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Variability in Smoking Status for Lobectomy Among Society of Thoracic Surgeons Database Participants

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Abstract

Background: Current smokers undergoing lobectomy are at greater risk of complications than former smokers. The Society of Thoracic Surgeons (STS) composite score for rating program performance for lobectomy adjusts for smoking status, a modifiable risk factor. We examined variability in the proportion of current smokers undergoing lobectomy among STS database participants. Additionally, we determined whether each participant's rating changed if smoking was excluded from the risk adjustment model.

Methods: This is a retrospective analysis of the STS cohort used to develop the composite score for rating program performance for lobectomy. We summarized the variability among STS

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database participants for performing lobectomy on current smokers and compared star ratings developed from models with and without smoking status.

Results: There were 24,912 patients with smoking status data: 23% current, 62% former and 15% never smokers. There was significant variability among participants in the proportion of current smokers undergoing lobectomy (3% to 48.6%, $p<0.001$). Major morbidity or mortality (composite) was greater in current (12.1%) than in former (8.6%) and never smokers (4.2%), $p<0.001$. Using the current risk adjustment model, participant star ratings were: 1 star, n=6 (3.2%), 2 star, n=170 (91.4%) and 3 star, n=10 (5.4%). When smoking status was excluded from the model, one participant shifted from a 2 to a 3 star program.

Conclusions: There is substantial variability among STS database participants with regards to the proportion of current smokers undergoing lobectomy. However, exclusion of smoking status from the model did not significantly impact participant star rating.

This year 228,150 people will be diagnosed with lung cancer and up to 40% may undergo surgical resection [1]. Smoking is the leading risk factor for the development of lung cancer [2]. There is a 10.4% incidence of major pulmonary complications among patients undergoing lung cancer resection [3] and current smokers are 1.8 times more likely to have a pulmonary complication compared to never smokers [4]. Moreover, current smokers have a 50% increased risk of mortality and 64% increased risk of major morbidity after lung cancer resection compared to never smokers [3]. As such, smoking status is an important predictor in the Society of Thoracic Surgeons (STS) General Thoracic Surgery Database (GTSD) risk-adjustment model of mortality and major morbidity for lung cancer resection [3].

As part of a recent focus on quality and performance measures, the STS Quality Measurement Task Force developed a comparative star rating measurement of participant programs' performance for lobectomy for lung cancer [5]. This metric utilizes the GTSD risk-adjustment model to calculate an STS lobectomy composite score combining individual participant programs' major morbidity and mortality rates compared to expected outcomes from an average provider in the STS GTSD with a similar case mix. The STS lobectomy composite score has been used to categorize programs as higher than expected (3 stars), not statistically distinguishable from expected (2 stars) and lower than expected (1 star) performance.

Though there are many patient level factors that contribute to the risk-adjusted models for morbidity and mortality, current smoking status remains predictive of major morbidity. Nearly a quarter of patients undergoing lobectomy in the STS GTSD are actively smoking or smoked within the month prior to their operation (i.e. current smokers). Preoperative smoking cessation practices for active smokers are widely variable amongst STS GTSD participating surgeons [6]. Smoking status is a modifiable predictor of morbidity after lung resection and programs may achieve better outcomes if patients stop smoking before surgery. Our primary objective was to examine the variability among STS database participants with regards to the proportion of current smokers undergoing lobectomy. Our secondary objective was to determine whether each STS database participant's rating

changed if smoking was excluded from the risk adjustment model for determining program performance.

Patients and Methods

We conducted a retrospective analysis of the STS GTSD including all patients undergoing lobectomy for lung cancer between January 1, 2014 and December 31, 2016. Primary outcomes were defined identically to the current methodology for calculating program performance ratings for lobectomy [5], with operative mortality defined as death in-hospital or within 30 days of the procedure. Major complications were defined as any one of the following: pneumonia, acute respiratory distress syndrome, bronchopleural fistula, pulmonary embolus, initial ventilator support greater than 48 hours, reintubation/respiratory failure, tracheostomy, myocardial infarction, or unexpected return to the operating room. Former smokers were those who had stopped smoking >1 month prior to surgery and current smokers continued to smoke within 30 days of surgery. We summarized the variability in practice of STS database participants for lobectomy on patients who are current smokers (defined as those who smoked within one month of surgery) among participants performing at least 30 lobectomies per year. We compared the proportion of patients undergoing lobectomy by smoking status among US Census Bureau-designated regions: Northeast, Midwest, South and West [7]. Additionally, we compared operative mortality, major morbidity and pulmonary function testing between smoking status groups by univariate analysis.

We summarized continuous variables with mean and standard deviation (or quartiles) and categorical variables with counts and percentages. We compared categorical variables across groups with the Pearson’s Chi-squared test, and continuous variables with Kruskal–Wallis one-way analysis of variance. We used exact 95% confidence interval for a participant’s proportion of patients who are current smokers at the time of lobectomy. Analyses were performed with the SAS Software 9.4 (SAS Institute, Cary, NC) and R software 3.1.2 [8].

The STS lobectomy composite score was calculated as described for program performance rating for lobectomy [5], using a Bayesian bivariate random-effects logistic regression model with a composite score calculated as a weighted sum of (1 minus the risk-adjusted operative mortality rate) and (1 minus the risk-adjusted major complication rate) of operative mortality and major complications. Based on inverse weighting of each outcome’s standard deviation across participants, mortality was weighted 4 times higher than major complications. Predictors within the model were identical to the previously utilized STS GTSD perioperative risk models [9]. The variables included were: 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, current smoking status, former smoking status, forced expiratory volume in 1 second (FEV_1) percent of predicted, Zubrod score (linear plus quadratic), American Society of Anesthesiologists (ASA) class (linear plus quadratic), and pathologic stage as defined by the American Joint Committee on Cancer staging manual, 6th edition [10].

Using this lobectomy performance model, we calculated the star rating of each participant program [5]. We then recalculated the star rating of each participant program utilizing the lobectomy performance model with the exclusion of smoking status. A minimum volume threshold of 30 lobectomies over the 3-year study period was used when assigning star rating to maximize reliability of the STS lobectomy composite score. A star rating was assigned based on the participant specific composite score Bayesian 95% credible interval. Higher than expected participants (3 stars) had a credible interval that fell entirely above the STS average and lower than expected participants (1 star) had a credible interval that fell entirely below the STS average. Participants with a credible interval including the STS average were deemed not statistically distinguishable from expected (2 stars). We compared the star ratings with exclusion of smoking status to the current star ratings to determine whether exclusion of smoking status from the risk adjustment model for the composite score changed the performance star rating of individual programs. This study adhered to STROBE guidelines for reporting of observational studies [11]. This study was exempt by the University of California, Davis Institutional Review Board.

Results

Clinical Characteristics

A total of 24,912 patients undergoing lobectomy for lung cancer from 233 participants were included in the composite score derivation. There were 186 participants (24,318 patients) that met the minimum volume threshold of 30 lobectomies over the 3-year study period. Patient characteristics are summarized in Table 1, with 5,739 (23.0%) current and 15,369 (61.7%) former smokers at the time of surgery. The majority of patients had an FEV1 percent predicted between 60 and 99% (68.6%), Zubrod score of 0 or 1 (96.1%), ASA class of III (76.3%), and stage I lung cancer (71.0%).

Perioperative Outcomes

Major morbidity or mortality (composite) was greater in current (12.1%) than in former (8.6%) and never smokers (4.2%, $p<0.001$) (Table 2). Similar results were seen for both major morbidity and for mortality. Mean FEV_1 percent predicted was significantly lower for current smokers compared to former smokers and never smokers (Table 3).

Variability Among Participants in Current Smokers Undergoing Lobectomy

There was significant variability among STS database participants with regards to the proportion of current smokers undergoing lobectomy (min=3% to max=48.6%, $p<0.001$) (Figure 1) with 47 participants operating on 3–17.9% current smokers, 46 participants on 17.9–24.9%, 46 participants on 24.9–31.4%, and 46 participants operating on 31.4–48.6% current smokers. There was variability by US region with participants in the West operating on fewer current smokers and more never smokers (Table 4).

Star Rating Recalculations

Using the current lobectomy performance risk-adjustment model to assign star ratings, there were 6 (3.2%) 1 star programs, 170 (91.4%) 2 star programs, and 10 (5.4%) 3 star programs. When smoking status was excluded from the risk adjustment model to assign star ratings,

only one participant shifted from a 2 to a 3 star program resulting in 6 (3.2%) 1 star programs, 169 (90.9%) 2 star programs, and 11 (5.9%) 3 star programs.

Comment

Our analysis demonstrates that there is significant variability amongst STS GTSD participants in the proportion of patients who are current smokers at the time of lobectomy. Despite this finding, exclusion of smoking status from the risk adjustment model for operative mortality and major morbidity used to assign star ratings for lobectomy performance did not significantly impact participant star rating.

Our study reinforces the association between smoking status and mortality and major morbidity after lung resection. Current smokers had a higher rate of mortality and major morbidity compared to former and never smokers. Furthermore, there was a dose response of mortality and major morbidity risk from current to former smokers, and from former to never smokers. This trend mirrored the increase in FEV_1 percent predicted for former and never smokers compared to current smokers. These data are concordant with prior studies of the effects of smoking on perioperative outcomes after lung resection [12,13]. In particular, recent studies have demonstrated the significant impact of duration of smoking cessation on pulmonary complications after lung resection [4,14]. As such, both primary care providers and thoracic surgeons should continue to be advocates for smoking cessation, especially in the preoperative phase of a patient's care.

We found significant variability among STS GTSD participants in the proportion of patients at each program who were current smokers at the time of lung resection. The confidence intervals for the institutions with the lowest current smoker rates did not overlap with those with the highest current smoker rates, suggesting substantial differences in patient cohorts between these programs with regard to smoking status. Though many single and multi-institution studies of lung resection patients report overall current smoker rates of 20–25% at the time of surgery [3,12,15,16], there are no studies, such as this, comparing a broad range of programs according to the proportion of current smokers undergoing lung cancer resection. Our data indicate that there is high variability amongst STS GTSD participants regarding the decision to operate on a current smoker.

This variability reflects the heterogeneity in opinions amongst thoracic surgeons in deciding whether to offer surgery to a current smoker. While the early postoperative pulmonary benefits of smoking cessation prior to elective lung resection are well known [12,14,15], there is little consensus among thoracic surgeons regarding whether smoking cessation should be mandatory before surgery. A recent survey of STS GTSD participants found that 40% of surgeons require patients to quit smoking prior to elective lung surgery, and most thought it was the surgeon's responsibility to ensure smoking cessation [6]. Another survey found similar results and that when stratified by operation, cardiothoracic surgeons' refusal to operate on a current smoker ranged from 49% for a VATS lobectomy to 77% for a pneumonectomy [17]. The National Comprehensive Cancer Network (NCCN) guidelines for NSCLC recognize that current smokers have an increased risk of postoperative pulmonary complications but state that this risk should not be considered prohibitive and that surgeons

should not deny surgery to patients solely based on smoking status as surgery provides the main opportunity for prolonged survival in patients with early stage lung cancer [18].

In an era of increasing transparency and public reporting of operative outcomes, thoracic surgical programs aim to improve their STS lobectomy star rating. The models used to calculate the STS lobectomy composite score are risk-adjusted and many patient level factors including smoking status are in the model. There may be a hypothetical concern for some thoracic surgical programs that operating on a higher proportion of current smokers may jeopardize their clinical outcomes and STS lobectomy composite score. However, our results indicate that excluding smoking status from the risk-adjustment model is highly unlikely to impact star rating. For an otherwise appropriate-risk lung cancer patient, thoracic surgeons should not decline to operate on patients who are current smokers for concern of negatively impacting their institution's STS lobectomy star rating.

There are innumerable factors from preoperative evaluation to intraoperative technical expertise to postoperative clinical care that can impact a patient's outcome after lobectomy. It is perhaps unsurprising that only one variable in the risk adjusted model such as smoking status is unlikely to significantly change the paradigm of a program to boost it from a 1 star to 2 star program, or from a 2 star to 3 star program. While patient factors such as smoking status, Zubrod score, and ASA classification may all contribute significantly to the risk-adjusted model for the lobectomy composite score, unmeasurable program factors may play a larger role in differentiating programs from the average. Some postoperative complications are unavoidable, yet it has been shown that failure to rescue and progression from a complication to mortality is less common in hospitals with closed intensive care unit staffing, higher rates of overnight coverage with board-certified intensivists and higher annual operative volume [19,20]. Removal of non-value items in the perioperative care of patients such as empiric placement of arterial lines, urinary catheters and postoperative transfer to intensive care units for all patients may help reduce exposure to complications [21]. Other processes that may improve program performance that are not captured in the risk adjusted models are preoperative pulmonary rehabilitation and optimal perioperative respiratory therapy, given that seven of the nine major complications included in the STS lobectomy composite score are respiratory in nature.

There are several limitations to this analysis, some of which have been discussed in the initial star rating calculation manuscript. First, these results represent the analysis of programs that voluntarily participate in the STS GTSD such that there is selection bias. Less than 50% of lung cancer resections performed nationally are captured in the STS GTSD. These data cannot be generalized to all programs and surgeons performing lung cancer surgery as the STS GTSD represents an enriched population of primarily American Board of Thoracic Surgery-certified surgeons with historically excellent outcomes [22]. Second, there may be reporting bias for smoking status, as the STS GTSD defines a patient who quit smoking less than one month prior to surgery as a current smoker, but one who quit smoking greater than one month prior to surgery as a former smoker. Similarly, the STS GTSD lobectomy risk adjusted model treats a former smoker who quit smoking 2 months ago identically to a patient who quit smoking 20 years ago. Furthermore, when analyzing the variability in proportion of patients undergoing lobectomy who are current smokers, it

is important to recall that current smokers are defined as those who smoked within one month of surgery. Therefore, even if a participant has a large proportion of current smokers undergoing lobectomy, it's possible that some of these patients quit within the month prior to surgery. Time since smoking cessation is important but unavailable given the categorical nature of smoking status in the STS GTSD. Nonetheless, the risk of mortality and major morbidity decreased in a dose response fashion between current, former and never smokers.

Future studies could attempt to elucidate why this dramatic variability in smoking prevalence at time of surgery exists across STS GTSD participants. It is possible that the lung cancer patient cohort treated at a particular program reflects the heterogeneity in the smoking prevalence of that geographic distribution. This hypothesis could be tested by linking STS GTSD participant data with smoking prevalence by geographic region or zip code. Additionally, each program's surgical volume may reflect a surrogate for selectivity, such that high volume programs may have the latitude to offer surgery preferentially to former or never smokers. Given recent initiatives for regionalization of high risk surgical care to centers with higher volumes [23], lower volume programs may consequentially feel pressure to increase their volumes by offering surgery to more current smokers. Alternatively, it is possible that higher volume centers have more institutional support and funding to facilitate smoking cessation and pulmonary rehabilitation prior to surgery.

In conclusion, there is substantial variability among STS database participants with regards to the proportion of current smokers undergoing lobectomy. STS lobectomy composite score and star ratings provide a two-domain composite performance metric for lobectomy that discerns between above-average, average and below-average performing institutions. Exclusion of smoking status from the risk adjusted models does not significantly impact the star rating of participants. Despite minimal impact on star rating, current smokers have higher morbidity and mortality after lobectomy and every attempt should be made to achieve smoking cessation prior to surgery.

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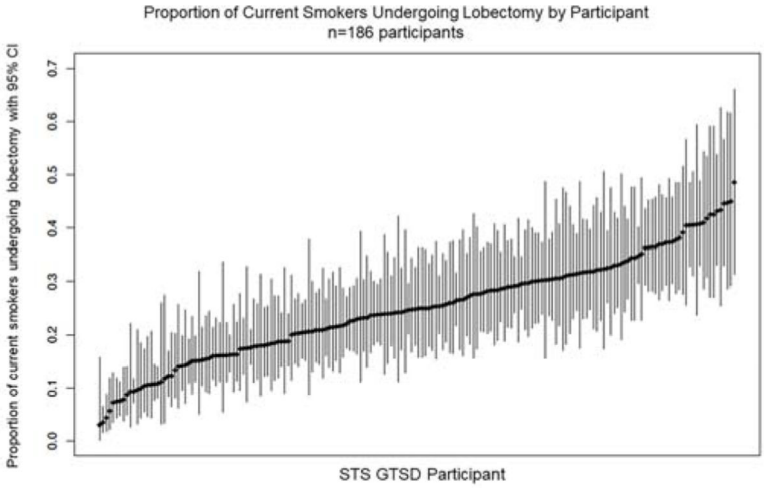

Figure 1:

Distribution of participant's proportion of patients who are current smokers at the time of lobectomy, with corresponding 95% CI. Included are the 186 participants that met the minimum volume threshold of 30 lobectomies over the 3-year study period.

Table 1:

Patient Characteristics

Characteristic	N=24,912	Current Smoker n=5,739 (23%)	Former Smoker n=15,369 (61.7%)	Never Smoker n=3,804 (15.3%)	*p*-value
Age	67.3 ± 9.5	63.7 ± 8.8	68.8± 8.9	66.2 ± 11.3	<0.001
Male	11,103 (44.6%)	2,640 (46.0%)	7,434 (48.4%)	1,029 (27.1%)	<0.001
Body Mass Index (kg/m^2)	27.6 ± 6.1	26.1 ± 5.9	28.1 ± 6.0	28.1 ± 6.4	<0.001
FEV_1 percent of predicted	84.5 ± 19.7	78.4 ± 17.9	84.2 ± 19.5	94.9 ± 19.0	<0.001
FEV_1 percent of predicted					<0.001
<60%	2,454 (9.9%)	818 (14.3%)	1,522 (9.9%)	114 (3.0%)	
60–99	17,147 (68.8%)	4,242 (73.9%)	10,653 (69.3%)	2,252 (59.2%)	
<=100	5,311 (21.3%)	679 (11.8%)	3,194 (20.8%)	1,438 (37.8%)	
Hypertension	15,434 (62.0%)	3401 (59.3%)	9959 (64.8%)	2074 (54.5%)	<0.001
Coronary Artery Disease	5,138 (20.6%)	1,189 (20.7%)	3,551 (23.1%)	398 (10.5%)	<0.001
Congestive Heart Failure	619 (2.5%)	119 (2.1%)	431 (2.8%)	69 (1.8%)	<0.001
Cerebrovascular Disease	1,884 (7.6%)	503 (8.8%)	1,210 (7.9%)	171 (4.5%)	<0.001
Peripheral Vascular Disease	2,221 (8.9%)	670 (11.7%)	1,462 (9.5%)	89 (2.3%)	<0.001
Diabetes Mellitus	4,669 (18.7%)	951 (16.6%)	3,052 (19.9%)	666 (17.5%)	<0.001
Renal Failure	286 (1.1%)	59 (1.0%)	205 (1.3%)	22 (0.6%)	<0.001
Dialysis	117 (0.5%)	25 (0.4%)	83 (0.5%)	9 (0.2%)	0.045
Preoperative Chemotherapy	1,620 (6.5%)	281 (4.9%)	1,141 (7.4%)	198 (5.2%)	<0.001
Steroid use	746 (3.0%)	176 (3.1%)	473 (3.1%)	97 (2.5%)	0.22
Reoperation	1,366 (5.5%)	287 (5.0%)	908 (5.9%)	171 (4.5%)	<0.001
Zubrod Score					<0.001
0	11,424 (45.9%)	2,259 (39.4%)	7092 (46.1%)	2,073 (54.5%)	
1	12,508 (50.2%)	3,216 (56.0%)	7662 (49.9%)	1,630 (42.8%)	
2	807 (3.2%)	226 (3.9%)	494 (3.2%)	87 (2.3%)	
3	146 (0.6%)	31 (0.5%)	105 (0.7%)	10 (0.3%)	
4	25 (0.1%)	7 (0.1%)	14 (0.1%)	4 (0.1%)	
5	2 (0%)	0 (0%)	2 (0%)	0 (0%)	
ASA Class					<0.001
I	57 (0.2%)	9 (0.2%)	32 (0.2%)	16 (0.4%)	
II	3,787 (15.2%)	626 (10.9%)	2,155 (14.0%)	1,006 (26.4%)	
III	19,001 (76.3%)	4,534 (79.0%)	11,868 (77.2%)	2,599 (68.3%)	
IV	2,056 (8.3%)	569 (9.9%)	1,307 (8.5%)	180 (4.7%)	
V	11 (0%)	1 (0%)	7 (0%)	3 (0.1%)	
Stage					<0.001
I	17,686 (71.0%)	4,137 (72.1%)	10,751 (70.0%)	2,798 (73.6%)	
II	4,269 (17.1%)	994 (17.3%)	2,718 (17.7%)	557 (14.6%)	
III	2,582 (10.4%)	519 (9.0%)	1,666 (10.8%)	397 (10.4%)	

Characteristic	N=24,912	Current Smoker n=5,739 (23%)	Former Smoker n=15,369 (61.7%)	Never Smoker n=3,804 (15.3%)	*p*-value
IV	375 (1.5%)	89 (1.6%)	234 (1.5%)	52 (1.4%)	

Table 2:

Major Morbidity and Mortality by Smoking Status

Outcome	Total n=24,912	Current Smoker n=5,739	Former Smoker n=15,369	Never Smoker n=3,804	*p*-value
Major Morbidity or Mortality	2,167 (8.7%)	694 (12.1%)	1,315 (8.6%)	158 (4.2%)	<0.001
Mortality	311 (1.2%)	82 (1.4%)	202 (1.3%)	27 (0.7%)	0.004
Major Morbidity	2,079 (8.3%)	668 (11.6%)	1,263 (8.2%)	148 (3.9%)	<0.001
Pneumonia	923 (3.7%)	312 (5.4%)	561 (3.7%)	50 (1.3%)	<0.001
ARDS	125 (0.5%)	40 (0.7%)	78 (0.5%)	7 (0.2%)	0.002
Bronchopleural fistula	70 (0.3%)	26 (0.5%)	43 (0.3%)	1 (0.0%)	<0.001
Pulmonary embolus	112 (0.4%)	19 (0.3%)	81 (0.5%)	12 (0.3%)	0.07
Initial ventilator support >48 hours	84 (0.3%)	25 (0.4%)	53 (0.3%)	6 (0.2%)	0.07
Reintubation/Respiratory failure	752 (3.0%)	259 (4.5%)	450 (2.9%)	43 (1.1%)	<0.001
Tracheostomy	187 (0.8%)	71 (1.2%)	108 (0.7%)	8 (0.2%)	<0.001
Myocardial infarction	77 (0.3%)	24 (0.4%)	44 (0.3%)	9 (0.2%)	0.2
Unexpected return to OR	773 (3.1%)	256 (4.5%)	452 (2.9%)	65 (1.7%)	<0.001

Table 3:

Pulmonary Function by Smoking Status

	Current Smoker n=5,595*	**Former Smoker n=14,902***	**Never Smoker n=3,577***	**Total n=24,070***	***p*-value**
FEV_1% of predicted Median (IQR)	78.0 (66.0–90.0)	84.0 (71.0–97.0)	95.0 (82.0–107.0)	84.0 (71.0–98.0)	<0.001

FEV_1 = forced expiratory volume in one second

* number of patients in this category with FEV_1 data

Table 4:

Variability in Smoking Status by Region

	Total n=24,851	**Northeast n=7,992 (32.3%)**	**Midwest n=5,725 (23.0%)**	**South n=8,091 (32.6%)**	**West n=3,043 (12.2%)**
Current Smoker	5,733 (23.1%)	1,706 (21.3%)	1,344 (23.5%)	2,082 (25.7%)	601 (19.8%)
Former Smoker	15,336 (61.7%)	5,086 (63.6%)	3,559 (62.2%)	4,864 (60.1%)	1,827 (60.0%)
Never Smoker	3,782 (15.2%)	1,200 (15.0%)	822 (14.4%)	1,145 (14.2%)	615 (20.2%)

$p<0.001$ for the comparison of smoking status by region