Geographic Variations in Lung Cancer Lobectomy Outcomes: The General Thoracic Surgery Database

A. Laurie Shroyer, PhD, MSHA, Jacquelyn A. Quin, MD, Maria V. Grau-Sepulveda, MD, MPH, Andrzej S. Kosinski, PhD, Babatunde A. Yerokun, MD, John D. Mitchell, MD, and Thomas V. Bilfinger, MD, SCD

Stony Brook University School of Medicine, Stony Brook, NY; VA Boston Healthcare System, Boston, Massachusetts; Duke Clinical Research Institute, Durham, North Carolina; and University of Colorado School of Medicine, Aurora, Colorado

Background. **Lung cancer ranks as the top cancer killer in the United States. Using The Society of Thoracic Surgeons General Thoracic Surgery Database (GTSD), the geographic variability of lung cancer lobectomy for operative mortality and major morbidity were examined.**

Methods. **From January 2009 to June 2015, the GTSD lung cancer lobectomy records (excluding robotic procedures) were assigned to a US Census region using hospital location. Surgeons performing fewer than seven lung cancer lobectomies per year were categorized as "low volume." The American College of Surgeons Oncology Group criteria were used to classify patients as "high risk." Applying the published GTSD risk algorithms, regional unadjusted and adjusted odds ratios were computed using univariable and multivariable generalized estimating equation logistic regression. Across geographic regions, patient risk factors and outcomes were compared using Kruskal-Wallis and χ^2 tests.**

Results. **From 2009 to 2015, there were 39,078 lung cancer lobectomies that met study inclusion criteria (31.5% Northeast, 23.5% Midwest, 31.1% South, and 14.0% West). Fewer high-risk cases were seen in the West region (18.9% Northeast, 19.6% Midwest, 19.9% South, and 15.9% West; $p < 0.001$). Across geographic regions, there was no statistically significant difference in the proportion of low-volume surgeons (39.8% Northeast, 44.8% Midwest, 45.8% South, and 56.3% West; $p = 0.0512$). Adjusted odds ratios for operative mortality and major perioperative morbidity did not show statistically significant differences across regions ($p = 0.761$ and $p = 0.600$, respectively).**

Conclusions. **Despite geographic variations in the proportion of high-risk lobectomies, the risk-adjusted mortality and morbidity outcomes did not vary by region.**

(Ann Thorac Surg 2017;104:1650–5)

Pulmonary lobectomy is a high-volume procedure, associated with low mortality and morbidity in the United States, that is performed for malignant and benign disease. For quality improvement and research purposes, clinical outcome risk models have been created using The Society of Thoracic Surgeons (STS) General Thoracic Surgery Database (GTSD) based on patient-related risk factors, tumor characteristics, and other factors not patient related, including processes of care [1–8]. A Nederland study of non-small cell lung cancer identified variations across their nine regions in the processes of care used and patients' outcomes [9]. To date, however, US-based lung cancer lobectomy geographic variations in patient risk factors and outcomes have not been previously evaluated.

Similar to a prior STS Adult Cardiac Surgery Database study that examined geographic variations in risk-adjusted outcomes of coronary artery bypass graft surgery across the four US Census Bureau regions (Northeast, Midwest, South, West) [10], the aim of this STS GTSD Access and Publications (A&P) Task Force–approved project was to evaluate regional variations in risk-adjusted outcomes after lung cancer lobectomy to identify opportunities to improve the future quality of patient care.

Patients and Methods

Geographical Region: Record Assignment

Based on the hospital where the patient's first lobectomy was performed, patient records were classified into four

Accepted for publication May 15, 2017.

Presented at the Fifty-third Annual Meeting of The Society of Thoracic Surgeons, Houston, TX, Jan 21–25, 2017.

Address correspondence to Dr Shroyer, Surgery Department, HSC 19-083, Stony Brook Medicine, Stony Brook, NY 11794-8191; email: annielaurie.shroyer@stonybrookmedicine.edu.

The Supplemental Tables can be viewed in the online version of this article [http://dx.doi.org/10.1016/j.athoracsur.2017.05.066] on http://www.annalsthoracicsurgery.org.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2017.05.066

Abbreviations and Acronyms

ACOSOG = American College of Surgeons Oncology Group
A&P = Access and Publications
BMI = Body Mass Index
GTSD = General Thoracic Society Database
VATS = Video Assisted Thoracoscopic Surgery
US = United States

geographic regions—Northeast, Midwest, South, and West—as defined by the US Census Bureau [11]. (See Supplemental Table 1).

Population: Patient Records Used in Analysis

This STS GTSD retrospective cohort study focused on first-time lung cancer lobectomy procedures performed by STS participants from January 2009 to June 2015. Lobectomy was defined to include pulmonary lobes removed using open, video-assisted thoracoscopic surgery (VATS), or robotic surgery. Classified by STS separately as pneumonectomy procedures, bilobectomies were not included.

Submitted to the STS GTSD, there were 298,061 procedures performed at 339 hospitals by 273 STS participants. Of these 298,061 records, 242,630 did not indicate a lobectomy performed. Of the remaining 55,431 lobectomy records, there were 8,649 procedures performed for nonmalignant diagnoses. Of the 46,782 lung cancer lobectomies performed, 27,952 (59.8%) were for upper lobe lung cancer, 15,066 (32.2%) for lower lobe lung cancer, and 3,154 (6.7%) for middle lobe lung cancer, with 610 cases of lung cancer location unspecified. As the primary procedure, there were 26,521 (56.7%) VATS versus 20,261 (42.3%) open cases. Per STS GTSD risk model specifications, patient records with nonelective status, occult or stage 0 tumors, and American Society of Anesthesiologists class VI, as well as records missing other required data elements (ie, age, sex, or discharge mortality status) were excluded [12].

Robotic lobectomy procedures were first introduced into clinical practice during the study period. With substantial geographic differences ($p < 0.001$), the South had the highest robotic use rate (11.8%) with the lowest use in the Midwest (7.3%). Because very few cases were accrued before 2013, the 4,154 robotic cases were also excluded. In addition, repeat procedures were removed. The final study population was 39,078 first-time, elective lung cancer lobectomies performed by 267 STS participant sites (804 surgeons operating at 320 hospitals). Interestingly, 26 surgeons (of the 804) operated at two or more hospitals located in different geographic regions.

Statistical Analyses

Patient characteristics, preoperative lung cancer status, process of care variables (eg, open versus VATS), and clinical outcome rates were compared in aggregate across the four US geographic regions using Kruskal-Wallis and χ^2 tests. For lung cancer resection procedures, the STS GTSD risk algorithms were adjusted for age, sex, year of operation, body mass index, hypertension, steroid therapy, congestive heart failure, coronary artery disease, peripheral vascular disease, reoperation, preoperative chemotherapy within 6 months, cerebrovascular disease, diabetes mellitus, renal failure, dialysis, past smoker, current smoker, predicted percent forced expiratory volume in 1 second (FEV_1), Zubrod score (linear plus quadratic splines), American Society of Anesthesiologists class (linear plus quadratic splines), and pathologic stage (as defined by the American Joint Committee on Cancer cancer staging manual, sixth edition) [1, 12, 13]. For categoric variables, missing data (less than 2%) imputed to the most common category or the one with the lowest risk. For continuous variables, missing data imputed with group-specific medians (eg, FEV_1, imputed with cigarette smoking–specific medians) or overall medians (eg, body mass index). Overall, the missing variable rate for study records was less than 5%.

Applying these GTSD risk algorithms, unadjusted and adjusted odds ratios for regions with 95% confidence intervals were computed using univariable and multivariable generalized estimating equation logistic regression to account for hospital clustering of patients. Given the tremendous range in surgeon-based volume and the large number of surgeons (n = 804; with 26 operating across multiple regions), clustering at the surgeon level was not pursued.

STS GTSD Database

Per STS definitions, operative mortality was defined as death either occurring in the hospital or after discharge, but within 30 days. Major morbidity was a composite of nine complications: pneumonia, bronchopleural fistula, pulmonary embolus, extended ventilation time, reintubation/respiratory failure, tracheostomy, acute respiratory distress syndrome, acute myocardial infarction, or an unexpected operating room return. To identify high-risk lobectomy lung cancer patients, American College of Surgeons Oncology Group (ACOSOG) criteria were applied: major criteria were FEV_1 50% or less or diffusing capacity of lung for carbon monoxide (DLCO) 50% or less; and minor criteria were (two of the following) age 75 years or more, FEV_1 51% to 60%, or DLCO 51% to 60% [13]. Where DLCO information was missing (approximately 16% of cases), these patients were assumed not to be ACOSOG high-risk patients.

For purposes of this analysis, low-volume centers and surgeons were defined based on the published literature [6]. A low-volume hospital had fewer than 17 cases per year on average. Facilities with less than 1 year of data were excluded. For this volume-based comparison, the hospitals evaluated were reduced from 320 to 276 (85.9%).

Low-volume surgeons had fewer than 7 cases per year on average [6]. Surgeons operating in multiple regions (n = 26) or with less than 1 year of data reported (n = 107) were removed. For this volume comparison, the surgeons