Thoracoscopic lobectomy is associated with acceptable morbidity and mortality in patients with predicted postoperative forced expiratory volume in 1 second or diffusing capacity for carbon monoxide less than 40% of normal

Bryan M. Burt, MD,[a] Andrzej S. Kosinski, PhD,[b] Joseph B. Shrager, MD,[a] Mark W. Onaitis, MD,[c] and Tracey Weigel, MD[d]

Objective: A predicted postoperative (ppo) forced expiratory volume in 1 second (FEV1%) or diffusing capacity of the lung for carbon monoxide (DLCO%) of <40% has traditionally been considered to convey a high risk of lobectomy owing to elevated postoperative morbidity and mortality. These recommendations, however, were largely derived from the pre–video-assisted thoracoscopic surgical (VATS) era. We hypothesized that VATS lobectomy would be associated with acceptable morbidity and mortality at ppoFEV1% and ppoDLCO% values < 40%.

Methods: PpoFEV1% and ppoDLCO% were calculated for patients undergoing open or VATS lobectomy for lung cancer in the Society of Thoracic Surgeons General Thoracic database from 2009 to 2011. Univariate comparisons, multivariate analyses, and 1:1 propensity matching were performed.

Results: A total of 13,376 patients underwent lobectomy (50.9% open, 49.1% VATS). A decreased ppoFEV1% and ppoDLCO% were each independent predictors for both cardiopulmonary complications and mortality in the open group (all $P \leq .008$). In the VATS group, ppoFEV1% was an independent predictor of complications ($P = .001$) but not mortality ($P = .77$), and ppoDLCO% was an independent predictor of complications ($P = .046$) and mortality ($P = .008$). With decreasing ppoFEV1% or ppoDLCO%, complications and mortality increased at a greater rate in the open lobectomy than in a propensity-matched VATS group (n = 4215 each). For patients with ppoFEV1% < 40%, mortality was greater in the open (4.8%) than in the matched VATS group (0.7%, $P = .003$). Similar results were seen for ppoDLCO% < 40% (5.2% open, 2.0% VATS, $P = .003$). The rate of complications was significantly greater at ppoFEV1% < 40% in the open (21.9%) than in the matched VATS (12.8%, $P = .005$) group and similar results were seen with ppoDLCO% < 40% (14.9% open, 10.4% VATS, $P = .016$).

Conclusions: VATS lobectomy can be performed with acceptable rates of morbidity and mortality in patients with reduced ppoFEV1% or ppoDLCO%. (J Thorac Cardiovasc Surg 2014;148:19-29)

Supplemental material is available online.

Lobectomy is the optimal treatment of early-stage lung cancer.[1,2] Patients considered for lobectomy often have existing pulmonary disease, and pulmonary function tests have become a cornerstone in the preoperative physiologic assessment of those evaluated for surgical resection. The forced expiratory volume in 1 second (FEV1) and diffusing capacity of the lung for carbon monoxide (DLCO) are the most commonly used pulmonary function tests, and their values have correlated inversely with postoperative mortality, complications, and respiratory failure after pulmonary resection.[3-12]

FEV1 and DLCO readouts have been considered as absolute values (eg, in expired volume for FEV1) and as a "percentage of predicted" value that has been normalized to population data for age, gender, height, and race. The use of the percentage of predicted FEV1 (FEV1%) and percentage of predicted DLCO (DLCO%) prevents bias against older patients, women, and those of small stature. FEV1% and DLCO% have been shown to correlate more

From the Department of Cardiothoracic Surgery,[a] Stanford University School of Medicine, Stanford, Calif; Department of Biostatistics and Bioinformatics[b] and Division of Thoracic Surgery,[c] Department of Surgery, Duke University Medical Center, Durham, NC; and Department of Cardiothoracic Surgery,[d] Maine Medical Center, Portland, Maine.

Disclosures: Authors have nothing to disclose with regard to commercial support.

Read at the 93rd Annual Meeting of The American Association for Thoracic Surgery, Minneapolis, Minnesota, May 4-8, 2013.

Received for publication April 29, 2013; revisions received March 4, 2014; accepted for publication March 10, 2014; available ahead of print April 22, 2014.

Address for reprints: Bryan M. Burt, MD, Department of Cardiothoracic Surgery, Stanford University School of Medicine, Stanford Hospitals and Clinics, 300 Pasteur Dr, Falk Building CV-227, Stanford, CA 94305 (E-mail: bburt@stanford.edu).

0022-5223/$36.00

http://dx.doi.org/10.1016/j.jtcvs.2014.03.007

Abbreviations and Acronyms

DLCO = diffusing capacity of the lung for carbon monoxide
DLCO% = percentage of predicted DLCO
FEV1 = forced expiratory volume in 1 second
FEV1% = percentage of predicted FEV1
ppo = predicted postoperative
VATS = video-assisted thoracoscopic surgical

accurately with postoperative morbidity and mortality than do their absolute values.[9]

FEV1% and DLCO% have been further refined to predicted postoperative (ppo) parameters of FEV1% (ppoFEV1%) and DCLO% (ppoDLCO%). These are values calculated preoperatively to estimate the degree of lung function that will remain after pulmonary resection. Ppo values have been suggested to more accurately stratify postoperative risk by normalizing to the extent of resection. For instance, these parameters take into consideration the differing amount of functional lung parenchyma that would remain after sublobar resection, lobectomy, or pneumonectomy. This approach can be useful in lobectomy candidates, in that a variable amount of lung parenchyma will remain after resection, depending on which lobe has been resected. In this regard, several investigators have demonstrated stronger relationships between ppoFEV1% and ppoDLCO% and postoperative risk after pulmonary resection compared with their parent FEV1% and DLCO% values.[7,8,10-12] Such comparisons have not, however, been analyzed using data from a large multi-institutional database.

ppoFEV1% and ppoDLCO% values of <40% of normal have traditionally been thought to indicate an increased operative risk for patients undergoing lobectomy. This impression has been derived mostly from single-institution data, relatively small patient cohorts, and populations that often included patients undergoing pneumonectomy (reviewed by Colice and colleagues[3]). In contrast, others have reported successful lung cancer resection in patients with severely reduced postoperative predicted lung function, with reasonable rates of morbidity and mortality.[13-16] The study populations in these reports, however, generally included a range of pulmonary resections, spanning sublobar resection to pneumonectomy.

It has become increasingly evident that video-assisted thoracoscopic surgical (VATS) lobectomy has an advantage over thoracotomy with regard to postoperative morbidity. Compared with matched patients undergoing thoracotomy and lobectomy, VATS lobectomy had a lower incidence of arrhythmia, reintubation, and blood transfusion.[17,18] An open surgical approach has also been shown to be an independent predictor of pulmonary complications, when compared with VATS.[19] Differences in postoperative mortality between VATS and open lobectomy have been more difficult to show, perhaps because of the overall small number of events.

We therefore set out to crystallize the utility of ppoFEV1% and ppoDLCO% in the prediction of postoperative cardiopulmonary complications and mortality in patients undergoing lobectomy for lung cancer, by the VATS and the open approach, using a multi-institution national general thoracic surgery database.

METHODS

The Society of Thoracic Surgeons General Thoracic Database (version 2.081, representing 2009 to 2011) was queried to identify a cohort of patients undergoing lobectomy for lung cancer in which ppoFEV1% and ppoDLCO% could be calculated. This required availability of data for FEV1% and DLCO%, laterality of the primary surgical procedure, and lobe resected (categories of disease including lung cancer, upper lobe [code 162.3], lung cancer, middle lobe [code 162.4], or lung cancer, lower lobe [code 162.5]). Because the coding nomenclature in version 2.081 of the database clusters VATS lobectomies and segmentectomies under a single designation (Common Procedural Terminology code 32663), segmentectomies and lobectomies were analyzed as a combined group in both the open and VATS cohorts. For reference, the rates of segmentectomy in the previous version of the database (version 2.07) were similar (open, 6.5%; VATS, 8%).[20] Patients undergoing sleeve lobectomy were intentionally excluded.

ppoFEV1% and ppoDLCO% were derived using the anatomic method in which preoperative FEV1% or DLCO% is multiplied by the fraction of the functional lung segments expected to remain after lobectomy. The ppoFEV1% values were calculated using the equation ppoFEV1% = measured FEV1% × (19 − number of segments resected)/19. The number of segments resected was assigned as 3 for right upper lobectomy, 2 for middle lobectomy, 5 for right lower lobectomy, 5 for left upper lobectomy, and 4 for left lower lobectomy.[4,11,19,20] The ppoDLCO% was calculated in a similar manner.

Mortality was defined as death within 30 days or before discharge after lobectomy. Cardiopulmonary complications were considered any of the following: atelectasis requiring bronchoscopy, pneumonia, adult respiratory distress syndrome, bronchopleural fistula, pulmonary embolus, initial ventilator support >48 hours, reintubation, tracheostomy, ventricular arrhythmia requiring treatment, and myocardial infarction.

Statistical analyses were approved through the Society of Thoracic Surgeons General Thoracic Database committee and performed as part of a contracted agreement with the Duke Clinical Research Institute. Comparisons of the preoperative characteristics between the groups were performed using the 2-sample nonparametric Wilcoxon test for continuous variables and the Fisher exact test for categorical variables. To identify correlates of cardiopulmonary complications and mortality, generalized mixed regression models with logit link and binomial error were considered separately for the open and VATS lobectomy cohorts. Hospital (participant) was considered as a random effect. When developing the multivariable models, we first considered univariable regressions to evaluate the univariable associations of each variable in Table 1 with each outcome. The multivariable analysis initially considered variables with a univariable P value < .10. Final models were created by manual backward selection with confirmatory forward selection, and variables with $P < .05$ were retained. The variables of primary interest, ppoFEV1% and ppoDLCO%, were added last to the developed models to evaluate their incremental value. Generalized mixed models were fit with the Statistical Analysis Systems, version 9.3, statistical software (SAS Institute, Cary,