Utilization of Supplemental Regional Anesthesia in Lobectomy for Lung Cancer in the United States: A Retrospective Study

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Background: Pulmonary lobectomy is the standard of care for the treatment of early-stage non-small cell lung cancer. This study investigated the rate of utilization of supplemental anesthesia in patients undergoing video-assisted thoracoscopic surgery (VATS) or open lobectomy using a national database and assessed the effect of regional block (RB) on postoperative outcomes.

Methods: Patients who underwent lobectomy for lung cancer between 2014–2019 were identified in the American College of Surgeons National Surgical Quality Improvement Program. The patients' primary mode of anesthesia and supplemental anesthesia were recorded. Preoperative characteristics and postoperative outcomes were compared between 2 surgical groups: those who underwent general anesthesia (GA) alone versus GA with RB. Multivariable regression analyses were performed on the outcomes of interest.

Results: In total, 13,578 patients met the study criteria, with 87% undergoing GA and the remaining 13% receiving GA and RB. The use of neuraxial anesthesia decreased over the years, while RB use increased up to 20% in 2019. Age, body mass index, and preoperative comorbidities were comparable between groups. Patients who underwent VATS were more likely to receive RB than those who underwent thoracotomy. RB was most often utilized by thoracic surgeons. An adjusted analysis showed that RB use was associated with shorter hospital stays and a reduced likelihood of prolonged length of stay, but a higher rate of surgical site infections (SSIs).

Conclusion: In a large surgical database, there was underutilization of supplemental anesthesia in patients undergoing lobectomy for lung cancer. RB utilization was associated with a shorter length of hospital stay and an increase in SSI incidence.

Keywords: Lobectomy, Anesthesia, National Surgical Quality Improvement Program, Outcomes

Introduction

Lung cancer is the leading cause of cancer-related deaths worldwide [1]. Survival in lung cancer continues to be among the lowest when compared to other cancers [2]. Approximately 80%–85% of all newly diagnosed lung cancers are non-small cell lung cancer (NSCLC) [3]. For early-stage NSCLC, lobectomy performed by thoracotomy or minimally invasive thoracoscopic or robotic-assisted surgery is the standard of care for oncological resection [4,5]. Thoracic surgery poses unique challenges in the anesthetic management and pain control of these patients. General anesthesia (GA) is the standard of care in the operative management of patients undergoing lobectomy, with supplemental anesthesia—including neuraxial (spinal or epidural) or regional block (RB)—being an important adjunct.

Supplemental anesthesia plays a significant role in optimizing postoperative pain management [6]. RB, including paravertebral, serratus anterior, and intercostal nerve blocks, has been proposed for pain control in patients undergoing lobectomy [7]. Some studies have reported similar analgesic efficacy for RB compared to neuraxial anesthesia in patients undergoing thoracotomy, with a better safety profile [8].

The available data on the use of regional anesthesia in lung cancer resection patients mostly come from single-institution studies with small numbers of patients [9-11]. There is a lack in the literature of a multicenter study assessing data on contemporary practice patterns of supplemental anesthesia use in patients undergoing video-assisted thoracoscopic surgery (VATS) or open lobectomy for lung cancer and evaluating the impact of RB on postoperative complications and outcomes. Using a large national surgical database, we aimed to investigate trends in the utilization of supplemental anesthesia and to assess the postoperative outcomes of patients undergoing lobectomy for early-stage NSCLC under GA alone versus GA with RB.

Methods

Due to its use of completely de-identified data, our study was deemed exempt by Virginia Commonwealth University Review Board. The requirement for informed consent from individual patients was omitted because of the retrospective design of this study.

Database and patient population

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was queried for patients who underwent lobectomy for lung cancer between 2014 and 2019. The ACS-NSQIP contains over 135 variables captured from de-identified surgical cases performed at participating hospitals. These variables include preoperative characteristics, intraoperative events, and postoperative outcomes within 30 days of the operation.

The Current Procedural Terminology codes 32663 and 32480 were used to identify patients who underwent lobectomy with the video-assisted thoracoscopic or open (thoracotomy) approach, respectively. Only patients with the following International Classification of Diseases (ICD), ninth revision codes for lung tumors were included: 162, 162.3, 162.4, 162.5, 162.8, and 162.9 for malignant neoplasms of the bronchus or lung; 209.7 for neuroendocrine tumors, 212.3 for benign neoplasms of bronchus and lung; 231.2 for carcinoma *in situ*; 235.7 for neoplasms of uncertain behavior of trachea, bronchus, and lung; and 239.1 for neoplasms of unspecified nature of the respiratory system. The ICD-10 codes included were C34 for malignant neoplasms of the bronchus and the lung, D02.21 and D02.22 for carcinoma *in situ*, D14.30 for benign neoplasms, D38.1 for neoplasms of uncertain behavior, D3A.090 for carcinoid tumors, D49.1 for other neoplasms of unspecified be-

havior of the respiratory system, and R91.1 for solitary pulmonary nodules.

Patients with metastatic disease, an American Society of Anesthesiologists Physical Status Classification (ASA) class of 5, and cases of surgery performed in emergent settings were excluded from the study. Patients who underwent lobectomy for other pathologies, including infectious diseases (pulmonary abscess, mycobacterial infection, coccidioidomycosis, and mycoses) were not included given the technical difficulties and heterogenicity of outcomes in these cases.

Patient demographics and clinical characteristics, and study outcomes

The patients' primary mode of anesthesia, as well as supplemental anesthesia (reported as other anesthetics in the NSQIP database), were recorded to assess the rate of utilization of regional anesthesia, including blocks and neuraxial (epidural and spinal) anesthesia, over the years. The patients were divided into 2 groups: those who underwent GA as a sole modality and those who underwent GA and RB. Patients who received GA and neuraxial anesthesia, as well as RB, were excluded.

The following preoperative variables were studied: demographic and anthropomorphic information (age, sex, and body mass index [BMI]), ASA class, history of weight loss greater than 10%, smoking (within the last year), and history of comorbid conditions (diabetes mellitus, hypertension, severe chronic obstructive pulmonary disease [COPD], congestive heart failure and chronic renal failure requiring dialysis). Severe COPD is defined by the NSQIP as a patient with a current diagnosis of COPD and functional disability from his/her disease, who requires chronic treatment or has had a recent hospitalization secondary to exacerbation [12].

The primary surgeon's specialty (thoracic surgery, general surgery, or others [including cardiac surgery]) were compared. Postoperative adverse outcomes included pneumonia, pulmonary embolism, prolonged intubation (>48 hours), unplanned re-intubation, wound infection, urinary tract infection, acute renal failure, myocardial infarction, cardiac arrest requiring cardiopulmonary resuscitation, bleeding requiring transfusion, deep venous thrombosis, stroke, sepsis, length of stay as a numerical variable (truncated to the nearest day), prolonged hospital stay (>6 days) and 30-day mortality. Other postoperative outcomes included the rates of discharge to a facility, reoperation, and readmission.

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Statistical analyses

Continuous variables were presented as mean±standard deviation or median and interquartile range and compared between the 2 surgical groups using 1-way analysis of variance or the Kruskal-Wallis test, whereas categorical variables were summarized via frequency and percentage and compared using the Pearson chi-square test or the Fisher exact test. For an adjusted analysis, multivariable linear or logistic regression models with a backward selection procedure via the Akaike information criterion were constructed for all postoperative outcomes of interest. The covariates considered in the model building process were preoperative demographics, comorbidities, the surgical approach, and the surgeon's specialty. Odds ratios (ORs) along with 95% confidence intervals (CIs) were computed for each of the estimated parameters in the model. Due to the heavy right-skewness and overdispersion in the distribution of length of hospital stay, a log-transformation was
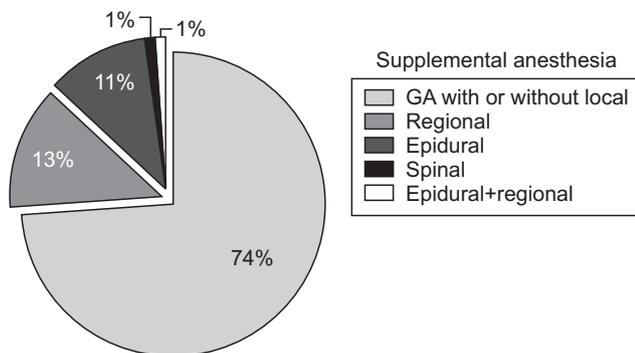
applied to the outcome before constructing the linear regression model. IBM SPSS for Windows ver. 27.0 (IBM Corp., Armonk, NY, USA) and SAS ver. 9.4 (SAS Institute Inc., Cary, NC, USA) were used for all analyses, and a p-value <0.05 was considered to indicate statistical significance.

Results

An analysis of the use of supplemental anesthetics for open and VATS lobectomy for lung cancer from 2014–2019 demonstrated that the majority (74%) of lobectomies during this period were performed using GA alone, whereas GA and RB were performed in 13% of procedures. GA was performed with epidural anesthesia in 11% of procedures, spinal anesthesia in 1%, and both neuraxial anesthesia and RB in 1%. The percentages of utilization of supplemental anesthesia are illustrated in Fig. 1. The use of neuraxial anesthesia decreased over the years, while RB use increased to 20% of the patients in 2019 (Fig. 2).

A total of 13,578 patients met the inclusion and exclusion criteria for the study, with 87% undergoing GA and the remaining 13% receiving GA and RB. Age and BMI were comparable between both groups, with a mean age of 67 years and a mean BMI of 28 kg/m^2. The GA-only group had a higher proportion of male patients than the GA with RB group. The proportions of patients with preoperative comorbidities such as diabetes mellitus, hypertension, congestive heart failure, end-stage renal disease on dialysis, and severe COPD were comparable between the groups. The patients who underwent VATS were more likely to receive RA than those who underwent thoracotomy (14.1% versus 10.4%, p<0.01). GA and RB were most often utilized by board-certified thoracic surgeons (96.6% versus 89.6%,
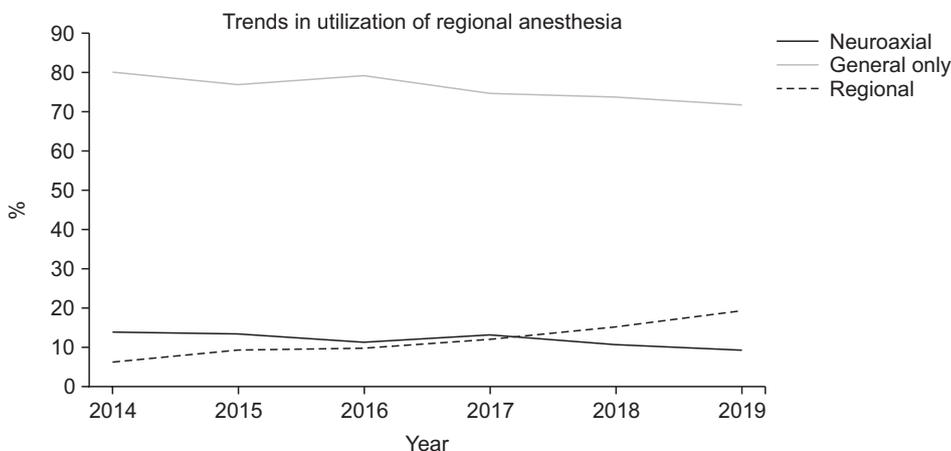

Fig. 1. The percentage of supplemental anesthesia utilization in patients undergoing lobectomy for lung cancer, 2014–2019. GA, general anesthesia.

Fig. 2. Trends in the utilization of neuraxial and regional block.

p<0.01), while a higher percentage of board-certified general surgeons performed lobectomy under GA only (7.85% versus 2.20%, p<0.01) (Table 1).

A baseline comparison of adverse perioperative outcomes showed comparable rates of pneumonia, sepsis, myocardial infarction, urinary tract infections, unplanned intubation, readmission, and mortality between the treatment groups. However, patients who underwent GA and RB had higher rates of surgical site infections (SSIs) (1.92% versus 1.00%, p<0.01), a longer total operative time (188.3±81.8 minutes versus 181.3±83.9 minutes, p<0.01), and a lower likelihood of a prolonged hospital stay (>6 days) (19.5% versus 23.2%, p<0.01). Patients in the GA and RB group had a shorter length of stay (4.89 days versus 5.21 days, p<0.01) (Table 2). The log-transformed length of stay was 1.67±0.53 in the GA group compared to 1.60±0.54 in the block patients (p<0.01).

Adjusted analyses of the impact of RB supplementation on postoperative outcomes demonstrated that patients with GA and RB had higher odds of SSI (OR, 1.97; 95% CI, 1.34–2.90) and a longer operative time (OR, 7.82; 95% CI, 3.68–11.97), but lower odds of a prolonged (>6 days) hospital stay (OR, 0.86; 95% CI, 0.76–0.99) (Table 3). RB did not impact the rates of other postoperative complications.

The predictors of length of hospital stay are delineated in Table 4. Adjusted for preoperative and demographic characteristics, the use of RB was associated with a 4.2% reduction in length of stay (p=0.001). Conversely, patients with COPD had an estimated effect of a 19% increase in length of hospital stay. The results of this analysis demonstrate that age, BMI, male sex, preoperative weight loss, smoking, hypertension requiring medication, dialysis, ASA class, and surgical specialty were also significant predictors of the length of stay.

Discussion

Our study, using the NSQIP database, demonstrated an increased use of regional analgesia from 2014 to 2019. Despite an increase in the utilization of this anesthetic technique, only 13% of all lobectomy cases used RB throughout the study period. The gold standard for locoregional anesthesia for VATS and open lobectomy has previously been thoracic epidural analgesia [13,14]. A recent study has suggested the importance and efficacy of incorporating regional anesthesia into Enhanced Recovery After Surgery

Table 1. Comparisons of demographics and preoperative clinical characteristics between the surgical groups

Characteristic	Total	General anesthesia	General anesthesia+ regional block	p-value
No. of patients	13,578 (100.00)	11,808 (87.00)	1,770 (13.00)	
Age (yr)	67.50±9.35	67.56±9.37	67.64±9.50	0.743
Male sex	5,967 (43.95)	5,234 (44.33)	733 (41.41)	**0.022**
Body mass index (kg/m²)	28.03±6.00	28.01±6.04	27.92±5.79	0.567
Weight loss >10%	257 (1.89)	227 (1.92)	30 (1.69)	0.513
Diabetes mellitus	2,301 (16.95)	2,007 (17.00)	294 (16.61)	0.690
Smoking	4,820 (35.50)	4,221 (35.75)	599 (33.84)	0.118
Severe COPD	3,273 (24.11)	2,817 (23.86)	456 (25.76)	0.080
Congestive heart failure	72 (0.53)	65 (0.55)	7 (0.40)	0.402
Hypertension	8,151 (60.03)	7,083 (60.00)	1,068 (60.34)	0.777
ESRD on dialysis	46 (0.34)	37 (0.31)	9 (0.51)	0.188
ASA class				0.398
1 & 2	2,438 (17.97)	2,133 (18.08)	305 (17.25)	
3 & 4	11,128 (82.03)	9,665 (81.92)	1,463 (82.75)	
Lobectomy				**<0.001**
VATS	9,532 (70.20)	8,184 (69.31)	1,348 (76.16)	
Thoracotomy	4,046 (29.80)	3,624 (30.69)	422 (23.84)	
Surgeon's specialty				**<0.001**
Thoracic surgery	12,332 (90.82)	10,622 (89.96)	1,710 (96.61)	
General surgery	966 (7.11)	927 (7.85)	39 (2.20)	
Others	280 (2.06)	259 (2.19)	21 (1.19)	

Values are presented as number (%) for categorical variables or mean±standard deviation for continuous variables. The bold type is considered statistically significant.

COPD, chronic obstructive pulmonary disease; ESRD, end-stage renal disease; ASA, American Society of Anesthesiologists; VATS, video-assisted thoracoscopic surgery.

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Table 2. Comparisons of adverse perioperative outcomes between surgical groups

Variable	Total	General anesthesia	General anesthesia+ regional block	p-value
No. of patients	13,578 (100)	11,808 (87)	1,770 (13)	
Pneumonia	637 (4.69)	548 (4.64)	89 (5.03)	0.472
Pulmonary embolism	74 (0.54)	64 (0.47)	10 (0.07)	0.903
Prolonged intubation	224 (1.65)	192 (1.63)	32 (1.81)	0.573
Unplanned intubation	342 (2.52)	298 (2.52)	44 (2.49)	0.925
Superficial and deep SSI	152 (1.12)	118 (1.00)	34 (1.92)	**<0.001**
Organ space SSI	87 (0.64)	77 (0.65)	10 (0.56)	0.668
Urinary tract infection	161 (1.19)	138 (1.17)	23 (1.30)	0.636
Sepsis	114 (0.84)	98 (0.83)	16 (0.90)	0.750
Cardiac arrest	91 (0.67)	80 (0.68)	11 (0.62)	0.788
Myocardial infarction	87 (0.64)	75 (0.64)	12 (0.68)	0.833
CVA with neurological deficit	70 (0.52)	61 (0.52)	9 (0.51)	0.965
Acute renal failure	46 (0.34)	39 (0.33)	7 (0.40)	0.660
Bleeding requiring transfusion	490 (3.61)	437 (3.70)	53 (2.99)	0.137
DVT/thrombophlebitis	76 (0.56)	63 (0.53)	13 (0.73)	0.291
Total operative time (min)	183.19±84.04	181.30±83.89	188.25±81.83	**0.001**
Length of hospital stay (day)	5.27±4.35	5.21±4.36	4.89±4.58	**<0.001**
Length of hospital stay (day)	4.00 (3.00–6.00)	4.00 (3.00–6.00)	4.00 (2.00–6.00)	**<0.001**
Prolonged hospital stay (>6 day)	3,089 (22.75)	2,744 (23.24)	345 (19.49)	**<0.001**
Length of stay >30 day	37 (0.27)	32 (0.27)	5 (0.28)	0.931
Mortality	157 (1.16)	141 (1.19)	16 (0.90)	0.287
Any complication	1,680 (12.37)	1,453 (12.31)	227 (12.82)	0.535
Discharge to a facility	682 (5.03)	606 (5.14)	76 (4.30)	0.217
Reoperation	552 (4.07)	468 (3.96)	84 (4.75)	0.120
Readmission	1,003 (7.41)	876 (7.44)	127 (7.20)	0.720

Values are presented as number (%) for categorical variables, mean±standard deviation for continuous variables, or median (25th–75th percentile interquartile range), unless otherwise stated. The bold type is considered statistically significant.
SSI, surgical site infection; CVA, cerebrovascular accident; DVT, deep venous thrombosis.

protocols in thoracic surgery patients [15]. With the increase in the use of regional analgesia in VATS and open thoracotomy cases, there is a need for contemporary research evaluating its effect on postoperative outcomes.

Our investigation found that, over time, more thoracic surgeons used RB during lobectomy for lung cancer. RB was more frequently used in VATS cases than in open thoracotomies. These 2 findings could potentially be related to each other. Thoracic surgeons' increasing experience and comfort in performing thoracoscopic surgery and their familiarity with postoperative care for these patients may encourage surgeons to use RB, including performing intercostal blocks, during VATS. The increased rate of utilization of RB is supported by evidence from other studies demonstrating equal efficacy to neuraxial anesthesia (specifically, thoracic epidurals) with fewer complications [8].

Our study also found a significant decrease in prolonged hospitalizations when supplemental RB use was implemented, with similar overall complication rates. Among other factors, the surgical approach could contribute to

prolonged hospitalization after lobectomy, as the VATS approach has been shown in previous studies to shorten the length of stay [16-18]. The use of RB in our analysis, after adjusting for other contributing factors including the surgical approach, was independently associated with a lower rate of prolonged length of stay. This finding could have been driven by better pain control and fewer sedative effects from narcotics; this would allow allowing patients to be more active and participate in pulmonary hygiene exercises following surgery, which would then lead to faster normalization to day-to-day activities and eventual early discharge [19].

Surgical trauma can lead to an increased surgical stress response, which can have an impact on the immune response because nociceptive receptors communicate with the brain and affect levels of proinflammatory cytokines and lymphocyte activity [20-22]. By providing improved analgesia, it would be reasonable to think that the level of immunosuppression following lobectomy would be reduced, leading to a lower risk of SSIs; this would be partic-

Table 3. Adjusted analysis of the associations of regional anesthesia associations with post-lobectomy outcomes

Outcome	Associations of regional anesthesia with outcomes	
	OR (95% CI)	p-value
Pneumonia	1.16 (0.92–1.47)	0.211
Pulmonary embolism	1.04 (0.53–2.03)	0.914
Prolonged intubation	1.19 (0.81–1.75)	0.371
Unplanned intubation	1.04 (0.75–1.44)	0.814
Superficial and deep SSI	1.97 (1.34–2.90)	**0.001**
Organ space SSI	0.89 (0.46–1.73)	0.736
Urinary tract infection	1.10 (0.71–1.73)	0.664
Sepsis	1.11 (0.65–1.90)	0.690
Cardiac arrest	0.99 (0.53–1.09)	0.980
Myocardial infarction	1.07 (0.58–1.98)	0.824
CVA with neurological deficit	1.00 (0.50–2.03)	0.995
Acute renal failure	1.36 (0.61–3.08)	0.454
Bleeding requiring transfusion	0.90 (0.67–1.20)	0.487
DVT/thrombophlebitis	1.46 (0.80–2.67)	0.219
Total operative time (min)	7.82 (3.68–11.97)	**<0.001**
Prolonged hospital stay (>6 day)	0.86 (0.76–0.99)	**0.030**
Length of stay >30 day	1.10 (0.42–2.86)	0.844
Mortality	0.78 (0.46–1.32)	0.355
Any complication	1.12 (0.96–1.30)	0.156
Discharge to a facility	0.87 (0.69–1.14)	0.344
Reoperation	1.25 (0.98–1.59)	0.069
Readmission	0.99 (0.82–1.20)	0.926

The bold type is considered statistically significant.
OR, odds ratio; CI, confidence interval; SSI, surgical site infection; CVA, cerebrovascular accident; DVT, deep venous thrombosis.

Table 4. Predictors associated with the length of hospital stay after lobectomy for lung cancer

Associated factor	Predictors associated with the length of hospital stay	
	Coefficient (95% CI)	p-value
Addition of regional anesthesia	0.96 (0.93–0.98)	**0.001**
Age	1.005 (1.004–1.006)	**<0.001**
Sex (male vs. female)	1.05 (1.03–1.07)	**<0.001**
Body mass index	0.996 (0.994–0.997)	**<0.001**
Preoperative weight loss >10%	1.10 (1.03–1.17)	**0.003**
Smoking	1.09 (1.07–1.12)	**<0.001**
Chronic obstructive pulmonary disease	1.19 (1.17–1.22)	**<0.001**
Hypertension requiring medication	1.03 (1.01–1.05)	**0.003**
Dialysis	1.34 (1.16–1.55)	**<0.001**
ASA 3/4 vs. 1/2	1.09 (1.07–1.12)	**<0.001**
Thoracoscopic vs. open	0.71 (0.70–0.72)	**<0.001**
Surgeon's specialty		**<0.001**
Thoracic vs. general	0.98 (0.95–1.01)	0.144
Other vs. thoracic	1.18 (1.10–1.25)	**<0.001**

The bold type is considered statistically significant.
CI, confidence interval; ASA, American Society of Anesthesiologists.

ularly reasonable to expect in patients undergoing VATS, which has lower rates of SSIs [23]. Our study found that patients receiving RB had higher rates of superficial and deep SSIs, which are typically managed with local drainage and antibiotics; however, the rates of sepsis and organ space infections were similar. This could potentially have been due to the introduction of extrinsic sources of infection via the migration of skin bacteria through a needle track site into the tissue surrounding the pleural cavity. These SSIs related to RB may result in potentially long-term adverse effects [24]. Although rare, the use of catheters during regional anesthesia could have introduced bacteria around the surgical site, leading to the increase in superficial and deep SSIs observed in our study [25]. This finding warrants further research and could potentially be an area for further improvement with the use of RB in thoracic surgery.

Lastly, our study evaluated various preoperative patient characteristics that had significant associations with length of stay. Age, male sex, preoperative weight loss, smoking history, history of COPD, hypertension requiring medication, dialysis dependency, and having a higher ASA score preoperatively are all correlated with an increased length of hospital stay following thoracic surgery. A focus on preventative medicine prior to surgery could reduce the length of stay for these patients following surgery. Smoking cessation education and the preoperative inclusion of registered dieticians for nutritional education can help to reduce comorbidities related to an increased length of stay, which can further reduce medical costs for the patients. The use of RB, the VATS approach, and surgery performed by a thoracic surgeon were all associated with a significantly shorter length of stay following lobectomy for lung cancer. Gaining more experience with focused postoperative management may help thoracic surgeons feel more comfortable discharging patients earlier after lobectomy.

This study has multiple limitations, most of which are inherent to the NSQIP database and the available variables. The NSQIP database is not specifically a thoracic surgery database; thus, it does not contain many perioperative factors that are important to this specialty, including preoperative pulmonary function tests, chest tube placement and duration, postoperative pain scores at various intervals, the extent of lymph node dissection, postoperative air leak, and tumor location. Many of these variables could have influenced the length of stay and complication rates, thus

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confounding the results of our study. The NSQIP database also does not go into detail regarding the type of block or the placement of catheters for RB versus a 1-time dose of anesthetic. Despite these limitations, we decided to use the NSQIP database, since it is a large national database that contains information from over 690 hospitals throughout the United States. This database is also risk-adjusted and case-mix-adjusted to account for differences between hospitals. These qualities made the NSQIP database desirable for answering our question regarding the impact of RB use on postoperative outcomes.

In conclusion, although there was an increasing trend in the use of RB in recent years, a large proportion of surgeons still solely utilized GA without the use of supplemental anesthesia. RB was used more frequently by thoracic surgeons and was independently associated with a shorter length of hospital stay and a lower likelihood of a prolonged hospital stay, but an increase in SSIs. RB did not affect other surgical complications, including pneumonia, organ space infection, sepsis, re-intubation, return to the operating room, and readmission.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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