Perioperative outcomes of thoracoscopic anatomic resections in patients with limited pulmonary reserve

Swapnil Kachare, BS,^a Elisabeth U. Dexter, MD,^{a,b} Chukwumere Nwogu, MD,^{a,b} Todd L. Demmy, MD,^{a,b} and Sai Yendamuri, MBBS^{a,b}

Background: Preoperative pulmonary function tests are used to assess operability for either lobectomy or pneumonectomy. Current guidelines for defining high-risk patients for anatomic lung resection on the basis of these tests were developed in the era of open thoracotomy. We studied the outcomes of such high-risk patients after video-assisted thoracoscopic surgical resections to assess the performance of these guidelines.

Methods: Records of all patients who underwent anatomic resection from 2001 to 2009 at a single institution were queried for pulmonary function and perioperative outcomes. Patients with predicted postoperative forced expiratory volume in 1 second or predicted postoperative lung carbon dioxide diffusing capacity less than 40% were considered to have limited pulmonary reserve. Perioperative outcomes of patients with limited pulmonary reserve who underwent thoracoscopic resection were documented and compared with those of similar patients who underwent open resection.

Results: Of 600 patients assessed, 70 had limited pulmonary reserve according to our criteria. Forty-seven of them underwent thoracoscopic resection. This cohort had excellent outcomes, with mortality of 2.1%, pneumonia rate of 4.3%, and discharge independence rate of 95.7%. Relative to contemporary patients undergoing open resection (N = 23, including 12 conversions), patients undergoing thoracoscopic resection had lower incidence of pneumonia (4.3% vs. 21.7%, $P < .05$) and shorter intensive care unit stay (2 vs 4 days, $P = .05$).

Conclusions: Patients with marginal lung function tolerate thoracoscopic anatomic resection well. Reassessment of the traditional pulmonary function test guidelines for operability is warranted in the current era of thoracoscopic lung surgery. (J Thorac Cardiovasc Surg 2011;141:459-62)

Current pulmonary function guidelines for patient selection for lung resection were developed in an era of open thoracotomy. Patients previously considered not to be candidates for operation because of poor lung function, however, may be able to tolerate resection with minimally invasive surgery and improved postoperative care. Although some data exist regarding the benefits of thoracoscopic sublobar resection in patients with borderline lung function,¹⁻³ few outcome data are available regarding thoracoscopic lobectomy in this fragile population. We reviewed the morbidity and mortality of patients with limited pulmonary reserve undergoing video-assisted thoracoscopic surgery (VATS) for anatomic lung resection. Secondarily, we compared their outcomes with those of a contemporary cohort of patients undergoing anatomic lung resection by thoracotomy.

MATERIALS AND METHODS

A retrospective review of patients who underwent lobectomy or pneumonectomy during the years 2000 to 2009 at Roswell Park Cancer

Institute, Buffalo, NY, was performed to select patients with predicted postoperative forced expiratory volume in 1 second (FEV₁) less than 40% or a predicted postoperative diffusing capacity of the lung for carbon monoxide (DLCO) less than 40%. Data were obtained from patients' medical charts and electronic medical records with institutional review board approval. Data recorded were age, sex, smoking history, current smoking status, preoperative FEV₁, preoperative DLCO, pathologic stage, complications, and 30-day mortality. The individual predicted postoperative FEV₁ and predicted postoperative DLCO values were calculated by multiplying the preoperative FEV₁ or DLCO by the number of lung segments being removed and then subtracting the calculated amount from the preoperative FEV₁ or DLCO. Adjustments were made with lung perfusion scan data where appropriate. Cardiopulmonary exercise testing was performed in 26 cases. The value of maximum oxygen consumption was available in 23 cases. Perioperative data also tabulated included the incidences of pneumonia, myocardial infarction, atrial fibrillation, adult respiratory distress syndrome, prolonged air leak, intubation, and discharge with chest tube or oxygen therapy; mean total hospital stay; mean intensive care unit stay; and whether the patient was discharged to his or her home or to a rehabilitation facility. Morbidities such as pneumonia and myocardial infarction were counted if they were noted in daily progress notes and supported by radiologic, laboratory, or other diagnostic tests (eg, electrocardiography). Continuous and categorical variables were compared across groups with the Student *t* test and the Fisher's Exact test, respectively.

RESULTS

Of 600 patients from 2001 through 2009 who underwent anatomic resection including lobectomy or pneumonectomy, 70 patients had limited pulmonary reserve according to our criteria. During this same period, 72 patients underwent

From the Department of Surgery,^a State University of New York; and the Department of Thoracic Surgery,^b Roswell Park Cancer Institute, Buffalo, NY.

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Address for reprints: Sai Yendamuri, Roswell Park Cancer Institute, Elm and Carlton Streets, Buffalo, NY 14263 (E-mail: Sai.Yendamuri@RoswellPark.org). 0022-5223/\$36.00

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Abbreviations and Acronyms

DLCO = diffusing capacity of the lung for carbon monoxide

FEV₁ = forced expiratory volume in 1 second

VATS = video-assisted thoracoscopic surgery

wedge resections for lung cancer but are not included in this analysis. Of these 70 patients, 47 patients (66.2%) had a resection completed thoracoscopically. The 23 patients with open resections included 12 patients with VATS procedures that were converted to thoracotomy for the following reasons: pulmonary arterial bleeding (2 patients), adhesions (2 patients), planned conversion (1 patient), and tumor anatomy (eg, sleeve resection required, 7 patients). Table 1 summarizes the patient characteristics in both the VATS and open groups. Patients in the VATS group were older. There were no differences between the 2 surgical groups in predicted postoperative FEV₁ or in predicted postoperative DLCO. There was a significant difference between the number of pneumonectomies in the VATS group (n = 1) and that in the open group (n = 6, *P* = .004). In the analysis of patient groups determined by the intraoperative procedure performed (actual surgery analysis), 10 patients in the VATS group and 7 patients in the open group had both a predicted postoperative FEV₁ and a predicted postoperative DLCO less than 40%. In the intent-to-treat analysis, 13 patients in the VATS group and 4 patients in the open group had both a predicted postoperative FEV₁ and a predicted postoperative DLCO less than 40%. Perioperative variables analyzed for the actual surgery received and the intent-to-treat groups are shown in Tables 2 and 3, respectively.

One patient in the VATS group died in the perioperative period of large bowel ischemia, liver infarction, and sepsis. One patient in the open group died of congestive heart failure. In the actual surgery analysis, the VATS group had a decreased rate of pneumonia (4.3% vs 21.7%, *P* = .035), shorter intensive care unit stay (2 days vs 4 days, *P* = .05), and a trend toward shorter overall hospital stay (7 days vs 10 days, *P* = .058) relative to the open group. In the VATS group both patients who acquired pneumonia had undergone a lobectomy, and in the open group 4 of the total 5 patients with pneumonia had undergone a lobectomy rather than a pneumonectomy. Adult respiratory distress syndrome occurred in more patients in the open group when the intent-to-treat analysis was performed (0% vs 18.2%, *P* = .023). At discharge, only 4.3% or 6.8% of the patients who had undergone VATS were transferred to a rehabilitation facility, versus 17.4% or 18.2% of those with open thoracotomy, according to the actual surgery and intent-to-treat analyses, respectively.

TABLE 1. Patient characteristics

Characteristics	VATS (n = 47)	Open (n = 23)	<i>P</i> value
Age (y, mean)	69.2	59.2	.003125
Sex (male/female)	16/31	11/12	
ASA	2.7	2.5	.265
Preoperative FEV ₁ (%, mean ± SD)	58.5% ± 21%	57.8% ± 14%	.883
Preoperative DLCO (%, mean ± SD)	44% ± 10%	48.0% ± 13%	.219
Predicted postoperative FEV ₁ (%, mean ± SD)	46.1% ± 17%	41.7% ± 11%	.201
Predicted postoperative DLCO (%, mean ± SD)	34.8% ± 8%	34.8% ± 11%	.985
Smoking status (no.)			
Current smoker	8 (17.0%)	4 (17.4%)	>.999
Nonsmoker or previous smoker	34 (72.3%)	12 (52.2%)	
Unknown	5 (10.6%)	7 (30.4%)	
TNM stage (no.)			
T1	17 (36.2%)	7 (30.4%)	.780
T2	22 (46.8%)	9 (39.1%)	.614
T3	0 (0%)	2 (8.7%)	.105
T4	1 (2.1%)	2 (8.7%)	.250
N0	32 (68.1%)	8 (34.9%)	.127
N1	6 (12.8%)	8 (34.9%)	.051
N2	2 (4.3%)	0 (0%)	>.999
N3	0 (0%)	0 (0%)	>.999
M1	1 (2.1%)	0 (0%)	>.999
Clinical stage (no.)			
IA	14 (29.8%)	6 (26.1%)	>.999
IB	17 (36.2%)	4 (17.4%)	.165
IIA	2 (4.3%)	1 (4.3%)	>.999
IIB	3 (6.4%)	6 (26.1%)	.051
IIIA	2 (4.3%)	1 (4.3%)	>.999
IIIB	1 (2.1%)	2 (8.7%)	.250
IV	1 (2.1%)	0 (0%)	>.999
Resection type (no.)			
Lobectomy	45 (95.7%)	16 (69.6%)	.004
Right upper lobe	14 (29.9%)	2 (8.7%)	.069
Right middle lobe	3 (6.4%)	2 (8.7%)	>.999
Right lower lobe	8 (17.0%)	3 (13.0%)	>.999
Left upper lobe	12 (25.5%)	5 (21.7%)	>.999
Left lower lobe	8 (17.0%)	4 (17.4%)	>.999
Bilobectomy (no.)	1 (2.1%)	1 (4.3%)	>.999
Right upper lobe and right middle lobe	1 (2.1%)	1 (4.3%)	>.999
Pneumonectomy (no.)	1 (2.1%)	6 (26.1%)	.004
Right lung	1 (2.1%)	2 (8.7%)	.250
Left lung	0 (0%)	4 (17.4%)	.010

VATS, Video-assisted thoracoscopic surgical group; ASA, American Society of Anesthesiologists physical status classification; FEV₁, forced expiratory volume in 1 second; DLCO, diffusing capacity of lung for carbon monoxide.

DISCUSSION

Anatomic surgical resection offers the best chance of cure for patients with resectable lung cancer. Thoracoscopic resections are associated with lower morbidity than are

TABLE 2. Comparison between video-assisted thoracoscopic surgical and open groups: Actual surgery analysis

	VATS (n = 47)	Open (n = 23)	P value
Pneumonia (no.)	2 (4.3%)	5 (21.7%)	.035
Myocardial infarction (no.)	0 (0%)	2 (8.7%)	.105
Atrial fibrillation (no.)	7 (14.9%)	0 (0%)	.087
Adult respiratory distress syndrome (no.)	0 (0%)	2 (8.7%)	.105
Intubation >24 h (no.)	2 (4.3%)	2 (8.7%)	.593
Discharge with chest tube (no.)	4 (8.5%)	0 (0%)	.295
Prolonged air leak (>5 d, no.)	6 (12.8%)	4 (17.4%)	.72
Oxygen at discharge (no.)	20 (42.6%)	10 (43.5%)	>.999
Oxygen at >4 wk (no.)	6 (12.9%)	5 (21.7%)	.49
Mean total stay (d)	7	10	.058
Mean intensive care unit stay (d)	2	4	.05
Rehabilitation (no.)	2 (4.3%)	4 (17.4%)	.09
Mortality (no.)	1 (2.1%)	1 (4.3%)	>.999

VATS, Video-assisted thoracoscopic surgical group.

open resections. These benefits are likely to be greater for high-risk patients, a group including patients with limited pulmonary reserve. For these patients, the decision to perform the oncologically optimal lobectomy or pneumonectomy rather than a wedge resection or a segmentectomy must be weighed against the mortality and morbidity associated with the larger resection. Selection criteria for these patients typically include a combination of standard pulmonary function testing with perfusion scans and pulmonary exercise testing.⁴ These tests, although imperfect,⁵ remain the most objective criteria available. The decision-making algorithm for selection for surgery is uniform across all surgeons at our institution. Although the decision to offer surgery depends on the overall functional status of the patient

TABLE 3. Comparison between video-assisted thoracoscopic surgical and open groups: Intent-to-treat analysis

	VATS (n = 59)	Open (n = 11)	P value
Pneumonia (no.)	5 (8.5%)	2 (18.2%)	.302
Myocardial infarction (no.)	1 (1.7%)	1 (9.1%)	.292
Atrial fibrillation (no.)	7 (11.9%)	0 (0%)	.587
Adult respiratory distress syndrome (%)	0 (0%)	2 (18.2%)	.023
Intubation >24 h (no.)	4 (6.8%)	0 (0%)	>.999
Discharge with chest tube (no.)	4 (6.8%)	0 (0%)	>.999
Prolonged air leak (>5 d, no.)	9 (15.3%)	1 (9.1%)	>.999
Oxygen at discharge (no.)	27 (45.8%)	3 (27.3%)	.331
Oxygen at >4 wk (no.)	9 (15.3%)	2 (18.2%)	>.999
Mean total stay (d)	7	12	.10
Mean intensive care unit stay (d)	2	4	.17
Home with or without home health care (no.)	54 (91.5%)	8 (72.7%)	.242
Rehabilitation (no.)	4 (6.8%)	2 (18.2%)	.242
Mortality (no.)	1 (1.7%)	1 (9.1%)	>.999

VATS, Video-assisted thoracoscopic surgical group.

coupled with objective pulmonary function tests, data from perfusion scans and cardiopulmonary exercise tests are included in the decision-making process. In general, we use a guideline of maximum oxygen consumption less than 10 mL/(kg · min) to exclude a surgical anatomic resection.

The primary focus of our analysis was the assessment of outcome of VATS resections in this high-risk population. The comparison with a contemporary group undergoing open resection was secondary and performed with the understanding that this comparison is statistically challenged by the small numbers in the open group. An audit of our perioperative data presented here demonstrates that thoracoscopic lobectomy is safe for patients with limited pulmonary reserve and may provide an advantage relative to open lobectomy. The morbidity and mortality associated with VATS resections presented here compare favorably with outcomes of anatomic surgical resections in patients considered to be at normal risk. The incidence of pneumonia among patients undergoing VATS lung resection in our series is comparable to incidences reported by Paul and colleagues⁶ and Villamazar and associates.⁷ The incidence of pneumonia among patients who underwent open lung resection in our series is comparable to incidences in other series of patients with less compromised lung function.⁸⁻¹⁰ The higher rate of pneumonia is not unexpected among patients with compromised pulmonary function after lung resection by thoracotomy. The etiology is likely multifactorial and related to the increased pain, the abnormality of chest wall mechanics, and the decreased ability to cough, breathe deeply, and ambulate after thoracotomy, all of which contribute to an increased risk for pneumonia. Although significantly more patients in our open group underwent pneumonectomy, only 1 of the 5 patients in the open group who acquired pneumonia had undergone pneumonectomy; the other 4 had undergone lobectomy. The higher incidence of pneumonia in the open group thus cannot be ascribed to the higher number of pneumonectomies in that group. Rates of atrial fibrillation, renal failure, and prolonged air leak, duration of chest tube, hospital stay, and mortality are comparable to values in other series of patients with less compromised pulmonary function.

In our series, although patients who underwent VATS lung resection were older, they had a lower incidence of postoperative pneumonia than did patients who underwent thoracotomy. The decreased incidence of pneumonia among these patients likely contributed to their shorter intensive care unit and overall stays and to their decreased need for transfer to a rehabilitation facility. These favorable outcomes support careful consideration of VATS lobectomy for patients with predicted postoperative FEV₁ and predicted postoperative DLCO of 40% or less. We recognize that a small number of patients who have unanticipated conversion to thoracotomy may end up with chronic debilitating respiratory status. This is reflected by the decrease in

the differences in the benefits of VATS in the intent-to-treat analysis. We recommend that such challenging cases not be undertaken by the surgeon negotiating his or her learning curve with thoroscopic resections. In experienced hands, however, thoroscopic resections for such high-risk patients may provide outcomes equivalent to open resections in patients considered to be at normal risk.

We recognize that any conclusions and analyses based on our data are limited by the small numbers and retrospective nature of our study. In light of our limited numbers, a statistically relevant comparison of the patients with conversion to those undergoing planned open surgery cannot be made. These issues, however, deserve further scrutiny with larger surgical databases.

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