfavorable, particularly in light of improvements in the anesthetic, surgical, and postoperative treatment of patients with advanced emphysema.

We previously reported the beneficial early- and intermediate-term results of lung volume reduction surgery (LVRS) in 150 selected patients with advanced emphysema.^{4,5} The long-term outcome of bilateral LVRS in 250 consecutive emphysema patients showed that LVRS produces significant functional improvement.⁶ The benefit appears to last at least 5 years for the majority of these patients.

Certain highly selected patients with clinically resectable lung cancer and severe respiratory limitation due to emphysema may have an acceptable operative risk by combining a suitable cancer resection with LVRS. This combination would provide the best treatment for early-stage lung cancer while at the same time be a palliative treatment for the symptoms of emphysema. We previously reported our early results in 5 patients who underwent a combined lung cancer resection and LVRS.⁷ The purpose of this report is to describe our experience in a larger number of patients with a longer follow-up who had combined cancer resection with LVRS at our institution.

Methods

Patient Population

Between January 1993 and December 2001, over 1000 patients with severe emphysema were evaluated at Barnes Hospital as potential candidates for LVRS. Among these, 332 were determined to be acceptable candidates and went on to have 280 bilateral and 52 unilateral LVRS procedures. Among the patients who were referred for evaluation and accepted for LVRS operations were 5 patients (1.5%) in whom chest x-ray films showed a pulmonary nodule suspicious for carcinoma. Another 16 patients were referred primarily for evaluation of newly diagnosed or suspected lung cancer in the setting of severe emphysema. These 21 patients form the basis for this report. A review was conducted from the medical records and prospective database that contains serial pulmonary function studies and exercise testing on all patients pre- and post-LVRS. The mean follow-up was 3.9 years with a minimum time interval since surgery of 1 year. Follow-up was complete and based on routine appointments after surgery as well as direct patient or family contact. This study was reviewed and approved by the Washington University School of Medicine Human Studies Committee. This report does not include patients who were found to have incidental cancer in the resected pathologic specimens following LVRS.

The patient evaluation included physical examination, pulmonary function tests with lung volumes determined by plethysmography, arterial blood gas analysis (at rest on room air), chest

radiograph, standardized computed tomography (CT) of the chest including views of the liver and adrenal glands, radionuclide ventilation-perfusion lung scan, 6-minute walk test, and Medical Research Council dyspnea scale. Systemic spread of disease was evaluated by brain CT and radionuclide bone scan.

Details of the selection process for lung volume reduction were reported previously.⁴⁻⁶ Marked hyperinflation of the chest and adequate regional distinction in the destruction pattern of emphysema to provide "target areas" of useless lung accessible to surgical resection were critical selection criteria in all patients.

The majority of patients judged suitable for surgery were enrolled in a preoperative pulmonary rehabilitation and smoking cessation program lasting 6 to 8 weeks. Patients were then reassessed the week before surgery by an interval history and physical examination, chest radiograph, chest CT, complete pulmonary function tests, arterial blood gas, 6-minute walk test, and dyspnea questionnaire. The postrehabilitation, immediate preoperative data were used as the baseline for comparisons with postoperative data. Five patients were felt to be in suitable physical condition when initially evaluated and went directly to surgery without pulmonary rehabilitation. In these patients, their initial evaluation measurements were used as the baseline for comparison.

Flexible bronchoscopy was performed on all patients. Biopsy of an endoscopically visible tumor or fine needle aspiration of a peripheral pulmonary lesion was performed when feasible. Mediastinoscopy was performed for all patients with proven lung cancer and for those with a suspected lung cancer when the suspicious lesion was larger than 1 cm, centrally located, or associated with lymph node enlargement on CT images. The general treatment policy of our group is that patients with histologically proven N2 disease are not offered surgery due to the poor 5-year survival in this group of patients. The purpose of performing a cervical mediastinoscopy in this subset of patients is to exclude N2 disease before proceeding to a combined lung cancer resection and LVRS as the primary justification for the procedure in these patients was to resect the cancer, employing our usual criteria and staging procedures.

Surgical Technique

Bilateral procedures were performed through a median sternotomy in 10 patients. The remaining 11 patients had a muscle-sparing thoracotomy for a unilateral procedure. One patient had a previous bleb excision and pleurectomy on the left side due to recurrent spontaneous pneumothorax and required staged thoracotomies for a right upper lobe volume reduction and subsequent completion left upper lobectomy for cancer. The decision to perform either a wedge resection or a lobectomy depends upon the location of the tumor and the distribution and severity of emphysema. Lobectomy is generally not performed in patients with severe emphysema unless there is a heterogenous distribution of emphysema and the tumor is located within a destroyed, virtually functionless lobe. If the tumor is in the middle lobe and there are suitable target areas for LVRS in other lobes, then a middle lobectomy may be performed in conjunction with ipsilateral or bilateral LVRS. If the tumor is located in the best-preserved lobe other than the middle lobe, then either a wedge resection is performed or the patient is considered not to be a suitable candidate. An ipsilateral or a contralateral LVRS is added to the cancer resection if there is a

TABLE 1. Pulmonary function and exercise test results before and after surgery

	Pre-pulmonary rehabilitation	Preoperative	6 months postoperative	1 year postoperative	3 years postoperative	5 years postoperative
n	16	21	21	20	14	7
FEV ₁ , L (% predicted)	0.7 ± 0.2 (27%)*	0.7 ± 0.2 (29%)	1.0 ± 0.3 (40%)‡	1.1 ± 0.4 (43%)‡	0.9 ± 0.2 (34%)†	0.8 ± 0.2 (28%)*
RV, L (% predicted)	5.3 ± 0.4 (260%)*	5.5 ± 1.0 (271%)	3.2 ± 0.9 (152%)‡	3.4 ± 0.6 (161%)‡	3.6 ± 0.7 (163%)‡	4.1 ± 1.2 (195%)†
DLCO, mL/min/mm Hg (% predicted)	8.4 ± 2.8 (35%)*	8.0 ± 2.2 (34%)	8.9 ± 2.9 (36%)*	9.0 ± 3.6 (36%)*	8.9 ± 3.2 (35%)*	8.4 ± 1.2 (30%)*
Six-minute walk (feet)	854 ± 332†	906 ± 354	1240 ± 171†	1292 ± 171†	1171 ± 113†	1101 ± 126*
MRC	3.4 ± 0.7*	3.5 ± 0.8	0.7 ± 0.6‡	0.8 ± 0.8‡	1.1 ± 0.4‡	1.6 ± 0.5‡

FEV₁, Forced expiratory volume in 1 second; RV, residual volume; DLCO, diffusing capacity for carbon monoxide; MRC, Medical Research Council dyspnea scale.

**P* ≥ .05 for paired analyses with preoperative scores.

†*P* < .05 for paired analyses with preoperative scores.

‡*P* ≤ .001 for paired analyses with preoperative scores.

TABLE 2. Alveolar gas exchange and oxygen supplementation requirements before and after surgery

	Preoperative	6 months postoperative	1 year postoperative	3 years postoperative	5 years postoperative
n	21	21	20	14	7
PACO ₂ (mm Hg)	42 ± 4	39 ± 5	39 ± 4	44 ± 6	44 ± 6
PAO ₂ (mm Hg)	67 ± 10	73 ± 11	73 ± 11	69 ± 9	68 ± 9
Steroid use (%)	19	9	6	7	14
Supplemental oxygen					
Required continuously (% of patients)	57	4	6	18	20
Required during exercise (% of patients)	86	38	47	55	80

suitable target area for LVRS such that the resection would be expected to result in a likely improvement in the patient's postoperative pulmonary function. Pleural tents were created in 7 patients for residual space remaining at the apex of the chest at the end of the procedure.

Immediate extubation in the operating room or shortly thereafter in the postanesthesia recovery area was achieved in all patients. One patient who was hemodynamically unstable required immediate reintubation, with successful extubation 2 days later.

Postoperative Management

A thoracic step-down unit provided specialized postoperative nursing care. A thoracic epidural catheter for continuous analgesia was placed with fluoroscopic guidance immediately prior to the thoracotomy as per our standard postoperative pain protocol. This decreased the need for systemic narcotics and provided optimal pain management with minimal risk for respiratory depression.

Chest physiotherapy and ambulation, initiated on the first postoperative day by experienced physical therapists and thoracic surgical nurses, was continued throughout the hospital stay. Postoperative bedside bronchoscopy and mini-tracheostomy placement were used when necessary to clear thick secretions.

Statistical Analysis

Descriptive statistics are expressed as mean ± standard deviation unless otherwise specified. Categorical data are expressed as counts and proportions. Comparisons were done with paired,

2-tailed *t* test for means of normally distributed continuous variables and the Wilcoxon rank sum test for skewed data. Chi-square or Fisher exact test was used to analyze differences among the categorical data. Kaplan-Meier estimate was used to depict survival. All data analysis was performed using SPSS (SPSS 11.0 for Windows; SPSS Inc, Chicago, Ill).

Results

Baseline

The mean age of the 21 patients was 66 ± 7 years (median: 65.5 years, range: 53-78 years). Eight were men and all were former smokers. All patients, with the exception of one who complained of chest wall pain, had no symptoms from their cancer with the suspicious lesion being first found on routine chest radiograph. All had symptoms of advanced emphysema. Twelve (57%) suffered from dyspnea at rest and required continuous supplemental oxygen, and 18 (86%) required oxygen supplementation during exercise. Seven (33%) patients were taking prednisone when first evaluated, three of whom were completely weaned prior to surgery. Preoperative pulmonary function, exercise test results, alveolar gas exchange, and oxygen supplementation are depicted in Tables 1 and 2.

During the baseline evaluation process, two patients were found to have extensive coronary artery disease. One

TABLE 3. Location of the tumor, operative procedure performed, pathologic features including stage for each of the patients

Patient	Location of tumor	Procedure	Histology	Stage
1	Right upper lobe	Lobectomy and contralateral LVRS	Adenocarcinoma	I
2	Right lower lobe	Lobectomy and contralateral LVRS	Adenocarcinoma	I
3	Right middle lobe	Lobectomy and contralateral LVRS	Adenocarcinoma	I
4	Left upper lobe	Wedge and contralateral LVRS	Adenocarcinoma	IIIb
5	Right middle lobe	Lobectomy and ipsilateral LVRS	Adenocarcinoma	I
6	Right lower lobe	Wedge and ipsilateral LVRS	Squamous	I
7	Left upper lobe	Lobectomy only	Adenocarcinoma	I
8	Left upper lobe	Lobectomy and contralateral LVRS	Squamous	IIb
9	Right lower lobe	Wedge and contralateral LVRS	Squamous	IV
10	Left lower lobe	Lobectomy only	Squamous	I
11	Left upper lobe	Lobectomy only	Poorly differentiated NSCLC	I
12	Right lower lobe	Lobectomy only	Squamous	I
13	Right upper lobe	Lobectomy and contralateral LVRS	Poorly differentiated NSCLC	I
14	Right upper lobe	Lobectomy and ipsilateral LVRS	Adenocarcinoma	I
15	Right upper lobe	Lobectomy only	Adenocarcinoma	I
16	Left upper lobe	Lobectomy only	Adenocarcinoma	IIa
17	Left upper lobe	Lobectomy only	Adenocarcinoma	I
18	Left upper lobe	Lobectomy only	Adenocarcinoma	I
19	Right upper lobe	Lobectomy and contralateral LVRS	Squamous	I
20	Right upper lobe	Lobectomy only	Squamous	I
21	Left upper lobe	Lobectomy and contralateral LVRS	Squamous	IIIb

LVRS, Lung volume reduction surgery; NSCLC, non-small cell lung carcinoma.

patient underwent coronary angioplasty 6 days prior to undergoing pulmonary resection and the other underwent coronary bypass grafting of 3 vessels 3 months prior to undergoing pulmonary resection. Two other patients were found to have cardiomyopathy and reduced left ventricular ejection fraction (<20%) resulting from a prior myocardial infarction.

All patients were felt to have early-stage, resectable lung cancer. Six patients had biopsy-proven malignancy prior to surgery. No evidence of systemic spread of disease was evident following the various staging procedures. In all patients the lesion was in a location suitable for a wedge resection or lobectomy.

Surgical Procedure and Pathology

Fifteen of the 21 patients had mediastinoscopy, which in all cases proved negative for regional lymph node involvement. In 9 patients, the cancer was located in a severely emphysematous lobe and the volume reduction component of the procedure was accomplished by an anatomic lobectomy alone. In the remaining 12 patients, the cancer resection (lobectomy: $n = 9$; wedge resection: $n = 3$) was supplemented with additional LVRS. The additional resection was ipsilateral in 3 patients, contralateral in 5 patients, and bilateral in 4 patients. Final pathologic staging was stage I in 16 patients, stage II in 2 patients, and stage III in 2 patients due to 2 separate tumor nodules within the same lobe (T4 disease). Cervical mediastinoscopy was performed in both patients with stage III disease (T4 N1 M0, T4 N0

M0) and did not reveal any evidence of mediastinal metastatic disease. One patient was found to have stage IV disease due to 2 multifocal tumors located in separate lobes (TX N0 M1 disease). The operative procedure as well as the location, histology, and pathologic stage of the resected tumor for each patient are depicted in Table 3.

Hospital Course

There was no hospital mortality. The most common post-operative complication was prolonged air leak (>7 days) in 11 patients (52%). Four of these patients were discharged with a chest tube connected to a Heimlich valve until complete resolution of air leak. Atrial fibrillation was noted in 6 patients (29%) and reintubation for ventilatory assistance in 2 patients (9%). One patient was taken back to the operating room for reexploration because of bleeding. A mini-tracheostomy was placed in 7 patients (33%) either in the operating room or later at the bedside. All patients were weaned from mechanical ventilation prior to discharge. The median length of hospitalization was 9 days (range: 5-24 days).

Follow-up Information

No patient was lost to follow-up. Nine patients (43%) had late death. The cause of death was recurrent cancer in 4 patients, respiratory failure in 3 patients, and cardiac failure in 2 patients. Kaplan-Meier estimation of survival at 1, 3, and 5 years was 100%, 73.7%, and 62.7%, respectively (Figure 1). Kaplan-Meier estimation of survival of patients

Figure 1. Kaplan-Meier estimation of survival at 1, 3, and 5 years.

with stage I disease at 1, 3, and 5 years was 100%, 79.0%, and 68.0%, respectively.

Cancer Status

Two patients received adjuvant radiation therapy as a result of unsuspected positive parenchymal margin identified in 1 patient by formalin fixed histology and by a positive hilar lymph node in the other patient. At the time of follow-up, 5 patients (24%) developed recurrent disease, first noted at 7, 8, 35, 46, and 48 months after resection. Four of the 5 recurrences were first noted on routine follow-up chest radiograph. The remaining patient complained of blood-streaked sputum, prompting further investigation. Further tests, such as chest and brain CT and radionuclide bone scan, F-18 fluorodeoxyglucose positron emission tomography (PET) scan, and biopsy, were all performed to confirm local and systemic recurrence of disease. All 5 patients went on to receive treatment under the care of a medical oncologist. Four subsequently died due to metastatic disease and 1 patient remains alive with evidence of disease. Kaplan-Meier estimation of freedom from cancer recurrence at 1, 3, and 5 years was 90.5%, 84.0%, and 68.7%, respectively (Figure 2). Kaplan-Meier estimation of freedom from cancer recurrence in patients with stage I disease at 1, 3, and 5 years was 90.0%, 84.0%, and 69.3%, respectively.

Functional Results

Pulmonary function tests are shown in Table 1. Spirometry, lung volumes, and gas exchange improved after surgery. The forced expiratory volume in 1 second (FEV₁) and residual volume (RV) showed a statistically significant improvement between preoperative values and each time point of follow-up through 3 years. Although the FEV₁ returned to baseline by 5 years, the RV remained significantly improved. As with LVRS patients in general, there was no statistical significance between the initial evaluation and

Figure 2. Kaplan-Meier estimation of freedom from recurrence of disease at 1, 3, and 5 years.

postrehabilitation FEV₁ and RV measurements. The diffusing capacity for carbon monoxide remained unchanged throughout all time points.

Supplemental oxygen requirements at rest substantially declined after surgery (57% preoperatively vs 6%, 18%, and 20% at 1, 3, and 5 years after surgery, respectively). Preoperatively 86% of patients required supplemental oxygen with exertion. At 1, 3, and 5 years the requirement was 47%, 55%, and 80%, respectively, as shown in Table 2.

Functional improvement was also measured by the 6-minute walk test and results are shown in Table 1. Significant improvement in preoperative physical stamina resulted in those patients who underwent pulmonary rehabilitation. Further improvement in performance was evident after surgery. This improvement was maintained throughout follow-up with a gradual decline toward baseline at 5 years.

As depicted in both Table 1 and Figure 3, 89% of patients reported improvement in symptoms of dyspnea at 6 months following surgery. At 1 year 88% remained improved, 8% were unchanged, and 4% showed worsening. These improvements were sustained throughout follow-up, with only 17% of patients measured reporting a worse score at 5 years.

Discussion

Cigarette smoking is an important cause of both lung cancer and emphysema.^{8,9} Complete resection by lobectomy or pneumonectomy remains the best treatment for patients with early-stage lung cancer. The presence of severe emphysema in patients with early-stage lung cancer can preclude them from anatomic resection. We previously reported on a small series of patients, otherwise considered inoperable on the basis of overall lung function and oxygen dependency, in whom a combination of LVRS and cancer resection proved worthwhile.⁷ There are a number of studies

Figure 3. Modified Medical Research Council dyspnea scale respondent's score change after surgery.

examining the relationship between the preoperative investigations and postoperative results to predict preoperative risk factors. In one study, FEV_1 was found to be the best predictor of postoperative mortality.¹⁰ Other studies found that the minimum criteria for a lobectomy were maximal voluntary ventilation greater than 40% of predicted value, an FEV_1 value greater than 1 L, and an FEV_{25-75} value greater than 0.6 L.^{11,12} In another study, diffusing capacity was found to be the most important predictor of death and pulmonary complications.¹³ The authors recommended that patients with a corrected diffusing capacity of less than 60% of predicted value should not be considered for major pulmonary resection. Other investigators attempted to better define the operative risks in patients with marginal pulmonary reserve by quantifying differential lung function by using xenon 133 ventilation radiospirrometry with or without technetium 99 perfusion scanning.¹⁴⁻¹⁷ One study found that patients with a predicted postresection FEV_1 value of less than 1 L were considered unfit for surgery.¹⁷ Impaired maximal oxygen consumption or the loss of pulmonary vascular compliance during exercise was suggested in other studies to help define patients at high risk for resection.

Recent studies reported on other methods to determine suitability for pulmonary resection in patients with moderate to severe respiratory limitation.¹⁸⁻²⁰ Korst and colleagues¹⁸ noted an improvement or minimal loss of pulmonary function following lobectomy for the treatment of non-small-cell lung carcinoma in 13 patients with an FEV_1 of less than or equal 60% of predicted value and an FEV_1 /forced vital capacity ratio of less than or equal 0.6. A scoring system combining these 2 parameters helped to identify patients who may have only a limited reduction or even an improvement of pulmonary function following lobectomy. Carretta and associates¹⁹ reported a subgroup of 10 patients in whom a higher radiological visual assessment

of emphysema correlated to an unchanged or even an increase of pulmonary function following a lobectomy. The radiological visual assessment utilized a scoring system that is a sum of the grading score of emphysema seen on lateral chest radiograph and chest CT scan. Edwards and coworkers²⁰ extended the selection criteria for lobectomy in patients with a predicted postoperative FEV_1 of less than 40% if the tumor was resectable, the target lobe was both emphysematous and contributed to less than 10% of overall perfusion, and there was evidence of hyperinflation on radiological assessment. Despite these various findings, no single test has been found to best define the patients who will and will not tolerate resection. Instead, these investigations, together with the physical condition of the patient and the surgeon's experience, help to select patients suitable for surgical resection.

Lung volume reduction surgery in well-selected patients with severe emphysema results in postoperative improvement of symptoms and measured pulmonary function.⁵ The combination of lung cancer resection with LVRS offers selected patients who have concomitant early lung cancer and severe emphysema the opportunity to undergo resection of their cancer with improvement rather than further reduction in their pulmonary function. By traditional criteria these patients would otherwise be considered unsuitable surgical candidates because of the limited pulmonary function. In this series, all patients had pulmonary function values in one or more categories well below the traditionally accepted minimal criteria for lobectomy. Following the combined surgery, these patients reported early- and long-term benefits similar to those who had LVRS alone.⁶ These early improvements were followed by a slow gradual decline of the pulmonary function tests, similar to the patients who had LVRS alone.⁶ The Kaplan-Meier estimation of survival at 1, 3, and 5 years in this group of patients was

100%, 73.7%, and 62.7%, respectively (Figure 1). This compares well to the reported long-term outcome of bilateral lung volume reduction in 250 consecutive patients with emphysema where the Kaplan-Meier estimation of survival at 1, 3, and 5 years was 93.6%, 84.4%, and 67.7%, respectively.⁶

Lobectomy is generally not performed in patients with severe emphysema unless there is a heterogeneous distribution of emphysema and the tumor is located within a destroyed, virtually functionless lobe. In our series, 9 patients had their cancer within a severely emphysematous lobe and complete lobectomy served to achieve the dual function of cancer resection and LVRS. Other patients, however, had their cancer located in a lobe separate to other additional LVRS target areas. In this group of patients, a small peripheral cancer was removed either by a wedge resection or segmentectomy; a centrally located cancer was removed by a lobectomy. These patients had supplementary LVRS in addition to their cancer resections. If the tumor was in the middle lobe and there were suitable target areas for LVRS in other lobes, then a middle lobectomy was performed in conjunction with ipsilateral or bilateral LVRS. If the tumor was located in the best-preserved lobe other than the middle lobe, then either a wedge resection was performed or the patient was not considered to be a suitable candidate.

There are several limitations to this study. It is small series of highly selected patients. It would not be appropriate to generalize the application of combined lung cancer resection and LVRS for all patients with resectable lung cancer associated with severe emphysema. Limited resection by wedge or segmentectomy may also lead to an increased risk of local or earlier recurrence; however, it is still likely the best option for a curative result. Primary radiation treatment is an alternative therapy for these patients with limited pulmonary reserve. However, radiation pneumonitis and fibrosis will worsen pulmonary function without providing any lung volume reduction effect. The rate of cure with radiation therapy is also inferior to that accomplished by surgical resection. A combined resection in suitable patients is therefore the only strategy that can potentially provide both a curative procedure and improvement in pulmonary function.

In summary, combined cancer resection and LVRS allows selected patients with early lung cancer and advanced emphysema to undergo the optimal treatment modality of cancer resection at a low risk with improvement of their pulmonary status.

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Discussion

Dr Larry R. Kaiser (Philadelphia, Pa). Among the added benefits of lung volume reduction surgery has been the realization that patients with much more severe obstructive lung disease potentially are candidates for pulmonary resection. It is almost a fact that very few patients are not candidates for resection on the basis of pulmonary function alone. This recognition has benefited many more patients than just the group undergoing lung volume reduction.

So I have several questions. Cliff, the group had a fairly high incidence of air leaks (52%) despite the use of buttressing. Is there any explanation for that? And did the air leaks occur from the area of the cancer resection, from the area where you did the lung volume reduction, or from both areas?

Dr Choong. I believe the majority of the air leaks would have occurred from the area of the lung volume reduction surgery. The

area where the lobectomy was performed for cancer resection, in terms of the frequency of air leakage, would not have been any different than other cases of lobectomy for patients without severe emphysema.

In terms of the high incidence of air leak of 52%, this is not very much different than the reported series by Anna Maria Ciccone last year where she reported 250 patients who had consecutive bilateral lung volume reduction surgery and the air leakage was about 50%. And also in other series, for example, Dr Rob McKenna, who reported his series of 325 lung volume reduction surgeries in the journal of *Chest* in 1996, the air leakage was just slightly below 50%. So I think the incidence of 52% itself, although high, is fairly expected in patients who undergo lung volume reduction surgery.

Dr Kaiser. But you defined it as prolonged air leak, so I assume that's greater than 7 days, so that does seem a little bit high. But you're absolutely right. Do you have comments on that?

Dr Cooper. No, except it is the same. Maybe we should do better. These people don't come out of the operating room with air leaks, but within hours or by the next day they frequently have them. And on the occasion when we have had to explore patients, we have usually found that it is either in the fissures or often a remote area, not the staple line, because once you've done volume reduction, the distending force on the remaining pleura is quite extensive and just a little cough or strain can tear it.

Dr Kaiser. How do you decide who is a candidate for this approach? I mean who is to say you couldn't take some of these patients and just do a resection? It seems to me that those patients who have a lower lobe lesion and upper lobe–predominant emphysema, without going into details, it seems that upper lobe–predominant emphysema does tend to be associated with a better functional outcome in these patients. So how do you decide who is a candidate for this procedure as opposed to just doing the resection alone? And who won't you operate on, for that matter? Who do you turn down?

Dr Choong. I think it is important to realize that this is a very highly selected group of patients, and the criteria that we have set for these patients are, first, they must have clinical evidence of early lung cancer. If they have any evidence of N2 disease or metastatic disease, they are excluded from this operation. Second, they need to have suitable target areas, similar to those patients selected for LVRS, heterogeneous, severe emphysema, suitable target areas. We were fortunate to have treated patients where the cancer was also located in a severely emphysematous lobe, thereby, when we did the lobectomy itself, for example, in 9 patients, the lobectomy itself served both the function of LVRS and cancer resection. So personally I think it is important to realize that this is a group of patients who are highly selected, who are treated by very experienced surgeons, and together with the experience and those criteria, I would think those would be the prerequisites.

Dr Kaiser. How much lung tissue do you take for your lung volume reduction? Is it the same amount that you take for your isolated lung volume reduction procedures or do you take a little bit less? Because you are, in some of these cases, resecting otherwise functioning parenchyma and then going ahead and doing a volume reduction procedure because that is the targeted area. So

how much do you take? I know just the right amount is the right answer.

Dr Choong. I would think that the group would still be taking about 20% to 30% of the lung when they are planning to do just a volume reduction of the upper lobe. However, patients are having lobectomy as their lung volume reduction surgery and cancer surgery resection, then, as you can see, some of those patients do not require any additional lung volume reduction.

Dr Cooper. I think it's fair to say that no lobectomies were done if the cancer was in the better preserved part of the lung. There may have been a couple wedges in that situation and the rest were lobectomies. I think there could be no lobectomy done if the cancer was localized in the better part rather than the worst part of the lung in a patient with heterogeneous pattern of emphysema.

Dr Kaiser. That's the question.

Dr Cooper. They would not be candidates, I think.

Dr Thomas W. Rice (Cleveland, Ohio). Congratulations on an excellent presentation, Clifford. Do you know about the denominator of this study, about patients who had emphysema and lung cancers who did not have surgery? Why didn't they? What was their outcome?

Dr Choong. I do not know the number of patients who were referred with cancer and emphysema and were turned down for surgery. I do not have those data with me.

Dr Mark J. Krasna (Baltimore, Md). Dr Choong, how many of these patients had PET scans as part of their evaluation? Knowing what we've heard about the chances of finding occult micrometastases in lymph nodes and the fact that these patients are high risk, would your group either advocate routine PET scanning in all these patients or would you actually do mediastinoscopies on them first even if they had a negative CT scan?

Dr Choong. The patients now routinely undergo PET scanning if they have either a proven lung cancer or are highly suspicious for lung cancer. Early in the series not all the patients had a PET scan because the technology of PET scan was still evolving. So the answer would be yes; first, PET scan would be performed now. Second, in terms of cervical mediastinoscopy, that would be performed if the patient had proven lung cancer or if the location of the tumor was central or there was CT evidence or PET scan evidence of mediastinal lymph node disease involvement.

Dr Kaiser. Except if it's Dr Cooper's patient, and then you will rest assured that the patient will get a mediastinoscopy.

Dr Walter Weder (Zurich, Switzerland). Why do you exclude all patients with N2 disease since dyspnea is reduced and quality of life improved after this procedure and long-term survival is of minor importance?

Dr Choong. The reason we exclude N2 disease is because we believe that patients with N2 disease have a much poorer prognosis, with a 5-year survival of around 10%. I think this surgery is not something to be taken lightly. I think they were being treated by a very experienced group of surgeons, but patients with N2 disease have poor long-term survival prognosis, and therefore were not offered the treatment.

Dr Darroch W. O. Moores (Albany, NY). I have a technical question. When you do these lobectomies in these patients, do you dissect the fissure or do you staple the fissure mass? Dissecting these fissures, I think, would be a big problem and you would have a lot of air leaks. Is there a different technique for a lobectomy in

this setting as opposed to a lobectomy for straightforward lung cancer without lung volume reduction?

Dr Choong. If you don't mind, I will refer this to the experts.

Dr Cooper. Although some lower lobectomies were done, the most common lobectomy in this situation would be an upper lobectomy, a right upper lobectomy, and although I would prefer normally not to staple a fissure to preserve the volume of the remaining lung, in these cases it would be stapled with a buttressed staple line, but it's usually the last thing done. It otherwise is a complete anatomic lobectomy, like you would do for anything else, with the individual ligation of the vessels and closure of the bronchus, and then finally, at the end, stapling off the fissure with a buttressed staple line.

Dr Peter W. Barrett (*New Haven, Conn*). Dr Kaiser is a proponent of little or no pleural suction. Are you guys in favor of that, and, if so, how many days do you wait?

Dr Cooper. As most of you know, I was maniacal about using suction in the early days of volume reduction, thinking that you

had to get the lung up against the chest wall to stop air leaks. Then I realized that all you're doing is tearing the lung more and that, unlike you or I, a 20% pneumothorax or a little positive pleural pressure does not lead to lung collapse. The patients have obstructive lung disease with loss of elastic recoil and their lungs don't collapse so easily. So that's when we began using only straight drainage, and this resulted in a shortened hospital stay. So our general rule is that they go to water-seal. If there's more than a 50% pneumothorax or if there is compression of remaining lung or if the degree of subcutaneous emphysema is unbearable, then we will put on a little bit of suction. Otherwise we'll leave it on water-seal for a couple of days. If there's a quarter of the chest filled with air, well, it was filled with emphysematous lung before and now it's filled with air—no problem. Then at about 48 hours, if we still have a space and it has become a problem, we might begin to cautiously increase the suction, feeling we're not going to tear the lung quite as much at that stage, by increasing the transpulmonary pressure.

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