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Inpatient lung cancer surgery outcomes in Illinois

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ABSTRACT

Objective: This study analyzed inpatient mortality and length of stay for lung cancer surgery in Illinois hospitals by patient clinical and demographic characteristics, procedure types, and hospital and surgeon volume.
Methods: The study analyzed lung cancer patients who underwent lobectomy or sublobar resection at Illinois hospitals from 2016 to June 2022. Trends in procedure type, inpatient mortality, one-day length of stay (LOS), and prolonged LOS (>10 days) were evaluated. Regression models were used to determine the likelihood of inpatient death and length of stay while controlling for clinical, procedure, hospital, and surgeon characteristics.
Results: There were 9602 admissions for lung cancer surgery at 89 non-federal Illinois hospitals. Overall, 0.7% of patients died, 12.2% of patients had one-day LOS, and 7.4% patients had prolonged LOS. From 2016 to 2022, rates of one-day LOS increased from approximately 5% to 23%, prolonged LOS dropped from almost 18% to under 5%, robotic lobectomies increased from <5% of procedures to over 40%, and VATS lobectomies went from almost 50% to 13%. The proportion of open lobectomy procedures remained stable. Robotic and VATS procedures were generally associated with better outcomes; however, VATS sublobar procedures were associated with worse LOS and mortality outcomes. Hospitals and surgeons with higher procedure volumes had significantly better outcomes.
Conclusions: Lung cancer surgery had low inpatient mortality and better LOS outcomes, with robotic steadily replacing VATS procedures. Higher hospital or surgeon volume was associated with better patient outcomes and may have been related to the greater utilization of Enhanced Recovery After Surgery Programs.

Introduction

Lung cancer is one of the most commonly diagnosed cancers. In 2022, there were projected to be around 350 lung cancer-related deaths per day [1,2]. Around one in five cancer-related deaths are due to lung cancer [3]. In Illinois, around 21% of lung cancer cases were initially treated with surgical resection [4]. Though, historically, surgical resection was performed with an open thoracotomy and was associated with 2.0% perioperative mortality and a 6-day length of stay, there have been many changes in patient management over the last decade with regard to patient safety, early discharge, and minimally invasive operative approach techniques [5,6]. Though previous research has sought to characterize the change in perioperative outcomes among patients who receive lung resection, contemporary rates of inpatient mortality, length of stay, and uptake of minimally invasive operative approach are less well known.

To shed further light on recent trends in lung cancer surgery, this population-based study analyzes inpatient outcomes for lobectomy and sublobar resections for lung cancer in Illinois. We explore variation in lung cancer surgical admissions for inpatient deaths, length of stay (LOS), one-day stays, and long stays >10 days, a usually reliable proxy for significant perioperative complications. Using Illinois hospital data for admissions for 78 months from January 2016 to June 2022, study findings present associations between patient, surgeon, hospital, and procedure type characteristics and inpatient outcomes.

Methods

Data source

We analyzed all ICD-10 coded lobectomy and sublobar procedures for patients with lung cancer using data from the Illinois Hospital Association's (IHA) Comparative Health Care and Hospital Data Reporting Services database. Data include admissions with procedures done from

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January 2016 to June 2022 at Illinois Hospital Association hospitals, which excludes Illinois Veterans Affairs hospitals. All study data were deidentified, publicly available, and exempt from Institutional Review Board (IRB) approval.

Patient sociodemographic and clinical characteristics

Patient characteristics included sex, race and ethnicity, classified as Non-Hispanic White, Non-Hispanic Black, Hispanic, Asian, and other/unknown, and insurance type, categorized as Medicaid/uninsured. Patient Charlson Comorbidity Index scores, a measure of 20 chronic disease comorbidities based on admission ICD-10 codes, were used as a severity of illness measure [7]. and categorized at five levels based on scores 2, 3, 4, 5-6, and >6. To provide an estimate of patient socioeconomic status, patient zip codes were matched to American Community Survey 2020 5-year file zip code census tract (ZCTA) data on the percent of households at or below the federal poverty line. ZCTAs were classified as <5%, 5%-9.99%, 10%-19.99%, 20%+ poor or non-Illinois resident.

Procedure types

Sublobar and lobectomy tumor resection procedures were uniquely categorized based on intention to treat as robotic, VATS, or open only, with the first two categories inclusive of conversion to open. Procedures were further categorized as either lobectomy or sublobar only, resulting in six possible procedure types: robotic sublobar, VATS sublobar, open sublobar, robotic lobectomy, VATS lobectomy, and open lobectomy.

Hospital lung cancer surgery volume, travel distance and surgeon volume

Monthly hospital volume was calculated from all admissions during the study period and characterized as one or less per month, 1-3 per month, or >3 per month. We calculated the distance in miles from the centroid of each patient's zip code to the centroid of the procedure facility's zip code, classified as 75+ miles. Annual surgeon volume was aggregated using data for the operating clinician national provider (NPI) number and categorized as <6 per year, 6-20 per year, or >20 per year.

Statistical methods

Statewide monthly procedures were calculated for the 78-month study period and plotted to analyze trends in procedure type and outcomes. Bivariate chi-square tests were utilized to determine the significance of associations between patient, hospital, and surgeon characteristics and inpatient death and one-day or >10-day stays, using a $p < 0.01$ significance level to account for multiple comparisons. To provide better estimates of relative risk than odds ratios, robust Poisson multivariate regression incidence rate ratios were estimated to analyze the association of patient, hospital, and surgeon characteristics with the likelihood of inpatient death [8]. The same model was estimated using odds ratios from logistic regression for one day and long LOS. All models adjusted standard errors for the clustering of observations within hospitals. Statistical analyses were done with STATA version 17 (College Station, TX).

Results

There were 9,602 admissions of patients undergoing lung cancer surgical procedures over the 78-month study period at 89 IHA hospitals. There were 227 surgeons, with 87 of those (38.3%) having only a single procedure and 40 (17.6%) having >50 procedures; the highest volume surgeon was listed for 719 procedures. Overall, 66 (0.7%) patients died, 1169 (12.2%) had one-day stays, and 715 (7.4%) experienced LOS>10 days. The median LOS was four days (IQR=2-6).

Fig. 1 presents a histogram of procedure volume by hospital. Hospital volume was clustered with almost half of the institutions with <200 procedures and three substantial volume institutions with 700 or more over the study period. Fig. 2 depicts monthly trends in procedure types, shown as a percentage of all lung cancer surgery procedures based on intention to treat over the study period. Robotic lobectomies show a considerable increase during the period, from less than 5% of procedures in the first months of 2016 to a peak of over 40% in April 2022. Conversely, the percentage of VATS lobectomies trended downward from 40-50% or more of procedures done in the first nine months of 2016 to only 13% of procedures by June 2022. Open lobectomy procedures fluctuated between 21 and 42% with a relatively stable monthly mean of 27%, while the percentage of admissions with sublobar procedures increased modestly in the first six months of 2022.

Fig. 3 illustrates monthly trends in inpatient death, one-day stays, and stays >10 days. Deaths were rare (zero in many months), and there was a substantial increase in the percent of admissions with one-day stays and a corresponding decrease in stays >10 days. Long stays >10 days went from a peak of almost 18% in a number of months in 2016 to less than 5% in May and June 2022. One-day stays increased from

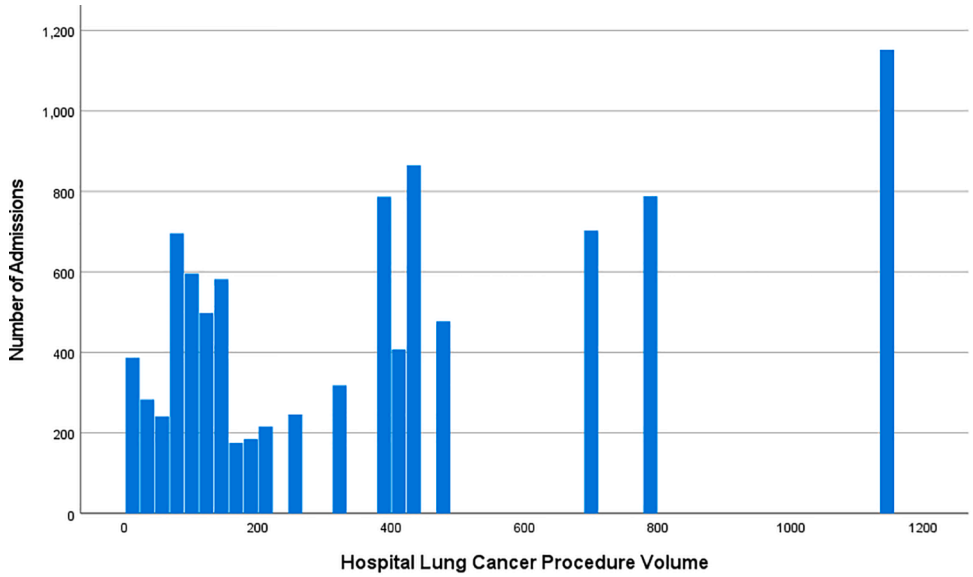

Fig. 1. Distribution of hospital lung cancer surgery volume, N-9602 admissions at 89 non-federal Illinois Hospitals, 1/2016-6/2022.

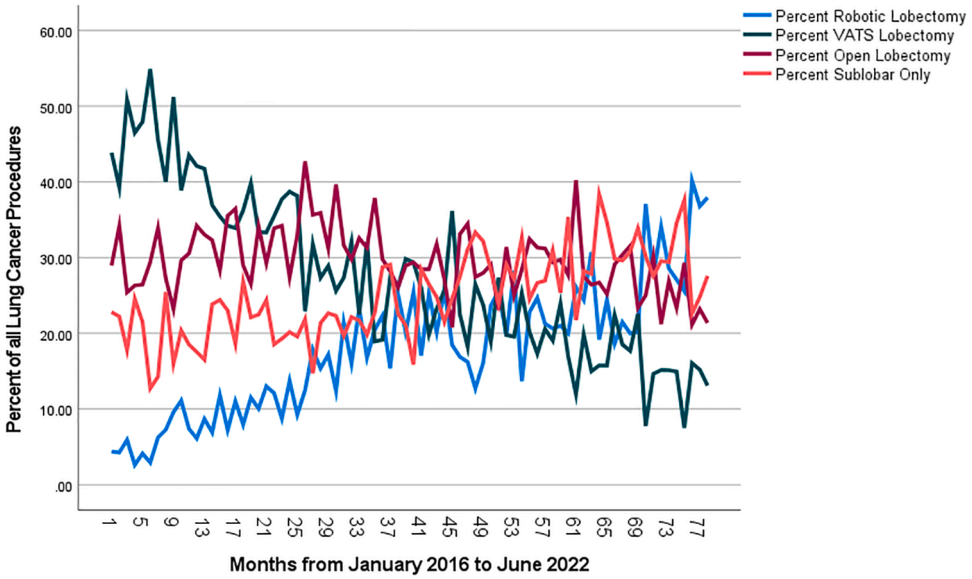

Fig. 2. Monthly percent of lung cancer surgery by procedure Type, N-9602 admissions at 89 non-federal Illinois Hospitals, 1/2016-6/2022.

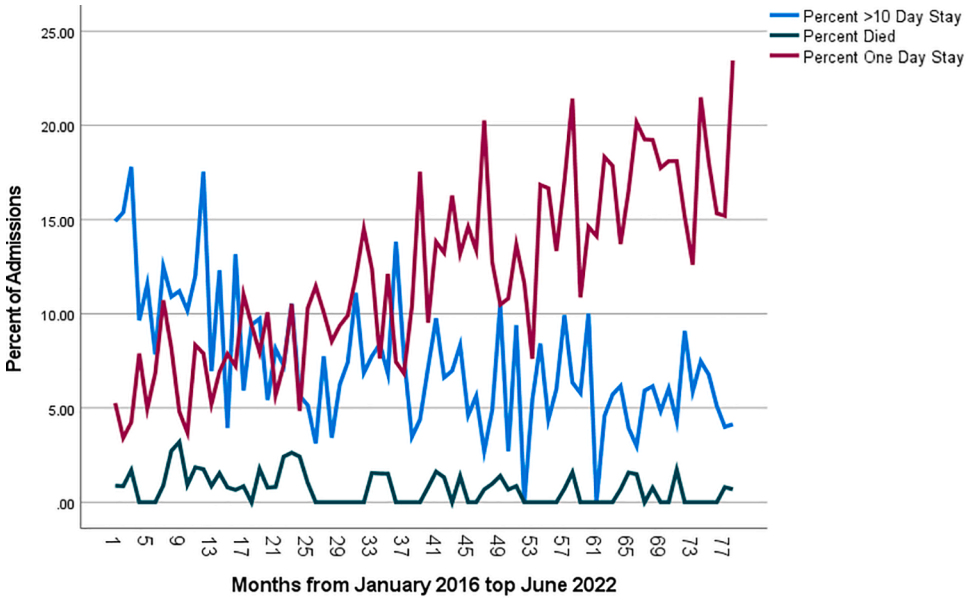

Fig. 3. Monthly percent of lung cancer surgery inpatient mortality and length of stay outcomes, N-9602 admissions at 89 non-federal Illinois Hospitals, 1/2016-6/2022.

around 5% in early 2016 to over 23% in June 2022.

Patient demographics and clinical characteristics

Male patients had significantly higher long LOS (Table 1). Patients aged 75 or older had a non-significant (at $p < 0.01$) higher death rate, fewer one-day stays, and a higher percentage of long stays. Non-Hispanic white and especially Asian patients had significantly higher one-day stays, with non-significantly fewer long stays. The small number of Hispanic patients had the highest death rate (1.5%), although this was also non-significant. A small number (5.6%) of Medicaid/uninsured patients had non-significantly worse mortality and higher long LOS. Patients from ZCTA areas with >10% poor residents had significantly lower one-day and higher long LOS. Patient Charlson scores showed a gradient of worse mortality and LOS outcomes as comorbidity increased.

Hospital procedure volume, procedure types, and surgeon volume

Almost 60% of admissions were to hospitals with >3 procedures per month. Higher hospital procedure volumes were associated with better LOS and non-significant mortality outcomes. Procedure outcomes differed significantly across all three outcomes. VATS sublobar and open lobectomy procedures had the highest death rates and the worst LOS outcomes, with the highest number of long LOS and the lowest number of one-day stays at the lowest volume institutions. VATS sublobar procedures had anomalous outcomes, with a high (1.7%) death rate, high (16.7%) numbers of one-day stays, and a high (14.7%) rate of long LOS. Conversely, 30% of open sublobar procedures had one-day stays, as did over 20% of sublobar lobectomies, with <5% having long LOS. Open lobectomy procedures had higher mortality (1.5%) and higher long LOS (14.2%).

Lower surgeon procedure volumes, which represented less than 10%

Table 1
Inpatient Lung Cancer Surgical Procedure Outcomes for 89 Illinois Hospitals N=9602 Admissions from 1/2016 to 6/2022.

	Column Percent All Patients	Row Percent Inpatient Death $N = 69$	Row Percent Length of Stay =1 Day $N =$ 1169	Row Percent Length of Stay >10 Days* $N =$ 715
All Patients	100	0.7	12.2	7.5
Male[c]	43.7	0.9	12.1	9.3
Female[c]	56.3	0.6	12.3	6.0
Age				
<65	31.1	0.4	12.4	6.7
65-74	42.4	0.8	12.5	7.5
75+	26.6	0.9	11.4	8.3
Race and Ethnicity[b]				
Non-Hispanic White	75.2	0.7	13.0	7.5
Non-Hispanic Black	10.9	1.0	8.6	9.0
Hispanic	2.7	1.5	11.9	6.2
Asian	2.5	0.8	15.2	5.1
Other/ Unknown	8.6	0.4	8.5	6.0
Insurance[b]				
Medicaid/ Uninsured	5.6	1.1	7.8	12.0
Travel Distance (miles)				
75+	3.2	1.0	12.8	8.6
Charlson Score[a,b,c]				
2	27.5	0.1	17.9	2.8
3	30.6	0.5	11.3	7.3
4	14.6	0.9	9.4	9.1
5-6	19.1	1.2	8.7	10.2
>6	8.2	1.9	9.1	14.9
Zip Code Census Tract Area Percent Poor Households[b,c]				
Non- IL resident	5.7	0.2	10.8	5.3
<5	37.9	0.4	15.9	6.2
5-9.99	28.7	1.1	12.2	8.1
10-19.99	22.1	0.8	7.0	9.0
20+	5.7	0.9	8.5	9.4
Hospital Procedure Volume[b,c]				
1 or less per month	14.1	1.0	4.1	11.8
1-3 per month	26.1	0.8	5.8	10.7
>3 per month	59.8	0.6	16.9	5.0
Type of Procedure[a,b,c]				
VATS Sublobar	2.4	1.7	16.7	14.7
Open Sublobar	16.1	0.2	30.5	4.5
Robotic Sublobar	6.5	0.6	20.5	2.1
Open Lobectomy	27.2	1.5	0.3	14.2
VATS Lobectomy	29.6	0.3	12.6	5.2
Robotic Lobectomy	18.2	0.6	9.4	4.7
Surgeon Volume[a,b,c]				
<6 per year	9.4	2.3	2.7	18.1
6-20 per year	18.1	0.5	6.4	12.7
>20 per year	72.5	0.6	14.8	7.1

[a] $p < 0.01$ Inpatient Death.
[b] $p < 0.01$ Length of Stay =1 Day.
[c] $p < 0.01$ Length of Stay >10 Days.
* Excludes $N = 40$ inpatient deaths with length of stay less than 11 days, $N =$ 9533.

of the sample admissions, had significantly worse outcomes. Low-volume surgeons performing less than six procedures per year had a very high (2.3%) inpatient death rate and worse LOS outcomes. Conversely, surgeons performing greater than 20 procedures per year, who accounted for almost three-quarters of sample admissions, had the highest (14.8%) number of one-day stays and the lowest (7.1%) long LOS stays.

Regression results

When controlling for all patient, hospital, and surgeon characteristics (Table 2), male patients had a significantly higher likelihood of having a long LOS. As compared to patients <65, patients 75 or older were significantly more likely to die, less likely to have one-day stays, and more likely to have long LOS. There were no significant differences in outcomes by race and ethnicity. Medicaid/uninsured patients were less likely to have one-day stays, and males had a greater risk of worse LOS outcomes than females. The 3.3% of patients who traveled over 75 miles were over four times as likely to die. As compared to patients from <5% poor ZCTAs, patients from ZCTAs with 10-19.99% poor households had a significantly lower likelihood of having one-day stays, but differences with patients from the poorest ZCTAs (only 5.7% of sample patients) were not significant. Charlson scores depicted a gradient of worse mortality and LOS outcomes as comorbidity increased compared to patients with a Charlson score of only two.

As compared to patients admitted to higher volume hospitals doing three or more lung cancer surgery procedures a month, patients admitted to lower volume hospitals had a significantly lower likelihood of having a one-day stay; although differences in long LOS between lowest volume hospitals (14.1% of sample patients) and highest volume hospitals were not quite significant, the 26.1% of patients admitted to hospitals with 1-3 procedures a month had 1.75 times the likelihood of stays 10 days or greater.

As compared to patients receiving open lobectomy procedures, patients undergoing VATS sublobar and open sublobar procedures had a significantly higher likelihood of one-day stays, and patients receiving robotic sublobar procedures had a significantly lower likelihood of having >10-day LOS. Patients receiving VATS lobectomy had a significantly greater likelihood of worse LOS outcomes than those who underwent open lobectomies. Surgeons who performed less than six procedures per year had a significantly higher incidence of inpatient death and >10-day LOS and a significantly lower likelihood of one-day LOS compared to surgeons conducting >20 procedures per year.

Discussion

Our study demonstrates the impacts of patient, procedure type, and hospital and surgeon volume characteristics on inpatient lung cancer resection mortality and length of stay outcomes. While there was little change in inpatient mortality over the 78-month study period, there was a significant increase in both one-day stays and a corresponding decrease in stays >10 days. As would be expected, being male, increasing Charlson score, and older age were associated with LOS. Higher-volume hospitals had significantly better LOS, while the lowest-volume surgeons had higher death rates and worse LOS outcomes. As compared to open procedures, VATS sublobar and lobectomy procedures had higher mortality and worse LOS outcomes, while robotic procedures were not significantly different.

The replacement of VATS with robotic procedures likely explains some of the improvements in LOS over the study period at the 89 non-federal Illinois hospitals in our sample. Another likely factor in improved inpatient LOS outcomes is the increased utilization of Enhanced Recovery After Surgery (ERAS) programs. ERAS programs are recommended sets of evidence-based perioperative measures that serve to reduce postoperative complications [9]. These recommendations are categorized by the amount of evidence (low, moderate, high) and the

Table 2
Poisson and logistic regression results for the likelihood of inpatient death or length of Stay>10 Days for lung cancer surgery, $N = 9602$ Admissions at 89 Illinois Hospitals from 1/2016 to 6/2022.

	Inpatient death	Length of stay = 1 Day	Length of stay ≥ 10 Days*
	Incidence Rate Ratio (95% Confidence Interval)	Odds Ratio (95% Confidence Interval)	Odds Ratio (95% Confidence Interval)
Male	1.35 (0.84 – 2.18)	1.16 (0.97 – 1.40)	1.39 (1.21 – 1.59)
Female	Reference	Reference	Reference
Age			
<65	Reference	Reference	Reference
65-74	3.09 (1.35 – 7.05)	0.88 (0.76 – 1.03)	1.13 (0.93 – 1.37)
75+	3.68 (1.89 – 7.19)	0.67 (0.56 – 0.81)	1.33 (1.02 – 1.75)
Race and Ethnicity			
Non-Hispanic White	Reference	Reference	Reference
Non-Hispanic Black	1.26 (0.66 – 2.42)	0.84 (0.51 – 1.40)	1.12 (0.80 – 1.56)
Hispanic	1.66 (0.63 – 4.34)	1.24 (0.87 – 1.76)	0.76 (0.48 – 1.20)
Asian	1.54 (0.36 – 6.61)	1.20 (0.77 – 1.88)	0.77 (0.39 – 1.51)
Other/ Unknown	0.16 (0.06 – 0.41)	0.81 (0.56 – 1.16)	0.84 (0.59 – 1.19)
Insurance			
Medicaid/ Uninsured	2.95 (1.30 – 6.67)	0.72 (0.54 – 0.97)	1.29 (0.95 – 1.77)
Travel Distance (miles)			
75+	4.22 (1.98 – 9.01)	0.71 (0.48 – 1.05)	1.12 (0.73 – 1.73)
Charlson Score			
2	Reference	Reference	Reference
3	4.14 (1.20 – 14.21)	0.65 (0.54 – 0.78)	2.18 (1.72 – 2.76)
4	6.23 (1.66 – 23.40)	0.53 (0.42 – 0.66)	2.66 (2.07 – 3.43)
5-6	8.06 (2.35 – 27.63)	0.54 (0.40 – 0.72)	3.02 (2.31 – 3.96)
>6	11.18 (3.04 – 41.13)	0.55 (0.40 – 0.77)	4.37 (3.12 – 6.13)
Zip Code Census Tract Area Percent Poor Households			
Non- IL resident	0.25 (0.04 – 1.72)	0.81 (0.52 – 1.26)	0.77 (0.53 – 1.12)
<5	Reference	Reference	Reference
5-9.99	2.39 (1.38 – 4.16)	0.80 (0.62 – 1.03)	1.27 (1.04 – 1.53)
10-19.99	1.46 (0.55 – 3.84)	0.51 (0.33 – 0.78)	1.20 (0.95 – 1.51)
20+	1.59 (0.49 – 5.14)	0.62 (0.37 – 1.03)	1.31 (0.98 – 1.75)
Hospital Procedure Volume			
1 or less per month	0.79 (0.36 – 1.72)	0.41 (0.18 – 0.94)	1.50 (0.96 – 2.33)
1-3 per month	0.78 (0.37 – 1.62)	0.40 (0.17 – 0.93)	1.75 (1.20 – 2.55)
>3 per month	Reference	Reference	Reference
Type of Procedure			
VATS Sublobar	4.56 (1.30 – 16.02)	1.65 (1.27 – 2.16)	2.68 (1.66 – 4.31)
Open Sublobar	0.60 (0.14 – 2.66)	3.48 (2.90 – 4.18)	0.76 (0.55 – 1.05)
Robotic Sublobar	2.39 (0.72 – 7.89)	2.05 (0.92 – 4.58)	0.35 (0.18 – 0.70)
Open Lobectomy	Reference	Reference	Reference
VATS Lobectomy	4.21 (1.85 – 9.57)	0.03 (0.01 – 0.09)	2.12 (1.47 – 3.06)
Robotic Lobectomy	2.27 (0.86 – 6.96)	0.86 (0.40 – 1.85)	0.78 (0.51 – 1.18)
Surgeon Volume			
<6 per year	2.86 (1.47 – 5.55)	0.42 (0.26 – 0.69)	1.52 (1.09 – 2.13)
6-20 per year	0.69 (0.34 – 1.40)	0.76 (0.43 – 1.36)	1.11 (0.83 – 1.49)
>20 per year	Reference	Reference	Reference

* $N = 9533$ after excluding $N = 40$ inpatient deaths with length of stay <11 days.

recommendation level (weak or high) each measure has to better inform surgeons and patients when devising treatment plans [9]. For example, one of ERAS's recommendations is to have patients undergo smoking cessation at least four weeks before surgery [9]. ERAS has been associated with improved postoperative outcomes [10]. Thus, compliance with ERAS programs and pursuing more minimally invasive approaches may imply higher short LOS rates than long LOS ones.

Older age and male sex were previously found to be associated with higher 30-day mortality rates [11]. However, with our sample size and lower inpatient death rates, these differences were no longer significant after controlling for other patient characteristics. Men did have significantly higher rates of long LOS compared to females. Increasing Charlson Scores were also associated with monotonically worse LOS and inpatient mortality rates. Birim et al. also found that the Charlson Scores validly assessed postoperative outcomes for non-small cell lung cancer surgery [12]

Overall, there has been an increasing trend towards robotic-assisted procedures due to their reduced risk of complications and better postoperative outcomes [13]. Our study supports these findings, showing an increasing number of robotic-assisted procedures from 2016 to 2022. However, as compared to our findings, Liu et al. indicated better outcomes associated with VATS procedures [14]. Cao et al. supported Liu et al.'s findings by showing that sublobar procedures had better survival outcomes than lobectomies [15]. In the PORTaL Study, Kent et al. found that minimally invasive approaches to lobectomy procedures (i.e., robotic-assisted and VATS procedures) are associated with shorter LOS and fewer postoperative complications [16]. In our study, robotic procedures had superior LOS outcomes (lesser incidence of LOS>10 days), and VATS lobectomies had inferior LOS outcomes (fewer one-day and more frequent >10 day stays) as compared to open lobectomy procedures. In particular, VATS sublobar procedures had a lower likelihood of one-day stays and a higher likelihood of prolonged stays with significantly higher inpatient mortality. These results may be attributable to VATS sublobar procedures being used for patients who were poor operative candidates. VATS sublobar procedures may also be utilized for diagnostic resections for metastatic patients whose overall condition would require extended hospitalization.

Our study replicated previous studies showing that high hospital volume is associated with better lung cancer resection outcomes. Previous literature shows that patients had better survival outcomes and lower postoperative complication rates at higher-volume hospitals [14, 17]. The Pollock et al. study showed that patients receiving lobectomies for lung cancer resection at high-volume hospitals had shorter median LOS than patients undergoing lobectomies at low-volume hospitals [18]. Furthermore, Pollock et al. depicted a positive correlation between higher hospital volume and lower rates of 90-day mortality [18]

Our results indicated that patients who received lung cancer resection procedures from low-volume surgeons (<6 procedures per year) had worse inpatient outcomes, including higher inpatient mortality, lower rates of one-day stays, and higher long LOS rates as compared to high-volume surgeons (>20 procedures per year). These findings are consistent with Smith et al.'s study, which found that patients receiving VATS procedures from higher volume surgeons had better outcomes and lower Intensive Care Unit admission rates [19]

Limitations

Our study did not have staging and other diagnostic data, which could inform reasons for the choice of procedure type and purpose. We also can only report inpatient mortality rates rather than 30-day or longer survival data, which may not be directly correlated with inpatient mortality. For instance, Rosen et al. found that the 30-day mortality rate of lobectomy procedures was 2.6%, wedge resection (i.e., sublobar resection) was 4.2%, and pneumonectomy was 8.5% [11]. Our study did not consider the joint effects of surgeon and hospital volume or attempt to determine the extent to which high-volume surgeons practiced at low-volume institutions or vice versa. Although limited by the lack of cancer tumor registry and survival data, population-based hospital claims data show important trends in surgical practice and can provide benchmarks for ongoing hospital quality improvement initiatives.

Conclusions

Between 2016 and mid-2022, lung cancer surgery at non-federal Illinois hospitals showed a significant decrease in prolonged LOS and a corresponding increase in one-day LOS. These improvements in LOS were associated with the replacement of VATS with robotic operative approaches and the likely dissemination of ERAS programs at higher-volume institutions. We confirmed previous findings of the benefits of higher hospital and surgeon volume for lung cancer surgery. This population-based hospital claims data study provides a valuable and contemporary method of epidemiologic monitoring of the continued improvement in lung cancer surgery quality of care.

Declaration of Competing Interest

All authors participated in analyzing study data (AA, JF) and writing and editing (DO CL) the manuscript and approve of this submission. All study data were deidentified, publicly available, and exempt from Institutional Review Board (IRB) approval at our institution.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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