



The Society of Thoracic Surgeons Lung Cancer Resection Risk Model: Higher Quality Data and Superior Outcomes

Felix G. Fernandez, MD, MS, Andrzej S. Kosinski, PhD, William Burfeind, MD, Bernard Park, MD, Malcolm M. DeCamp, MD, Christopher Seder, MD, Blair Marshall, MD, Mitchell J. Magee, MD, Cameron D. Wright, MD, and Benjamin D. Kozower, MD, MPH

Emory University, Atlanta, Georgia; Duke Clinical Research Institute, Durham, North Carolina; St. Luke's Health Network, Allentown, Pennsylvania; Memorial Sloan Kettering Cancer Center, New York, New York; Northwestern University, Chicago, Illinois; Rush University, Chicago, Illinois; Georgetown University, Washington, DC; Medical City Hospital, Dallas, Texas; Massachusetts General Hospital, Boston, Massachusetts; and University of Virginia, Charlottesville, Virginia

Background. The Society of Thoracic Surgeons (STS) creates risk-adjustment models for common cardiothoracic operations for quality improvement purposes. Our aim was to update the lung cancer resection risk model utilizing the STS General Thoracic Surgery Database (GTSD) with a larger and more contemporary cohort.

Methods. We queried the STS GTSD for all surgical resections of lung cancers from January 1, 2012, through December 31, 2014. Logistic regression was used to create three risk models for adverse events: operative mortality, major morbidity, and composite mortality and major morbidity.

Results. In all, 27,844 lung cancer resections were performed at 231 centers; 62% (n = 17,153) were performed by thoracoscopy. The mortality rate was 1.4% (n = 401), major morbidity rate was 9.1% (n = 2,545), and the composite rate was 9.5% (n = 2,654). Predictors of mortality included age, being male, forced expiratory volume in 1 second, body mass index, cerebrovascular

disease, steroids, coronary artery disease, peripheral vascular disease, renal dysfunction, Zubrod score, American Society of Anesthesiologists rating, thoracotomy approach, induction therapy, reoperation, tumor stage, and greater extent of resection (all $p < 0.05$). For major morbidity and the composite measure, cigarette smoking becomes a risk factor whereas stage, renal dysfunction, congestive heart failure, and cerebrovascular disease lose significance.

Conclusions. Operative mortality and complication rates are low for lung cancer resection among surgeons participating in the GTSD. Risk factors from the prior lung cancer resection model are refined, and new risk factors such as prior thoracic surgery are identified. The GTSD risk models continue to evolve as more centers report and data are audited for quality assurance.

(Ann Thorac Surg 2016;102:370–7)

© 2016 by The Society of Thoracic Surgeons

The Society of Thoracic Surgeons (STS) has utilized its clinical registry, the STS National Database, to create risk-adjustment models to predict outcomes for common cardiothoracic operations based on patient characteristics [1–6]. These risk models inform clinical decision making and allow cardiothoracic surgeons to analyze their risk-adjusted outcomes for purposes of quality improvement. With regular feedback of results to participating sites, outcomes for major cardiothoracic procedures have continued to improve over time. In part owing to these risk-adjustment models, the STS National Database is

recognized as the premier clinical data registry in the United States.

In 2008, the first risk model for lung cancer resection was created utilizing the STS General Thoracic Surgery Database (GTSD) [4]. The primary clinical outcome measure in this model was postoperative length of hospital stay, as the database was relatively small and there were relatively few numbers of complications to allow for creation of a robust model. As the penetrance of the GTSD increased, the lung cancer resection model was updated in 2010 [5]. With the availability of more data, outcome measures at that time were changed to mortality, major morbidity, and composite mortality and major morbidity.

Since the publication of the last lung cancer resection risk model, several important changes have occurred in the general thoracic surgical community and with the GTSD. The use of minimally invasive techniques for pulmonary resections has become more widely

Accepted for publication Feb 12, 2016.

Presented at the Sixty-second Annual Meeting of the Southern Thoracic Surgical Association, Orlando, FL, Nov 4–7, 2015.

Address correspondence to Dr Fernandez, The Emory Clinic, 1365 Clifton Rd NE, Ste A2214, Atlanta, GA 30322; email: felix.fernandez@emoryhealthcare.org.

disseminated in the thoracic surgical community, particularly among surgeons submitting to the STS GTSD. In addition, the penetrance of the GTSD has increased and, consequently, the number of centers submitting data and the number of patients included in the database has significantly increased. Furthermore, in part owing to education of data abstractors, the amount of missing data in the GTSD has notably decreased. That allows the use of more representative data in the generation of risk models. Finally, the GTSD has also undergone regular external audits since the creation of the last risk model, and high degree of accuracy in the data fields has been demonstrated [7]. Our objective was to update the STS GTSD lung cancer resection risk model on a larger, contemporary cohort of patients.

Material and Methods

The Society of Thoracic Surgeons Database

In 2002, The STS formally established the GTSD component of the STS National Database as a voluntary effort to support continued quality improvement efforts of thoracic surgeons and hospitals. The GTSD provides participating members with risk-adjusted national thoracic surgical benchmarks for lung and esophageal cancer resections. Risk-adjusted short-term results are provided to participating institutions on a twice-yearly basis. The STS GTSD has been externally audited since 2010 [7]. Audits have demonstrated high agreement rates with hospital records and validated the accuracy and completeness of the data. Each participating center exempted this investigation from formal Institutional Review Board approval as it represents an analysis of data collected for quality review and secondary research purposes with the absence of Health Insurance Portability and Accountability Act patient identifiers.

Patient Population

We queried the STS GTSD for patients treated with surgical resection for primary lung cancer from January 1, 2012 through December 31, 2014. Surgical procedures included were the following: wedge resection, segmentectomy, lobectomy, sleeve lobectomy, bilobectomy, and pneumonectomy. Patients were excluded if they had an extrapleural pneumonectomy, completion pneumonectomy, carinal pneumonectomy, occult carcinoma or benign disease on final pathology, or an urgent, emergent, or palliative operation. Furthermore, patients with missing age, sex, discharge mortality status, and predicted forced expiratory volume in 1 second were also excluded. Of 28,473 patients eligible for analysis, 629 (2.2%) were excluded from analysis, resulting in a final cohort of 27,844.

Outcome Measures

The primary outcome measures were operative mortality and major morbidity, as done in prior STS GTSD risk models [5]. Postoperative events were defined according to the STS GTSD [8]. A death during the index

hospitalization for surgery or within 30 days of the procedure is classified as an operative mortality. Major morbidity was previously defined in the first GTSD lung cancer resection risk model through empiric selection of important adverse outcomes [5]. These include tracheostomy, reintubation, initial ventilatory support longer than 48 hours, adult respiratory distress syndrome, bronchopleural fistula, pulmonary embolus, pneumonia, unexpected return to the operating room (changed from bleeding requiring reoperation), and myocardial infarction. Three separate outcomes were examined: mortality, major morbidity, and composite mortality and major morbidity. Mortality is the most extreme complication but has a low event rate. Examining major morbidity and the composite measure allows for comparison of participants.

Covariate Selection

Covariates included for risk adjustment were selected a priori from the most recent version of the STS GTSD data collection instrument (version 2.2). Diffusion capacity of the lung for carbon monoxide was excluded from analysis owing to 14% (3,805) missingness. An imputation approach was not used for diffusion capacity of the lung for carbon monoxide as the authors believed that the missing at random assumption was not met. Body mass index was missing in only 1% of population and was imputed by a sex-specific median. Table 1 depicts the baseline characteristics selected for analysis in our patient cohort.

Statistical Analysis

Three multivariable hierarchical logistic regression models were created to estimate the association of patient baseline characteristics with the primary outcome measures of mortality, morbidity, and composite mortality and morbidity. A hierarchical model with participant-specific random effects was utilized to account for potential dependence between patient outcomes within a participant. The composite outcome was defined as having either mortality or at least one major morbidity. All covariates were retained in the models. Model discrimination was assessed by examining the area under the receiver-operating character curve (C-statistic). Model calibration was assessed with the Hosmer-Lemeshow goodness-of-fit test.

Additionally, we examined variation in hospital performance for the composite outcome of mortality or major morbidity. The same hierarchical model as above was utilized but the Bayesian approach facilitated computation of a standardized incidence ratio (SIR) for each hospital (participant), along with 95% Bayesian credible intervals. The SIRs summarize participant performance variation, as previously described [4, 6]. The SIR is the ratio between the participant's risk-adjusted rate and the risk-adjusted rate of a hypothetical average participant. A SIR greater than 1.0 is consistent with a higher risk-adjusted mortality or major morbidity in comparison with an average participant. Analyses were performed using SAS 9.4 statistical

Table 1. Patient Baseline Characteristics

Variable	Values
Total	27,844 (100)
Age, years	67.2 ± 10.1
Male	12,647 (45.4)
Race	
White	24,099 (87.0)
Black	2,369 (8.6)
Other	1,217 (4.4)
Body mass index, kg/m ^{2a}	27.6 ± 6.2
Coronary artery disease	6,196 (22.3)
Diabetes mellitus	5,158 (18.5)
Renal dysfunction	504 (1.8)
Induction chemotherapy or radiation	1,801 (6.5)
Cigarette smoking	
Never	3,895 (14.0)
Past (stopped more than 1 month)	17,368 (62.4)
Current	6,581 (23.6)
Steroids	965 (3.5)
Minimally invasive	17,153 (61.6)
Thoracotomy	10,691 (38.4)
Primary procedure	
Wedge resection	3,815 (13.7)
Segmentectomy	1,685 (6.1)
Lobectomy	19,836 (71.2)
Sleeve lobectomy	412 (1.5)
Bilobectomy	980 (3.5)
Pneumonectomy	1,116 (4.0)

^a Missing values imputed to median by sex.

Values are n (%) or mean ± SD.

package utilizing the GLIMMIX and MCMC modules (SAS Institute, Cary, NC).

Results

A query of the STS GTSD from January 1, 2012, through December 31, 2014, revealed 27,844 patients having undergone surgery for primary lung cancer from 231 centers. Baseline patient characteristics are depicted in Table 1. The majority of patients were Caucasian (87.0%) with a past or current history of smoking (86.0%), a Zubrod performance status of 0 or 1 (95.8%; 26,678 of 27,844), and an American Society of Anesthesiologists (ASA) rating of 3 (75.3%; 20,953 of 27,844). More than half of pulmonary resections for lung cancer were performed through thoracoscopy (61.6%).

Rates of individual major morbidities in lung cancer surgery patients are shown in Table 2. The rates of other important postoperative complications are shown as well. The operative mortality rate was 1.4% (n = 401), major morbidity rate was 9.1% (n = 2,545), and the composite major morbidity or mortality rate was 9.5% (n = 2,654). Table 3 demonstrates these rates stratified by procedure type.

Table 2. Frequency of Complications

Variable	Values
Tracheostomy	283 (1.0)
Reintubation	899 (3.2)
Initial ventilatory support >48 hours	148 (0.5)
Adult respiratory distress syndrome	159 (0.6)
Bronchopleural fistula	149 (0.5)
Pulmonary embolus	131 (0.5)
Pneumonia	1,116 (4.0)
Unexpected return to operating room	1050 (3.8)
Myocardial infarction	92 (0.3)
Deep vein thrombosis requiring treatment	148 (0.5)
Atrial arrhythmia requiring treatment	2,974 (10.7)
Renal failure, RIFLE criteria	209 (0.8)
Blood transfusion	
Intraoperative	696 (2.5)
Postoperative	1438 (5.2)
Sepsis	189 (0.7)
Chylothorax	
Requiring surgical ligation	49 (0.2)
Medical treatment only	100 (0.4)
Recurrent laryngeal nerve paralysis	139 (0.5)

Values are n (%).

RIFLE = Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease.

In Table 4, the three multivariable logistic regression models demonstrating the relation of patient baseline characteristics to the outcome measures of mortality, major morbidity, and composite mortality and major morbidity are shown. The C-statistics for the models are 0.78 for mortality, 0.68 for major morbidity, and 0.68 for composite mortality and major morbidity. Significant predictors of operative mortality included age, being male, body mass index (BMI), steroids use, congestive heart failure, coronary artery disease, peripheral vascular disease, reoperation, cerebrovascular disease, forced expiratory volume in 1 second, induction therapy, renal dysfunction, Zubrod score, ASA rating, thoracotomy approach, tumor stage, and greater extent of pulmonary resection. For operative mortality, predictors with a large effect included a Zubrod score of 2 or greater, an ASA rating of 4 or 5, a thoracotomy operative approach, stage IV cancer, and a bilobectomy or pneumonectomy. For major morbidity cigarette smoking increases the risk of complications by 60%, whereas stage, renal dysfunction, congestive heart failure, and cerebrovascular disease lose significance. A large effect is observed for lobectomy, sleeve lobectomy, bilobectomy, and pneumonectomy, with the risk increasing with extent of resection. Finally, for the composite mortality and morbidity model, similar predictors are observed as seen in the morbidity model.

The SIRs with 95% Bayesian credible intervals for the composite measure of mortality and major morbidity for all 231 hospitals are shown in Figure 1. There is no overlap in credible intervals between some of the best

Table 3. Mortality, Major Morbidity, and Composite Mortality or Major Morbidity Rates Stratified by Procedure Type

Procedure	Mortality	Major Morbidity	Composite Mortality or Major Morbidity
Wedge	0.8 (30/3,815)	5.3 (204/3,815)	5.6 (214/3,815)
Segmentectomy	0.8 (14/1,685)	6.5 (109/1,685)	7.0 (118/1,685)
Lobectomy	1.3 (262/19,836)	9.3 (1,852/19,836)	9.7 (1,920/19,836)
Sleeve lobectomy	1.7 (7/412)	12.1 (50/412)	12.9 (53/412)
Bilobectomy	3.4 (33/980)	15.3 (150/980)	15.7 (154/980)
Pneumonectomy	4.9 (55/1,116)	16.1 (180/1,116)	17.5 (195/1,116)

Values are % (n/N).

performing sites (3.5%; 8 of 231 sites with upper limit below 1) and worst performing sites (6.9%; 16 of 231 sites with lower limit above 1), indicating that this model provides meaningful discrimination between best and worst performers.

Comment

Surgeons submitting data to the STS GTSD perform surgical resection for lung cancer with low mortality and morbidity. Important predictors of mortality and major morbidity after lung cancer resection are identified with these models. Knowledge of such predictors informs clinical decision making by allowing physicians and patients to focus on individual patient characteristics and their impact on outcomes. These models replace prior versions of the lung cancer resection risk models [5]. The STS will utilize these models to provide risk-adjusted outcomes for lung cancer resection with respect to operative mortality, major morbidity, and composite mortality or morbidity. Centers will continue to receive feedback on their results, and centers of excellence and underperformers will be identified. Without knowledge of such outcomes, true quality improvement cannot occur.

Operative mortality in the GTSD has decreased from 2.2% in the years 2002 to 2008 to 1.4% from 2012 to 2014 [5]. These data represent the highest quality lung cancer surgery in the United States. Kozower and colleagues [9] have previously demonstrated that compared with the Nationwide Inpatient Sample database, from 2002 to 2008, patients in the GTSD had lower unadjusted discharge mortality rates, median length of stay, and pulmonary complication rates for lobectomy. The major morbidity rate has increased from 8.6% to 9.1% during the same time. A potential explanation for this observation is more complete coding of complications by data abstractors as the result of education efforts from STS, as well as inclusion of unexpected return to the operating room for any reason instead of only for bleeding.

We identified several predictors of operative mortality after lung cancer resection. The Zubrod performance score continues to be a strong predictor of mortality, and has demonstrated good predictive ability in other settings [10]. The ASA rating, a surrogate for patient comorbidities, also continues to predict mortality. Zubrod score and ASA also predict major morbidity and the composite mortality or major morbidity outcome. Coronary artery disease and peripheral vascular disease were predictors

of all three outcome measures, whereas cerebrovascular disease and renal dysfunction were predictors of mortality. All are markers of systemic atherosclerosis, and their importance is intuitive.

Operative approach had a significant effect on all three models, with a thoracotomy approach predicting worse outcomes. The utilization of thoracoscopy increased from 36.9% in the first risk model to 61.6% in the current analysis. Such a finding is expected, as Paul and colleagues [11] have demonstrated decreased morbidity with thoracoscopy compared with thoracotomy approaches to lobectomy in an analysis of GTSD data. Further, as previously identified, the extent of pulmonary resection was found to be predictive of adverse events. In comparison to a nonanatomic wedge resection, lobectomy, sleeve lobectomy, bilobectomy, and pneumonectomy were all significant predictors; sleeve resections, bilobectomies, and pneumonectomies had particularly large effects. That is consistent with a GTSD review of 1,267 pneumonectomies from 2002 to 2007 by Shapiro and colleagues [12] that determined perioperative major morbidity occurred in 30.4% and mortality in 5.6%.

Older age and being male continue to be predictors of all three outcome measures. Being male has consistently been identified as a negative predictor in other lung cancer surgery models [13, 14]. Increasing BMI is protective against major morbidity and composite mortality and major morbidity in this analysis, whereas a very low BMI indicates higher risk. Prior GTSD analysis has found an association with higher BMI and operative times for lobectomy but not complications [15].

A reoperation is a predictor of adverse outcomes in our updated models, as opposed to the last iteration of the lung cancer resection models. That may be the result of the use of a different definition. Rather than any prior cardiothoracic operation, the variable used in the present model was any prior cardiothoracic surgery that affects the operative field. The administration of induction chemotherapy or radiation and the use of systemic steroids were also significant predictors.

A lower percent predicted forced expiratory volume in 1 second increased the risk of all adverse outcomes, similar to what has been previously identified. Being a current smoker was also identified as increasing risk of major morbidity and the composite measure. Mason and colleagues [16] have examined this association in the GTSD and found that current smoking status confers a greater risk of mortality and pulmonary complications.

Table 4. Predictors of Mortality, Major Morbidity, and Composite Mortality and Major Morbidity^a

Variable	Mortality Model OR (95% CI)	p Value	Major Morbidity Model OR (95% CI)	p Value	Composite Model (Mortality or Major Morbidity) OR (95% CI)	p Value
Age, 10-year increase	1.64 (1.44–1.87)	<0.001	1.13 (1.08–1.19)	<0.001	1.14 (1.08–1.90)	<0.001
Male	1.54 (1.23–1.92)	<0.001	1.39 (1.28–1.52)	<0.001	1.41 (1.29–1.53)	<0.001
Body mass index, kg/m ²		0.006		<0.001		<0.001
≥18.5 to <25	1.00		1.00		1.00	
≥6.0 to <18.5	1.44 (0.85–2.44)		1.33 (1.07–1.65)		1.35 (1.09–1.66)	
≥25.0 to <30.0	0.96 (0.75–1.22)		0.83 (0.75–0.91)		0.83 (0.75–0.92)	
≥30.0 to <35.0	0.61 (0.43–0.85)		0.72 (0.64–0.82)		0.72 (0.63–0.82)	
≥35.0 to ≤99.9	1.17 (0.82–1.67)		0.81 (0.69–0.96)		0.83 (0.71–0.97)	
Hypertension	0.93 (0.73–1.17)	0.51	1.08 (0.98–1.19)	0.12	1.06 (0.96–1.16)	0.25
Steroids	1.72 (1.14–2.60)	0.01	1.28 (1.05–1.57)	0.017	1.33 (1.09–1.62)	0.005
Congestive heart failure	1.51 (1.01–2.25)	0.046	1.17 (0.95–1.44)	0.15	1.19 (0.97–1.46)	0.10
Coronary artery disease	1.32 (1.05–1.67)	0.019	1.13 (1.02–1.25)	0.022	1.14 (1.03–1.26)	0.011
Peripheral vascular disease	1.49 (1.13–1.96)	0.005	1.43 (1.26–1.62)	<0.001	1.43 (1.26–1.63)	<0.001
Reoperation	1.38 (1.00–1.94)	0.052	1.35 (1.16–1.58)	<0.001	1.32 (1.13–1.54)	<0.001
Cerebrovascular disease	1.42 (1.05–1.90)	0.021	1.08 (0.94–1.24)	0.29	1.11 (0.97–1.28)	0.14
Diabetes mellitus	1.08 (0.85–1.39)	0.53	1.01 (0.90–1.12)	0.93	1.01 (0.91–1.13)	0.84
% FEV ₁ , 10% decrease	1.07 (1.01–1.12)	0.02	1.13 (1.10–1.15)	<0.001	1.12 (1.10–1.15)	<0.001
Induction therapy	1.51 (1.09–2.10)	0.014	1.20 (1.02–1.40)	0.024	1.20 (1.03–1.39)	0.022
Renal dysfunction	1.74 (1.06–2.86)	0.029	1.07 (0.81–1.42)	0.64	1.11 (0.84–1.46)	0.47
Cigarette smoking		0.14		<0.001		<0.001
Never	1.00		1.00		1.00	
Past smoker	1.54 (1.00–2.38)		1.20 (1.02–1.41)		1.23 (1.05–1.44)	
Current smoker	1.54 (0.96–2.49)		1.64 (1.38–1.94)		1.64 (1.38–1.94)	
Zubrod score		<0.001		<0.001		<0.001
0	1.00		1.00		1.00	
1	1.60 (1.25–2.04)		1.14 (1.04–1.25)		1.16 (1.06–1.28)	
2–5	2.21 (1.45–3.37)		1.57 (1.29–1.91)		1.60 (1.32–1.95)	
ASA		0.007		<0.001		<0.001
1 or 2	1.00		1.00		1.00	
3	1.67 (1.05–2.65)		1.25 (1.08–1.45)		1.27 (1.09–1.47)	
4 or 5	2.26 (1.34–3.80)		1.72 (1.42–2.09)		1.76 (1.45–2.13)	
Approach		<0.001		<0.001		<0.001
Minimally invasive	1.00		1.00		1.00	
Thoracotomy	1.87 (1.49–2.36)		1.49 (1.35–1.64)		1.51 (1.37–1.66)	
Pathologic stage		0.008		0.30		0.25
I	1.00		1.00		1.00	
II	1.15 (0.89–1.48)		1.07 (0.96–1.19)		1.05 (0.95–1.17)	
III	1.46 (1.10–1.96)		1.13 (0.99–1.29)		1.14 (1.00–1.30)	
IV	2.23 (1.23–4.02)		1.01 (0.73–1.40)		1.04 (0.75–1.42)	
Procedure		<0.001		<0.001		<0.001
Wedge	1.00		1.00		1.00	
Segmentectomy	0.98 (0.51–1.88)		1.19 (0.93–1.53)		1.24 (0.97–1.57)	
Lobectomy	1.69 (1.14–2.53)		1.96 (1.67–2.30)		1.93 (1.65–2.26)	
Sleeve	1.72 (0.72–4.09)		1.93 (1.36–2.75)		1.96 (1.39–2.77)	
Bilobectomy	3.57 (2.09–6.12)		2.98 (2.34–3.80)		2.91 (2.29–3.70)	
Pneumonectomy	4.80 (2.87–8.02)		2.74 (2.15–3.48)		2.83 (2.24–3.58)	
C-statistic	0.78		0.68		0.68	

^a Intercept values for the models are –10.822 for mortality, –5.651 for major morbidity, and –5.657 for composite. Covariate specific coefficients can be obtained by taking natural logarithm of the odds ratios.ASA = American Society of Anesthesiologists; CI = confidence interval; FEV₁ = forced expiratory volume in first second of expiration; OR = odds ratio.

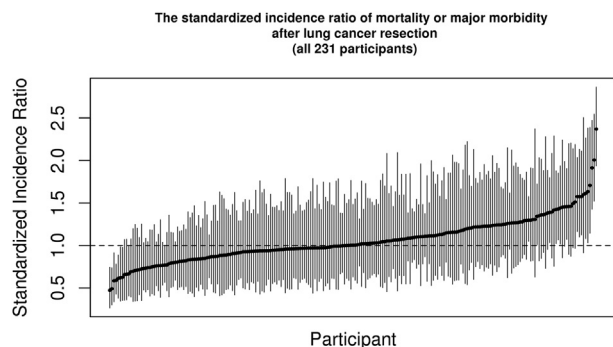


Fig 1. Hospital performance variability. The standardized incidence ratios with 95% Bayesian credible intervals are shown for the composite measure of mortality and major morbidity after lung cancer resection among The Society of Thoracic Surgeons database participating centers.

There are several limitations that must be considered when interpreting these lung cancer surgery risk-adjustment models. First, because of missing data for approximately 14% of patients, diffusing capacity of lung for carbon monoxide was not included as a covariate for analysis [17]. Next, the performance of the separate risk models varies. The mortality model has a C-statistic approaching 0.8, which would indicate strong performance. However, the C-statistic of the major morbidity and composite models approached 0.7, which represents fair performance. Furthermore, results from these models may not be generalizable to surgeons not participating in the GTSD [9]. Another limitation is that the GTSD has been limited to 30-day follow-up. Outcomes such as 90-day mortality, hospital readmissions, and long-term survival are of critical importance to measure [18–20]. The GTSD is beginning to collect long-term survival data after lung cancer resections. In addition, linkage of GTSD data to administrative data from the Centers for Medicare and Medicaid Services has been established, and longitudinal follow-up for persons aged 65 years and older will soon be available [21]. Also, owing to missing data, pathologic stage was used as a surrogate for clinical stage in this analysis. Finally, the selection of which complications constitute a major morbidity has been done empirically. These complications were selected by the General Thoracic Surgery Database Task Force and are based on their frequency in the data and their clinical significance.

These analyses also have strengths. As demonstrated through external audit, the data in the STS GTSD are of very high quality [7]. Additionally, the use of robust clinical registry data provides greater granularity than other less detailed registries or administrative datasets. Data currently used for making treatment decisions in lung cancer surgery include pulmonary function, performance status, smoking status, weight loss, and other comorbid medical conditions. None of these variables is present in the Surveillance Epidemiology and End Results, National Cancer Database, Nationwide Inpatient Sample, and Centers for Medicare and Medicaid Services databases, or any other existing large dataset.

In conclusion, thoracic surgeons contributing to the STS GTSD perform high-quality lung cancer resections. Risk models generated from this database have identified several factors that are predictive of adverse events and can be used to measure hospital performance variation. With an ever-increasing experience, these models continue to be refined to guide the quality improvement efforts of thoracic surgeons across the nation.

This project was supported by grant number R01 HS022279 from the Agency for Healthcare Research and Quality. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.



Author Interview: The Author Interview can be viewed in the online version of this article [<http://dx.doi.org/10.1016/j.athoracsur.2016.02.098>] on <http://www.annalthoracicsurgery.org>.

References

1. Shahian DM, O'Brien SM, Filardo G, et al. Society of Thoracic Surgeons Quality Measurement Task Force. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 1—coronary artery bypass grafting surgery. *Ann Thorac Surg* 2009;88(Suppl):2–22.
2. O'Brien SM, Shahian DM, Filardo G, et al. Society of Thoracic Surgeons Quality Measurement Task Force. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 2—isolated valve surgery. *Ann Thorac Surg* 2009;88(Suppl):23–42.
3. Shahian DM, O'Brien SM, Filardo G, et al. Society of Thoracic Surgeons Quality Measurement Task Force. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 3—valve plus coronary artery bypass grafting surgery. *Ann Thorac Surg* 2009;88(Suppl):43–62.
4. Wright CD, Gaissert HA, Grab JD, et al. Predictors of prolonged length of stay after lobectomy for lung cancer: a Society of Thoracic Surgeons general thoracic surgery database risk-adjustment model. *Ann Thorac Surg* 2008;85:1857–65.
5. Kozower BD, Sheng S, O'Brien SM, et al. STS database risk models: predictors of mortality and major morbidity for lung cancer resection. *Ann Thorac Surg* 2010;90:875–83.
6. Wright CD, Kucharczuk JC, O'Brien SM, et al. Predictors of major morbidity and mortality after esophagectomy for esophageal cancer: a Society of Thoracic Surgeons general thoracic surgery database risk adjustment model. *J Thorac Cardiovasc Surg* 2008;137:587–95.
7. Magee MJ, Wright CD, McDonald D, et al. External validation of The Society of Thoracic Surgeons general thoracic surgery database. *Ann Thorac Surg* 2013;96:1734–9.
8. The Society of Thoracic Surgeons national database. Available at <http://www.sts.org/national-database>. Accessed September 8, 2015.
9. LaPar DJ, Bhamidipati CM, Lau CL, et al. The Society of Thoracic Surgeons general thoracic surgery database: establishing generalizability to national lung cancer resection outcomes. *Ann Thorac Surg* 2012;94:216–21.
10. Bucchieri G, Ferrigno D, Tamburini M. Karnofsky and ECOG performance status scoring in lung cancer: a prospective longitudinal study of 536 patients from a single institution. *Eur J Cancer* 1996;32A:1135–41.
11. Paul S, Altorki NK, Sheng S, et al. Thoracoscopic lobectomy is associated with lower morbidity than open lobectomy: a

- propensity-matched analysis from the STS database. *J Thorac Cardiovasc Surg* 2010;139:366-78.
12. Shapiro M, Swanson SJ, Wright CD, et al. Predictors of major morbidity and mortality after pneumonectomy utilizing The Society for Thoracic Surgeons general thoracic surgery database. *Ann Thorac Surg* 2010;90:927-35.
 13. Fernandez FG, Force SF, Pickens A, et al. Impact of laterality on early and late outcomes after pneumonectomy. *Ann Thorac Surg* 2011;92:244-9.
 14. Khullar OV, Gillespie T, Nickleach D, et al. Risk factors for long-term mortality after pulmonary resection for lung cancer: an analysis of over 90,000 patients from the national cancer data base. *J Am Coll Surg* 2015;220:156-68.
 15. St Julien JB, Aldrich MC, Sheng S, et al. Obesity increases operating room time for lobectomy in The Society of Thoracic Surgeons database. *Ann Thorac Surg* 2012;94:1841-7.
 16. Mason DP, Subramanian S, Nowicki ER, et al. Impact of smoking cessation before resection of lung cancer: a Society of Thoracic Surgeons general thoracic surgery database study. *Ann Thorac Surg* 2009;88:362-7.
 17. Ferguson MK, Vigneswaran WT. Diffusing capacity predicts morbidity after lung resection in patients without obstructive lung disease. *Ann Thorac Surg* 2008;85:1158-65.
 18. Hu Y, McMurtry TL, Isbell JM, et al. Readmission after lung cancer resection is associated with a 6-fold increase in 90-day postoperative mortality. *J Thorac Cardiovasc Surg* 2014;148:2261-7.
 19. Farjah F, Wood DE, Varghese TK, et al. Health care utilization among surgically treated Medicare beneficiaries with lung cancer. *Ann Thorac Surg* 2009;88:1749-56.
 20. Bryant AS, Rudemiller K, Cerfolio RJ. The 30- versus 90-day operative mortality after pulmonary resection. *Ann Thorac Surg* 2010;89:1717-23.
 21. Jacobs JP, Edwards FH, Shahian DM, et al. Successful linking of The Society of Thoracic Surgeons adult cardiac surgery database to Centers for Medicare and Medicaid Services Medicare data. *Ann Thorac Surg* 2010;90:1150-7.

DISCUSSION

DR STEPHEN C. YANG (Baltimore, MD): I want to thank the Association for the opportunity to discuss this paper. I want to congratulate Dr Fernandez and the rest of your committee on not only a great presentation and a well-written manuscript but also for having the trifecta of having three papers during the session this afternoon.

Today your group has updated your original risk model presented by Dr Kozower in 2010. You have nicely shown that there has been expanded growth in the use of The Society of Thoracic Surgeons (STS) database, with 1,900 cases over 6 years in the first iteration to nearly 28,000 cases in just over 2 years. Similarly, the number of centers has grown from 111 to 231 centers. Most characteristics and complications have not changed much, not surprisingly, but there are noticeable differences, such as 5% more women, near doubling of the minimally invasive technique rate, and a further drop in the overall mortality to 1.4%, which may need to make sure that our nonsurgical colleagues are still quoting the 5% rate. The list of perioperative risk factors has grown larger, and much like our electronic entry systems like Epic, our patient population is getting much more complex. As you stated in your manuscript, we look forward to the data concerning the 90-day mortality rates and the readmission rates. I have three questions.

Similar to the first version, diversity appears to remain an issue and perhaps underreporting of groups who have less access to medical care. In both reports, Caucasians make up 87% of the cohorts, with the African-American population stable at 8%. Being in the "other" category, I know for a fact that lung cancer in nonsmoking Asian females continues to increase dramatically not only in the United States but also overseas. How can we improve upon access and outcome for all patients?

Secondly, I am putting my educator's hat on, feedback is very important, and we know the purpose of the STS database is to improve quality improvement. Since the 2010 analysis, can you tell if the standardized incidence rating has improved in the lesser performing centers, that is, how do we know that the bad performers have improved since your first analysis?

And finally, much like the cardiac risk assessment tools that are available, will we have now a readily available application for our smart phones to calculate such risks, or perhaps an artificial intelligence computer like Dr DiMaio spoke of this morning like an IBM Dr Watson to help us do these calculations? What about the role of the eyeball test that we all use in clinic and the frailty

scores that Dr Ferguson is producing? If not, what do you think are the three top practical points we can take home for our immediate practice? I would like to thank the Association for the privilege of discussing this paper.

DR FERNANDEZ: Thank you, Dr Yang. First about diversity, the population in the STS database is reflective of the sites submitting data, and it has been an ongoing effort of the General Thoracic Surgery Database Task Force to increase participation. It is certainly much less than the percentage participation in the adult cardiac database and the congenital database, but it has increased from 111 to 231, as you mentioned, so this is improving. But that is the one thing, increased participation, I think that will account for more diversity in the population.

Your second question, please remind me of that one again?

DR YANG: That is the question about how do we see if the standardized incidence rating has improved in those who are performing worse.

DR FERNANDEZ: The database task force just has deidentified data. So we see that there are underperformers and better performers, but we do not know who they are. The individual centers know who they are, so you know your own data over time, and certainly the people doing the analytics know, but perhaps in the participant reports that are submitted it may be of value to track your standardized incidence ratio over time. But that is not something we see right now.

DR YANG: With the role of the STS database, how do we know that those centers are really on that far end of the curve?

DR FERNANDEZ: That is an excellent point. That is not something that the database task force is tracking. I do not speak for the STS or the Duke Clinical Research Institute, but you can imagine additional regulatory agreements to be able to track and disclose that data. That is an excellent point; individual sites can track their own over time.

DR ROBERT J. CERFOLIO (Birmingham, AL): First of all, you had a fastball down the middle at 80 miles an hour and you fouled it off. We did not come to Florida to hear that people who are older and sicker and have worse lung function and are

weaker do worse. I have got kids at home that know that and they are not even doctors. We came to find out how to get better. So you got a fastball down the middle. You have got to tell us how to get better. We have got to stop hiding behind the lawyers. We have got to find out the surgeons who are really good, what they are doing so I can get better. Do you have any granular details on that or we going to say everything is deidentified, everybody comes in first place, everyone gets a trophy for signing up?

DR FERNANDEZ: I am not sure how to answer that question other than to say this is a voluntary task force. If you have some ideas to contribute, we welcome you to come and help us out.

DR CERFOLIO: I think that is what we need. We need data like that.

DR FERNANDEZ: All right. Thank you.

DR JOHN E. MAYER (Boston, MA): This has become an increasingly important topic I think, and that is, what do we do with the data? I would just like to remind everybody of the ethic that started with the Northern New England Cardiovascular Study Group, which was to use variation in outcomes as a tool for improvement, not as a means for profiling. I think if we keep that in mind, then a lot of our concerns about the database and what it is going to be used for, can perhaps be reconsidered using that principle.